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**ECOLOGY OF GASTROPODS AND THEIR TREMATODE
INFECTIONS IN OBUTU LAKE, ORUMBA NORTH LOCAL
GOVERNMENT AREA OF ANAMBRA STATE, NIGERIA**

BY

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**A THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENT FOR THE AWARD OF DOCTOR OF
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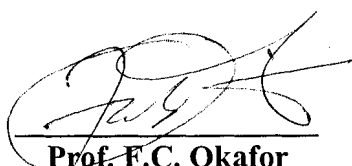
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TITLE PAGE

ECOLOGY OF GASTROPODS AND THEIR TREMATODE INFECTIONS IN OBUTU LAKE, ORUMBA NORTH LOCAL GOVERNMENT AREA OF ANAMBRA STATE, NIGERIA

CERTIFICATION

Mr. Azugo, Wilson, a postgraduate student, in the Department of Zoology, has satisfactorily completed the requirements for research work for the degree of Doctor of Philosophy (Ph.D) in Zoology (Parasitology). The work embodied in his thesis is original and has not to our knowledge been submitted in part or in full for any other Diploma or Degree in this or any other University.



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DEDICATION

To my wife, Juliet and her children who endured deprivation.

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ABSTRACT

Macrodistribution of gastropods in freshwater systems is a subject of many surveys. Opinions vary on the effect of certain factors favouring the presence of snails in aquatic habitats. No such investigation has been done in Obutu lake. Gastropods are very efficient transmitters of helminth parasites, but how they do this within snail species and between species is not well understood. Habitat overlap and biotic interactions may explain the role of gastropods in the overall ecology of freshwater systems. This study aims at providing a checklist of gastropod species with emphasis on the ecological factors affecting their distribution in Obutu lake. The study was conducted between October 2000, and September 2004. The samples were collected fortnightly using scoopnet. The snails were identified and screened for cercariae. To do this, each snail from each demarcated area was put in a 300ml beaker filled halfway with filtered tap water and placed in sunlight for 2h. At the end of the screening, snails from each sampled area were randomly selected and dissected to search for any developing larvae that could not emerge. Factors that affect gastropod bionomics, other biological interactions within the lake and other indexes such as pH, temperature, dissolved oxygen, alkalinity and turbidity, were assessed using standard procedures. The aquatic microphytes and macrophytes that support growth were also investigated by direct observations. The foods and feeding habits of the different gastropods were studied using stomach content analyses. Simpson's Index for the whole species collected was calculated with a view to determining the degree of dominance of the species. Other statistical analyses performed included finding the level of association of helminth parasites between snails, the frequency of occurrence as well as mean levels of infection using analysis of variance.

Altogether, eleven species of gastropods were collected and identified. These were made up of two pulmonates (*Lymnaea natalensis* and *Gyraulus costulatus*) and nine prosobranchs (*Lanistes lybicus*, *Lanistes ovum*, *Pila wernei*, *Pila ovata*, *Potadoma freethii*, *Bythinia* sp. *Orthalicus* sp, *Drymaeus multilineatus* and *Bulimulus* sp). The last three species were arboreal gastropods and amphibious in character. *Lanistes ovum* was the dominant species and it was circumboreal in distribution and dispersed over 60% of the total area of the lake. There was a close association between these snails and aquatic macrovegetation, macrophytes and microphytes. The microphytes were made up of diatoms, desmids, filamentous algae and fungi. Six trematode larval stages were isolated. Infected snails showed a form of nestedness in their distribution. Analysis of association using Chi-squared showed no significant differences ($P>0.05$) between prosobranchs and the macrophytes. Similar values for pulmonates showed significant association ($P<0.05$). Aquatic macroinvertebrates and vegetations were found to be main bulk of foods of these gastropods. Stomach content analyses suggested that organisms of wide size ranges and of various shapes were used as foods by the snails. Other factors like consumption time, searching time and the ration combinations were found to overlap, indicating some level of co-existence. Physico-chemical factors investigated did not significantly influence ($P>0.05$) the abundance of gastropods.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

As with their terrestrial counterparts, aquatic ecosystems in tropical and sub-tropical environments leave much to be investigated, especially in view of their diverse and unique fauna and flora. Among aquatic ecosystems, lakes have attracted a lot of attention both as natural habitats and as impoundment created by man in his quest for development.

Snail-borne infections move back and forth through freshwater bodies between man and snails in the course of the life cycles of the parasites (Sturrock, 1993). The snail is the passive bystander in the whole process and, therefore, it is man that is the vector of most snail-borne infections. Human activities and human behaviour relating to the water bodies have played major roles in modifying the habitats and transmission patterns of the various snail-borne diseases. Human and livestock contact with water relevant to snail-borne infections involve two processes: -

- (a) Contamination of the habitat with parasite ova.
- (b) Exposure of man to the infective stages of the parasites.

In most cases, people or animals contaminating a habitat are different from those that are later exposed to the infection. But those contaminating can also be those infected. The two scenarios lead to two processes also: - The first leads to the spread of the snail-borne diseases, and the other leads to super-infection which does not extend transmission but increases morbidity.

A number of studies show that the prevalence, intensity and incidence of snail-borne infections diminish with distance from a known transmission site, usually a freshwater system (Jordan, 1985). These sites are usually many in any given freshwater, and so, catchments areas of transmission sites overlap, presenting a real problem to parasitologists and public health planners, especially where disease prevalences are to be

plotted on a map to guide control teams. This allows planners to fall back to studying the ecology, host-parasite relationships and transmission dynamics, to avoid a situation where known diseases in one site can be controlled while adjoining areas are left out, thus prolonging transmission and increasing prevalence.

Ecological studies concerning snails and disease transmission have shown that there is a relationship in a given snail-parasite combination, that is expressed as compatibility. This is measured as the size of infective stages produced by a given number of exposed snails throughout the lifespan of the snail population or as the infection rate in a population of exposed snails.

In compatible snail-parasite combinations, known results of studies show that highly compatible relationships are characterized by a high production of infective stages, being the result of a high infection rate, a low mortality among the infected snails and a high daily production of parasite infective larvae per infected snail. The demonstration of naturally-acquired infections in snails has been the principal sure way of incriminating a snail population as hosts for a particular parasite population in a given particular habitat. These realizations have led to in-depth studies of the ecology of snail habitats, the distribution of snails, and their natural infections in given habitats. Furthermore, using experimentations involving both sympatric and allopatric snail-parasite combinations, significant contributions have been made in elucidating the snail species strains and possible hybridization characteristics of parasites within given snail-parasite combinations in specific environments. These have also yielded a lot of information on the taxonomy of many freshwater gastropods, thereby extending our knowledge in the direction of which gastropod (or snail) is responsible for the transmission of which parasite; on the subjects such as transmission seasons; and transmission potentials of the various habitats (Okafor, 1990a).

Transmission of snail-borne infections is an area that is rarely continuous except in few cases. Usually, changes in climate affect both the humans or animals and the snail

populations (Chandiwana *et al.*, 1987). Despite this known seasonality of transmission of snail-borne infections due to climate, there appears to be a circadian rhythm of discharge of parasite eggs and peak abundance of infective larvae in the habitats at given times (Wright, 1971).

The biological advantage of these rhythms is that they are means of facilitating transmission. The other implication is that they show that the snails are readily available for the miracidia hatching out of trematode eggs within defined periods that support abundance of snails. It thus becomes imperative that for any identified snail habitat, a full understanding of the snail population dynamics, the bionomics and other biotic interactions are important, in the overall assessment of the habitat with respect to its role in snail-borne disease transmission.

Macrodistribution of gastropods in freshwater systems has become the subject of many surveys. In most habitats, it has been found to be limited by temperature, rainfall and drought. For this reason, species will probably fail to colonize some habitats, while in some other habitats they are abundant. It is, therefore, very important that factors of the environment that affect the macrodistribution of gastropods in any environment are investigated and used to understand the biological interactions within the habitats.

While serious attention is paid to the macrodistribution of snail genera and species, a lot more attention needs to be paid on the microdistribution parameters of the species. For example, it will be highly instructive to understand the factors that support oviposition, egg hatching and survival of the young snails in their preferred habitats. In his studies, Boag (1985) found that thermic stability appeared to determine substrate selection in adult gastropods and it would be interesting to find out if the young snails are similarly affected. According to Barrientos (1998) the number of eggs and juveniles increase with the increase of temperature during the morning (from 6.30 am), and with decrease of temperature later in the morning (around 10.00 am). This finding suggests the need to study the roles of aquatic macrophytes in the freshwater habitats as agents of thermic

stability, beyond their traditionally known roles of serving as oviposition sites and food for the snails.

It is also known that certain habitat factors may clearly correlate differently between eggs, juveniles and adults. For example, in land gastropods, it has been noted that humidity of litters and soil and season correlate mainly more for eggs than other stages (Okafor, 1990a). In similar studies, earlier, others found correlation to be highly stage specific. They also found that high relative humidity is also an important factor for snail and egg abundance which was an expected result due to the hygroscopic nature of such snail eggs and to the snails' slime trail production. The influence of some factors on egg oviposition site selection, and choice of snail microhabitats, will be investigated. Findings of such investigations suggest that certain factors definitely favour the presence of snails even when the majority of other studies suggest an integrative role of the various environmental factors.

Brown and Lodge (1993) stressed the relationship between abundance and habitat structural complexity, the latter increasing the area that can be colonized by the snails. Abramsky *et al.* (1990, 1992) and Brown and Lodge (1993) showed that habitat depths are correlated also with snail abundance, as substrates further down are used to lay eggs and hide from predators. Whether this also occurs in aquatic habitats needs to be investigated.

Other studies indicate new interests and the roles of factors like phosphorus and pH values on snail oviposition (Barrientos, 1998), on feeding, oviposition (Barrientos, 1996, 1998, Boag and Wishart, 1982, who also recorded that in high density populations, the most frequent food plants were usually the common ones in the plant community, in a more opportunistic way. Chatfield (1975) showed that more diverse habitats make specializations less desirable and may lead to high diversity.

It is common in many snail habitats, to see live snails occurring side by side with empty shells. The ecological significance of this has been investigated in very few habitats. In those studied, it was noted that the different results of the analysis of living

snails and shells' tendencies suggest that those categories should not be considered together as some of the scientists do (Coppo, 1984). Shell occurrence can be the result of factors that operated in the past but that may be currently absent. Such past events must be investigated for the prevention of future occurrence of its mortality cycle.

Much of the evidence available now on parasite community structure suggests a non random pattern in parasite species distribution among hosts. Therefore, there is the potential for spatial and temporal variation in community structure and thus the detection of important short term or very local processes. Results from field surveys suggest that even when there are departures from random assembly (expressed as positive associations between the most prevalent parasites, species or nested patterns) no repeatability in parasite community structure existed in time or space. The study of snail ecology has thrown up several interesting results: the influence of snail size differences within each locality; the presence of positive correlation in most of the pairwise comparisons; the nature of subgroups exhibiting nestedness, and the influence of distance between localities on the likelihood of finding nestedness.

One of the most influential variables is the size of the individual. In fish species, localities within nestedness in any subgroup also had a significant correlation between fish size and the logarithm of the total number of parasites per fish (Poulin, 2000; Poulin and Valtonen, 2001) for the internal parasite communities of 23 populations of fish. Whether this is true of aquatic freshwater snails needs to be ascertained.

Concerns for the role of gastropods in disease transmission have prompted increased quantitative monitoring of snails and their habitats, providing evidence that some populations are undergoing cyclical changes in population density following changes in physico-chemical changes in their habitats. Furthermore, parasites represent an increasing threat to natural populations and recently, attention was focused on examining methods by which disease threats can be managed in free-ranging wildlife (Lafferty and Gerber, 2002). To assess and manage snail-borne infection risks effectively, baseline

information on patterns of infection in natural populations is critical. Many field studies have examined within population infection patterns by focusing on the effects of factors such as host behaviour (Rubenstein and Holimann, 1989); demography (Halvorsen, 1986) and genetics, on infection rates.

Very few studies tried to look at the effects of community level interactions on infection rates despite the fact that many parasites infect and are transmitted by multiple host species within the same community. To understand the dynamics of community level interactions on infection rates, a community level approach is needed because both inter-specific as well as intra-specific processes influence transmission. This is particularly true for parasites like trematodes whose cercariae accumulate in the external environment and in which spatial overlap between sympatric hosts is sufficient for cross-species parasite transmission to occur.

For parasites shared across host species, it is expected that increasing overlap among species will correlate with increased rates of infection. Increased habitat overlap among species is also expected to be positively correlated with parasite taxa richness.

Aims and Objectives of the Study: The aim of this study is to study the ecology of gastropods and their trematode infections in Obutu Lake, an inland lake in the Orumba North Local Government Area of Anambra State. The lake has not been characterized by anybody in the past, and the present study of the ecology of its gastropod mollusks presents a good opportunity to do so.

The objectives of this study are to: -

1. Characterize some of the physico-chemical variables in the lake.
 2. Investigate the interactions and associations between these variables.
 3. Investigate the roles of the investigated variables on the observed abundance and distribution of the gastropods in the lake.
 4. Studies on abundance and frequency of occurrence of gastropod snails in these habitats.
-

5. Studies on biotic interactions within the lake.
6. Studies on transmission of parasites through their snail hosts.
7. An assessment of habitat overlap, patterns of infections across snail host species, and, comparative studies on habitat nestedness, overlap and parasite prevalence and richness.

It is believed that a good knowledge of the ecology of these gastropods would have been gained, for us to be able to predict the status of snail-borne infections of man, fish and other livestock in the area. All these will be used to determine health risks; make environmental assessments; and for rapid assessment records (e.g. use of key informants) in the area.

LITERATURE REVIEW

Using the principle of competitive exclusion, which states that two species requiring the same resources cannot co-exist, one will assume that in nature, the competing species and their biotic environment remain genetically constant (Pimentel *et al.*, 1965). From what is known about gastropods, this may be a broad assumption, as various studies show that a habitat may contain as many as 17 gastropod species, each competing with one another and yet co-existing. Ecology of gastropods in freshwater systems is a study on interspecific competition, co-existence and sharing of resources in the ecosystem, be it food, space, or other necessary resources.

Observations in nature show that molluscs generally are abundant and species are evenly distributed in favourable habitats with focal dominance of species as a result of environmental requirements and adaptation (Okafor and Obiezue, 2004). Field studies on distribution and abundance of gastropods suggest that stronger species are increasing in number while weaker species are sparse. Strength can be judged within two very important processes namely:–

1. The ability to show adaptive plasticity and
2. Possession of a high biotic potential. Both attributes confer strength to a species and, therefore, determine abundance and frequency within and between habitats.

Evolutionary adjustments between species of gastropods and their environment would function in either a non-random or random distribution. The sparse species, non-randomly distributed in scattered small colonies would have an advantage because this distribution provides the most favourable opportunity for evolutionary advance which Wright (1937) suggested was important for any species survival. Furthermore, it has been seen that more space and larger populations should provide the necessary time for developing adaptations needed for co-existence among the species sharing resources in the same ecological niche. It is also known that as a competing species becomes the dominant species, it is at an evolutionary disadvantage because intraspecific competition is the main

selective force acting on it. The sparse species, because it is under selective pressure from interspecific competition, has an evolutionary advantage. Given sufficient time, a genetic adjustment between the competing species should result (Pimentel, 1965). Space-time structure of the environment and the survival of animal species have been well studied (Pimentel *et al.* 1963; Learner and Ho, 1961). They showed that to keep two or more competing species co-existing would require the manipulation of a portion of the genotypes making up each species population with competitive ability being selected for.

In populations with dominant species, intraspecific competition selection predominates because there is a greater chance for individuals of this species to interact with their own kind than with individuals of the sparse species. This principle might be playing itself out in gastropod populations in freshwater systems. Looking at the gastropod lists found in malacological surveys shows that this is the case. One other feature of gastropods is that dominance amongst them shifts between species and individual habitats. As a result, the gastropod dominant in habitat A is always different from those dominant in habitat B. It is, therefore, very important and makes ecological sense to study the frequency, abundance, distribution and associations between gastropods in any given habitat, in order to put on record, the character of the habitat and the nature of species interaction at work therein.

Various aspects of feeding in pulmonate gastropods have been described, in particular, the relationship between snails and vegetation; food selection; feeding rates and assimilation (Chatfield, 1975); feeding and growth; and feeding behaviour and distribution.

There is paucity of information on diets of other freshwater gastropod species in nature. Further, little information seems to exist on the types and amounts of nutrients required by them for normal growth. Many of the available studies show that because gastropods live in habitats that support rich microflora and microfauna, they mostly feed on these and other organic matter (Watson, 1958; WHO, 1965).

It was also noted that of these species and genera, the food items vary from habitat to habitat (Ndifon and Ukoli, 1989). Calow (1973) demonstrated that *Planorbis contortus* selectively ingests the detritus materials which adhere to the surfaces of submerged stones, rather than on the encrusting algae.

Following from these, it is apparent that there is an important need that for each habitat, the items of diet should be known in addition to the other biological interactions between species growth and distribution.

There are relatively few adequate field studies on molluscan growth rates and life cycles (Russell-Hunter, 1964, Okafor and Anya, 1991). For many species of freshwater snails, the results are based on studies of the linear measurements of shell dimensions.

Studies on the timing of egg-laying indicate that there is a high correlation between this and humidity of the environment (Barrientos, 1998). During the periods of low humidity, gastropods prepare themselves physiologically while aestivating, to lay eggs at the beginning of rainy season (Hodgson and Shachak, 1957). Other factors that adversely affect the number of eggs that eventually hatch are noted to be predators, pH changes and drying as a result of desiccation.

Studies on parasitic infections in field populations of gastropods show that transmission is purely vertical and is predicted to cause low pathogenicity in their hosts (Kelly *et al.*, 2003). While parasites do not have any effects on host gastropod survival, they cause a reduction in juvenile growth. This effect is also modulated by resource availability and intra-specific competition, with infected individuals (Washburn *et al.*, 1991). Parasites are also known to be transmitted horizontally between unrelated or related hosts of the same or different generations. Studies of Agnew and Koella (1997) showed that selection for successful horizontal transmission favours a high parasite burden that is often associated with high levels of pathogenicity in the hosts. Dunn *et al.* (2001) were also of this view. They showed that horizontal transmission contrasts with vertical transmission as in the latter, the parasites are transmitted from parents to offspring through

successive host generations. It was also noted from the studies of Ewald (1987), Smith and Dunn (1991), Hurst and Majerus (1993) and Dunn *et al.* (1995) that vertically transmitted parasites depend on host reproduction for successful transmission: It is also noted that vertical transmission is often associated with low pathogenicity and burden (Herre, 1993; Ewald, 1994; Dunn and Smith, 2001) and causes a reduction in the growth of hosts during development from hatching to adult, as well as reduction in weight of the infected host as much as 20 % in comparison with uninfected hosts. These findings are in keeping with known patterns of host-parasite relationships in many animal groups. It is, therefore, believed that parasite-induced reduction in growth rate is likely to lead to decrease in host fecundity and a concomitant decrease in opportunities for vertical transmission of parasites to hosts of subsequent generations.

Several studies have been carried out on the compatibility of different trematode species to their different intermediate molluscan hosts, to evaluate if the intermediate host-parasite relationship influences the prevalence of the snail-borne diseases or transmission of the parasites (Taylor, 1970; Tchuem-Tchuente *et al.*, 1999). There has also been interesting comparisons of the cercarial output of each parasite species from the intermediate host snails especially between pure strains and hybrids, which showed that cercaria production was lower in hybrids. (Webster and Southgate, 2003)

Field studies also show that the distribution of parasites and their prevalence were historically restricted to a small number of foci, in spite of the fact that the gastropod intermediate hosts are very widely distributed. It has been suggested also that there exist, many interactions of parasite species, environmental changes or ecology, and host susceptibility to parasites, that affect the distribution of parasites within snail populations (Mutani *et al.*, 1985, and Southgate *et al.*, 1998).

Studies on the survival of the life cycle stages show that environmental parameters like high water temperatures, low pH, salinity, and hardness of water all induced mortality to the life cycle stages. Most effects are seen on the physiology of the stages e.g. inhibition

of the utilization of glycogen reserves and antagonistic actions of a mixture of chemical elements that affect survival of the stages. Majority of these survival studies suggest that the different stages of development of the parasite are as susceptible to environmental effects as have been demonstrated for other aquatic invertebrates.

It is well known that cercariae possess a period of maximum infectivity which is much shorter than their life span, but there have been few attempts to analyze their mortality over this period. Working with *Fasciola gigantica* cercariae, Okafor and Igbinosa (1988) found that activity ceases after 9 hours of active swimming.

Available literatures indicate that only acute concentrations of substances can induce any effect on cercariae during their initial crucial period of activity. They showed that it is not only infectivity of the cercariae that was affected by environmental parameters, but that also their tail loss was affected in addition to the decaudised cercarial life span. They found that tail loss increased in parallel with a decrease in survival of the cercariae.

Studies on metacercarial survival have been limited to metacercariae residing in protective multilayered cysts in invertebrate intermediate hosts. Studying *Echinoparyphium recurvatum* within the second intermediate host *Lymnaea peregra* has shown that a five-day exposure to certain environmental toxicants did not significantly affect metacercarial viability but that it reduced mean survival to about 74.3 %. This showed that there is a high tolerance of metacercariae to environmental parameters and pollutants. Studying the functional biology of the cycle stages, a range of polluting materials and conditions have been demonstrated to have toxic effects on the embryonation and hatching of miracidia from the egg. The materials and conditions include heavy metals, pesticides, fertilizers and acidification. Survival of developing embryos was reduced in the presence of high toxicant concentrations (Guttowa and Borriecka, 1975; Guttowa, 1976); while low concentrations reduced the activity of the reduction- oxidation enzymes in the embryos of *Fasciola hepatica* (Guttowa, 1975).

Extending this investigation further, it was found that during acute short duration exposure, there was a reduction in penetration ability of the cercariae. It was also reported that different species of target hosts may have differing susceptibilities to toxicant-exposed cercariae. Furthermore, it was revealed that the exposure of the target hosts to toxicants can induce an increase or decrease in susceptibility to cercariae, probably via immunosuppression or immunostimulation.

There are inherent complexities in studying parasite transmission dynamics in natural multi-host systems. These have limited our understanding of host-parasite or host-community environment ecology. Despite the difficulties, attempts are being made to understand these systems. In communities comprising closely-related species, cross-species contact is an important determinant of generalist parasite infection risk and should be considered even when evaluating patterns of infection even within single host populations. It is also known that hosts living in diverse habitats may be more susceptible to parasite "spillover" than other hosts (Begon and Bowers, 1995). Adequately quantifying cross-species contact rates in natural ecosystems may be instructive.

Different species do not interbreed because they are separated by barriers to hybridization or isolating mechanisms. If the barrier is geographic or ecological, the species are allopatric. If two species have overlapping ecological ranges, they are sympatric and are separated by some type of reproductive or genetic isolation. Allopatric species may or may not be genetically isolated, but sympatric species must be. As populations become isolated, they find ecological regions or niches where they can live and to which they become adapted.

Allopatric and sympatric populations have been well studied in most animal species. For example, in tree frogs it was found that the mating call, a behavioural characteristic, is probably the key isolating mechanism (Littlejohn, 1966). In gulls, food preferences seem to isolate two species. They pointed out that with a great abundance of human refuse the barrier appears to be breaking down. Whether two similar species can

occupy the same niche at the same time has been debated. The subject was discussed with relation to food preferences of grasshoppers. Using the Acridian species *Melanoplus bivittatus*, *Melanoplus differentialis* and *Melanoplus lakinus*. Littlejohn (1966) also observed that they occurred in the same habitat, utilizing the same foods and suggested that such coexistence show that the species were in the same niche and in competition for a common food supply. Their food usages were investigated by offering samples of the dominant and semi dominant vegetation from the common habitat to caged populations of each species and then estimating the amount consumed. The overall usage of foods of each species formed a preferential pattern sufficiently different from the patterns of the other two species, to indicate that the three species populations occupied separate niches in the community and were not in complete competition for food.

Variations within a population may occur in a series of gradual changes ranging from one extreme to the other. Nelson (1967) described such a cline for two forms of each of two races of *Prunella vulgaris* and discussed their habitats. He showed in California by two sequential common garden studies, the existence of a first year flowering low elevation race adapted to mild winters and a second year flowering montane race adapted to severe winters. Characteristics of habitat and growth rates provide for the recognition of coastal and inland forms within the low elevation race and cascade and sierran forms within the montane race. The distribution of these four racial forms in California was found to be correlated with climatological features. Clinal variation correlated with latitude and elevation and can be demonstrated within each form. A sequence by which the four forms might have evolved was postulated from the study. Further analysis of the Californian results and comparison with results from European studies suggested that modes of intraspecific variation in California and Europe may be more comparable than previous studies would indicate.

A large homogenous population may fragment into several populations occupying different niches to which they become better adapted by natural selection. Such adaptive

radiations have been subject of various studies in animal species. Steeves (1966) showed that affinities and distribution followed adaptive radiation of three groups of troglobitic asellids in the complex of limestone caves in Florida. The habitat exerts some control over animal distribution by creating feedback loops on which natural selection acts on to determine the kind of organism that will prevail in a certain ecological situation (Heslop-Harrison, 1966).

The environmental control may be driven by regular seasonal alterations with some environmentally modulated distribution, encouraging species diversification. The success of animal species can only be understood in relation to these general ecological principles and the kind of community to which they belong. To date, no serious studies in these directions exist for gastropods. Most studies are limited to providing checklists of species present in any habitat, the diets of few species, and their roles in disease transmission, without showing why, for example, *Pila wernei*, *Pila africana* and *Pila ovata* will thrive successfully in the same habitat, or the microdistributional forces controlling the distribution of *Lanistes moerchii* and *P. freethii* in the same habitat. It will also be instructive to investigate the food preferences of gastropods within their freshwater habitats. Studies by Kamykowski (1978) using computer modeling, investigated the interactions between internal seiches and planktonic organisms that undergo vertical diurnal migrations. He observed some form of patchiness. The character of the patchiness was seen to be influenced by physical variables such as:

- (i) The sampling interval in the field.
- (ii) The frictional damping of the basin, and
- (iii) The phase angle between the internal seiche and the daylight cycle of vertical migrations; and by biological variables such as (1) organism behaviour patterns and (2) movement speed. The computer models yielded results that compared favourably with some of the zooplankton distribution reported in the literature. Thus, the population dynamics of a migrating prey (predator) is probably affected by occasional coincident

encounters with various bands of migrating predators (prey). Other similar studies indicated that vertical migration of planktonic organisms was made possible by the ability to move against the physical water movements such as upwelling and wind mixing. The migration of macrophytes was found to be planktonic in nature, responding to the light intensity at the water surface. Such will affect the spatial distribution patterns of the various aquatic animal species. For gastropods, Todd (1978) working with *Onchidoris muricata* (Mollusca: nudibranchiata) found that recruitment of the benthic phase of the life cycle occurred in late June/early July with settlement and metamorphosis of the planktotrophic veliger, the post metamorph juveniles exhibiting an overdispersed distribution. This was interpreted as an expression of environmental heterogeneity. An apparent change in behavioural response of the individuals has been detected by following changes of "patchiness", and mortality has been shown to be of an "all or none" type operating on clumps of individuals, with the conclusion drawn that predators adopted the strategy of seeking out the high density clumps of the nudibranchs. Mortality, in this case, was viewed as a mechanism inadvertently easing the energetic stress placed upon the individuals of the population in seeking resources, this stress arising from the aggregated nature of their spatial dispersion. It is yet to be verified if similar things happen with freshwater gastropods,

According to Krebs (1996t), habitat selection has been defined as the interactive expression of responses which tend to maintain the association of an animal with a particular type of habitat. This is distinct from the establishment of home ranges where a specific site is chosen within a favourable habitat. It is also speculated that habitat selection is influenced by (1) habitat changes (2) invasion of a new habitat (3) changes in climate (4) vegetation (5) structural alterations to the environment of the original habitat (6) selection for behavioural, morphological and physiological alternatives i.e. those facilitating survival in and successful exploitation of new conditions (7) intraspecific interactions (8) aggressive interactions between individuals of different sexes or sizes that

force segments of the population to occupy marginal habitation (9) selection within marginal habitats to facilitate survival and resource utilization (10) interspecific interactions (11) competition, by coalescing of previously separate ranges or by human impact on the habitat (12) aggressive interactions that result in one or both having to occupy new areas (13) selection for adaptation to survive in a new habitat (14) reinforcement of habitat utilization by development of appropriate behavioural responses to habitat features.

