STUDIES ON THE SALINITY TOLERANCE OF TWO PULMONATE SNAILS *(BULINUS TRUNCATUS AND BIOMPHALARIA PFEIFFERI)*, INTERMEDIATE HOSTS OF *SCHISTOSOMA SPECIES*

BY

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GOD BLESS YOU ALL !!!

DEDICATION

WITH ALL HUMILITY TO THE LORD JESUS CHRIST

AND TO

LOUIS FOR HIS LOVE, CONCERN AND FINANCIAL ASSISTANCE

DECLARATION

I hereby declare that this thesis has been written by me and that it is the record of my own research . It has neither in whole nor in part been presented for another degree elsewhere. Work of other researchers have been duly cited by references to the authors and all assistance received also acknowledged.

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Afua Serwaa Boakye–Yiadom

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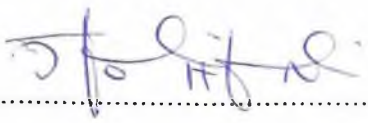

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Dr. John E. K. Kpikpi

(Supervisor)

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ABSTRACT

Bulinus truncatus and *Biomphalaria pfeifferi* were cultured in varying concentrations of seawater to study the effect of salinity on the survival and growth of adults and juveniles. The eggs were investigated for their hatchability. The experiment was conducted over a period of seven weeks for the snails while the eggs were studied over a two week period. Daily and weekly percentage mortality were determined . Weekly changes in weight and shell length was determined and used as an index of growth. Eggs of the snails were in culture medium for a minimum of two weeks.

Salinity affected the mortality of the snails (i.e. high salinities caused high mortalities of the snails). Salinities of 3.5% to 1.7% did not significantly affect weight but significantly affected shell length, (i.e. the snails increased in shell length). Salinity affected the hatching ability of the eggs of the snails. The higher the salinity, the lower the hatchability of eggs.

CHAPTER 1

GENERAL INTRODUCTION

1.1. BRIEF HISTORY OF THE DISEASE

Schistosomiasis is undoubtedly the most important helminth disease in the world today. Worldwide the disease is endemic in some 75 countries (WHO, 1985) and 200 million individuals are infected. 500-600 million more are at the risk of exposure to the infection (Webbe, 1981). In 1851 Theodor Bilharz a German physician discovered the causative agent of haematuria during an autopsy at Kasr El Aimy hospital in Cairo, and named it *Distomium haematobium.* Meckel von Hemsbach described it as *Bilharzia haematobium* in his thesis in 1856. However in 1858 Weinland named the parasite *Schistosoma haematobium* being unaware of Meckel von Hemsbach's thesis.

The International Commission of Zoological Normenclature (I.C.Z.N.) validated the generic name *Schistosoma* in 1889. This was confirmed by the International Zoological Congress in 1948. In 1902 Sir Patrick Manson suggested that there were two species of *Bilharzia* one with lateral spined ova, depositing its eggs in the rectum and the other in the bladder. Sambon then formally named the species *Schistosoma mansoni* in honour of Sir Patrick Manson (Abdel-Wahab, 1982). Currently, five species of *Schistosoma* are known pathogenic parasites of man, namely *S. japonicum, S. mansoni, S. intercalatum, S. haematobium, and S. mekongi, S. haematobium* is present in Africa and Arabia, Mauritius, Malagasy and India. *S. intercalatum* occurs in North Eastern region of Zaire (now Democratic Republic of Congo), Gabon, Cameroun and the Katanga region of the Congo. *S. japonicum* is confined to the Far East, infected areas being China, Japan, Thailand and Laos. *S. mansoni* is common in Africa and South America.

Leiper, 1915 revealed the link between the disease, freshwater bodies and freshwater planorbid snails which are intermediate hosts of the schistosome parasite. He also established the skin as the route of infection and further pointed out the different snail species which acted as intermediate hosts of the parasites. These are :-

Schistosoma mansoni: -	*Biomphalaria glabrata, B. straminea.*
S. mekongi: -	*Tricula aperta.*
S. haematobium: -	*Bulinus africanus* group and *B. forskali* group.
S. intercalatum: -	*Bulinus africanus* group. (Smyth, 1994)

1.2. SCHISTOSOMIASIS IN AFRICA

Schistosomiasis is associated with water developmental projects such as irrigation schemes and dams, because the intermediate host snails of the parasites breed in freshwater lakes and streams. In Africa dams are constructed for hydroelectricity and irrigation purposes. Unfortunately the creation of these dams in many African countries has provided suitable environments for the schistosome intermediate host snails. (Khallayoune et al, 1995) pointed out that in Morocco, extensive irrigation networks have contributed to the creation of suitable habitats for the intermediate host of *Schistosoma*. The transmission of the disease was restricted to irrigated areas alone, but it occurred in natural foci such as marshy plains, temporary swamps and residual water in pre-Saharan groves in the south of the country. Liese (1986) stated that in Egypt and Sudan where large irrigation schemes have existed for many years, schistosomiasis ranks as a public health problem. Nelson (1972) mentioned the Aswan Dam in Egypt as an example of a situation where control of schistosomiasis has been largely ineffective in spite of a great deal of effort over many years. Stephenson (1947) stated that schistosomiasis is endemic throughout most of Sudan due to the development of the

Gezira irrigation scheme and called for serious measures to be implemented to prevent schistosomiasis from becoming endemic in Gezira, but they failed to control the disease.

In Burkina Faso a study was conducted to investigate the potential intermediate hosts of schistosome parasites. It was reported that of 496 positive biotopes of the host identified, 2.33 % were found in natural lakes, 3.44 % in irrigation channels, 19.64 % in temporary ponds, 33.8 % in rivers and 40.89 % in man-made reservoirs (Poda et al, 1997). Appleton (1996), reported that in Southern Africa schistosomiasis occurs in most of Zimbabwe, Mozambique, Swaziland, North West Mpumalonga and Kwazulu-Natal.

In Nigeria schistosomiasis is the second most prevalent parasitic disease (Akogun, 1991). The disease has been found to be endemic in Borno state due to the construction of the South Chad irrigation project (Betterton, 1984).

1.2.1. SCHISTOSOMIASIS IN GHANA

Schistosomiasis in Ghana has been studied extensively over the years by (Bozdech, 1973; McCullough, 1959, 1962; Odei, 1961, 1983; Paperna, 1968, 1969; Kuma,1979 and Amankwa et al, 1994). Odei (1961) stated that the earliest report of schistosomiasis was made in the 1895 Annual Report of the colony of the Gold Coast in which it stated that a patient had been admitted to hospital as a result of "*bilharzia haematobia*" infection. *Schistosoma* infection was then largely confined to two extensive areas, one in the central region of Southern Ghana and the other in the Northern parts of Ghana, as well as the Southern Volta Region, and around Hohoe district. The prevalence of schistosomiasis is associated with the presence of slow moving freshwater habitats, which creates a congenial environment for the schistosome intermediate host. In the drier regions of Ghana the snail habitats are mostly seasonal streams, dams, ponds, lagoons, swamps and marshes. Odei (1961) explained that, in the

secondary forest areas they are mainly swamps, choked pools, sluggish streams and pools. The damming of rivers for fishing, irrigation and livestock watering may create more snail habitats. It is believed that schistosome parasites existed in some areas of the Volta River before the Akosombo dam was constructed. Odei, (1983) reported that freshwater lagoons in the Osudoku and Battor areas, which were associated with the Volta River