Although the population dynamics of animal species has been studied extensively, the factors that regulate them remain controversial (Krebs, 1996). Populations of animals tend to fluctuate cyclically or regularly (Krebs, 1966, Boonstra *et al.*, 1998) and these periodic fluctuations may be caused by variations in their food supply, climatic changes and other density-dependent factors. Thus, both seasonal and spatial variations in density and biomass are quite high. Most studies, however, show that despite this, mean values are comparatively low and disjunct distribution is common – distribution being controlled by such other factors as hypolimnic oxygen depletion, food supply (especially chlorophyll – a concentration habitat morphology and perhaps, by substrate composition in addition to the already – mentioned predator – prey interactions.

Drift rates have been measured in most aquatic organisms but not the gastropods. Results from insect studies show that there is a relationship between periodically-occurring increases in drift and activity due to partly exogenous control and partly due to endogenous rhythms, and that there is a gradation among behavioural groups in their tendency to leave the substrate and enter the water column (Corkum, 1978).

Physico-chemical Properties of Lakes: Limnological studies of water bodies, as well as the nature of the environment, impact seriously on the malacological aspects of such bodies of water. Lakes are known to be home to many snails, and numerous studies have been carried out on as many lakes as are accessible. Studies on gastropod fauna of such freshwater systems have aided in understanding the ecology of the bodies of water, as well

as the distributional relationship within the snail communities, and between them and the character of their habitats. Such studies also open up hidden areas of the environmental biology, life cycles and biotic potential characteristics of the fauna.

Snails appear to exist in endemic foci (Solem, 1969; Breure, 1979). There is a general assumption that when snails are found in a given environment, they interact in many ways with themselves and with their immediate environment. Pimentel (1965) noted that they both compete and yet co-exist. He further noted that interspecific competition may change genetically so that species later co-exist. And when they do, they begin to utilize the same resources in the ecosystem. In most cases, there is often a divide of stronger and weaker species, each fluctuating in population depending on their responses to environmental parameters and resources. This fluctuation leads to abundance of one group and a decline in the population density of the other.

Many field surveys suggest that apart from the intrinsic intraspecific interactions, certain factors of the environment like temperature, pH, alkalinity, dissolved oxygen and other climatic and edaphic factors, support and sustain oscillations in the population of groups of species thus allowing for shifts in dominance of species even within the same habitat. Co-existence, especially of apparent relatedness has been found to support the establishment of communities in suitable environments while in harsh areas no species can thrive. The implication of this is that distribution of species is judged against the resource gradients. This often gives an impression that the species pack in relation to abundance or lack of particular components of the environment. Understanding the dynamics of this relationship helps to resolve the underlying force determining the phenomenon of species overlap on a particular resource gradient.

Obutu Lake is apart from being a favourable habitat for many species, also provides water for human consumption and allows for other human activities, including fishing and processing of agricultural produce. It also has the potential of being developed into a recreational facility. It is a near-closed water body with almost no hydrological

connection with either any sea or rivers. Its volume reflects interactions with direct precipitation and recharge from rivulets and run-off water from the adjoining farm lands and forests. This situation makes characterization of the lake imperative not only for its gastropod fauna but also to know its physico-chemical composition and hence, the character of the lake. Quantitative characterization of environmental variables playing in the lake is, therefore, of very important value (Arie and Boyd, 1980).

Studies such as those by Imevbore, 1970; Vannote *et al.*, 1980; Vannote and Sweeney, 1980; Rabeni and Minshall, 1977; Clifford *et al.*, 1989; Clifford and Carney, 1991, have shown that environmental factors interact in assorted combinations, producing their effects on the flora and fauna of the lakes or other similar freshwater bodies for that matter.

2. Abundance and Distribution of Gastropods in lakes: Patterns of snail species diversity and distribution have been the subject of diverse and varied studies in many freshwater ecosystems. Examples abound both in the international studies and among the local Nigerian scientists. Most of the studies point at habitat diversity as a feature controlling the number and diversity of species in any given ecosystem. Thus, species richness and/or similarity between species within a given habitat, are attributed to this factor. In adverse habitat conditions, snail species abundance becomes nearest its minimum sustainable population size and sometimes may not be found. The reverse is the case when conditions in the habitat are favourable and so, snail abundance approaches the maximum sustainable population size.

The aim of this study is to investigate the snail abundance and factors that control fluctuations in the snail numbers and diversity of species.

3. Food and Feeding Habits of Snails: Feeding of gastropods had attracted a lot of attention, bringing to the fore, the structural architecture of the snails, the mode of feeding and the foods. For example, it is now known that snails may feed on many aquatic macrophytes. Beyond these, it is also known that many species live on leaf moulds under

or near rocks on beds of their habitats, while others feed on epiphytic growths such as algae, fungi and lichens. Most importantly, because of the nature of their radulae (which differ with genera) they feed mainly on glabulous materials (Okafor, 1990b).

There is controversy over the actual roles of aquatic macrophytes relating to the distribution of gastropods in freshwater habitats. Many scientists like Okafor (1984), Ndifon and Ukoli (1989), showed the importance of aquatic macrophytes in freshwater snail ecology, and some even worked out indices of association between them. Most also suggested that snails depended on these plant species for shelter, eg oviposition sites eg and food eg. Others claimed that there was no significance in the association between freshwater gastropods and aquatic macrophytes. Thus, we find ourselves in a state of flux.

Paucity of literature on the food of mollusks had led scientists to study the diets of slugs in nature, stressing on the nature and types and amounts of nutrients required for normal growth. Within the same period, Calow (1970) showed that there was close relationship between diet and growth of fresh water gastropods.

Detailed study on pulmonates by Runham (1975) showed explicitly that diet is a very important component of snail biology. In this work, qualitative studies were conducted on the diets of pulmonates and prosobranchs found in Obutu Lake, through the examination of their stomach contents, in order to complement the observations made in the field.

4. Parasitic Helminth of Gastropods Freshwater invertebrates have been known to cause severe medical, veterinary and economic problems. They may also have adverse effects on other biota within the freshwater ecosystems. For gastropods, many species serve as intermediate hosts of trematode parasites. The trematodes (i.e. flukes) are responsible for large losses and considerable economic impact on the livestock industry in many countries. The gastropods play very crucial roles in the transmission of the flukes because the intermediate asexual stages of the parasites develop in them. The snails, because they

have high biotic potentials, spread rapidly and are often abundant in suitable habitats subjected to human disturbances (Williams, 1970).

Trematode parasites are known to generally impose costs on their snail hosts in terms of fitness, growth, reproduction and survival (Lehman, 1993; Jaenike *et al.*, 1995). Part of the effects on fitness can be modulated by availability of resources and intraspecific interactions, but the infected individuals still suffer higher costs than the uninfected (Washburn *et al.*, 1991).

It is common for trematode parasites to be transmitted horizontally i.e. they are transmitted between unrelated host species, and between related species of different or the same generations. This is commonly found in parasites transmissible through feeding of the infective stages or tissues. Any parasite that is transmitted horizontally favours high parasite burden in snail communities (Agnew and Koella, 1997; Dunn *et al.*, 2001). In nature, however, vertical transmission is the norm and most studies show that the parasites are transmitted from parents to offspring through successive host generations. It is believed that vertical transmission of parasites depends on host reproductive performance for its success (Smith and Dunn, 1991; Hurst and Majerus, 1993).

Empirical studies have shown that vertical transmission is often associated with low burden in host communities (Herre, 1993; Ewald, 1994). However, most trematode diseases have a wide geographical distribution because there is an extremely close host - parasite relationship between the larval stages and their snail hosts.

The distribution of trematodes is largely influenced by the distribution of their intermediate snail hosts whose distribution is, in turn, dependent on environmental and ecological factors. This relationship has generated a lot of interests among parasitologists, leading to numerous studies on their susceptibility, environmental requirements, focality and other transmission dynamics of parasites within snail communities.

The present study looks at the parasitic trematode infections of gastropods in Obutu Lake. The data obtained were used to explain the association between the parasites, their snail hosts and their environment.

CHAPTER TWO

MATERIALS AND METHODS

2.1 Study Area: Obutu Lake is an inland freshwater lake that is situated within a vast agricultural area of Omogho in the Orumba North Local Government area of Anambra State. Omogho, an autonomous community in Orumba North Local Government Area, is about 10 km from Ekwulobia, on the Ekwulobia/Umunze Federal Road. It has a population of 4,619 (2005 projected). The inhabitants are mainly farmers and fishermen.

Obutu lake stretches from its eastern end at the Omogho/Ndikelionwu boundary, runs north-eastwards, and finally gives out an outlet into the Ota – Alu River which, in turn, empties into the Aghomili River that crosses the boundary between Omogho and Ufuma, along the Ekwulobia/Umunze Road. The lake which is a large body of water is wedge-shaped, with its widest portion close to its discharge into the Ota-Alu River. In the map (Fig. 1) drawn from aerial photographs, the actual location of the lake could be seen. At the peak of the rains when the lake overflows its banks, small temporary rivulets join it and meander into the surrounding farmlands which, together with direct precipitation, are fully inundated. A consequence of this situation is that the overflow of the lake water into the farmlands through the rivulets carries along with it, biotic components which include invertebrate fauna and flora, higher invertebrates including freshwater snails of various species, and vertebrate members which are represented mainly by snakes, fish, frogs, alligator lizards and turtles.

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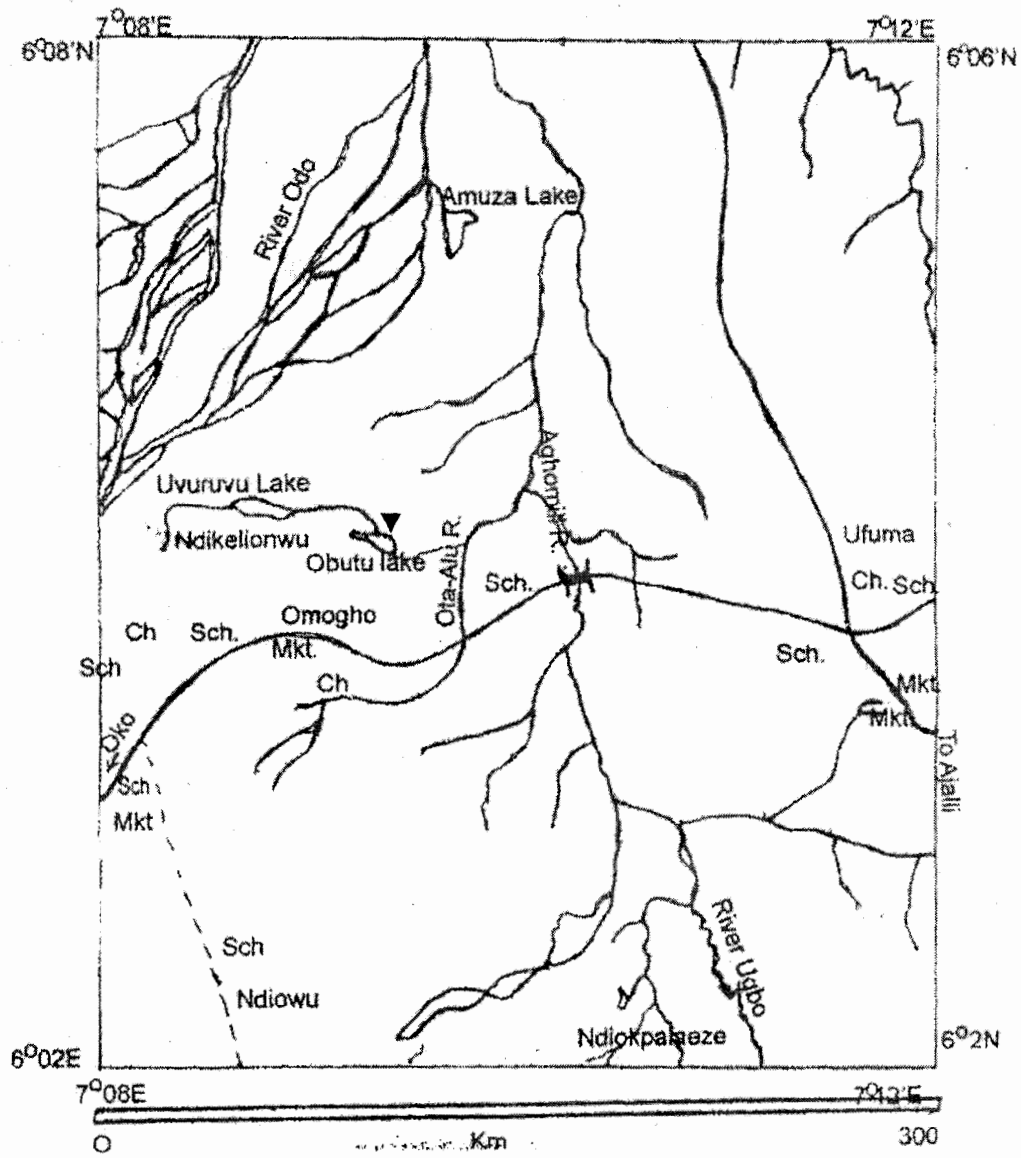


Fig. 1: Map showing part of Orumba North Local Government Area, where Obutu lake (▼) is located.

Therefore, at this particular time of the year when the adjoining farmlands are fully inundated, the water bodies of both the lake and the surrounding areas coalesce to present similar biotic and abiotic features in their ecosystems. But at the beginning of the dry season, many fish, snails and some other animal and plant species which swam actively through the rivulets or were drifted by the currents from the lake into the farmlands at the peak of the rains, are left behind as the water begins to recede. The people of the area take advantage of this to collect such trapped organisms even by hand.

The entire Omogho land area has the advantage of a rich soil which, according to the New Comprehensive System of Soil Classification (multi- category), falls into the type that is known as mollisols. Mollisols are characterized by a thick, dark surface horizon which is high in organic matter. The surface horizons usually have granular or crumb structures and are not hard when the soils are dry, hence the mollisols are referred to as soft soils. Because of the high native fertility of mollisols, they are cultivated extensively during the farming seasons by the natives, to raise cassava, cocoyam, yams, rice, maize and groundnuts, depending on the level of inundation and on the gradient of the area. This is, indeed, why the inhabitants (natives and immigrant labourers) are almost all farmers, including public servants who engage on this practice on part-time basis. Thriving fishing activities and tapping of raphia palms for wine are also important activities that provide means of livelihood to many of the inhabitants who, in some cases, combine these with land cultivation. Grazing of cattle and other domestic animals form part of important activities of the inhabitants, especially at the southern part of the lake. Worthy of note also is the presence of large populations of such economic trees as breadfruit (*Treculia africana*), oil palm trees, (*Elaeis guineensis*), coconut trees, (*Cocos nucifera*), native pear (*Dacryodes edulis*), mango trees (*Mangifera indica*), raphia palms (*Raffia vinifera*), and Cola trees (*Kola accuminata*). Indeed, it would appear that the activities of the domiciled people of the area are mainly farming, wine-tapping, fishing, processing of farm produce, sale- of the products, and grazing of animals.

The vegetation lining the shores of the lake consists of many species of hydrophytes, including *Pistia*, *Ceratophyllum*, *Nymphaea*, *Aspilia*, *Jussiaea*, etc. There is also a variety of grasses which coexist with these hydrophytes. The major trees that are found in some places near the shores are the raphia palms, bamboo trees, palm trees, and mango trees.

The shorelines, from which some samples were taken at designated sites (Fig. 2), were basically similar in nature but differed in some cases, on the composition of the lining vegetation (Table 1). At the bottom of the shores, the mollisols mix up with fine sand, silt and decaying organic matter consisting mainly of fallen leaves, agricultural wastes and dead plant tissues, to form organic detritus. This type of substratum provides suitable habitat particularly for juvenile snails some of which feed on the organic detritus, as well as for concealment from predators.

The bottom of the shoreline consists mainly of a high ratio of alluvium to mud, suggesting low current speed. In some locations, however, the bed consists of red mud mixed with fine black clay mixed with sand. The bottom of mid stream is mainly sandy.

Various species of gastropods were seen at the shores, particularly early in the mornings and late in the evenings, to attach themselves to the a hydrophytes which also afforded them some level of shelter as well as provided them with suitable environment particularly when the shores were burst at the peak of the rains.

The area is under the influence of two climatic seasons – the dry season and the rainy season. Normal rainy seasons occur between May and October, with a short break between late July and early August, but in 2003, this short break was witnessed entirely in early August.

With precipitation and overspill, the habitat becomes enlivened, leading to the rapidity of growth of higher vegetation, increase in the population of microfauna and microflora, as well as increased growth and enhanced population of aquatic macrofauna and higher invertebrates.

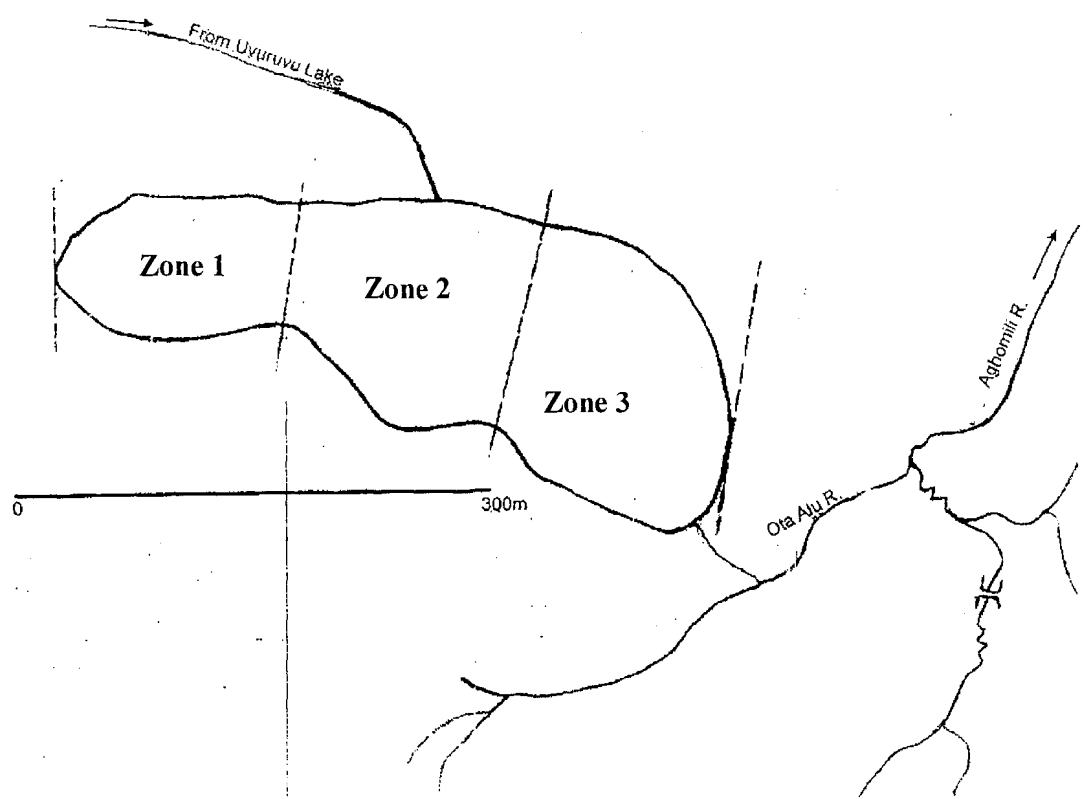


Fig. 2: Obutu lake showing three demarcated zones along its stretch

Table 1: Vegetation lining of Obutu Lake

VEGETATION TYPE	AREA COVERED (ZONES)
Large aquatic plants	3 rd zone
<i>Potamogetin pectinatus</i>	2 nd zone
<i>Myriophyllum</i>	3 rd zone
<i>Ceratophyllum</i>	3 rd zone
<i>Elodea</i>	3 rd zone
<i>Chara</i>	2 nd zone
<i>Utricularia</i>	2 nd and 3 rd
<i>Nitella</i>	3 rd
<i>Vallisneria</i>	3 rd
<i>Nymphaea</i>	2 nd
<i>Nuphar</i>	2 nd
<i>Brassenia</i>	3 rd
<i>Scripus</i>	2 nd
<i>Eleocharis</i>	2 nd
<i>Carex</i>	2 nd
<i>Calla</i>	2 nd
<i>Sagittaria</i>	2 nd
<i>Alisma</i>	2 nd
<i>Typha</i>	2 nd
<i>Alternanthera sesillis</i>	3 rd

This period also witnesses the emergence and increased activities of such aquatic vertebrates as amphibia, fish and reptiles. The habitat thus becomes favourable to these organisms for feeding, recreation, migration to new habitats, and reproduction. Indeed, as could be seen through cursory observations, the beginning of the rains marks the end of the aestivation period for some snails and the commencement of egg-laying, while for the fish and the amphibia, the assured rainfall leads to spawning.

Because of its low altitude of under 300 metres above sea level, the temperatures are uniformly high, but fall during thunderstorms which are, of course, usually accompanied by copious precipitation which itself, tends to lower the temperature of the water still further.

2.2 Area of the Lake: The determination of the area of the lake was undertaken so as to have an idea of its size and also to compare its size with those of the other lakes already studied in Nigeria and elsewhere.

Two principal methods were used to calculate the area of the lake. One was the use of ordinate lengths from the scaled map of the lake. Here, the area was worked out by applying two rules – the Trapezoidal Rule, and the Simpson's Rule. In the other method, the area of the lake was determined by direct calculation. The methods are described below.

2.2.1 Using ordinates: In this method, the calculations were based on measuring the area of the lake, drawn to a known scale, from ordinates, using either the Trapezoidal Rule or the Simpson's Rule. In doing this, a line was described axially through its area, of equal distances along this irregular wedge-shaped body of water, and perpendicular ordinates were drawn and their lengths were scaled as illustrated in Fig. 3. The area of the lake was then determined either by the Trapezoidal Rule or by the Simpson's Rule as follows:

(a) Trapezoidal rule: In the Trapezoidal Rule, it is assumed that the short lengths of the boundary between the ordinates are straight lines, so that the area is divided into a series of trapezoids.

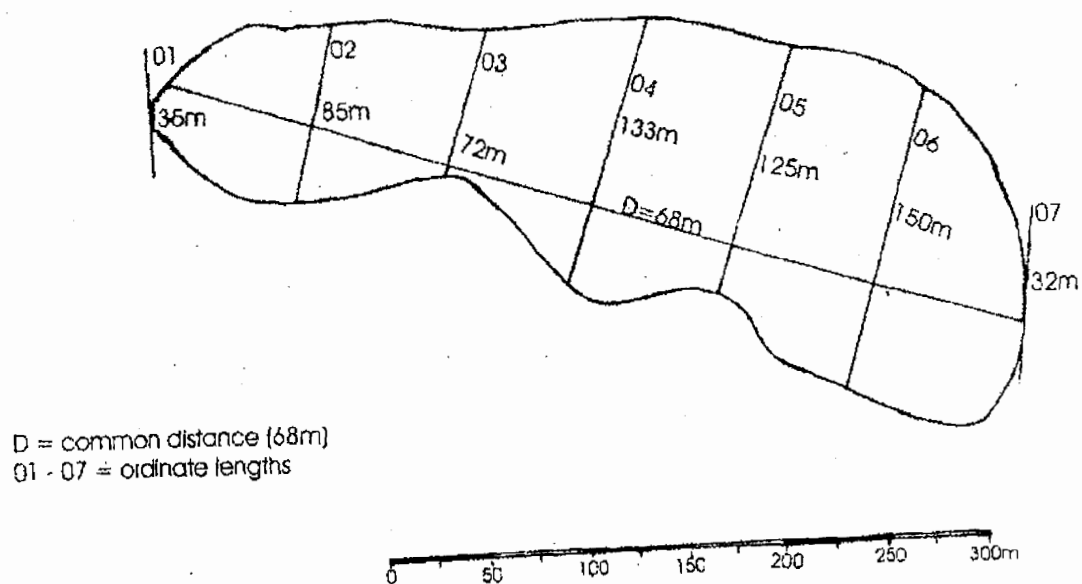


Fig. 3: Scaled map of Obutu lake showing ordinate lengths

If d = the common distance between the ordinates and $O_1, O_2, O_3 \dots O_n$ = ordinate lengths, then: The area of the first trapezoid = $O_1 + O_2 \div 2 \times d$. The area of the second trapezoid = $O_2 + O_3 \div 2 \times d$. The area of the last trapezoid = $O_{(n-1)} + O_n \div 2 \times d$. Summing up, the total area = $d (O_1 \div 2 + O_2 + O_3 + \dots + O_{n-1} + O_n \div 2)$. The total area, therefore, equals the common distance apart multiplied by the sum of half the first and last ordinates, plus all the others. It is important to note that where the length of either the first or last ordinate happens to be zero it must all be included, or otherwise, the area of the first or last trapezoid, which is then in fact, a triangle, will be omitted.

(b) Simpson's rule: The Simpson's rule assumes that the short lengths of boundary between alternate ordinates are parabolic curves. The area of such a segment is $\frac{2}{3}(p \times 2d)$, where p is the mid-ordinate of the segment (Fig. 3). The total mid ordinate for both segments on either side of the axial line is the difference between the whole mid ordinate, O_2 , and the mean of the two end ordinates of the two sections $(O_1 + O_3) \div 2$. The area of each pair of sections can then be calculated from the area of a trapezoid plus two parabolic segments. The area of the first two sections can be calculated thus: = $d \div 3 (O_1 + 4 \cdot O_2 + O_3)$. Area of next two sections was computed using the formula: = $d \div 3 (O_3 + 4 \cdot O_4 + O_5)$. And so on until the last pair of sections, ending with n th ordinate, the area of which is $d \div 3 [O_{(n-2)} + 4 \cdot O_{(n-1)} + O_n]$. Summing up, the total area = $d \div 3 [O_1 + 4 \cdot O_2 + 2 \cdot O_3 + 4 \cdot O_4 + \dots + 2 \cdot O_{(n-2)} + 4 \cdot O_{(n-1)} + O_n]$. This illustration expresses Simpson's Rule, which states that the area equals one third the common distance apart, multiplied by the sum of the first and the last ordinates, plus twice the sum of the other ordinates, plus four times the sum of the even ordinates. Simpson's Rule requires an even number of divisions of the area, i.e. the total number of ordinates must be odd.

2.2.2 Direct calculation: The scale provided in the original survey map (Fig. 4) was proportionately blown up to facilitate the measurement of the lake by direct calculation. In doing this, the figure of the lake was parcellated into rectangles and right-angled triangles

which were numbered serially (A – T). The area of each compartment in m² was then determined using the usual formula for finding the area of rectangle or triangle thus:

$$\text{Area of Rectangle} = (\text{Length} \times \text{Width}) \text{ m}^2$$

$$\text{Area of Right-angled Triangle} = (\frac{1}{2} \text{ base} \times \text{height}) \text{ m}^2$$

For the right-angled triangle, the hypotenuse was not considered, since the investigation did not involve such values as sine, cosine, tangent, etc.

2.3 Physico-Chemical Properties: Samples of the lake water were taken every 14 days to examine for some physico-chemical variables that may be influencing the ecology of the lake. The samples were taken from 20 sites (15 with snails and 5 without snails). Samples were usually collected bi-weekly between 8.00 am and 10.00 am for 12 months, from January to December, 2003. Numbers were assigned to the sampling sites of the lake which, for the purposes of this study were zoned into 4 depending on the position within the lake and the extent and type of vegetation cover. The physico-chemical factors studied include rainfall, temperature, turbidity, water level, water velocity, pH, water density, alkalinity and dissolved oxygen. These were studied according to the methods recorded in Ogbogu and Hassan (1996) which, in most details are those in APHA (1976). Details of how they were studied are as follows:

The lake was demarcated into three zones (A, B and C) for the purposes of this study. Zone A comprised all sites in marginal areas with vegetation cover, Zone B were all sites with submerged vegetation, and Zone C comprised all sites in open lake water.

The snail sampling data were compared with the physico-chemical variables to get some range of data on the snail abundance (abundance and density) and the variables. The relationships between the variables and between the snails and the variables were also investigated using correlation coefficients(r), coefficient of determination and stepwise

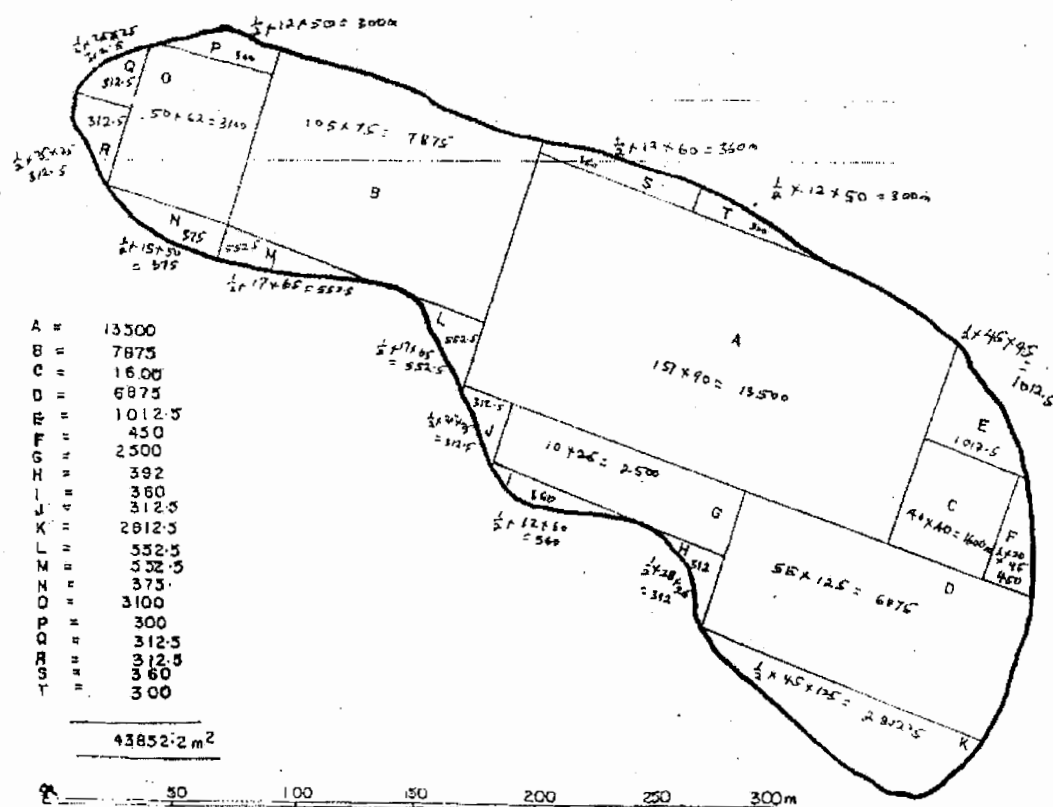


Fig 4: Scaled map of Obutu lake – direct calculation

regression analyses. These were used to elucidate the effects of the variables on snail distribution and abundance within Obutu Lake.

2.3.1 Rainfall: With the assistance of the officials of the Federal Department of Meteorology, a 'Casella London' rain gauge meter of 146 mm rim diameter was mounted at an open place within the premises of Community Primary School, Omogho, which is fairly close to the lake area. Readings were taken strictly at the end of the month, after which the instrument was completely emptied, thoroughly dried and remounted for the following month's investigation.

2.3.2 Temperature: Visits to the study area to take bi-weekly readings of air and water temperatures were a great task. To this end, officials of the Federal Department of Meteorology were mobilized to assist in taking some of the readings which were as much as possible made between 8.00 am and 10.00 am each day. A simple mercury-in-glass thermometer was used.

For air temperatures, the instrument was held upwards, ensuring that the hand held it firmly near the top, to avoid touching the bulb. This was left for two minutes in this position to attain a uniform temperature that was subsequently recorded immediately. Three such attempts in each zone were averaged to attain the air temperature during each visit, and the two values for the two visits to each zone in the month were averaged to obtain that zone's monthly air temperature.

Water temperatures were taken using the similar procedures employed for the air temperatures, but here, the thermometer bulb was held 0.5m below the surface of the water, and also left in that position for two minutes before it was pulled up and read off immediately. There were no measurements to indicate diurnal variations in temperature.

2.3.3 Turbidity: The turbidity of water (measurement of its transparency) is normally due to the presence of phytoplanktons and particulate materials in water. Imevbore (1970) showed that suspended matter in water was the major factor affecting its transparency.

Secchi disc was used in determining the transparency, otherwise referred to as the turbidity of the water in each zone. To do this, the disc was gradually lowered into the

water. The depth at which it disappeared was noted. It was again pulled up to the surface. The depth at which the disc reappeared was also noted. The average of the two readings gave the disc visibility value for the water. This process was repeated once more to get the final average values.

2.3.4 Water Depth: Wooden poles, graduated in metres, were used as depth gauges, to determine the depth of water in each zone. Bi-weekly readings were taken on each sampling day between 8.00 am and 10.00 am.

2.3.5 Water velocity: This was determined by measuring the distance covered downstream by a weighted floating cork per unit time. Here, the wooden pole used for the measurement of water levels, was taken as the starting point. The distance moved by the weighted cork in ten seconds was noted. This was repeated three times for each bi-weekly investigation, and the sum of the readings was averaged to determine the distance covered by float in ten seconds. The water velocity was then calculated as follows: - Distance moved by the cork (m) / Time (s); where m = metres; s = seconds

2.3.6 pH: Readings of the pH of the water were taken using a make model 23A direct-reading pH metre. Samples for the determination were secured 0.5m below the surface of the lake. Three readings were taken at the same time, and the average for each set of readings was recorded. The equipment was standardized to put it in order before use.

2.3.7 Water density: This is the ratio of mass of a substance to its volume. A 25 ml density bottle was cleaned thoroughly. The interior of the bottle and the capillary of the stopper were cleaned with a little industrial methylated spirit. This was repeated with a little diethyl ether. The bottle and stopper were allowed overnight to dry separately in an oven at 110 °C, after which they were removed, cooled in a desiccator and weighed empty. The weight of this bottle and stopper was noted. Then, the bottle was rinsed with fresh sample of the lake water, and filled with the sample, stoppered and weighed. This new weight was also noted. The density of the water sample was then calculated thus: -

Weight of bottle and sample = x; Weight of bottle = y; Weight of sample = (x-y);
 Volume of sample = 25 ml; Density of sample = (x - y) / 25.

2.3.8 Alkalinity: 100 ml of the fresh water sample was measured out using a measuring cylinder, into a 250 conical flask. Two drops of phenol red indicator were added to the sample. The sample was titrated against 0.02N H₂SO₄. The end point was reached when the colour changed from yellow to orange. Calculation was done by applying the formula:-
 Phenol red Alkalinity = $A \times N \times 50 \times 1000 / 100$; where A = Volume of acid used; N = Normality of the acid (0.02N)

2.3.9 Dissolved oxygen: Monthly samples were taken from the three zones from January to December, 2003. the samples were collected using 250 ml glass – stoppered reagent bottles which were put under water, filled with the water and stoppered under the water in that position, to exclude air.

The dissolved oxygen in each bottle was fixed using Winkler's reagents A and B. In this method, 2 ml of reagent A (manganous sulphate) were put into each bottle, followed with 2 ml of reagent B (alkaline potassium iodide). This precipitates out the dissolved oxygen in form of manganous hydroxide. The bottles were then transported to the laboratory for titrimetric analysis.

To each bottle, 2 ml. of concentrated sulphuric acid were added to dissolve the manganous hydroxide, and 100 ml of this water sample were transferred to a 250 ml volumetric flask and titrated against sodium thiosulphate, using eight drops of starch indicator. The end point was reached when the blue colour disappeared, and the volume of the titre was noted. Dissolved oxygen (mg of O₂/ litre of water) was determined thus:
 $\text{Volume of titre} \times N \times 8 \times 1000 / 100$ (volume of water sample). Where 8 is a constant (Equivalent weight of oxygen) and N= Normality of sodium thiosulphate (0.025)

2.4 Macrovegetation, Macro-Microphytes and Plankton Sampling: The macrovegetations and macrophytes were sampled using direct enumeration. The student plankton net was used for microphytes and planktons collection. This device consists of a

long, wooden handle with netting quite different from that of the scoop net. The nettings are very fine. A test tube is attached to the lower end of the net to aid in the collection of the planktons that must have entered through the open end of the netting which is attached to a circular metal frame. To use this net, the handle was held by hand while the frame, netting and the attached test-tube were lowered into the water column and moved along the water, to collect drifting organisms. All the materials collected were preserved in plastic bottles containing 10 % formalin and labelled according to the locations.

The preserved specimens were brought to the laboratory for identification. Every content of the plastic bottle was emptied into a white tray or Petri dish, according to the location from which it was collected, washed with water and separated from the attached mud, sand and other materials. The next step was to identify the organisms based in observed morphological structures recommended as taxonomic characteristics for the families, genera and species using (Pennask, 1953; Pimentel, 1967) as guides. In doing this, the samples which had sedimented on storage, were taken routinely and stirred to disengage the organisms which were then mounted on a slide and viewed under a x 40 light microscope.

2.5 Macroinvertebrates and Microinvertebrates Sampling: The collection of the snails from the lake was simultaneous with that of the macroinvertebrates, using the same scoop net as per the details of the collection shown above. To effect the recovery of the macroinvertebrates from the complex of suspended materials, sieves of 0.6 mm and 0.4 mm mesh sizes were used. The coarse mesh of 0.6 mm was placed over that of the thin mesh of 0.4 mm. The scooped sample was emptied into the top sieve to sieve out sand and mud, thereby exposing the animals to be collected with forceps. Jonasson (1955) observed that the commonly used sieve of 0.6 mm mesh size was insufficient, having failed to retain many chironomid larvae. This was what informed the use of the smaller mesh size of 0.4 mm to catch smaller larvae and eggs.

To extract smaller animals from the sample, the sediments were shaken with clean water and allowed to settle. Then the animals released from the soil particles, were filtered through the fine mesh. Care was taken during the sieving not to destroy some organisms. The remaining items were emptied into a shallow Petri dish and examined, and any small animal found was mounted on a slide and examined under the light microscope of x40 magnification.

2.6 Snails Sampling Programme: The study was conducted between October, 2000 and September, 2004. It involved visits to the lake twice every month to collect snails and other materials (e.g. plants, substratum, etc). The collection of snails was done using quantitative methods recorded by Hairston *et al.* (1958) as adapted by Okafor (1984). This method has been severally used by many other field workers, and it involved fractional sampling of the habitat and collection of snails from a given area of habitat. The scoop net of 0.6 mm and 0.4 mm mesh sizes were used.

The scoop net is a sac-like device attached to a triangular metal frame and an iron handle of a suitable length, for the collection of pelagic organisms and bottom dwellers including snails, as well as microinvertebrates and macroinvertebrates, and small-sized vertebrates including fish and amphibians, which are found in water about 2 metres from the surface.

To take samples, the lake was divided into 53 sites and each site was studied and searched for 15 minutes over an area covering 100 m² from the grassy fringes bordering the shorelines each time it was visited. Ropes and pegs were used to demarcate the area to be sampled during each visit, when the substratum, floating debris, inundated vegetation and aquatic plants were also examined. Three groups of trained snail collectors comprising three men in each group, were engaged to collect the snails from the sites. Each group worked for approximately four hours during each visit to be able to cover the 53 sites.

In scooping out the bottom, the handle of the net was held firmly and the open end of the net was dipped into the water until it touched the substratum. By applying pressure

on the handle, the iron frame of the net was pushed a bit into the substratum. The net was then dragged upstream against the current, to scoop the bottom substrate into the net. The net was consequently hauled out of water, and the contents were poured into a clean, dry, plastic bucket, after which they were screened using sieves. The snail specimens were then collected from the sieves. Care was taken to ensure that the net was not moved too fast so that it would push aside some water and the animals in it. The net was also not moved too slowly because more agile animals with good vision might be able to avoid it. These measures were taken since the collection of the snails was simultaneous with that of macro invertebrate bottom dwellers in some instances.

This method by which a scoop net of 0.6 mm and 0.4 mm mesh sizes was used for sampling, at least, six metres from the shore-line into the body of the lake, ensured the collections of as representative a sample of snails as possible from any site visited. In these ways snails from the substratum, floating debris, inundated vegetation and aquatic plants were collected. The most important feature of this net was its ability to maintain a constant mesh size under all working conditions.

2.6.1 Identification of snails: The identification of the snails was made directly in the field. However, those which could not easily be identified were taken to the laboratory and identified with the assistance of my supervisor, and through reference to relevant publications on snail taxonomy eg Brown (1980), as well as through web downloads.

2.6.2 Preservation of snails: The fate of the specimens collected and identified depended on the investigations to which they were put. For instance, those that were used for studies on abundance, frequency of occurrence and their biotic interactions within the lake, and which were also used for correlation values for interspecies associations, as well as their reactions to physico-chemical factors, were partly identified in the field and partly in the laboratory. Thereafter some of them were either maintained alive for further analyses or preserved in 10 % formalin for statistical measurements.

The snails for studies on parasitic interactions/transmissions were jealously guarded, as they were subjected to careful examinations immediately they were collected and transported to the laboratory where they were subsequently screened for cercariae for many days before they were preserved in 10 % formalin. The gastropods, whose gut contents were investigated to know the natural foods of the snails in the lake, were all sacrificed and their stomach contents were examined using photomicrograph. Care was taken to ensure that very little time was lost between the capture of the snails and the investigation of the gut contents. This was to inspect the stomach contents before they were subjected enzymatic deterioration. Other details concerning this aspect of the work will be given in the relevant chapters.

2.6.3 Distribution and abundance of snails: Individual sites were sampled as earlier stated and the collection for each site was kept apart and analysed separately. The snails were collected from different sites within the lake. They were taken to the laboratory where they were washed, measured and identified.

Snail infra-communities are defined as communities of intraspecific populations within a site. Species richness, Brillouin's diversity index and Simpson's index of dominance were calculated for each snail species according to Magurran (1983). Brillouin's index was used for snail species diversity evaluation and calculated for each infra-community as $H = 1/N \log_e (N!/N_1! N_2! N_3! \dots N_s!)$

Where N is the total number of a particular species; $N_1, N_2, N_3, \dots N_s$ are the numbers of species in each site. Simpson's index of dominance was calculated as follows:

$D = \sum [n_i(n_i - 1) / N(N - 1)]$ where n_i is the number of species i and N is the total number of individuals.

For qualitative comparison between samples, Jaccard's index of similarity was used: $J = 100c / (a + b + c)$, where a is the number of snail species in the first site, b is the number in the second site, c is the number of snails which occur together in both sites.

For quantitative comparison between samples, Steinhaus's coefficient was used as $S = 2W (A + B)$, where A and B are the sums of the abundances of all species in one study site, W is the sum of the minimum abundances of different species in one site (i.e. the sum is calculated using snail species with the lowest abundance in each site. All these indices were used as in Legendre and Legendre, (1998).

2.7 Stomach Content Analysis: Snails in this study were sacrificed by cracking their shells and immediately dropping them into 10% formalin. Later, in the laboratory, they were washed and transferred into fresh 10% formalin.

The snails were opened using forceps. The entire stomach (which included crop, gizzard and pyloris) was removed and the contents were emptied into the Petri dish.

Drops of formol-glycerol were added and the contents were mixed together. The contents were subsequently examined under the light microscope.

Direct observations were also made of the feeding habits and food preferences during the day. Where possible, faeces were collected the day after the observed feeding and examined for undigested materials.

2.8 Trematode Infections of Snails: The study was conducted between October 2000 and September 2004. It involved several visits to the lake to collect snail samples and other environmental data. The snails collected from their habitats were maintained in filtered lake water and on a diet of lettuce leaves. White blackboard chalk was added to serve as a source of calcium for the snails. The snails were sorted out into genera and were kept in groups. Each group was initially screened collectively for cercariae shedding. In the group where cercariae were found, individual snails were screened by isolating them in a beaker containing 25 ml of clean water. All the snails were kept in the same area of the laboratory, at the same temperature of 29 °C and received the same light intensity and periods of light and darkness (approximately 12 hours each).

Every 24 hours the water from each group was taken and put in a watch glass after shaking and a 1 ml aliquot was taken. 10 drops of lugol solution were added to the 1 ml sample and viewed under the microscope. The lugol solution kills and stains any cercariae in the water, allowing the number of cercariae per ml of water to be calculated. This was repeated many times for each sample of water and the mean of the several counts and hence the total number of cercariae per 25 ml sample was calculated for each snail isolate.

After each set of counts the water sample was changed so that the cercariae production of the group was not affected.

Any cercaria found was identified. The level of parasite infection was assessed. Prevalence was calculated as the percentage of snails infected by any trematode species. Mean intensity of a parasite is the average intensity of parasite species in a sample of snails collected at one site. Mean abundance of parasites is the average abundance of a parasite species among all snail host individuals of the snail population.

Parasite nestedness was analyzed using the method of Atmar and Patterson (1995). When doing the nested analysis, the presence - absence matrix is constructed. The matrix specifies which species occur in which sites and reflects the relative hospitability of sites to the species. The matrix is then packed to the state of maximal nestedness. The site positioned on the top of the matrix is considered as the most hospitable. The species positioned in the left corner of the matrix presents a species for which niche requirements are most common and prevalent. This species is more stable. In the perfectly nested matrix (i.e. the matrix which is created by packing to maximal nestedness), the set of species on any site is the subset of all species on the sites preceding in the matrix. To calculate the distribution of the parasites, presences and absences were used.

CHAPTER THREE

RESULTS

3.1 Area of Obutu Lake: The area of the lake was determined either by the Trapezoidal Rule or by Simpson's Rule using the ordinate lengths, and also by direct calculation.

a) Trapezoidal rule: Each interval (equal distance) was 68 m, and half the sum of first and last ordinates was $\frac{1}{2} (3.5 + 32) = \frac{1}{2} (35.5) = 17.75$ m. Summing up of the remaining ordinates gave $85 + 72 + 133 + 125 + 150$, which is equal to 565 m. The total ordinate lengths = $17.75 + 565 = 582.75$ m. The area therefore was $68 \times 582.75 = 39,627 \text{ m}^2$.

b) Simpson's rule: Sum of first and last ordinates = $3.5 + 32 = 35.5$. Twice the sum of all other odd ordinates was $4(85 + 133 + 150) = 4(368) = 1472$. The total ordinate lengths = $35.5 + 394 + 1472 = 1901.5$. The area therefore was $68/3 \times 1901.5 = 43,100.665 \text{ m}^2$.

c) Direct calculation: The areas of all the compartments (A – T) were then summed up to give the area of the lake which, according to Fig. 4 was calculated as $43,852.20 \text{ m}^2$. Furthermore, the lake had maximum length of 450 m, maximum width of 150 m, and perimeter of 1,100 m

3.2 Physico-chemical Properties of Obutu Lake

3.2.1 Rainfall: There were varying levels of monthly rainfall throughout that year (Fig. 5). July, 2003 recorded the highest rainfall of 425.4 mm. The sharp drop to 212.5 mm in August was due to the short break in the rains in early August. The figure rose again to 383.3 mm in September, and dropped to 249.5 mm in October. December 2003, recorded the lowest rainfall of 1.3 mm. The annual average rainfall was 156.9 mm.

3.2.2 Temperature: The temperatures were uniformly high with a small monthly air temperature range of 7.2°C and a monthly water temperature range of 5.0°C . The highest air temperature of 36.1°C was recorded in February, 2003, while the highest water temperature of 28.8°C was documented in March, 2003 (Table 2).

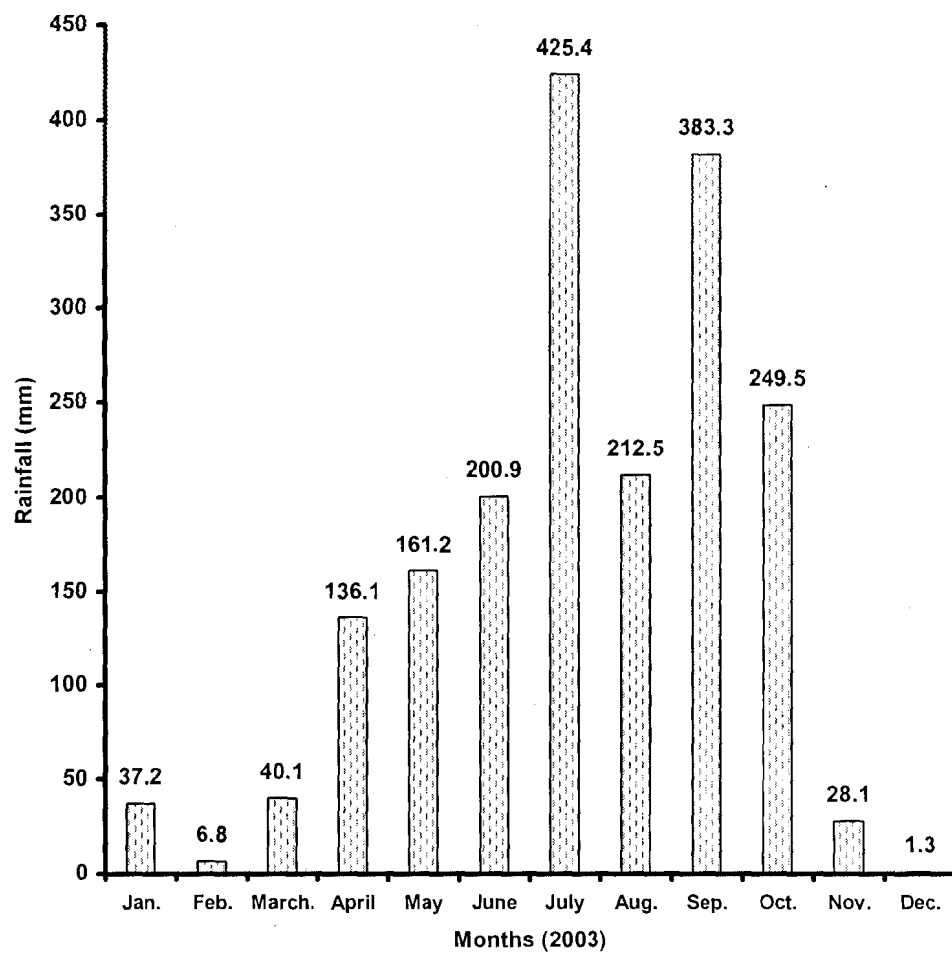


Fig. 5: Monthly rainfall patterns in Obutu lake

Table 2: Monthly distribution of air and water temperatures in Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
Air Temperature				
January	33.4	34.6	34.8	34.3
February	34.7	35.3	36.1	35.4
March	34.2	34.8	35.5	34.8
April	33.5	33.5	34.0	33.7
May	32.8	33.0	33.2	33.0
June	32.5	32.9	33.2	32.9
July	31.0	31.5	32.4	31.6
August	28.9	29.2	29.6	29.2
September	29.2	29.7	30.2	29.6
October	29.8	31.3	31.8	31.0
November	31.6	31.8	32.0	31.8
December	32.0	32.3	32.7	32.3
Range per zone	28.9- 34.7	29.2 – 35.3	29.6 – 36.1	-
Average per zone	32.0	32.5	32.9	-
Water Temperature				
January	27.5	27.9	28.0	27.8
February	28.0	28.4	28.6	28.3
March	28.2	28.5	28.8	28.5
April	27.9	28.0	28.5	28.1
May	26.5	28.2	28.6	27.8
June	24.6	25.0	25.5	25.0
July	24.0	24.8	25.0	24.6
August	23.8	24.0	24.2	24.0
September	26.6	26.9	27.1	26.9
October	27.0	27.3	27.8	27.4
November	27.6	28.0	28.3	28.0
December	26.9	28.2	28.4	27.8
Range per zone	23.8 – 28.2	24.0 – 28.5	24.2 – 28.8	-
Average per zone	26.6	27.1	27.4	-

3.2.3 Turbidity: The turbidity of the lake which ranged from 0.32 to 0.46 was as a whole poor (Table 3). The lowest turbidity values were recorded during the peak of the rains in August (0.32) and September (0.32) 2003. The highest level of transparency was recorded in February (0.46). The range of values for the zones as well as the annual average values did not show marked variations, as they were 0.35 – 0.45 for zone A; 0.33 – 0.46 for zone B and 0.32 – 0.39 for zone C. Zones A, B and C had annual turbidity values of 0.40, 0.39 and 0.36 respectively.

3.2.4 Dissolved oxygen: Monthly average values ranged from 5.99 mg O₂/litre of water in March, to 7.52 mg O₂/litre water in August, 2003. The highest value of dissolved oxygen (7.52 mg O₂/litre of water) was taken in Zone B in January 2003, while the lowest DO value (5.99 mg O₂/litre of water) was recorded in Zone A in March 2003. There was indeed a narrow range of mean values between the zones thus: 6.60 – Zone A, 7.25 – Zone B and 7.07 – Zone C. From Table 9, the oxygen content of the water was more during the rains than in the dry season months.

3.3 Macrovegetation, Macro-Microphytes and Planktons of Obutu Lake

Only 2 species of macro vegetation namely *Napoleona volgelli* and *Lagerstroemia indica* were found in the lake. Out of the 312 specimens collected in all, 198 (63.46 %) belonged to *N. volgelli*, while 114(36.54) were those of *Lagerstroemia indica*. Few specimens of *L. indica* 9(7.89) were the only macrovegetation found in zone C (Table 10.) Furthermore, Table 10 showed that a total of 1438 macrophytes comprising 15 identified species were found in Obutu lake. Out of this number, *Aspilia africana* was the most numerous 203(14.12 %). This was followed by *Ceratophyllum* sp, 154(10.71 %) and *Commelina* sp 144(10.01 %) respectively. Graminae 24(1.67%) recorded the least group of macrophytes within the lake. There appeared to be the general trend for the greatest abundance of these species in zone A, followed by zone B. However, *Nymphaea* sp was most abundant in zone B, while *Commelina* sp., *Acroceras* sp., *Ceratophyllum* sp., *Altenanthera* sp and graminiae were most abundant in zone C. *Melanther scandens* was not found in zone C. Table 10 also shows that 6 species of

aquatic microphytes were identified from Obutu lake. The microphytes, which totaled 1349, were represented by desmids (*Cosmarium sp* and *Closterium sp*), diatoms (*Gomphonema sp* and *Navicula sp*) and filamentous alga (*Oscillatoria*) and non-filamentous algae (*Phacus sp*).

Table 3: Monthly Turbidity Patterns of Obutu Lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	0.42	0.40	0.38	0.40
February	0.45	0.46	0.39	0.43
March	0.45	0.45	0.38	0.43
April	0.43	0.40	0.36	0.40
May	0.41	0.38	0.35	0.38
June	0.41	0.36	0.34	0.37
July	0.40	0.34	0.33	0.36
August	0.37	0.34	0.32	0.34
September	0.35	0.33	0.32	0.33
October	0.36	0.39	0.35	0.37
November	0.41	0.39	0.36	0.39
December	0.40	0.39	0.38	0.39
Range per zone	0.35 – 0.45	0.33 – 0.46	0.32 – 0.39	-
Average per zone	0.40	0.39	0.36	-

Table 4: Monthly variations in water level patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	2.9	4.9	5.1	4.3
February	2.4	4.6	5.0	4.0
March	3.9	5.1	5.5	5.4
April	4.8	5.6	5.9	5.7
May	5.1	5.9	6.2	6.5
June	6.0	6.5	6.9	8.6
July	6.5	9.2	10.0	6.5
August	8.1	8.9	9.4	8.8
September	5.8	8.5	8.8	6.7
October	4.8	7.9	8.3	7.0
November	4.3	5.6	6.2	5.4
December	3.1	3.8	4.5	3.8

Table 5: Monthly variations in water velocity (m/sec) patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	0.068	0.070	0.073	0.070
February	0.065	0.071	0.075	0.070
March	0.066	0.070	0.074	0.070
April	0.067	0.071	0.075	0.071
May	0.068	0.072	0.078	0.073
June	0.073	0.079	0.081	0.078
July	0.078	0.082	0.088	0.083
August	0.080	0.085	0.090	0.085
September	0.082	0.085	0.094	0.087
October	0.081	0.080	0.088	0.083
November	0.070	0.072	0.086	0.076
December	0.068	0.070	0.078	0.072
Range per zone	0.065 – 0.082	0.070 – 0.085	0.073 – 0.094	-
Average per zone	0.073	0.076	0.082	-

Table 6: Monthly variations in pH patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	7.02	7.18	7.23	7.14
February	7.20	7.28	7.30	7.26
March	7.28	7.35	7.26	7.30
April	7.35	7.35	7.28	7.33
May	7.10	7.23	7.30	7.21
June	6.89	6.96	7.12	6.99
July	6.67	6.80	6.82	6.76
August	6.56	6.70	6.85	6.70
September	6.15	6.55	6.95	6.55
October	6.21	6.30	6.25	6.25
November	6.45	6.60	6.82	6.62
December	6.96	6.98	7.02	6.99
Range per zone	6.15 – 7.35	6.30 – 7.35	6.25 – 7.30	-
Average per zone	6.82	6.94	7.02	-

Table 7: Monthly variations in water density patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	1.0722	1.0692	1.0620	1.0680
February	1.0760	1.0700	1.0658	1.0706
March	1.0790	1.0724	1.0680	1.0731
April	1.0792	1.0715	1.0695	1.0734
May	1.0647	1.0578	1.0547	1.0591
June	1.0615	1.0599	1.0482	1.0565
July	1.0586	1.0505	1.0464	1.0518
August	1.0525	1.0490	1.0460	1.0492
September	1.0505	1.0480	1.0440	1.0475
October	1.0547	1.0475	1.0435	1.0486
November	1.0590	1.0535	1.0495	1.0540
December	1.0612	1.0573	1.0565	1.0583
Range per zone	1.0505 – 1.0792	1.0475 – 1.0724	1.0435 – 1.0695	-
Average per zone	1.0641	1.0589	1.0545	-

Table 8: Monthly variations in water alkalinity (mg C_2CO_3 /litre of water) patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	193.0	187.3	178.0	186.1
February	191.3	187.0	186.4	188.2
March	190.5	188.0	185.6	188.0
April	190.4	187.4	185.7	187.8
May	187.8	187.0	186.0	186.9
June	187.3	184.6	184.0	185.3
July	186.2	184.7	182.9	184.6
August	185.0	182.5	181.1	182.9
September	184.5	182.6	181.4	182.8
October	191.0	186.0	185.1	187.4
November	191.6	187.5	187.0	188.7
December	192.8	188.6	187.5	189.6
Range per zone	184.5 – 193.3	182.5 – 188.6	181.1 – 187.5	-
Average per zone	189.5	185.9	185.2	-

Table 9: Monthly variations in Dissolved Oxygen (mg O₂/ litre of water) patterns of Obutu lake (2003)

Month	Zones			Monthly average
	A	B	C	
January	6.10	7.52	6.75	6.79
February	6.11	6.93	6.93	6.66
March	5.99	7.30	6.99	6.76
April	6.10	7.50	7.20	6.93
May	6.83	7.40	7.22	7.15
June	6.99	7.38	7.20	7.19
July	6.84	6.92	6.89	6.88
August	6.80	6.89	6.91	6.90
September	6.89	7.20	7.30	7.13
October	6.77	7.25	7.25	7.09
November	6.74	7.30	7.25	7.10
December	6.98	7.45	7.00	7.14
Range per zone	5.99 – 6.99	6.89 – 7.52	6.75 – 7.30	-
Average per zone	6.60	7.25	7.07	-

Table 10: Macrovegetation, Macro-Microphytes and Planktons of Obutu lake(2003)

Taxon	Species	Total number collected	Zone		
			A	B	C
Macrovegetation (312)	<i>Napoleona volgelii</i>	198(63.46)	135(68.18)	63(30.30)	-
	<i>Lagerstroemia indica</i>	114(36.54)	78(68.42)	27(23.68)	9(7.89)
Macrophytes (1438)	<i>Lemna sp</i>	62(4.31)	24(38.71)	16(25.81)	22(35.48)
	<i>Andropogon sp.</i>	108(7.51)	50(46.30)	20(18.52)	38(35.19)
	<i>Pistia stratiotes</i>	107(7.44)	40(37.38)	36(33.64)	31(28.97)
	<i>Nymphaea sp</i>	123(8.55)	22(17.89)	87(70.73)	14(11.38)
	<i>Commelina sp</i>	144(10.01)	39(27.08)	43(29.86)	62(43.06)
	<i>Acrocerus zizanoides</i>	66(4.59)	24(36.36)	13(19.70)	29(43.94)
	<i>Ludwigia leptocarpa</i>	92(6.40)	46(50.0)	33(38.87)	13(14.13)
	<i>Sphenoclea zeylanica</i>	62(4.31)	23(37.10)	17(27.42)	22(35.48)
	<i>Ceratopteris cornuata</i>	154(10.71)	14(9.09)	37(24.03)	103(66.88)
	<i>Aspilia Africana</i>	203(14.12)	81(39.90)	63(30.03)	59(29.06)
	<i>Melanther scandens</i>	37(2.57)	19(51.35)	18(48.65)	-
	<i>Altenanthera sessilis</i>	46(3.20)	7(15.22)	11(23.91)	28(60.87)
	<i>Graminiae</i>	24(1.67)	7(29.17)	4(16.67)	13(54.17)
	<i>Solanum sp.</i>	118(8.21)	52(44.07)	31(26.27)	35(29.66)
	<i>Cyclosorus sp</i>	92(6.40)	46(50.0)	28(30.43)	18(19.57)
Microphytes (1349)					
Desmids	<i>Cosmarium sp</i>	240(16.25)	144(60)	62(16.25)	34(14.17)
	<i>Closterium sp</i>	107(7.25)	56(25.83)	39(36.45)	12(11.21)
	<i>Gomphonema sp</i>	252(17.06)	126(50)	74(29.37)	52(20.63)
Diatoms	<i>Navicula sp</i>	306(29.38)	133(30.65)	94(21.66)	79(8.20)
Filamentous algae	<i>Oscillatoria sp</i>	184(12.46)	92(50)	56(30.43)	36(19.57)
Non-filamentous algae	<i>Phacus sp</i>	260(17.60)	109(41.92)	82(31.54)	69(26.54)
Total		3099	1367	954	778

Note: Figure in bracket represents percentage of total number of macroinvertebrates collected

The diatoms 558(41.64) were the most abundant microphytes found in the lake. These microphytes were recovered mostly from zones A and B (areas with vegetation cover and submerged vegetation).

3.4 Macroinvertebrates and Microinvertebrates of Obutu lake

The total of 27,958 macroinvertebrates collected and identified comprised 4 phyla namely, Arthropoda, Mollusca, Annelida and Nematoda. Arthropoda was represented by three classes (the Insecta comprising 9 orders; the Arachnida with 4 species, and Crustacea also with 4 species). Phylum Mollusca consisted of 11 species (9 prosobranchs and 2 pulmonates); Phylum Annelida was represented by 2 classes – Hirudinea and Oligochaeta (Table 11). Phylum Nematoda had 2 species *Cosmocercoides* sp and *Aplectana gigantica*. The arthropoda, comprising 14318 (51.21 %) members were the most abundant in the lake, with the coleopteran 3822 (13.67%) and the Odonata 3624 (11.67%) topping the list, while the Lepidoptera 122(0.44%) was the least group of arthropods found in the lake. Phylum Mollusca with a total of 13149 members (47.03) were also abundant in the lake. Of this group, *Lanistes* and *Pila* were preponderant. The distribution of the arthropods and macroinvertebrates in the three zones of the lake was broadly similar but differed in abundance. Zones A and B (areas with vegetation cover and submerged vegetation respectively) harboured more macroinvertebrates than zone C (open water). The gastropod mollusks which were abundant in the lake were found mostly in zone A (marginal areas with vegetation cover) and in zone A (areas with submerged vegetation). With the exception of in *Gyraulus costulatus* and *Bythinia* sp, all the species of gastropods encountered were found in zone A. The arboreal snails (*Orthalicus* sp, *Bulinulus* sp, and *Drymaeus multilineatus*), *Gyraulus constulatus*, *Potadoma freethii* and *Bythinia* sp were absent in zone C (open water). With the exception of *Dero* sp (Oligochaeta), all the other species of the Phylum Annelida and of the Phylum Nematoda taken were not found in zone C (open water). The distribution of microinvertebrates in the lake was fairly similar.

Table 11: Macroinvertebrates and Microinvertebrates of Obutu lake

Taxon	Species	Total No. Collected	A	B	C
Phylum Arthropoda 14318 (51.21)					
Class Insecta 13949 (49.89)					
Ephemeroptera 106 (0.38)	- <i>Baetis</i> sp (Plate 1)	30	8(26.7)	19(63.3)	3(10.0)
	- <i>Centroptilum</i>	28	6(21.43)	22(78.6)	-
	- <i>Procladius</i> sp	48	18(37.5)	24(50)	6(12.5)
Plecoptera 228 (0.81)	- <i>Belostoma</i> sp (Plate 2)	152	29(19.1)	114(75.0)	9(5.92)
	- <i>Neoperia bredoana</i>	46	18(39.1)	22(47.8)	6(13.0)
	- <i>Nemileptocerus gregarius</i>	19	6(31.6)	9 (47.4)	4(21.1)
	- <i>Pseudoleptocerus</i> sp	11	4(36.4)	7(63.6)	-
Trichoptera 281 (1.01)	- <i>Orthotrichia</i> sp	48	14(29.2)	23(47.9)	11(22.9)
	- <i>Macronema</i> sp	59	38(64.4)	16(27.1)	5(8.5)
	- <i>Dipseudopsis capiensis</i>	52	23(44.2)	16(30.8)	13(25.0)
Lepidoptera 122 (0.44)	- <i>Nymphula</i> sp (larva). (Plate 3)	122	44(36.1)	62(50.8)	16(13.1)
Coleoptera 3822 (13.67)	- <i>Synchortus</i> sp (Plate 4)	76	14(18.4)	53(69.7)	9(11.8)
	- <i>Dytiscus</i> sp (Plate 5)	48	12(25.0)	31(64.6)	5(10.4)
	- <i>Hydrous piceus</i> (Plate 6)	54	16(29.6)	29(53.7)	9(16.7)
	- <i>Gyrinus natator</i> (Plate 7)	2462	621(25.2)	1446(58.7)	395(16.0)
	- <i>Haemonia</i> sp (Plate 8)	558	126(22.58)	338(60.57)	94(16.85)
	- <i>Hydrophilid</i> sp (Plate 9)	624	226	320(52.3)	78(12.5)
Orthoptera 3187 (11.40)	- <i>Grylotalpa</i> sp (Plate 10)	125	37(29.6)	84(67.2)	4(3.2)
Diptera 2919 (10.22)	- <i>Chironomus</i> sp (larva) (Plate 11)	243	16(6.58)	184(75.72)	43(17.78)
	- <i>Tanutarsus</i> sp	2354	596(25.3)	1456(61.9)	302(12.8)
	- <i>Phallomacromia</i> sp (Plate 12)	262	92(35.1)	146(55.7)	24(9.2)
Odonata 3264 (11.67)	- <i>Libellula</i> sp (Plate 13)	629	118(18.8)	438(69.6)	73(11.6)
	- <i>Coenagrion</i> sp (Plate 14)	1341	522(38.9)	684(51.0)	135(10.1)
	- <i>Presba</i> sp	334	124(37.1)	166(49.7)	44(13.2)
	- <i>Panatala</i> sp	960	340(35.4)	524(54.6)	96(10.0)
Heteroptera 1332 (4.76)	- <i>Corixa</i> sp (Plate 15)	803	260(32.4)	442(530)	101(12.6)
	- <i>Plea</i> sp (Plate 16)	242	102(42.15)	124(51.24)	16(6.61)
	- <i>Rhagovelia</i> sp (Plate 17)	287	99(34.5)	126(43.9)	62(21.6)
Hemiptera 1199 (4.29)	- <i>Gerris</i> sp	746	198(26.5)	450(60.3)	98(13.1)
	- <i>Ranatra</i> sp	60	13(21.7)	43(71.7)	4(6.7)
	- <i>Naucoris</i> sp (Plate 18)	170	62(36.5)	96(56.5)	12(3.2)
	- <i>Notonecta</i> sp (Plate 19)	62	19(30.6)	41(66.1)	2(3.2)
	- <i>Nepa</i> sp (Plate 20)	161	42(26.1)	106(65.8)	13(8.1)
Arachinda	- <i>Hygrobates</i> sp (Plate 21)	49	12(24.5)	33(67.3)	4(8.2)

235 (0.84)	- <i>Hydrachna</i> sp (Plate 22)	102	32(31.4)	26(25.5)	44(43.1)
	- <i>Aranea</i> sp	41	19(46.3)	22(53.7)	-
	- <i>Argyronecta</i> sp (Plate 23)	43	33(76.7)	10(23.3)	-
Crustacea	- <i>Neglectus</i> sp	88	14(15.9)	66(75)	8(9.1)
369(1.32)	- <i>Stenocypris</i> sp	69	33(47.8)	22(15.2)	14(20.3)
	- <i>Acocypris</i> sp	65	32(49.2)	22(33.8)	11(16.9)
	- <i>Cardina africana</i>	147	29(19.7)	76(51.7)	42(28.6)
Phylum Mollusca	- <i>Lanistes lybicus</i>	1794	818(45.60)	976(54.40)	-
13149(47.03)	- <i>Lanistes ovum</i>	6480	2540(39.2)	3682(56.1)	258(4.0)
	- <i>Lymnaea natalensis</i>	1564	1564(100)	-	-
	- <i>Pila wernei</i>	306	297(97.1)	-	9(2.9)
	- <i>P.ovata</i>	2036	1564(76.8)	-	472(23.2)
	- <i>Gyraulus costulatus</i>	9	-	-	9(100)
	- <i>Bythinia</i> sp	102	-	-	102(100)
	- <i>Potadoma freethii</i>	444	444	-	-
	- <i>Orthalicus</i> sp	124	124 (100)	-	-
	- <i>Drymaeus multilineatus</i>	196	196(100)	-	-
	- <i>Bulimulus</i> sp	94	94(100)	-	-
Phylum Annelida					
Class Hirudinea	- <i>Piscicola</i> sp	168	82(48.8)	39(23.2)	47(28.0)
242(0.86)	- <i>Others (unidentified)</i>	74	23(32)	22(29.7)	29(39.2)
Class Oligochaetae	- <i>Dero</i> sp	145	44(30.3)	89(61.2)	12(8.3)
193	- <i>Euridilus</i> sp	48	12(21.1)	36(63.2)	-
Phylum Nematoda	- <i>Cosmocercoides</i> sp	38	6(15.8)	32(84.2)	-
56(0.20)	- <i>Aplectana gigantea</i>	18	9(50)	9(50)	-
Total		27958	12028	13172	2758
Phylum Rotifera	- <i>Monostyla</i> sp	69(12.83)	16(23.19)	24(34.78)	29(42.0)
293(54.47)	- <i>Branchionus</i> sp	126(23.42)	56(44.44)	48(38.10)	22(17.46)
	- <i>Lecane</i> sp	98(18.22)	44(44.90)	31(31.63)	23(23.47)
Phylum Protozoa	- <i>Diffugia</i> sp	103(19.14)	38(36.90)	46(44.66)	19(18.45)
245(45.54)	- <i>Arcella</i> sp	142 (26.39)	56(39.44)	62(43.66)	14(9.86)
Total		538	210	211	107

Note: Figure in bracket represents percentage of total number of macroinvertebrates collected.

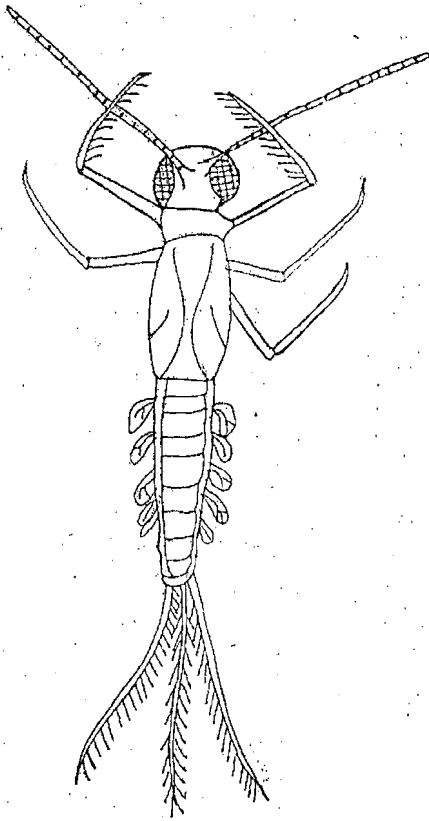


Plate 1: *Baetis* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Ephemeroptera
 Family: Baetidae
 Genus: *Baetis* [Mag. x 5]

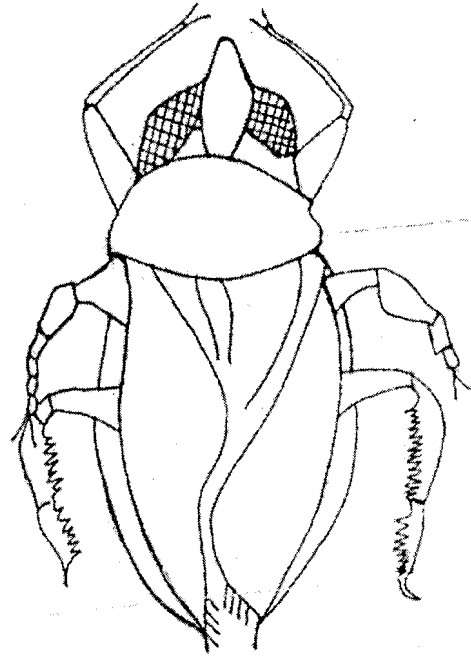


Plate 2: *Belostoma* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Plecoptera
 Family: Belostomidae
 Genus: *Belostoma* [Mag. x 8]

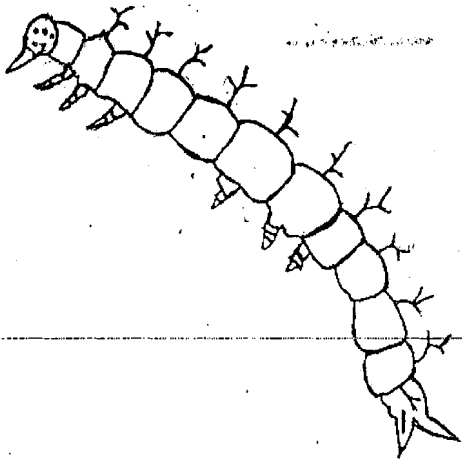


Plate 3: *Nymphula* sp (larva)
 Phylum: Arthropoda
 Class: Insecta
 Order: Lepidoptera
 Family: Nymphulidae
 Genus: *Nymphula* [Mag. x 6]

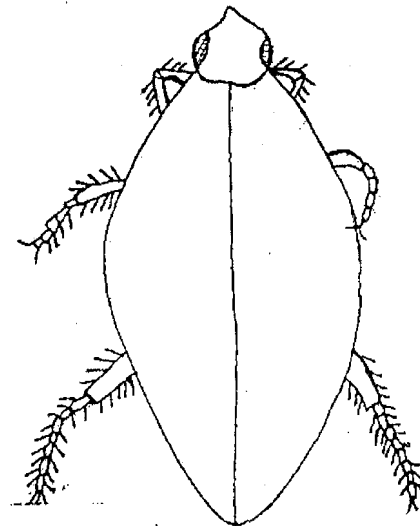


Plate 4: *Synchronus* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Synchronidae
 Genus: *Synchronus* [Mag. x 5]

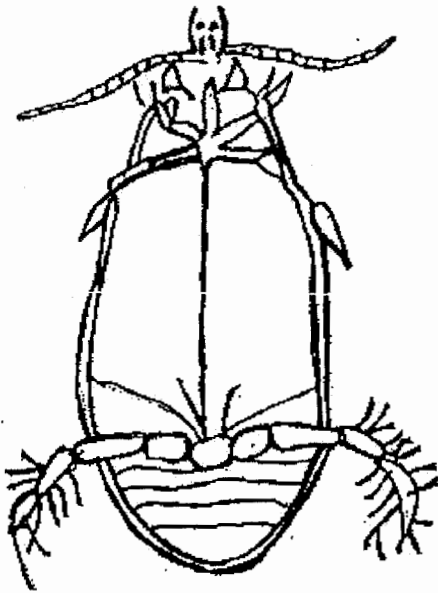


Plate 5: *Dytiscus* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Dytiscidae
 Genus: *Dytiscus* [Mag. x 8]

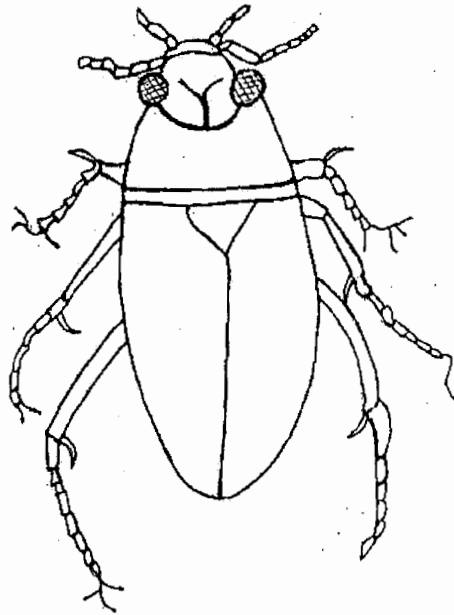


Plate 6: *Hydrous piceus*
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Hydrophilidae
 Genus: *Hydrous* [Mag. x 8]

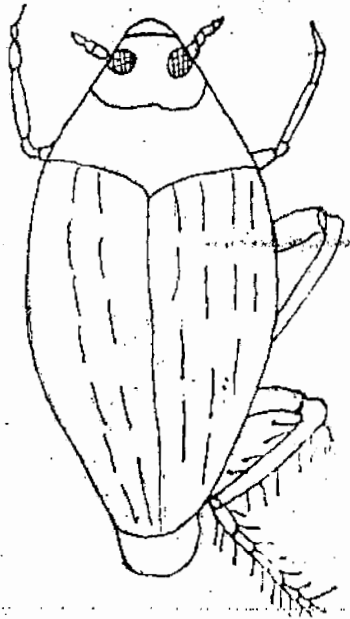


Plate 7: *Gyroux natator*
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Gyrinidae
 Genus: *Gyroux* [Mag. x 6]

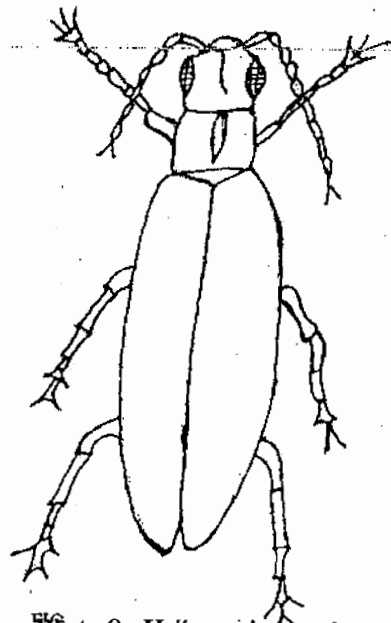


Plate 8: *Haëmonia* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Chrysomelidae
 Genus: *Haëmonia* [Mag. x 8]

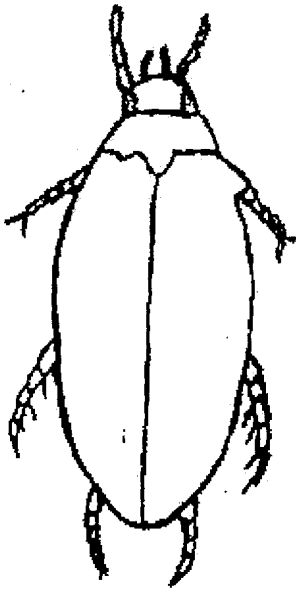


Plate 9: *Hydrophilid* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Coleoptera
 Family: Hydrophilidae
 Genus: *Hydrophilid* [Mag. x 7]

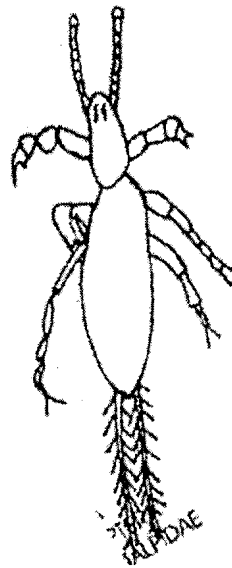


Plate 10: *Gryllotalpa* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Orthoptera
 Family: Gryllotalpidae
 Genus: *Gryllotalpa* [Mag. x 8]

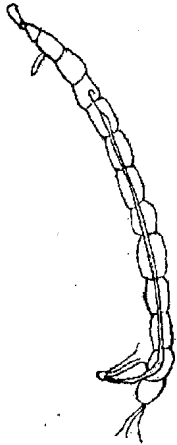


Plate 11: *Chironomus* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Diptera
 Family: Chironomidae
 Genus: *Chironomus* (larva) [Mag. x5]

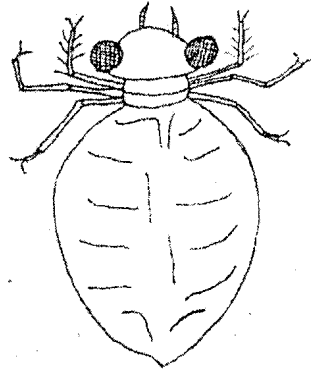


Plate 12: *Phallomacromia* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Odonata
 Family: Cordullidae
 Genus: *Phallomacromia* [Mag. x 7]

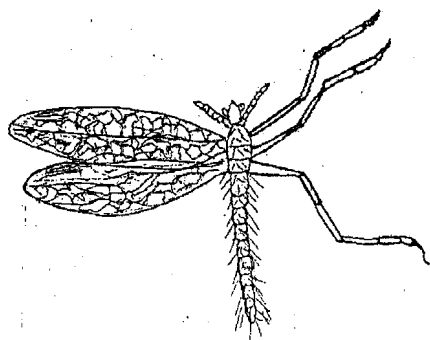


Plate 13: *Libellula* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Odonata
 Family: Libellulidae
 Genus: *Libellula* [Mag. x 3]

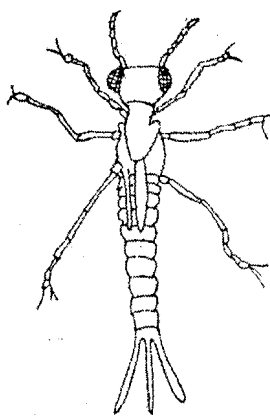


Plate 14: *Coenagrion* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Odonata
 Family: Coenagrionidae
 Genus: *Coenagrion* (nymph) [Mag. x 6]

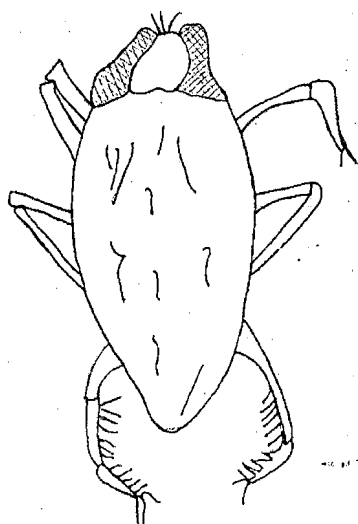


Plate 15: *Corixa* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Corixidae
 Genus: *Corixa* [Mag. x 5]

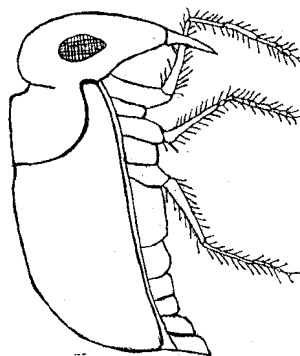


Plate 16: *Plea* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Pleidae
 Genus: *Plea* [Mag. x 8]

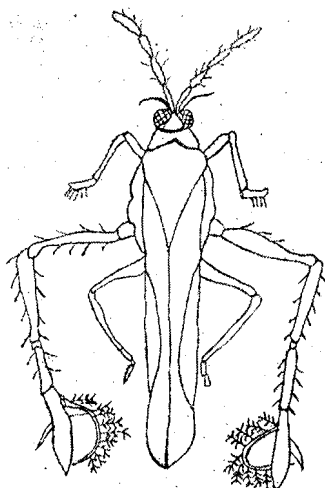


Plate 17: *Rhagovelia* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Velidae
 Genus: *Rhagovelia* [Mag. x 5]

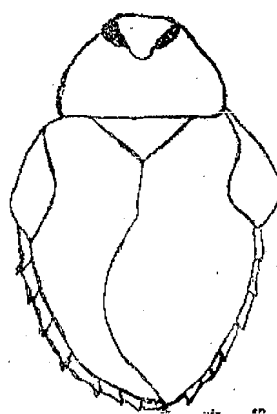


Plate 18: *Naucoris* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Naucoridae
 Genus: *Naucoris* [Mag. x 8]

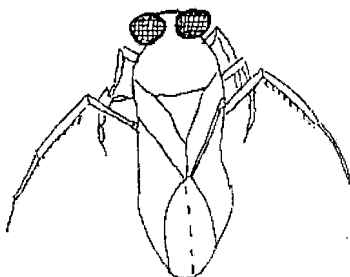


Plate 19: *Notonecta* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Notonectidae
 Genus: *Notonecta* [Mag. x 4]

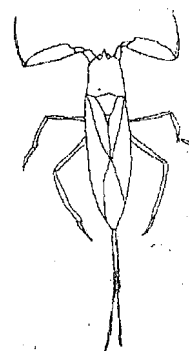


Plate 20: *Nepa* sp
 Phylum: Arthropoda
 Class: Insecta
 Order: Heteroptera
 Family: Nepidae
 Genus: *Nepa* [Mag. x1]

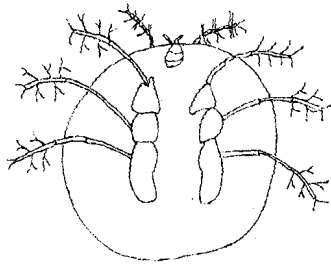


Plate 21: *Hygrobates* sp

Phylum: Arthropoda
 Class: Arachnida
 Order: Acarina
 Family: Hygrobatidae
 Genus: *Hygrobates* [Mag. x 8]

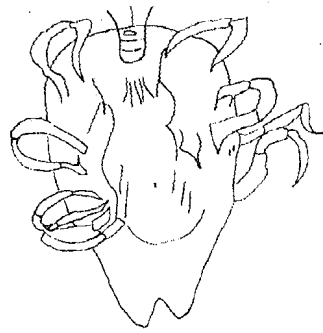


Plate 22: *Hydrachna* sp

Phylum: Arthropoda
 Class: Arachnida
 Order: Acarina
 Family: Hydracarina
 Genus: *Hydrachna* [Mag. x 8]

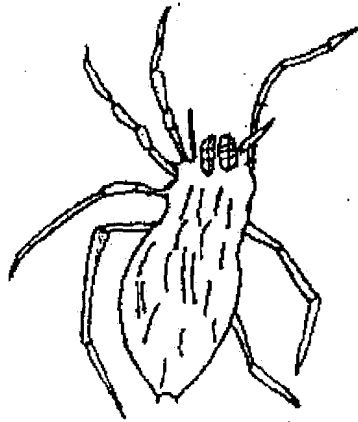


Plate 23: *Argyronecta* sp

Phylum: Arthropoda
 Class: Arachnida
 Order: Araneida
 Family: Aranaea
 Genus: *Argyronecta* [Mag. x 8]

3.5 Gastropod Snails of Obutu lake

Table 12 presents the eleven species of snails found in the lake. The observed ecological variables were as follows:

***Pila spp* eg *Pila ovata* (Plate 24 a)**

Shell: 125 – 129 mm in height. Short spine. Aperture round at the bottom and sharp at the top. Umbilicus is wide and deep. Thickened lip. Operculum two times higher than wide and has calcified inside. Dextral. Colour brown to olive green.

Habitat: Inhabit a wide range of ecosystems, e.g. swamps and lentic water (stagnant water).

Food: Various water plants. They are not selective. Prefer soft and digestible vegetation. Often leave water to search for food on land and vegetation

Life cycle: Short life cycle. They reproduce all the year round.

Active periods: They are very active in the night. Controlled by food, temperature and rainfall. They respire by sucking in air. They aestivate during the dry season when they bury themselves in the mud up to a depth of 80 cm.

Predators: Serve as food for many animals e.g. insects, fishes, and snail hawks. During the dry season lizards eat them up. Mammals feed on them. They respond to alarm by dropping and burial of themselves in the substratum.

Egg deposition: The male snails climb the female from behind during mating. Egg laying is at night or early morning. Calcareous white eggs are deposited above water line on emerging vegetation. Egg clutches are visible, sometimes or often attached on green vegetation emerged from water. Most predators ignore their eggs.

***Orthalicus spp* (Plate 25)**

Shell: Large snail up to 70 mm long. They resemble *Achatina spp* Shell is solid, opaque to slightly transparent and not fragile. Umbilicus is imperforate. Apex microscopically smooth.

Table 12: Snail Species Encountered in Obutu lake

1.	<i>Lymnaea natalensis</i> Krauss, 1848
2.	<i>Gyraulus costulatus</i> Krauss, 1848
3.	<i>Lanistes lybicus</i> Morelet, 1848
4.	<i>Lanistes ovum</i> Troschel, 1845
5.	<i>Pila wernei</i> Philippi, 1851
6.	<i>Pila ovata</i> Olivier, 1804
7.	<i>Potadoma freethii</i> Gray, 1831
8.	<i>Bythinia</i> sp. Leach, 1818
9.	<i>Bulimulus</i> sp. Bruguiere*
10.	<i>Orthalicus</i> sp Say*
11.	<i>Drymaeus multilineatus</i> Say*

* Jane E. Deisler: Tree snails of Florida, *Drymaeus* spp., *Orthalicus* spp., *Liguus* sp. (Gastropoda: Bulimulidae) file://A:Tree % 20 snails % 20 of % Florida, % 20 *Drymaeus* % 20 spp, % 20 *Orthalicus* % 20 spp. Accessed 10/8/2004

Habitat: Amphibious snails found on trees and on water and sometimes on land. They are arboreal most of their life.

Food: They feed on epiphytic growths, algae, fungi and lichens on trees.

Life cycle: Short life cycle.

Active periods: Active during the night.

Predators: Birds, lizards, fish.

Egg deposition: Found on the ground during egg laying.



Plate 24 (a): *Pila ovata*

Phylum: Mollusca

Class: Gastropoda

Order: Prosobranchia

Family: Ampullariidae

Genus: *Pila* [Mag. x 1]

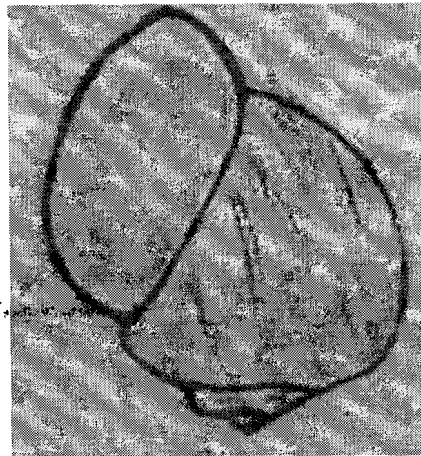


Plate 24 (b): *Pila wernei*

Phylum: Mollusca

Class: Gastropoda

Order: Prosobranchia

Family: Ampullariidae

Genus: *Pila*

Species: *P. wernei* [Mag. x 2]

***Bulimulus spp* (Plate 26)**

Shell: Size ranges from 15 mm to 70 mm. Ovate to conical shells. Shell surface are smooth and glossy with protuberances, thin and translucent. Shell colours vary from ivory to tan with brown markings. Umbilicus perforation is narrow.

Habitat: Live partly arboreal and partly on land. They are found under rocks, in leaf moulds, on rock surfaces or floating vegetation, or on trees and shrubs.

Food: Feed on epiphytic growths, algae, fungi, lichens on trees and dead plant tissues.

Life cycle: Short life cycle.

Active periods: Active during the night.

Predators: Birds, lizards, fish and crustaceans

Egg deposition: Eggs laid on twigs and buried in soil.

***Drymaeus multilineatus* (Plate 27)**

Shell: 25 – 30 mm in height. Shell thin-walled and porcelain-like. Shell has vertical chestnut brown bands and basal bands. Lip is slightly flared. Length of aperture is more than half the overall length of the shell. Aperture is white to pink inside. Blue-black apex.

Habitat: Found on terminal twigs of trees and shrubs usually with smooth bark.

Food: Feed on epiphytic growths, algae, fungi and lichens on trees.

Life cycle: Short life cycle. An annual egg-laying creature.

Active periods: Active period during the day. Aestivates during the dry season.

Predators: Birds and lizards.

Egg deposition: Eggs are laid on the ground.

Lymnaea natalensis

Shell: Up to 70 mm in height, without operculum and conical with a somewhat pointed end. Shell surface is smooth. Colour is tan. The two tentacles are broadened and nearly look like ears. Eyes at bases of tentacles – Basommatophora



Plate 25: *Orthalicus* sp
 Phylum: Mollusca
 Class: Gastropoda
 Order: Prosobranchia
 Family: Bulimulidae
 Genus: *Orthalicus* [Mag. x 1]



Plate 26: *Bulimulus* sp
 Phylum: Mollusca
 Class: Gastropoda
 Order: Prosobranchia
 Family: Bulimulidae
 Genus: *Bulimulus* [Mag. x 1]



Plate 27: *Drymaeus multilineatus*
 Phylum: Mollusca
 Class: Gastropoda
 Order: Prosobranchia
 Family: Bulimulidae
 Genus: *Drymaeus* [Mag. x 2]

Habitat: Forages along the shorelines. Lives in swamps associated with the lake and in other lentic environments within the lake

Food: Feeds on plant materials – macrophytes, algae, fungi, insects and crustaceans.

Life cycle: Hermaphrodite. Development is direct from egg richly supplied with albumen. No larval stage.

Active periods: Pulmonate snail with mantle cavity that has become a lung. Without ctenidia. To breathe, it has to surface, although it is also able to breathe through the skin like frogs. Always active in the night and has great affinity for water.

Predators: Serves as food for man and aquatic vertebrates like turtles, lizards and snakes.

Egg deposition: Egg clutches are positioned below water line on green vegetation.

***Lanistes* spp (Dominant Species in Obutu lake)**

Malacological studies of Obutu Lake shall always consider this lentic water body as home for *Lanistes*. Two species of *Lanistes* were identified namely: *Lanistes lybicus* Morelet, 1849 and *Lanistes ovum* Peters, 1845. *Lanistes ovum* is more abundant than *L. lybicus* in the lake. It is circumboreal in distribution and dispersed over 66 % of the total area of the lake. With its shell height varying from 35 mm to 77 mm, the shell is smooth, egg-shaped and hyperstrophic sinistral. The whorls of the shell have a round base with flat upper part, while the shell which has an aperture also has a round base but with a pointed tip. The umbilicus is narrow to wide and its colour is yellow to brown with faint spiral bands. Its operculum is corneous, while the cephalic and labial tentacles are long. The breathing siphon is short, while the general body colour is grey to brown or greyish brown with banding patterns that break the shell into several parts which, in some cases, are interspersed with dark spots. *Lanistes* inhabits shallow parts of the lake, and can also often be seen in muddy pools. Its lung/gills respiratory apparatus reflects an adaptation to oxygen – poor water conditions often present in swamps and shallow water. In the dry season, oxygen reduction occurs when the temperatures are high, as well as the organic materials like dead vegetation begin to decay.

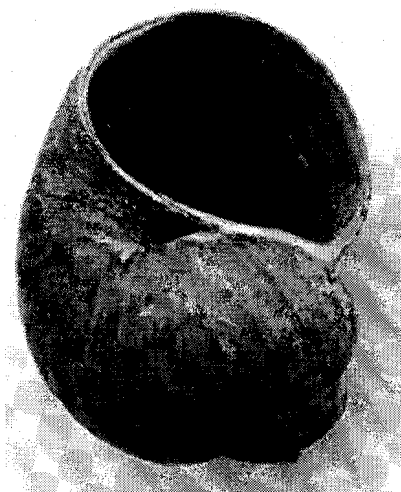


Plate 28(a): *Lanistes lybicus*

Phylum: Mollusca

Class: Gastropoda

Order: Prosobranchia

Family: Ampullariidae

Genus: *Lanistes* [Mag. x 2]

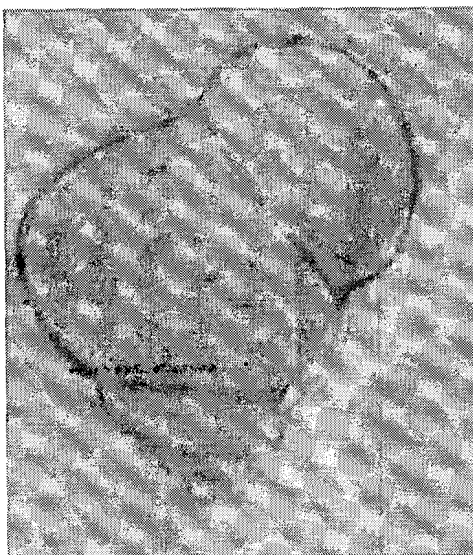


Plate 28(b): *Lanistes ovum*

Phylum: Mollusca

Class: Gastropoda

Order: Prosobranchia

Family: Ampullariidae

Genus: *Lanistes* [Mag. x 3]



Plate 29: *Potadoma freethii*

Phylum: *Mollusca*

Class: *Gastropoda*

Order: *Prosobranchia*

Family: *Thiaridae*

Genus: *Potadoma* [Mag. x 16]

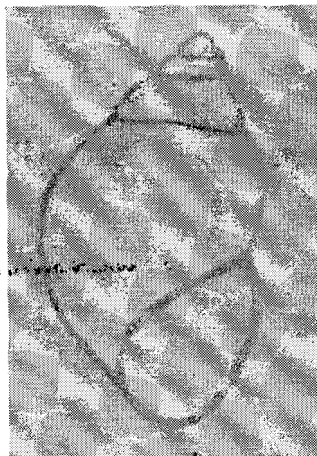


Plate 30: *Bythinia* sp

Phylum: *Mollusca*

Class: *Gastropoda*

Order: *Prosobranchia*

Family: *Bythiniidae*

Genus: *Bythinia* [Mag. x 5]

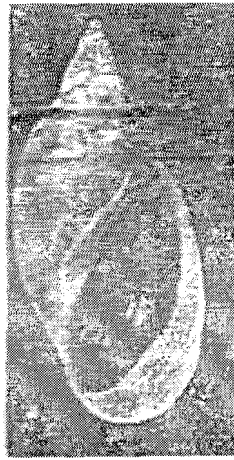


Plate 31: *Lymnaea natalensis*

Phylum: *Mollusca*

Class: *Gastropoda*

Order: *Palmonata*

Family: *Lymnaeidae*

Genus: *Lymnaea* [Mag. x 2]

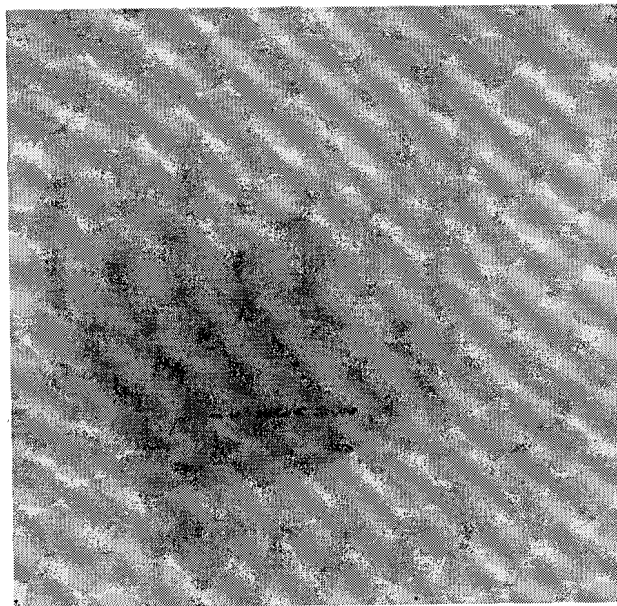


Plate 32: *Gyraulus costulatus*

Phylum: *Mollusca*

Class: *Gastropoda*

Order: *Palmonata*

Family: *Planorbidae*

Genus: *Gyraulus* [Mag. x 15]



Plate33: Sampling zones for aquatic snails in Obutu lake

Marginal areas with vegetation cover (A), Marginal areas without vegetation cover (B),
Open water with submerged vegetation (C) and Open water without vegetation (D)

At this time, their lungs prove very useful to survive the hard conditions which if worsen, may lead the snails to bury themselves into the substrate, to decrease their metabolism and enter a period of aestivation which, however, does not show well defined seasonality, as the snails are active throughout the year.

Feeding in an opportunistic manner, *Lanistes* is not selective and eats almost everything available in the environment, especially such soft and digestible vegetation it is able to grasp with its radulae. It also eats dead animal tissues.

This prosobranch also employs ciliary feeding to augment its food needs. Here, it crawls to the surface and forms a foot funnel to trap pelagic organisms as well as particles that are attached to the surface of water plants. There are indications that surface/ciliary feeding provides proteins from the protein monolayer often present on the surface of quiet bodies of water. This thin layer is often visible as an oil-like reflection on the surface and is produced by and consists of micro-organisms.

With the seasonality of the climate of Obutu Lake, (dry season and rainy season), reproduction takes place from the beginning of the rainy season, when water and food supplies are high. The usually high tropical temperature enhances this process in which this prosobranch exhibits a rather short life cycle of about three months.

Mating, oviposition, hatching and emergence of young snails occur at the beginning of the rains. When the snails are about to mate, the male approaches the female from behind and creeps on her shell. Once he has reached the last whorl at the front of the female's shell, he secures her aperture by grasping her with his penial apparatus and inserts his thin whip-like penis into her genital tract. The mating snails remain in this position for the entire period of copulation which lasts for about two hours, during which the male hides his head under his shell while the female snail may still move around searching for food. The male snail is always persistent while mating and does not lose grip of the female even if the couple is lifted from the water.

Vision is not important for the prospective couples to come together, since their

visual elements have limited ability to form images with their eyes. Snail-snail communication is not much known, but they possibly communicate with chemical substances. A strong indication of this is that when the female snails are ready to mate, the male is attracted to the female even in complete darkness.

Egg-laying takes about two days during which 100-1000 eggs are laid, depending on prevailing environmental conditions. The eggs which are hidden in different positions e.g. between vegetations, in gelatinous masses below waterline, are transparent and are ignored by predators because of their bitter taste.

In hatching within a week from egg deposition, the young snails eat up all the yolk inside the egg and emerge as juveniles. The hatchlings start to grow fast within the first two months, after which the growth rate decreases and comes to a complete halt at maturity, when reproduction takes place, after which the snail starts to grow again at a high rate until the next reproductive period begins. This reduced growth during the reproductive periods may not, however be attributed solely to the costs of mating and production of sperm and eggs, since growth arrest is also present in the snails raised without mating partners.

Since *Lanistes* serves as a popular food for man and various animals – birds, turtles, fishes, insects, and crocodiles, etc., it is not surprising that it develops several techniques to avoid predation.

One basic defence mechanism it employs to avoid predation consists of camouflage. The shell colour (grayish brown) resembles the vegetation and the banding patterns breaks the shell into several parts, less visible between the branches and the stems of the vegetation.

Protection against small predators like insects (e.g. water bugs) and small fishes consists of retracting the body into the shell and closing the shell with the operculum. For those predators that eat their tentacles, the snail avoids them by keeping its head and tentacles under its shell. It can also wiggle its shell from side to side to remove insects and

other possibly dangerous animals from its shell.

By far, the most effective defence mechanism against larger predators is the drop-off and burial mechanism. Once the snail is alarmed, it closes its operculum, loosens its grip from the twig and drops to the bottom where it buries itself on the spot within five to ten minutes, or crawls until it is in contact with an object like stone to which it grasps. The young snails are less reactive and do not bury themselves. There is no snail-snail alarm but other organisms generate alarm responses.

The stimulus to which *Lanistes* reacts to alarm responses is either mechanical or chemical. Mechanical disturbance could be in form of sudden water flow and vibrations, while chemical stimulus consists of sensing the juice of crushed members of the apple snail family, and the odour of predators like turtles,

Alarm response to odours of predators is a fascinating adaptation against predation. It appears to be specific to certain predators in the same environment with the snail.

Vision as said earlier, is not important for *Lanistes* and indeed, all apple snails, as mechanism to detect predators or other forms of danger. This is because of the inadequacies of the visual elements. In this study the snail does not show an alarm response to sudden changes in light intensity, or moving objects above the water surface. Therefore, the combined sensitivity to mechanical disturbance and chemical stimuli (snail juice and predator's odour) appears to be sufficiently adequate for the snail to survive in its habitat.

3.5.1 Comparative Characteristics of Pilid Snails of Obutu lake

The comparative characteristics of the pilid snails of Obutu lake (Fig. 6) indicated that *Lanistes* shell is turned left (hyperstrophic sinistral) while that of the Genus *Pila* is turned right (dextral). The colour of the shell of *Lanistes* is yellow to brown with faint spiral bands, while in *Pila*, the colour is yellow to dark brown to almost black with or without spiral bands. The operculum of *Lanistes* is corneous while that of *Pila* is calcified inside.

The eggs of *Lanistes* are deposited below waterline, while that of *Pila* are deposited above waterline.

3.5.2 Arboreal snails of Obutu lake

Obutu Lake has three endemic genera of Bulimulidae – These are *Orthalicus*, *Drymaeus*, and *Bulimulus*. These snails are not exclusively arboreal, as they are also amphibious. They are found mainly on aquatic herbs, macrophytes and shrubs. They are also found on the ground also especially when dislodged from their perches. They can be found on leaf moulds, under or near rocks and sometimes swimming in the lake.

These Bulimulids have ovate to conical shells that at maturity range in size from 15 mm to 70 mm. These snails have shells that vary from ivory to tan in colour and often with brown markings. Their shell surfaces are smooth, sometimes glossy and with protuberances.

The Bulimulids are often confused with the giant snail *Achatina achatina* but can be differentiated from them by the grayish cast of their stripes. In *Achatina* these stripes have reddish lines. The underlying spiral bands and a columella continuous with the aperture which are not truncated are some other differentiating features.

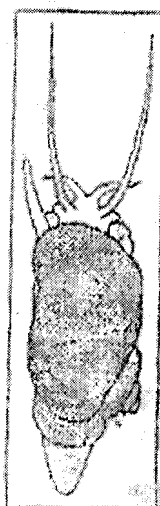
The biology and systematic relationships of these collected species were investigated. The diets of the snails were found to be epiphytic growths, algae, fungi, lichens and some fresh leaves. They were observed to have restricted ranges even within the lake and its environs.

Characteristics of the genus *Lanistes*:



Shell:	surface:	smooth
	shape:	egg-shaped, globose
	direction:	left (~~hyperstrophic sinistral~~)
	whorls:	round base with flat upper part
	shell-opening (aperture):	round base, pointed top
	umbilicus:	narrow to wide
	colour:	yellow to brown with faint spiral bands
Operculum: corneous		
Body:	head (cephalic) tentacles:	long
	labial tentacles:	long
	breathing siphon:	short
	colour:	grey with darker spots
Eggs:	aquatic	Deposited below waterline

Characteristics of the genus *Pila*:



Shell:	surface:	smooth to rough (growth lines)
	shape:	egg-shaped, ovoid to globose
	direction:	right (dextral)
	whorls:	round
	shell-opening (aperture):	oval to egg-shaped
	umbilicus:	wide, narrow to closed
	colour:	yellow, dark brown to almost black, with or without spiral bands
Operculum: corneous outside, calcified inside		
Body:	head (cephalic) tentacles:	long
	labial tentacles:	long
	breathing siphon:	medium
	colour:	grey-yellow to grey, with dark spots
Eggs:	above the waterline	

Fig. 6: Comparative Characteristics of Pilid Snails of Obutu lake

The Bulimulids have been a subject of intensive studies by malacologists because the species of this family are threatened by extinction and are not widespread.

3.5.3 Distribution and abundance of gastropod snail species of Obutu lake

The large number of snails collected (111834) were found in 15 sites out of the 53 sites (28.30 %) in the three zones for a period of 4 years (2000 - 2004). Nine (9) genera comprising eleven (11) species of snails were identified. The highest number of snails was collected from the areas located at the sites with vegetation cover (zone A – marginal areas with vegetation cover, and open water with submerged vegetation) (Plate 23 and Table 13).

The most abundant snail species that were caught belonged to the genus *Lanistes* (that include *L. ovum* 64, 867 and *L. lybicus* 16, 881). *Lanistes* occurred in all the sites with snails. They were followed by the genus *Pila* (including *Pila wernei* 2, 890 and *Pila ovata* 9, 551) (Table 13).

The snail species with the least abundance encountered in this study was *Gyraulus costulatus* (78). *Lanistes* was found in all the sites, *Pila* was found in 11 sites, *Lymnaea* was found in 7 sites, *Drymaeus* was found in 6, whereas *Orthalicus*, *Bulimulus*, *Potadoma*, *Gyraulus* and *Bythinia* were found in 5, 3, 6, 2, and 3 sites respectively (Table 13).

Table 13: Distribution and Abundance of Snail Species within some Sites in Obutu Lake

Sampled sites		Snail species											Total
		<i>Lo</i>	<i>Li</i>	<i>Pw</i>	<i>Po</i>	<i>Ln</i>	<i>Orth</i>	<i>Drym</i>	<i>Bulim</i>	<i>Gy</i>	<i>Pot</i>	<i>Byth</i>	
Marginal areas with vegetation cover	1	7603	7307	1000	503	5709	709	206	200	-	237	-	23474
	2	902	636	95	500	406	34	35	-	-	205	-	2813
	23	9715	6474	57	146	104	133	126	-	-	527	-	17282
	44	7506	-	-	457	146	3	24	-	-	-	-	8136
	53	8116	-	-	220	457	115	-	77	-	-	-	8985
Marginal areas without vegetation cover	16	900	-	-	-	-	-	-	-	25	-	204	1129
	37	280	-	-	-	-	-	-	-	53	-	263	596
	38	356	171	-	-	-	-	-	-	-	-	218	745
	49	405	263	-	-	-	-	-	-	-	-	-	668
Open water with submerged vegetation	11	9900	660	987	6302	3205	-	206	804	-	1312	-	23376
	22	9080	640	-	860	220	-	707	-	-	860	-	12367
	43	8045	730	692	222	-	-	-	-	-	115	-	9804
Open water without vegetation	14	507	-	59	181	-	-	-	-	-	-	-	747
	15	367	-	-	101	-	-	-	-	-	-	-	468
	26	1185	-	-	59	-	-	-	-	-	-	-	1244
Total		64867	16881	2890	9551	10,247	994	1304	1081	78	3256	685	111834

Lo = *Lanistes ovum*; *Li* = *Lanistes lybicus*; *Pw* = *Pila wernei*; *Po* = *Pila ovata*; *Ln* = *Lymnaea natalensis*; *Orth.* = *Orthalicus* sp; *Drym* = *Drymaeus* sp; *Bulim* = *Bulimulus* sp; *Gy* = *Gyraulus costulatus*; *Pot* = *Potadoma freethii*; *Byth* = *Bythinia* sp

3.5.4 Gastropod snail abundance and aquatic macrophytes

A total of 111834 snails was collected from 15 sites out of the 53 sites in the 3 zones. Most individual samples gave mean density of 7.3 ± 8.4 snails per site in heavily inhabited areas. 95 % confidence intervals were taken as ± 1.96 SD; and are therefore, approximately (7.2, 8.8). From these figures an attempt was made to estimate the density of snail for the whole lake and it came up to 2.18 ± 0.45 snails/m³

The density of these snails varied along the transect sites. The detected density of snails over all transects was significantly higher in sites with vegetation cover (mean density per sampling 13.3 snails) than the mean density found around the open parts of the lake which is 0.75 snails ($t = 6.94$, $df = 6$, $P < 0.001$). The mid region of the lake was found to have intermediate snail density (mean density = 3.3 snails / 10,000 cubic m). There was also significant difference between the marginal area and this portion of the lake.

The density decreased with increasing depth (regression log density on mean depth is $r = 0.946$, $P < 0.001$). This was found to be due to underutilization of the deeper areas of the water column by the snails. It was observed that 91 % of the snails were collected from the top 20 cm of water in transects with mean water depth > 90 cm. Thus, as one moves lower down the column one encounters smaller number of snails per linear distance along this transect. Again this varied according to the region of the lake. The mean catches were 0.69 snails / 100m at the North side of the lake; 6.11 snails / 100m at the Southern fringe. Thus, there was significant difference between the densities of snails obtained.

Testing of site distances within the study area and the abundance of the snails as potential factors determining similarity of snail component communities (Table 13) showed that qualitative similarity exists in snail abundance and was higher between sites close to each other than those farther apart irrespective of similarity in the site ecology.

Snail species richness increased with decrease in distances between the sites but the similarity in species richness decreased with increase in site distances apart from each other.

Another important observation is the association of the freshwater gastropods with vegetation cover, aquatic macrophytes and aquatic microphytes.

Chi-square differences in association showed for example, that the values for *Lanistes* and *Pila* and the plants were: 20.12, 20.24, 18.76, 26.94, 10.20, 29.70, 26.60, 39.60, 20.15 and 22.40 respectively. For *Lymnaea natalensis*, an important intermediate host for *Fasciola gigantica*, the values were 4.14, 2.28, 20.62, 29.84, 15.40, 36.60, 30.40, 50.80, 24.20 and 25.60 respectively. For Bulimulidae, however, the values were 4.60, 8.40, 9.80, 10.30, 18.40, 7.60, 20.10, 4.80, 6.90, and 5.70 respectively. These figures can be interpreted to mean that for *Lanistes* and *Pila* all the values were statistically not significant at $P < 0.05$. For *Lymnaea*, the values showed significant association with *Pistia* and *Nymphaea*, and for the Bulimulidae, there was significant association between them and all macrophytes except *Adropogon* and *Cyclosorus*.

All the gastropods associated with one another and they were found to be sharing their resources including niches within the habitats. The degree of association with one another varied between 9.0% and 39.4%. *Lanistes* associated more with *Pila* and both were found more in marginal areas. Aquatic macrophytes play very important role in snail to snail association. It is noteworthy that this lake is a rich source of *Lanistes* and leeches.

Snail species richness, snail species diversity (Brillouin's diversity index) and dominance (Simpson's indices) and total abundance at the community levels are given in Tables 14 and 15.

The highest species diversity was found along the marginal areas with visible vegetation cover and submerged vegetation, while the lowest diversity was recorded for species occupying open water and marginal areas without vegetation cover.

Table 14: Studies on Snail Communities in Obutu Lake (Brillouin's Diversity Index)

Some sampled sites	Number of snail genera collected	Snail abundance	Species richness	Brillouin's diversity index
1	7	23,474	9	1.232
2	6	2,813	8	0.568
23	6	17,282	8	1.208
53	5	8,985	5	0.223
37	3	596	3	0.158
38	3	745	3	0.142
11	6	23,376	8	1.158
22	5	12,367	6	1.096
43	3	9,804	5	1.03

Table 15: Simpson's Index of Dominance among the Snail Species

Snail species	Population size	Simpson's index of dominance
<i>Lanistes ovum</i>	64,867	0.965
<i>Lanistes lybicus</i>	16,881	0.954
<i>Pila werneri</i>	2,890	0.844
<i>Pila ovata</i>	9,551	0.457
<i>Lymnaea natalensis</i>	10,247	0.427
<i>Orthalicus sp</i>	994	0.401
<i>Drymaeus sp</i>	1304	0.352
<i>Bulimulus sp</i>	1081	0.206
<i>Potadoma freethii</i>	3256	0.285
<i>Bythinia sp</i>	685	0.154
<i>Gyraulus costulatus</i>	78	0.068

Highest species diversity was found along marginal areas with vegetation cover and submerged vegetation. Lowest diversity was recorded for species occupying open water areas and marginal areas without vegetation cover.

Snail species in the sites of the lake had different indices of diversity but they showed similar dominance indices (Tables 14 and 15). Qualitative similarity of snail species (at the various sites) was evaluated and the Jaccard's index obtained showed a high level of qualitative similarity between the marginal areas with vegetation cover and marginal areas with submerged vegetation. Further analysis of the data obtained using Steinhaus's index did not show quantitative similarity of the snail communities between the sites (Table 16). The highest values of this index were found still among the sites around the marginal areas with vegetation cover and in areas with abundant submerged aquatic macrophytes.

These observations indicated that the factors which may possibly be influencing the observed trend in abundance of snails within the lake, and also affecting the dominance of snail species and diversity, are site position, water depth, vegetation cover, nature of the substratum and distance between the sites. Nature of the substratum and vegetation cover were the factors influencing the similarity in abundance of snails within the lake (for substratum the value was 0.646, $P = 0.001$, for vegetation cover it was 0.436, $P = 0.001$). The coefficient of determination obtained for the factors (r^2) was 0.768, $P = 0.001$.

The distribution of snails was compared with a Poisson distribution to examine whether the number of suitable snail habitats per m^3 was distributed randomly or not. The difference was not significant. Thus, there was no evidence against the distribution of suitable habitats being random but limited to only favourable areas (Table 17).

Table 16: Values for Jaccard's Index for Qualitative Similarity and Steinhaus's Index for Quantitative Similarity

Snail Population	Site 1	2	23	53	37	38	11	22	43
Site 1		0.67	0.56	0.25	0.25	0.5	0.25	0.77	0.56
2	0.33		0.44	0.1	0.29	0.38	0.28	0.67	0.44
23	0.21	0.58		0.28	0.34	0.43	0.33	0.54	0.5
53	0.34	0.53	0.55		0.28	0.57	0.28	0.67	0.63
37	0.01	0.55	0.10	0.07		0.5	1	0.25	0.33
38	0.49	0.49	0.33	0.23	0.1		0.5	0.25	0.43
11	0.315	0.64	0.53	0.78	0.07	0.39		0.5	0.34
22	0.398	0.34	0.62	0.74	0.06	0.31	0.28		0.44
43	0.163	0.45	0.63	0.39	0.02	0.34	0.07	0.28	

Table 17: The number of snails per m² of lake area

Variables	Number of snails /m ³		
Number of snail habitats /m ³	0	1	72
Observed frequency (m ³)	38	1	14
Expected frequency	39.63	2.60	10.76

$X^2 = 2.09$ which is not significant at $P = 0.10$

Table 18: Results of Multiple Regressions on Distance Between Sites to Explain the Effect of Variables Related to the Lake on The Similarity of Snail Species.

Dependent variables	Independent variables	b	P	r ² (P)
a.				
Qualitative similarity of between snail community (Jaccard's index)	All snail species influence of the Lake	- 0.864	0.001	0.750
		- 0.35	0.001	(0.001)
				0.306
				(0.026)
b.				
Quantitative similarity of between snail communities (Steinhaus's Coefficient)	Site distance from one another	- 0.32	0.028	0.407
				(0.001)
	Other snail species	- 0.55	0.019	
				0.381
				(0.001)
c.				
Brillouin's index of diversity	Substratum of Lake	-0.55	0.001	
d.				
Simpson's index of dominance	Substratum of Lake	-0.36	0.017	
e.				
Snail species richness	Lake quality	-0.41	0.003	
	Substratum of Lake	-0.12	0.004	

The interpretation of Table 18 on the results of multiple regressions on distance between sites to explain the effect of variables related to the lake on the similarity of snail species showed that for:

(a). **Jaccard's Index of Qualitative Similarity of between snail Communities**

- i. All snail species: Significant, showing similar species in all the sites.
- ii. Influence of the lake: Not significant, indicating that it is not the lake that determines the distribution of the snails.

(b). **Steinhaus's Coefficient of Quantitative Similarity between snail Communities**

- i. Site distance between one another: Significant: these show that site differences are significant for snail populations, as there are no two sites with the same population size.
- ii. Other snail species: Same as above.

(c). **Brillouin's Index of Diversity**

- i. Substratum of lake: Significant, showing that substratum affects diversity.

(d). **Simpson's Index of Dominance**

- i. Substratum of lake: Significant. This reveals that substratum does not support dominance.

(e). **Snail Species Richness**

- i. Lake quality: Significant. This shows that lake quality does not support species richness.
- ii. Substratum of lake: Significant. This shows that substratum does not support species richness.

3.5.6 Relationships between physicochemical parameters and gastropod snail abundance in Obutu lake

The general patterns seem to be a negative and insignificant correlation between snail abundance and physicochemical variables (Table 19).

3.6 Natural Foods and Feeding Habits of Gastropod Snails of Obutu Lake

Field data suggest that organisms of a wide size range (18 – 20 μ) and of various shapes are available as food for the snails. The time necessary to consume large algae is the same for all species of pulmonates and less than those of prosobranchs. Searching time was less for prosobranchs than for pulmonates.

The rations were different significantly. The revealed feeding differences were due to size differences and consequently, to differences in the velocity of movement. The rate at which the snails consumed food was found to be inversely related to the food hardness.

The quality of the stomach contents of adult pulmonates and prosobranchs are shown in Table 20. Filamentous and non-filamentous algae, diatoms, desmids, rotifers, tissues of macrophytes, parts of crustaceans and insects, plus other invertebrate tissues, were found in the pulmonate stomach, whereas tissues of macrophytes and parts of leaves of macrovegetations were found as their stomach of prosobranchs

In both groups, sand particles, detritus, radulae and fungal mycelia, were found in their stomach contents.

Minor variations in the quality of food which were found related to the site/habitat of the snails. Those found near the edges had macrophytes and macro vegetation predominating, whereas those found in the more open water sites had microphytes and macro-invertebrates predominating in their stomach contents. Among the crustaceans, the predominant group found within the snail stomachs were the ostracods. Among the desmids, *Cosmarium* and *Closterium* were mostly encountered. The micro-invertebrates had *Diffugia* and *Arcella* spp as the dominant members. The diatoms were represented by *Gomphonema*, *Navicula* and others difficult to identify.

Table 19: Correlation coefficients (r) for the relationships between abundance of gastropods and physicochemical variables in Obutu lake

Zones	Current	Temperature	pH	Total alkalinity	DO ₂
A	0.043	0.469	0.258	0.098	0.228
B	0.062	0.265	-0.289	-0.185	0.175
C	0.170	0.209	0.199	-0.290	-0.308

Table 20: The Stomach Contents of Gastropods found in Obutu Lake

Gastropods	Stomach Contents
<i>Lymnaea natalensis</i>	<i>Neglectus sp</i> , <i>Oscillatoria sp</i> , <i>Gomphonema sp</i> , <i>Phacus sp</i> , <i>Monostyla sp</i> , <i>Closterium sp</i> , Carcasses of crustaceans, Insect cuticles, hard parts of leaves, parts of fresh leaves, sand particles, radulae
<i>Gyraulus costulatus</i>	<i>Monostyla sp</i> , <i>Closterium sp</i> , <i>Phacus sp</i> , <i>Oscillatoria sp</i> , Insect cuticle, hard parts of leaves, detritus, fungal mycelia
<i>Lanistes sp</i>	<i>Gomphonema</i> , <i>Navicula</i> , <i>Diffugia</i> , anemones, Parts of fresh leaves of macrovegetation; hard parts of leaves; radulae; insect cuticle, fungal mycelia
<i>Pila sp</i>	<i>Phacus sp</i> , <i>Oscillatoria sp</i> , <i>Neglectus</i> , Insect cuticle, mud sand particles, radulae, parts of fresh leaves, hard parts of leave, detritus
<i>Potadoma freethii</i>	Carcasses of crustaceans, sand particles, insect cuticles, <i>Phacus sp</i> , hard parts of leaves, Parts of leaves of macrovegetation.
<i>Bythinia sp</i>	<i>Oscillatoria sp</i> , Tissues of macrophytes; parts of leaves of macrovegetation, carcasses of crustaceans, insect cuticles, radulae
<i>Bulimulus sp.</i>	Hard parts of leaves, stalked sporangia of fern plant, detritus materials, sand particles, mud.
<i>Orthalicus sp.</i>	Hard parts of leaves, basidia and conidia of mushroom, unidentified non-septate fungal mycelia sand particles, mud, detritus materials.
<i>Drymaeus multilineatus</i>	Detritus materials, non-septate coenocytic fungal hyphae, septate, loosely-matted fungal mycelia.

The commonest non-filamentous algae encountered were members of *Phacus* species. *Oscillatoria* was the dominant filamentous alga encountered.

The rotifers found both on the shells of living snails, were part of their stomach contents. *Monostyla* sp was the commonest rotifer found, but depending on the site, these were mixed with either *Branchionus* sp, *Lecane* sp or both. Parts of other invertebrates were found including whole carcasses of water mites, small beetles etc.

Field studies also revealed an interesting strategy used by *Lanistes* to secure floating food on water surface. Here, the snail forms a foot-funnel to trap particles from the surface. This is known as filter feeding or ciliary feeding. Once the funnel is filled, the snail brings its head in the funnel and eats the collected materials. This surface feeding provides proteins from the protein monolayer often present on the surface of the lake. The protein consists of micro-organisms.

Lanistes was also seen to prey on its members particularly when starved by gnawing holes into the victim's shell with its radulae and eating the exposed tissues.

3.7 Digenean Trematodes of Gastropod Snails of Obutu lake

Six types of trematode cercariae were isolated from eight out of eleven (72.7 %) species of snails collected from Obutu lake. The prevalences of cercariae identified were Xiphidiocercariae (3.6%), *Gymnocephalus* cercariae (6.8 %), Echinostome cercariae (Plate 30) (1.8 %), Amphistome cercariae (Plate 34) (2.4 %), Furcocercous cercariae (Plate 32) (3.5%) and Zygodercous cercariae (Plate 37) (1.64 %). The arboreal snails did not shed any cercariae.

The total number of snails collected from Obutu Lake was 111,834. The number found with active infections was 30,445. The infected snails were, therefore, few (27.22%). The maximum value of prevalence was from Pilid and Lymnaeid snails. Of the infected snails, *Gyraulus costulatus* was least infected (1.3%).

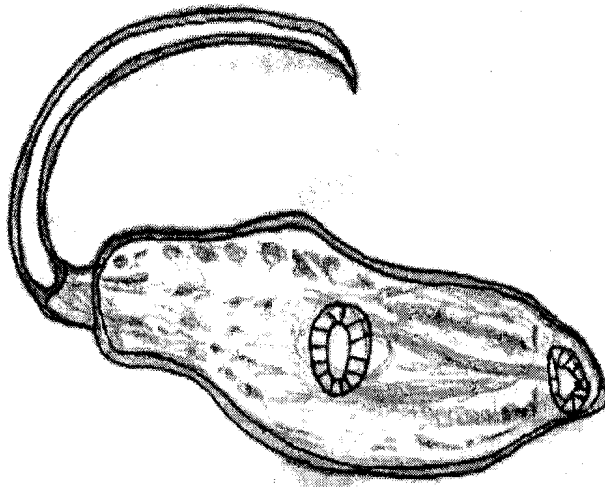


Plate 34: *Echinostome cercaria*

Phylum: Platyhelminthes
 Class: Trematoda
 Subclass: Digenea
 Order: Echinostomida
 Family: Echinostomatidae [Mag. x 1500]

Host: *Bythinia sp*

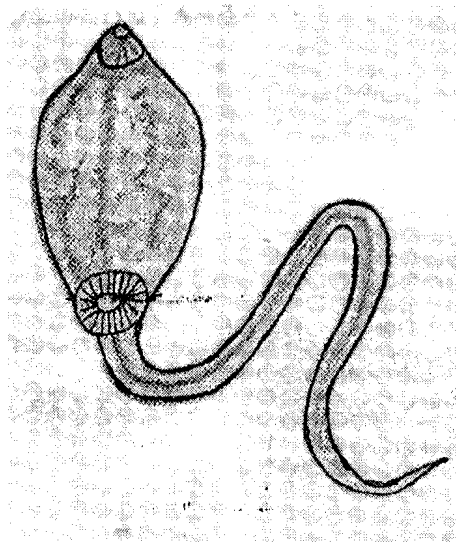


Plate 35: *Amphistome cercaria*

Phylum: Platyhelminthes
 Class: Trematoda
 Subclass: Digenea
 Order: Echinostomida
 Family: Amphistomatidae [Mag. x 1500]

Hosts: *Lanistes lybicus*
Gyraulus costulatus

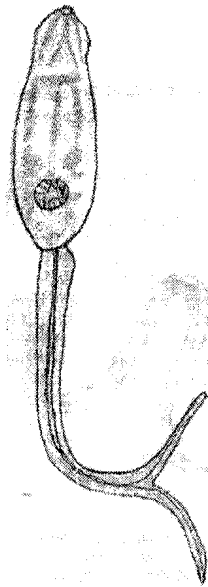


Plate 36: Furcocercous cercariae

Phylum: Platyhelminthes
 Class: Trematoda
 Subclass: Digenea
 Order: Strigeatoidea
 Family: Schistosomatidae [Mag. x 1500]

Hosts: *Lanistes lybicus*
Lanistes ovum
Lymnaea natalensis

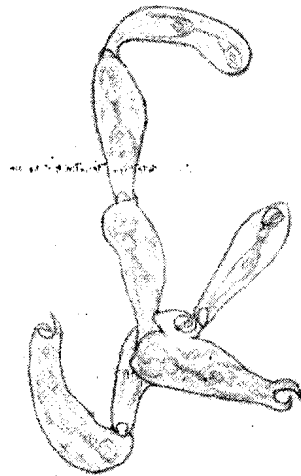


Plate 37: Zygocercous cercariae

Phylum: Platyhelminthes
 Class: Trematoda
 Subclass: Digenea [Mag. x 200]

Hosts: *Pila werneri*
Pila ovata

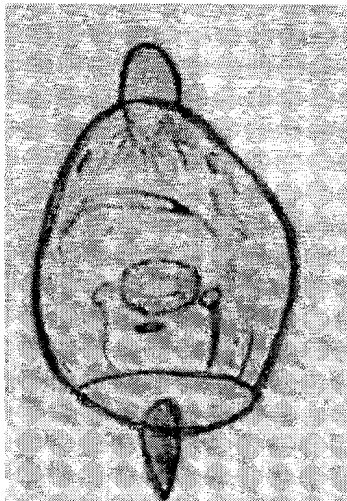


Plate 38: *Microcercous xiphidiocercaria*

Phylum: *Platyhelminthees*

Class: *Trematoda*

Subclass: *Digenea*

Order: *Plagiorchida*

Family: *Troglotreumatidae* [Mag. x 800]

Host: *laniates lybicus*

Lanistes ovum

Potadoma freethii

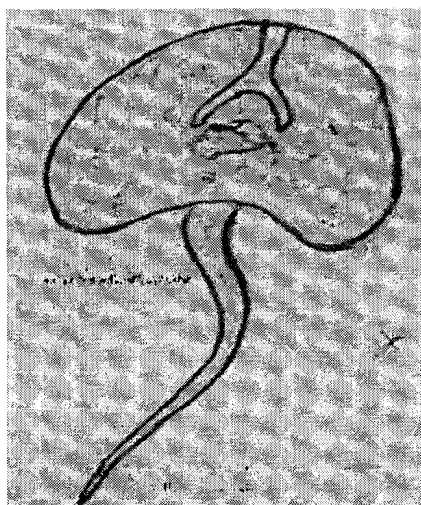


Plate 39: *Gymnocephalus cercaria*

Phylum: *Platyhelminthees*

Class: *Trematoda*

Subclass: *Digenea*

Order: *Echinostomida*

Family: *Fasciolidae* [Mag. x 800]

Hosts: *Pila ovta*

Pila wernei

Lanistes lybicus

Lanistes ovum

Lymnaea natalensis

The matrix of infection among gastropod snails from different sites of Obutu lake has been presented on Table 21. Infected snails, irrespective of genera, congregated in some sites. Infected snails were preponderant in some sites and absent or scarce in some other sites, irrespective of snail density. Infected snails were separated from those without infections. The five (5) places with maximum prevalence were those sites with macrovegetation and submerged macrophytes. Snails in sites 44, 53 49 and 15 were not infected by trematode parasites.

Table 21: Infection of gastropod snails with digenean parasites

Snail species	Gymno- cephalus cercariae	Zygo cercariae	Xiphidio cercariae	Enchino- stome cercariae	Furcoc- ercous cercariae	Amphi- stome cercariae
<i>Pila ovata</i>	++++	++	-	-	-	-
<i>Pila wernei</i>	+++	+++	-	-	-	-
<i>Lanistes lybicus</i>	++	-	+	-	++	++
<i>Lanistes ovum</i>	+++	-	+++	-	++	-
<i>Lymnaea natalensis</i>	++	-	-	-	++	-
<i>Potadoma freethii</i>	-	-	++	-	-	-
<i>Bythinia sp</i>	-	-	-	++	-	-
<i>Gyraulus costulatus</i>	-	-	-	-	-	++
Percentage prevalence	6.8	1.64	3.6	1.8	3.5	2.4

Table 22: Prevalence of digenean trematodes among snails collected from Obutu Lake

Snail species	Number examined	Number infected	Percentage infected
<i>Lanistes ovum</i>	64867	21860	33.7
<i>Lanistes lybicus</i>	16881	3781	22.4
<i>Pila wenei</i>	2890	739	25.6
<i>Pila ovata</i>	9551	2234	23.4
<i>Lymnaea natalensis</i>	10247	1762	17.2
<i>Gyraulus costulatus</i>	78	1	1.3
<i>Potadoma freethii</i>	3256	58	1.8
<i>Bythinia sp</i>	685	10	1.5
<i>Orthalicus sp</i>	994	0	0
<i>Drymaeus multilineatus</i>	1304	0	0
<i>Bulimulus sp</i>	1081	0	0
Total	111,834	30,445	27.22

Table 23: Matrix of infected snails in the different sites

Infected snail species	Site														
	1	2	23	44	53	16	37	38	49	11	22	43	14	15	26
<i>Pila ovata</i>	+	+	+							+	+		+		
<i>Pila wernei</i>	+	+	+							+		+	+		
<i>Lanistes lybicus</i>	+	+	+							+	+	+			
<i>Lanistes ovum</i>	+	+				+		+		+	+	+	+		+
<i>Lymnaea natalensis</i>	+									+	+				
<i>Potadoma freethii</i>			+							+	+	+			
<i>Bythinia sp</i>						+	+	+							
<i>Gyraulus costulatus</i>							+								

3.7.1 Nestedness matrix of gastropods in Obutu lake: Nestedness of snails in Obutu lake is shown on Table 24. From the table all the snails except *Potadoma freethii* had about the same level of nestedness. The very low values of calculated t are very highly significant showing that all the snail species are predisposed to nestedness on infection.

3.7.2 Distributions of Infections by Sites in Obutu Lake: Results of the distribution of infections by site (Table 25) showed that the prevalence of infection was significantly higher in the sites with vegetation cover and in those sites with submerged vegetations. These areas also correlated positively with snail density and species richness. Snails in site 44, 53, 49 and 15 were not infected by trematode parasites.

3.7.3 Infections of freshwater prosobranch in the sites in Obutu lake: Table 26 shows the infection of the prosobranchs of Obutu lake. *Lanistes ovum* had the highest percentage infection (33.70%). This was followed by *Pila wernei* (25.57%). The other two species of the pilid snails *Lanistes lybicus* (22.40%) and *Pila ovata* (23.4%) were comparatively fairly infected. The remaining two species of prosobranchs, *Potadoma freethii* (1.78%) and *Bythinia sp* (1.50%) had very low infections.

Highest infections were recorded in marginal areas with vegetation cover. This level of infection was followed with snails from areas with submerged vegetation (sites 11, 22 and 43). However, the high percentage infection of the pilid snails in site 14 (open water without vegetation) has been noted, but the snails from all other open water areas had no infections.

In all, 28682 out of 98130 of these prosobranchs were infected, giving an overall percentage infection of 29.23%. The overall infection rate of the prosobranchs was, therefore, low.

3.7.4 Infection of the freshwater pulmonates in the sites in Obutu lake: Table 27 showed that out of a total of 10,247 specimens of *Lymnaea natalensis* collected, 1762 (17.20%) were infected by trematode parasites in sites 11 and 22 only.

Table 24: Nested analysis using nestedness matrix (P was calculated after many repetitions)

Nested analysis	Host snail population	Prevalence of infection	Random $\pm$ SD	P(t<random)
Among snail host populations	Host snail population	18.16	46.88 $\pm$ 9.52	0.001
In host populations	<i>Pila ovata</i>	17.74	52.69 $\pm$ 6.41	<0.001
	<i>Pila wernei</i>	7.37	48.62 $\pm$ 7.38	<0.001
	<i>Lanistes lybicus</i>	2.38	40.77 $\pm$ 8.62	<0.001
	<i>Lanistes ovum</i>	14.66	46.37 $\pm$ 7.06	0.001
	<i>Lymnaea natalensis</i>	14.93	51.4 $\pm$ 7.10	<0.001
	<i>Gyraulus costulatus</i>	5.12	44.25 $\pm$ 9.65	<0.001
	<i>Potadoma freethii</i>	15.18	40.7 $\pm$ 8.98	0.002
	<i>Bythinia sp</i>	12.24	47.04 $\pm$ 8.08	<0.001

Table 25: Distribution of Infections by sites in Obutu lake

Site	Number of snails collected	Number Infected	Percentage Infection
1	23474	7998	34.07
2	2813	1569	55.78
23	17282	5670	32.81
44	8136	0	0
53	8985	0	0
16	1129	172	15.23
37	596	104	17.43
38	745	103	13.83
49	668	0	0
11	23376	7769	33.23
22	12367	3726	30.13
43	9804	3058	31.19
14	747	135	18.07
15	468	0	0
26	1244	141	11.33
Total	111834	30,445	27.22

Table 26: Infections of Freshwater Prosobranchs in the Sites in Obutu lake

Sites	<i>Lanistes ovum</i>			<i>Lanistes lybicus</i>			<i>Pila wernei</i>			<i>Pila ovata</i>			<i>Potadoma freethii</i>			<i>Bythinia sp</i>		
	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection
1	7603	3775	49.65	7307	1759	24.07	1000	281	28.1	503	119	23.66	237	-	-	-	-	-
2	902	565	62.4	636	88	13.84	95	28	29.47	500	88	17.60	205	-	-	-	-	-
23	9715	-	-	6474	1597	24.67	57	16	28.07	146	44	30.14	527	13	2.47	-	-	-
44	7506	-	-	-	-	-	-	-	-	457	0	0	-	-	-	-	-	-
53	8116	-	-	-	-	-	-	-	-	220	-	-	-	-	-	-	-	-
16	900	459	52.11	-	-	-	-	-	-	-	-	-	-	-	-	204	3	1.47
37	280	-	-	-	-	-	-	-	-	-	-	-	-	-	-	263	4	1.52
38	356	10	2.81	171	0	-	-	-	-	-	-	-	-	-	-	218	3	1.38
49	405	-	-	263	0	-	-	-	-	-	-	-	-	-	-	-	-	-
11	9900	5898	59.58	660	102	15.45	987	272	27.56	6302	1724	27.36	1312	30	2.29	-	-	-
22	9080	5353	58.95	640	96	15.00	-	-	-	860	210	24.42	860	12	1.40	-	-	-
43	8045	4795	59.60	730	139	19.04	692	120	17.34	222	-	-	115	3	2.09	-	-	-
14	507	364	71.79	-	-	-	59	22	37.29	181	49	27.72	-	-	-	-	-	-
15	367	-	-	-	-	-	-	-	-	101	0	0	-	-	-	-	-	-
26	1185	641	54.09	-	-	-	-	-	-	59	0	0	-	-	-	-	-	-
Total	64867		33.70	16881	3781	22.40	2890	739	25.57	9551	2234	23.4	3256	58	1.78	685	10	1.50

Table 27: Infection of Freshwater Pulmonates in the Sites in Obutu Lake

Sites	<i>Lymnaea natalensis</i>			<i>Gyraulus constulatus</i>		
	No. Collected	No. Infected	% Infection	No. Collected	No. Infected	% Infection
1	5709	964	16.89	-	-	-
2	406	-	-	-	-	-
23	104	-	-	-	-	-
44	146	-	-	-	-	-
53	457	-	-	-	-	-
16	-	-	-	25	-	-
37	-	-	-	53	1	1.89
38	-	-	-	-	-	-
49	-	-	-	-	-	-
11	3205	743	23.18	-	-	-
22	220	55	25.0	-	-	-
43	-	-	-	-	-	-
14	-	-	-	-	-	-
15	-	-	-	-	-	-
26	-	-	-	-	-	-
TOTAL	10247	1762	17.20	78	1	1.30

Gyraulus constulatus was infected in site 37. Infection of *L.natalensis* occurred only at those sites with vegetation cover and submerged vegetation, while *G. constulatus* was infected in the marginal areas without vegetation. Of the 10,325 of these freshwater pulmonates collected, 1763 (17.08 %) were infected. This overall infection rate was lower than that of the prosobranchs, which was shown to be 29.23 %.

CHAPTER FOUR

DISCUSSION

Area of the Lake

Obutu Lake is located in the humid tropics and is climatically hot with two distinct seasons. During the rains, water current assumes a moderate increase in speed. This is the situation found in other lakes of this nature (Gorman and Karr, 1978). At this period a lot of materials are brought into the lake and the volume swells but the concentrations of various ions are lower due to dilution. In the dry season the water level drops and so the current also drops but the ionic concentration rises. Obutu lake had not been characterized before by anybody, and the present study of some aspects of the ecology and its gastropod fauna and their helminth infections is an opportunity to do so.

Its morphometric data show that it is a large body of quiet, flowing water that is 450m long and 150m at its widest portion, and which during the rains, could assume up to 10m at its deepest portion. Also lying within a vast agricultural area that experiences intensive farming activities each year, it receives huge agricultural wastes mainly through run-off water from the surrounding farmlands during the rains, thereby making it characteristically eutrophic.

Physicochemical Properties of Obutu lake

Rainfall: Figure 5 shows that the area (lake) experienced abundant rainfall ranging from 1.3 ml in January, 2003, to 425.4 ml in July, 2003, with an average monthly rainfall of 156.9 ml.

Temperature: Located in the humid tropics, and climatically hot with two distinct seasons, the temperatures are uniformly high throughout the year with small air and water temperature ranges which might be due to the fact that waters in lower latitudes are not subjected to extremes of temperatures in the tropics. The range of monthly mean values of the physico-chemical variables have already been presented in each component study table. Observations show that generally, the

temperature of the lake was almost the same in all the sites. Water temperatures which ranged from 23.8°C in August, 2003 to 28.8°C in March, 2003, with a small annual range of 5.0°C , were considered suitable enough for the presence and comfort of the resident snails of Obutu lake. Inorganic ions were higher in quantities during the dry season. Other factors found to be closely temperature dependent include pH, turbidity, water level, dissolved oxygen and total alkalinity. The mean values recorded for all the zones did not show any significant difference ($P < 0.05$), although there were no measurements to show diurnal variations, which allow for warming effects of the sun on the water body, since the temperature of the surrounding water should impart characteristic variations on the surface water of the lake. The rather small air and water temperature ranges might be due to the fact that waters in lower latitudes are not subjected to temperature extremes in this tropical environment.

Turbidity: The rather poor transparency and underwater light penetration of the lake as a whole, were directly associated with the high values of soil particles transported from nearby gullies by seasonal streams and rivers during the rainy season. For this reason, the water of the lake assumed a faint yellowish-brown colour. The lake gives out an outlet into the Ota-Alu river which, in turn, flows into the Aghomili river that finally discharges into the Mamu river that runs across the Enugu/Onitsha expressway at Amansea. This rather muddy Mamu river flowing north-westwards finally empties into the Anambra river at Otuocho. The decrease of transparency was also as a result of large introduction of allochthonous materials from the adjoining farmlands forming the catchment areas of the lake. Human and agricultural activities produce substantial wastes which are carried by the floods during the rains, from the inundated farmlands, into the lake, thereby aggravating its turbidity.

Also noteworthy is the place of phytoplanktons. With precipitation and overspill, the habitat is enlivened, leading to the rapidity of growth of phytoplanktons, which, along

with particulate matter and suspended solids, greatly reduce the water transparency of the lake. Secchi disc readings showed that lowest values were obtained during the rains as a result of the introduction of allochthonous materials, discharge of agricultural wastes into the lake, the rapidity of the growth of phytoplanktons and re-suspension of bottom sediments.

Table 3 shows that the lowest values were obtained in August and September, 2003, reflecting the high turbidity during this period of the rains. The period of greater light penetration (October to March) may be due to the sedimentation as a result of high evaporation, decrease in phytoplankton production, and reduced rainfall.

The effect of turbidity is difficult to assess. Short periods of high turbidity such as occur during the flooding are not known to have adverse effects upon snails. However, prolonged turbidity will probably affect the growth of algae on which the snails are apparently dependent for their proper development.

Water Depth: Zone C (open water of the lake) holds itself as the deepest portion of the lake. It recorded 10.0 m deep in July 2003, and throughout the year, did not go below 4.5 m deep. The depth regime shows that zone B closely came behind C, while zone A was comparatively shallowest (Table 4). Considering the recorded figures from the designated zones, this shows that this moving water body can be considered to be a deep lake, since no person can stand at its mid stream any time of the year without being submerged, as the lake had maximum depth of 10.0 m, minimum depth of 2.4 m and mean depth of 5.7 m.

Water Velocity: Water current has been considered as a selective factor in biological assemblages in the lake system. Only certain species are able to adapt successfully in high water current in Obutu Lake. Current values recorded were moderate enough to stabilize the composition of the biotic community. The recorded speed values in Obutu Lake fell within the range suitable for snail habitation, and that was probably why, along with other ecological factors, many species of snail were found within the lake, probably at the shore lines, quiet backwaters and the fringes of the lake. A wide fluctuation in current velocity

occurred between the sites around the marginal areas and the open lake area. December to April each year was the period of extreme dryness and caused reduction in lake levels and fluctuations in the quantitative measurement of many factors studied. It is important to note that snail love slow flowing habitats. In this lake, in the marginal area where vegetation blocks the water current, the snails tend to congregate. This finding is in accordance with the general expectations expressed in Odum (1985) and Quinn and Hickey (1993). The impact on the snail species seemed to be varied accounting for differential species responses.

Water velocity is a factor of potential limnological significance in the malacological studies of Obutu Lake. It is produced by the discharge from the upstream within the lake in which the circulation and water movement mechanisms have also been associated with storms in the rainy season, as well as the topographical status of this lake. Monthly averages for zone B (0.076 m/sec) and zone C (0.082 m/sec) were higher than those of zone A (0.073 m/sec). The values are shown in Table 5.

In Obutu lake, with the slope fairly constant, the velocity of the water was, according to Table 5, faster during the rainy season, because of the increased volume of water within it. But in the dry season, the velocity was lower because the water level receded, leading to increased resident time for each volume of water that came into an area along its course. Any probable increase in the velocity of the water occasioned by the harmattan north-east trade winds during the dry season months of November to January could be considered marginal. Highest water velocity of 0.094m/sec was recorded in September 2003 while the lowest current speed of 0.066m/sec, was observed in February and March, 2003.

pH: Table 6 showed that the lake was, therefore, on the acid side during the rains. But during the dry season, when the lake was not recharged by run-off water, the water became less acidic because of the absence of humic acids that usually resulted from the decomposition of organic matter brought in by the floods during the rains. Water in Zone

A was acidic, because this was the area of greatest human activity, as the people of Omogho regularly go there for processing of agricultural produce including the fermentation of cassava tubers and washing – off of breadfruit seeds. These activities decrease the hydrogen ion concentration of the water in the area, which, therefore, maintains its acidity almost throughout the year.

The pH range of Obutu lake for months in 2003 was 6.15 – 7.35 (Table 6). Lowest monthly mean values were obtained during the rainy season, with introduction into the lake, of allochthonous agents etc., through run-off water from the agricultural farmlands that also brought with them, large quantities of agricultural wastes. The monthly averages of the pH of the lake, which ranged from 6.15 in September to 7.35 in March and April, 2003 were comparatively narrow and appeared to fall within the recommended range (6.5 – 9.0) suitable for aquatic life. Of the three zones, the water was comparatively acidic in zone A (6.82) than in zones B (6.94) and C (7.02).

Water density: Monthly values ranged from 1.0435 in October 2003, to 1.0792 in April 2003 (Table 7). Average monthly values showed that the density of the water was higher during the dry season. The lowest average monthly values of 1.0435 were obtained in October 2003. The enhanced value at A during the dry season was also due to the decrease in the rainfall at this period, resulting in fall in water level of the lake.

Total alkalinity: Total alkalinity is known to affect among other things conductivity of water (Adebisi, 1981) and this is felt to be due to its effect on the ionic balance of the water. The significant absence of snails in most open water areas of the lake must be related to this form of interaction. The study of Beauchamp (1953) had pointed out that African inland waters generally lack sulphates and this was the case in this lake. He attributed this to the low concentration of the ion in the non-sedimentary nature of the drainage areas around these water bodies. Similar to water hardness, Alkalinity is expressed in terms of mg CaCO_3 /litre of water, because the cations of hardness and the anions of alkalinity are derived from carbonate solutions. Average monthly values

ranged from 181.1 mg CaCO_3 /litre of water in August (rainy season) to 193.3 mg CaCO_3 /litre of water in January, 2003 (Table 8). There were also slight differences in the average values for the zones, ranging from 185.2, in Zone C to 189.5 mg CaCO_3 /litre of water in Zone A, reflecting progressive loss of moisture in the zones over the months. The general high values of carbonates in this lake water may not be unconnected with the chalky materials usually brought into the lake from the eroded gullies by the floods during the rains.

Dissolved oxygen: The DO was high during the rains than dry seasons. This was because of the enlivened habitat that resulted in the rapidity of growth of phytoplanktons and higher vegetation that produced oxygen during their photosynthetic activities. The eutrophic nature of the lake supported the growth of these plants by supplying nutrients to them. Generally, the levels of dissolved oxygen were considered high because of the eutrophic nature of the lake, adequate temperature and possibly, low rate of evaporation.

The relationship exhibited is that whenever increase occurs, say in pH and total alkalinity, there is a corresponding decrease in dissolved oxygen (see Table 6 and 9), and during this period the water was seen to become turbid and in some areas were foul-smelling and a high mortality of snails was recorded. The effect of inorganic ions on snail in all of these is however not very clear.

The significant possible correlation between pH and snails in two of the zones may have resulted from the influx of ions which help in formation of chelation complexes with compounds which may either increase or lower the pH and thus affects snail numbers. Increases in pH will also result in decrease of free carbon dioxide in the lake. Similar findings by Willoughby (1976) suggest that the presence of large amount of inorganic ions always accounts for increases in pH and alkalinity.

The general patterns seem to be a negative and insignificant correlation between snail abundance and the physico-chemical variables (Table 19). There was no very significant correlation between snail abundance and any variable in this lake and,

therefore, characterizes the lake as unstable. The negative correlations between snail abundance and many of the variables in zone B and C is noteworthy but no special reason for this can be adduced now. The conclusion is that the physico-chemical property of the lake has little effect on snail abundance.

Distribution and Abundance of Gastropod Snails in Obutu Lake

Studies on abundance and frequency of the gastropods of Obutu lake showed the incidence of 11 species of snails belonging to 9 genera, of which the genus *Lanistes* was the most abundant. Of the 111,834 snails collected over the four-year study period, 81,748 representing 73.10 % were members of the genus *Lanistes*. Next in abundance was the genus *Pila* (11.12 %), while the least abundant genus of gastropods in the lake was *Gyraulus costulatus* (0.07 %).

There are 21 species of the genus *Lanistes* in Africa. The type species is *Lanistes carinatus* Olivier, 1804. The distinguishable feature of this genus is the sinistral shell (shell is turned to the left) while the body is dextral. This paradox is called hyperstrophic sinistral. In Africa, native species of *Lanistes* are found in all countries south of the Sahara, from West Africa, through the Central and East Africa to the entire South Africa excluding the Kalahari Desert. Native species of this genus are also found throughout Madagascar.

The pattern of species abundance found in the lake cannot be fully explained. Further studies are expected to expose the factors that for example, make *Lanistes* so abundant in this lake, whereas they are lacking in the neighbouring Agulu Lake in the same area (Emejulu et al 1992).

Correlation values showed that there was a close association between these gastropods and aquatic macrophytes, microphytes and macrovegetations, which these snails use as oviposition sites, hiding/resting places, and food. Besides, aquatic macrophytes are agents of thermic stability within the lake.

One other useful finding from this study was the incidence of three endemic genera of arboreal snails in the lake, belonging to the family Bulimulidae. These are *Bulimulus* sp, *Orthalicus* sp, and *Drymaeus multilineatus*. They are also amphibious. They are found mainly on aquatic herbs, macrophytes shrubs and on the ground particularly when they are dislodged from their perches or while laying eggs. It was interesting to note that as their diets were found to be mainly epiphytic growths, algae, fungi and lichens, they did not constitute agricultural pests, while they were also observed to have restricted ranges even within the lake and its environs. These Bulimulidae now being reported for the first time in this country, and are, therefore, new geographical records.

Deisler (1982) described these snails as either rare, endangered or gem snails, whereas the systematics, phylogeny and zoogeography of the Bulimulids have been reported by Pilsbry (1946) and Breure (1979). Pilsbry (1946) described the shells of these snails as banded, ovate, and white in colour but usually shedding into cream buff on the parts of the last whorl. Ever since then several other morphological forms have been collected and described.

Originally, these snails were thought to be only endemic in the Gulf States of USA especially Florida, Sugar loaf key, Summerland key, and the Everglades. Recent studies have shown that they are found in tropical and subtropical regions of the world (Thompson, 1976).

The three genera of the Bulimulidae now being reported for the first time in this country are endemic to this lake and are new geographical records. The key to facilitate the identification of the Bulimulidae has been given (Deisler, 2004).

The measures of the community structure are usually studied in order to characterize a community by the relative density, relative dominance and importance value of each species. It also provides a means of describing the complexity of the community, or the diversity of types of individuals in the community. This measure will combine the relative proportion of individuals (evenness) with the number of species present (richness).

The inter-relationships of the components of communities are exceedingly complex. At the most simplified level, it is possible to categorise organisms as producers, consumers and decomposers. The organisms interact with each other to form a complex food web. In gastropods some or most feed directly on plant and animal detritus while others consume the detritivores. The number of organisms that can live in a habitat is limited. When this is true the population growth may be logistic.

Logistic growth is characterized by growth at an exponential rate when population size is small, followed by a decrease and leveling off of the growth rate as the habitat carrying capacity is approached. The carrying capacity is the maximum population size that a habitat can support. Many factors contribute to the determination of the habitat's carrying capacity.

Many studies of population growth are made under the assumption that all individuals are the same, but it is usually not so, thus the study of ecological details such as the age specific growth, reproduction and death of the individuals in the population, are crucial. As a first step, the study of population distribution, population size and associations between the environment (both biotic and abiotic) are made. This study represents that for Obutu Lake. In terms of distribution of snails, this study suggests that the pilid apple snails are well established in Obutu Lake and reports for the first time in this country the existence of amphibious (tree or arboreal) snails in any local habitat. As can be seen, *Lanistes* was ubiquitous and was collected from every site and often, they were the dominant species constituting a very large population in the lake.

Association of the gastropods in this lake presents an interesting aspect of the study. For example, there seem to be snail preferences for some species of plants. It is common to associate *Lymnaea* with *Nymphaea lotus*, as well as associate the tree snails with *Ludwigia* when they descend into the water, and the pilids are circumboreal. This close association between snails and aquatic macrophytes has been noted for other freshwater systems in Nigeria (Ndifon, 1980, and Okafor, 1984). However, this study

found the snails not only associating with macrophytes but tried to separate the association between macrovegetation, macrophytes and microphytes - a situation which will be further investigated. The common macrovegetation that these freshwater snails associate most include *Napoleona volgelii* and *Lagerstraemia indica*, whereas the macrophytes include *Commelina* sp. *Acroceras zizanoides*, *Ludwigia* sp, *Leptocarpa* sp, *Lemna* sp and *Nymphaea lotus*. Most were found in habitats with heavy microphyte distribution. For example, the abundance of the snails was higher in sites with high density of desmids, diatoms, filamentous and non filamentous algae. Analysis of some of these associations using Chi squared has shown that there are great divides between the gastropod taxons and these plant species. For example, while the arboreal prosobranchs prefer plants like *Pistia*, *Nymphaea*, *Solanum*, *Sphenoclea*, *Ludwigia*, *Commelina*, *Lemna* and *Alternanthera* for food, the pulmonates seem to prefer them as resting and ovipositing sites, as well as representing a large component of their diet.

Going back to earlier studies on the ecology of freshwater snails, one important fact is prominent. This fact stressed by Ukoli and Asumu (1975) and echoed by subsequent ecological studies in Nigeria, show that freshwater snails are usually abundant in slow-flowing habitats. This fact was amplified by Okafor (1984) whose study further showed that the abundance was seasonal. This study supports the claim that this lake that has low current speed contains not only abundant snail population but a high diversity of species.

High abundance of snails is known to increase interspecific interactions by competition for resources, but also limits niche space for individual snail species (Bush and Holmes, 1986). Studies verifying why these happen, show as in this study, that the nature of the environment (e.g. vegetation cover and the nature of the substratum) has tremendous influence on snail distribution and abundance (Okwuosa, 1979, Ndifon 1980, Okafor and Anya, 1991). Factors such as these are also suspected to facilitate the successful entrenchment of given species in certain sites no matter the distance from each

other have similar snail communities. In the present study, the fact that vegetation cover is a key factor controlling distribution of the gastropods is not in doubt. This study suggests that in addition to this, it also controls the snail population size as sites within areas of high vegetation cover house more snails than the open water areas.

Inter-site differences in distance combine with the nature of the substratum in a very unclear way, to also affect both snail abundance and snail population size. This relationship exhibited here needs further study.

The species-areas relationship between abundance and population size seem to coincide with such phenomenon recorded in Guegan and Hugueny, (1994) and accounts for the species richness. It can also account for snail community similarity existing between similar sites but why differences exist with increasing distance between sites is not clear. One thing is clear though, and that is that there is similarity in abundance related to vegetation cover. Poulin and Morand (1999) suggested that such relationship hinges on the ecological character of the habitat. The study shows that the pilids are dominant in this lake, suggesting that they are good at exploiting the excessive vegetation associated with many sites in the lake. These species of snails are known for their excessive plant feeding habit that often make them pests in rice growing areas. Thus, the similarity in abundance of the pilids existing between similar sites but differing with increasing distance between the sites depends on these arguments.

A further look at the role of the lake bottom (nature of the substratum) suggests that the more diversified the bottom substratum coupled with the presence of these vegetation, the abundance of snails is facilitated, thus increasing the species richness. It also shows that diversity and dominance were similarly affected. The pattern of species abundance and dominance found here cannot be fully explained, further studies is expected to expose the factors that for example, make *Lanistes* so abundant in this lake whereas they are lacking in the neighbouring Agulu lake in the same area (Emejulu et al., 1992). Such effort is also required to show why the arboreal tree snails are endemic to this

lake and not in other similar lakes dotting the country. One may hazard a guess that distance from resource patches or their absence may be the explanation. Rigby et al., (1997) suggested that animal communities from similar habitats are usually the same but when they occupy different ecological patches even within the same habitat the difference in species richness and species abundance may be due to increasing or decreasing distances between the ecological patches.

In this study, while no qualitative similarity was found between the snail species between the studied sites, there were definitely quantitative similarity in species richness and abundance between habitats with similar vegetation cover as well as qualitative difference influenced by distance between the sites.

Stomach Contents of Gastropods found in Obutu Lake

Gastropods were both diverse and abundant in the lake. Trophic analysis showed high degree of food specialization with considerable dietary overlap among the often many coexisting species, but little overlap between genera.

The diets of the snails show that apart from the occasional filter feeding behaviour and the cannibalistic attitude of the prosobranch members when starved, the bulk of the foods of the snails in the lake as shown through their stomach content analysis were macroinvertebrates, microinvertebrates, microphytes, macrovegetation, rotifers, desmids and diatoms. Although certain species showed food preferences, there were considerable dietary overlaps, indicating a level of coexistence among the gastropods. The eutrophic nature of the lake enhances availability of the foods for the snails throughout the year. The food contents, identified in Table 20 were by no means exhaustive, since a lot more might have passed through enzymatic degradation and therefore, could not be seen on examination. This is particularly true of rotifers, protozoa, microphytes, desmids, diatoms, and larval stages of arthropods. The organisms listed at Plates 1 – 23 could, no doubt, also serve as the foods of these gastropod snails depending on their individual food

preferences. Dietary generalists were uncommon and the food sub-webs appear compartmentalized.

Grazing by the snail caused marked changes in the biomass, species diversity and dominant microphytes in the lake. The selective feeding abilities of the various snail species and the gut passage survival abilities of the algae were reasons for the observed changes.

Digenean Trematodes of Gastropod Snails of Obutu lake

A total of six digenean trematode cercariae was found after screening the 111834 snails. As separate species were considered, it was found that few snails shed cercariae and that the types and numbers of cercariae shed per snail varied from one to two.

If all the parasite species were considered, the prevalence of infection was low (27.22 %). The maximum value of prevalence was found in five sites which were also the places with macrovegetation and submerged macrophytes.

The most prevalent species (type of cercaria found) was the gymnocephalus cercariae (strigeidae) which was found in five out of the eight infected species of snails, while the least prevalent was zygocercariae.

Zygocercariae which infected only *Pila spp* are little known in Nigeria. Zygocercariae – aggregation of cercariae, is referred to in literature as Rattenkonig cercaria. They aggregate to form clusters or rosettes after emergence from their molluscan hosts. They were first reported from marine molluscs by Clauss in 1880. In 1888, Monticelli named it *Cercaria clausii*. The first freshwater zygocercous cercaria was named *Cercaria gorgonocephala* by Ward in 1916. Each cercaria is non-oculate, pharyngeate, distomate and brevifurcocercous. Ever since then, such cercariae were being collected from freshwater prosobranchs. *Cercaria laraminesis* has been reported from *Pila wernei* obtained from River Obinna in Adani, Uzo-Uwani Local Government area, Enugu State (Okafor, 1990a). That was the first report of zygocercous cercariae in the pilid snails in Nigeria.

The distribution of infection by sites showed that the snails were infectedd mostly in the sites with vegetation cover and submerged vegetation (Table 23), as could be seen from the pilid snails (*Lanistes* and *Pila*), *Lymnaea natalensis* and *Potadoma freethii* which were infected mostly in those sites. *Bythinia* sp and *Gyraulus costulatus* were infected in marginal areas without vegetation.

There were significant associations between the months and the release of the cercariae, By far, the largest releases were obtained in December, while no releases were found from snails collected from February to October each study year.

Studying the structure of the parasite community showed that some of the infected snails were not distributed randomly but rather, some nested patterns were observed with the snail species infected, irrespective of genera, congregating in the sites and being separated from those without infection. Species abundance, distance between sites and months, were probable risk factors for snail infection and were also limited by the qualitative and quantitative similarities of parasite communities among the host species.

Analysis of the findings using nested patterns of snail species isolated has been shown above in Table 23. Analyzing the matrix of presence or absence data of the digenean species from different host populations, showed that the parasite species show close affinity to certain snail species (i.e. there was a narrow host range) (Table 21). The closer they were, they became placed as outliers in the matrix. For example, the gymnocephalus cercariae use the lymnaeid and pilid snails as intermediate hosts; the amphistomes also used *Lymnaea natalensis*. Thus, the gymnocephalus cercariae utilized more than two species of snails as intermediate hosts. *Bythinia* sp release cercariae resembling that due to *Prosthogonimus* sp. Nested patterns observed indicated that infected snails were few and these congregated to particular sites. These sites showed the presence of high concentrations of cercariae irrespective of types. The arboreal snails did not shed any cercaria.

Nestedness (a departure from random) copiously observed from November to January, was an interesting finding from this study. A nested pattern occurs when the parasite species found in infracommunities represent non-random subsets of progressively richer infracommunities. This implies that the distribution of different parasite species among host individuals are not mutually independent. Nestedness is not a feature of the parasite communities in a given host species, but instead, is a characteristic of certain communities at specific times and places.

In recent years, a popular approach to the study of parasite community structure has involved searching for a nested pattern in infracommunity composition within the component parasite community (Worthen, 1996; Worthen and Rhode, 1996; Wright et al, 1998; Poulin and Guegan, 2000; Poulin and Valtonen, 2001, 2002). Using fish parasites, studies by (Carney and Dick (2000), and Poulin and Valtonen, (2002) on whether nestedness patterns were repeatable in space and time presented several shortcomings to address the question about repeatability in both space and time. But advancing further Videl-Martinez and Poulin (2003) assessed the repeatability of parasite community structure, using pairwise interspecific associations and nestedness patterns in fish hosts across space and time. They concluded that nested patterns in community structure and their repeatability for spatial data might be affected by the distance between localities as well as the fish size. In the case of the temporal data, at least in a locality, the presence of nestedness and its repeatability appeared to relate to the reproductive biology of the fish host.

In this study, infected snails congregated in the sites which were not only contiguous, but were the sites with macrovegetation and abundant macrophytes (marginal areas with vegetation cover and open water with submerged vegetation), but they were scarce or absent in the intervening infra-communities (sites) which were devoid of vegetation. For these snails that showed nestedness, these places could be taken to be the

sites where niche requirements were most common and prevalent. In other words, they could be said to be sites of relative hospitality.

Results from this study show that the nature of the subgroups that exhibited nestedness was not relevant to this departure from randomness. The most likely explanation for the spatial data is that species composition is not always the same among the sites, which in turn produces a random assignment of the species forming the regional pool of digenean parasites to specific localities. On the other hand, the lack of nestedness indicates that the same species of larval digenean parasites were not present in all the sites or in all the individual hosts in one site, which in turn, produces differences in species composition.

Distance between sites and the sampling period should also be considered as factors affecting species composition and thus, nestedness. As the sites are close to one another the snails are exposed to the same local pool of digenean trematode larvae, and therefore, similar nested patterns (i.e. repeatability) are possible. However, the extent to which distance between sites affects repeatability can only be determined by producing databases taking into account this variable, and determining actually, whether or not there exists spatial structure in the data.

In the case of temporal, there was a rough tendency for nestedness to be present mainly from November to January. This period coincided with both the post-reproductive season of the snails, and the beginning of two harsh weather conditions namely, the harmattan period and the dry season.

This finding appears to agree with those of Vidal- Martinez and Poulin (2003) who attributed nestedness and its repeatability in some subgroups of fish infra-communities, from October to February, to the post-reproductive season of the fish.

Therefore, although yet to be studied with more appropriate databases, nested patterns in snail infra-communities in Obutu lake and their repeatability in space seem to be deeply affected mainly by the extent and type of vegetation cover as well as the

distance between the sites, while temporal repeatability appeared to relate to both the reproductive biology of the snails and the costs imposed by the weather. There is, indeed, the need for in-depth investigations into whether or not there is actually spatial and temporal repeatability in the digenean trematode community structure in snails' infra-communities in particular localities. It is, however, being emphasized that one cannot extrapolate the results from one infra-community to those of the other parasite communities in the different populations of the same host species.

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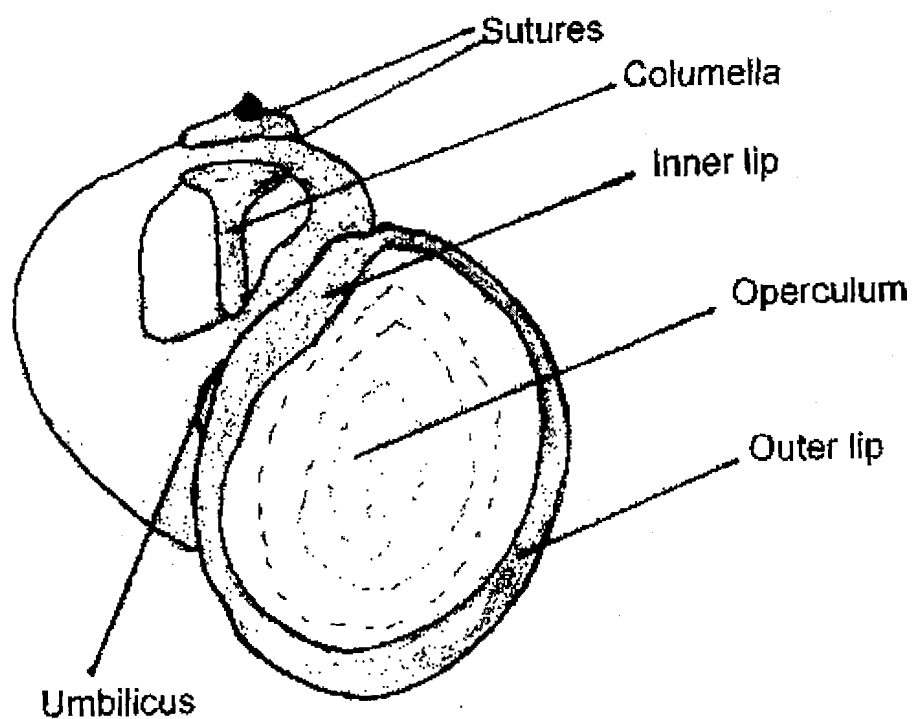
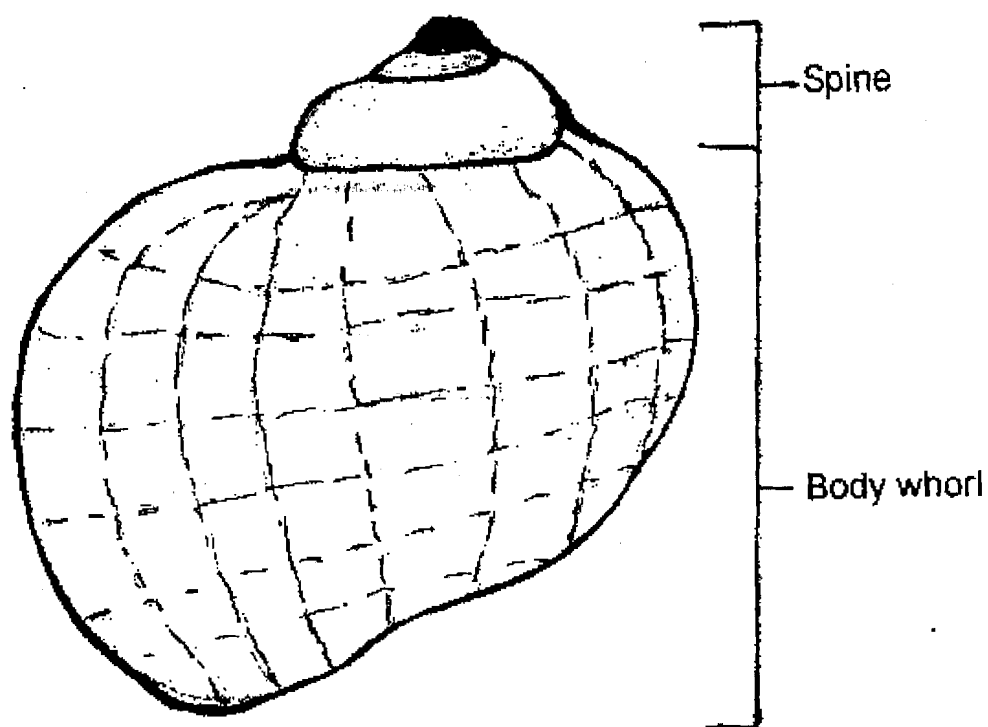
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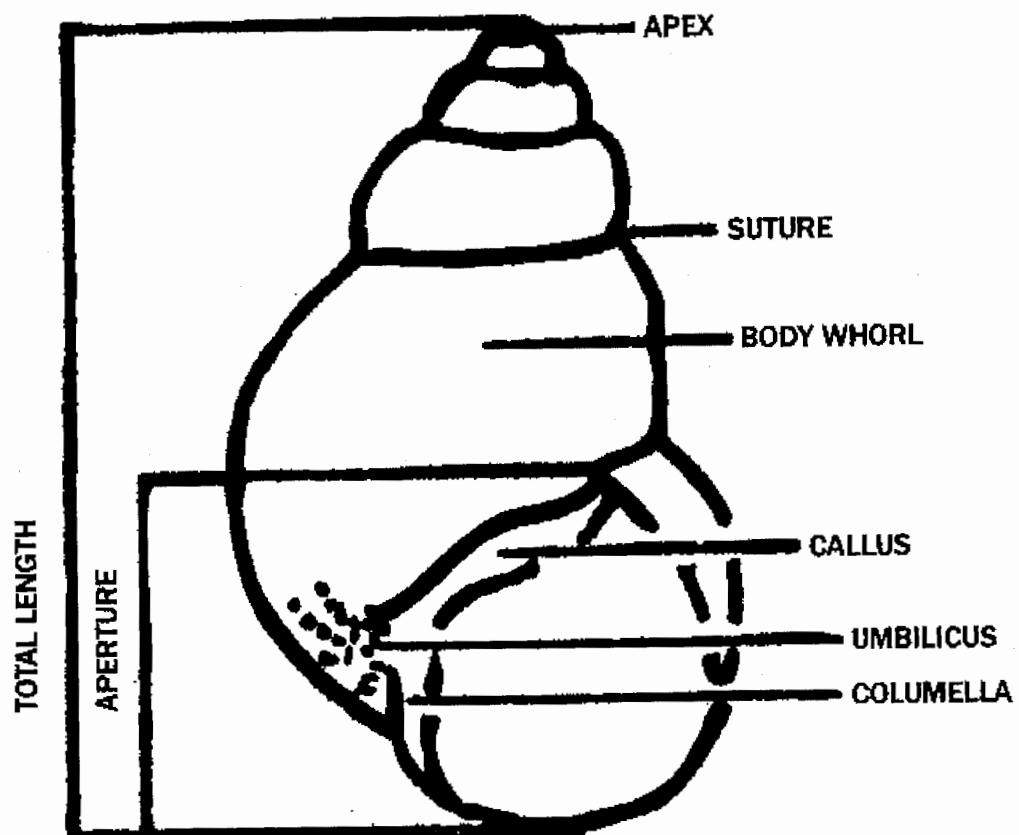
APPENDIX ONE

Apple Snail Shell Morphology

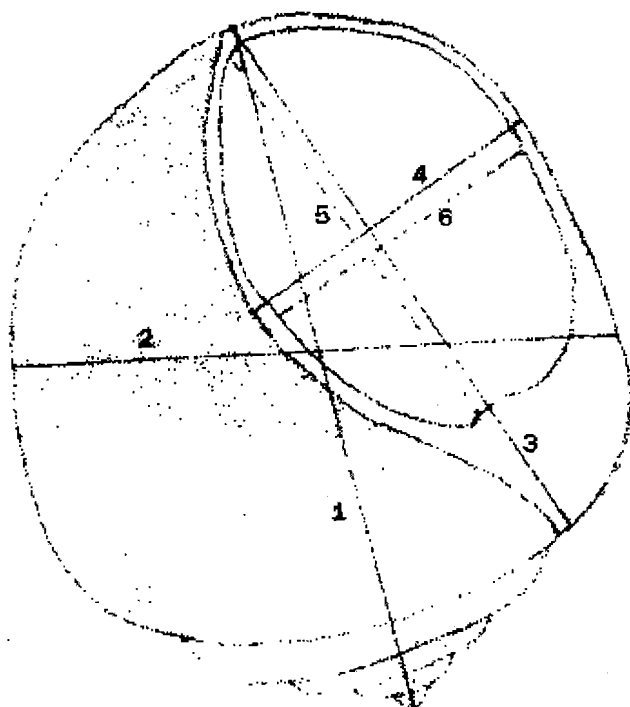
*Pila sp**Lanistes sp*

APPENDIX TWO

Arboreal Snails Shell Features

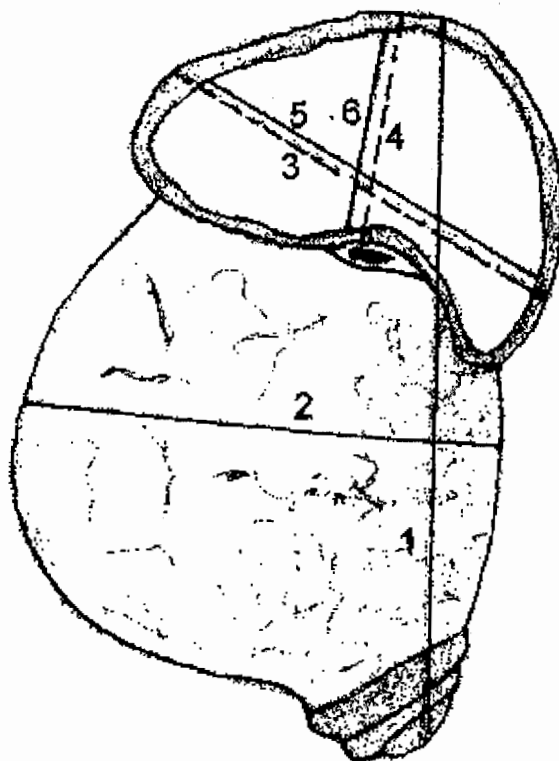


APPENDIX THREE

Pila sp Shell Dimensions

- | | | |
|---|---|------------------|
| 1 | - | Shell height |
| 2 | - | Shell diameter |
| 3 | - | Opercular height |
| 4 | - | Opercular width |
| 5 | - | Aperture height |
| 6 | - | Aperture width |

APPENDIX FOUR

Lanistes ovum Shell Dimensions

1. Shell height
2. Shell diameter
3. Aperture height
4. Aperture width
5. Opercular height
6. Opercular width

APPENDIX FIVE

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Shell Height	60	65	55	65	48	40	55	42	52	58	35	45	31	10	8	7
Shell Diameter	40	41	43	40	34	34	42	35	44	39	23	32	25	8	6	5
Number of whorls	5	5	5	5	4	4	5	4	5	5	4	4	4	3	3	2
Aperture height	30	23	28	25	25	25	27	25	29	30	20	23	20	8	7	5
Aperture width	15	16	19	20	13	17	20	18	20	14	11	16	13	4	3	3
Opercular height	27	20	23	22	23	23	24	23	24	26	13	21	18	6	5	4
Opercular width	15	16	11	15	11	14	12	15	12	14	8	12	8	4	4	3
Weight (gm)	13.1962	11.8793	7.2540	10.0125	6.5368	8.0453	6.5109	6.6611	6.6174	7.1371	2.6168	7.1132	3.3933	0.3869	0.1114	0.1562

Measurement	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Shell Height	6	55	64	44	50	43	66	52	40	55	64	38	64	65	50	53
Shell Diameter	5	42	39	31	43	35	40	43	33	43	40	33	40	41	42	41
Number Of whorls	2	5	5	4	5	4	5	5	4	5	5	4	5	5	5	4
Aperture height	5	27	27	23	28	26	30	28	24	27	27	24	27	24	27	29
Aperture width	3	20	20	15	20	18	18	18	16	20	21	16	21	23	20	20
Opercular height	4	24	24	20	23	23	26	23	22	25	24	22	24	24	22	24
Opercular width	3	11	11	12	12	13	12	13	11	15	12	14	11	17	13	12
Weight	0.1498	8.9263	10.4614	8.3635	7.6572	3.9544	13.4966	7.9482	4.9126	7.0688	11.9388	3.4905	11.3008	19.5761	6.7476	7.8815

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Shell Height	58	58	50	40	53	43	55	40	46	38	30	41	57	30	58
Shell Diameter	38	37	41	33	42	34	42	33	32	27	24	33	37	24	36
Number Of whorls	5	5	5	4	4	4	4	4	4	4	4	4	5	4	5
Aperture height	28	28	28	24	28	28	26	25	23	20	20	24	28	19	28
Aperture width	14	14	20	18	21	18	20	18	17	14	12	16	14	12	13
Opercular height	27	26	23	23	24	22	24	23	21	18	17	23	27	17	27
Opercular width	15	15	12	13	13	13	11	12	12	10	9	13	18	10	16
Weight	9.8452	7.9314	6.0361	2.7423	6.1634	5.2276	8.5883	5.2612	5.2857	3.2739	7.6028	7.5002	10.3770	3.6920	8.0765

Measurement	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Shell Height	40	62	65	64	44	60	40	60	62	42	30	30	30	31	61
Shell Diameter	32	42	43	43	30	41	31	40	40	32	24	23	25	23	40
Number Of whorls	4	5	5	5	4	5	4	5	5	4	4	4	4	4	5
Aperture height	23	23	33	33	23	29	23	31	28	22	23	22	20	18	28
Aperture width	16	16	17	16	15	17	15	16	16	15	16	16	14	12	18
Opercular height	23	29	31	30	20	26	23	28	26	23	21	21	18	17	26
Opercular width	15	19	20	20	12	18	13	17	16	12	11	12	9	9	15
Weight	6.3440	7.8899	10.3001	8.7201	8.9872	7.7092	3.6786	10.6200	10.0701	6.6610	6.0339	6.0303	6.0522	6.2123	13.4161

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107
Shell Height	12	40	62	10	65	55	47	32	45	35	34	40	41	44	11
Shell Diameter	8	35	41	7	40	41	34	25	30	23	23	33	33	32	8
Number Of whorls	3	4	5	3	5	5	4	4	4	4	4	4	4	4	3
Aperture height	7	26	31	8	28	26	24	19	22	20	19	24	20	23	8
Aperture width	4	17	16	4	17	20	13	13	15	11	12	17	12	16	4
Opercular height	6	24	26	5	22	23	23	18	20	13	24	23	15	21	6
Opercular width	4	14	14	4	13	12	12	9	11	9	9	14	9	12	4
Weight	2.6777	8.0114	11.3446	0.4001	13.0682	6.7264	5.4116	3.8004	7.1919	2.8003	3.7230	8.2006	8.5081	5.3503	0.2458

Measurement	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122
Shell Height	56	58	31	32	51	34	76	39	40	40	37	40	35	34	33
Shell Diameter	44	39	26	26	43	21	45	30	35	34	28	20	16	23	19
Number Of whorls	5	5	4	4	5	4	5	4	4	4	3	6	6	4	3
Aperture height	27	29	20	20	29	18	40	26	23	23	25	15	18	20	25
Aperture width	20	15	13	13	19	12	26	15	14	13	13	10	12	12	14
Opercular height	25	27	18	17	24	13	37	24	24	23	23	11	13	14	23
Opercular width	12	15	9	10	16	9	25	13	13	12	11	7	9	9	13
Weight	6.502	6.8702	3.3899	3.5114	6.5003	3.6992	43.6823	10.9910	7.5197	4.6509	5.0809	4.0985	4.1483	3.7069	8.0092

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137
Shell Height	40	54	60	61	60	56	62	77	55	40	36	44	57	60	41
Shell Diameter	32	40	43	41	40	39	44	45	40	33	26	32	40	45	34
Number Of whorls	4	5	5	5	5	5	5	6	5	4	4	4	5	5	4
Aperture height	24	25	32	28	28	29	32	27	26	19	20	22	29	32	24
Aperture width	18	20	17	16	16	15	16	20	19	12	13	16	14	17	17
Opercular height	27	23	29	26	26	25	30	32	23	15	19	21	26	28	23
Opercular width	18	15	18	18	16	13	19	20	12	9	12	12	17	18	14
Weight	9.9207	8.2043	14.2116	12.8024	11.9234	6.9114	8.6924	10.6498	8.510	3.9006	3.9726	4.2986	7.5320	10.7249	7.9864

Measurement	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152
Shell Height	59	55	59	64	44	41	53	54	43	47	55	56	46	58	60
Shell Diameter	40	41	39	40	30	33	45	43	36	34	44	36	33	41	41
Number Of whorls	5	5	5	5	4	4	5	4	4	4	4	5	4	5	5
Aperture height	30	27	30	22	22	23	28	28	25	24	27	27	23	31	30
Aperture width	16	20	15	17	15	16	20	20	18	12	20	14	16	15	15
Opercular height	27	24	26	20	20	22	26	24	23	23	24	26	21	27	26
Opercular width	15	12	14	16	12	11	15	13	15	11	13	16	11	15	15
Weight	13.0202	6.6204	7.0968	11.8924	8.8962	4.9432	7.2432	6.2010	6.7010	6.6222	6.1924	7.3248	5.1829	12.9286	7.1016

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167
Shell Height	40	38	32	32	64	38	45	65	40	32	31	55	61	50	40
Shell Diameter	31	26	41	26	41	27	31	44	33	25	25	42	40	44	33
Number Of whorls	4	4	5	4	5	4	4	5	4	4	4	5	5	5	4
Aperture height	24	20	24	20	24	20	23	32	19	20	20	25	29	29	25
Aperture width	18	13	22	13	22	14	16	16	12	13	12	20	17	20	17
Opercular height	27	19	19	18	19	19	21	30	15	17	18	23	26	24	23
Opercular width	17	12	8	9	8	10	13	19	9	10	9	13	17	17	14
Weight	12.7126	4.0196	3.6243	3.6924	3.9910	4.0924	8.7021	3.9210	3.8216	6.1414	7.6201	10.6401	7.2114	7.9004	6.1092

Measurement	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182
Shell Height	42	32	45	55	55	30	41	50	60	41	53	37	30	32	56
Shell Diameter	30	26	33	39	44	24	19	40	43	31	41	26	24	26	38
Number Of whorls	4	4	4	5	5	4	6	5	5	4	4	4	4	4	5
Aperture height	22	19	24	29	28	18	16	26	30	23	27	19	19	19	28
Aperture width	15	13	16	16	19	12	10	18	15	15	21	14	12	13	18
Opercular height	20	18	21	25	23	16	11	12	27	20	24	17	17	19	26
Opercular width	11	9	13	13	12	9	6	6	15	11	13	12	11	9	18
Weight	8.4210	5.9926	6.1049	9.2004	6.2009	3.9501	4.2615	4.3114	12.4014	8.1107	13.1100	4.0986	4.0121	3.8926	7.8243

Lanistes ovum Measurement of Shell Dimensions and Weight

Measurement	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197
Shell Height	20	34	29	20	24	9	18	23	60	22	28	42	40	25	28
Shell Diameter	17	24	14	14	13	7	15	15	43	15	18	29	29	18	19
Number Of whorls	4	4	5	4	4	4	4	4	5	5	4	5	5	5	5
Aperture height	14	19	16	11	11	8	12	12	31	12	18	21	21	19	14
Aperture width	7	10	8	6	6	5	7	8	21	7	8	14	11	7	10
Opercular height	16	18	14	9	9	7	9	9	28	11	11	19	18	12	13
Opercular width	6	10	13	6	5	5	5	6	16	6	7	12	11	7	7
Weight	1.0821	4.5087	1.5829	0.3527	0.9180	0.3698	1.0761	0.8454	16.1613	0.6920	1.3081	3.3333	6.0323	0.9707	2.7069

Measurement	198	199	200	201	202	203	204	205
Shell Height	59	22	26	41	32	53	31	35
Shell Diameter	41	19	20	23	21	32	23	23
Number Of whorls	5	4	5	5	5	5	5	5
Aperture height	30	14	14	19	23	28	18	18
Aperture width	20	8	9	10	10	18	11	9
Opercular height	29	12	13	16	17	25	15	13
Opercular width	19	8	7	10	9	13	9	9
Weight	18.6754	0.8200	1.7275	4.0848	3.8260	19.4890	2.2090	3.1955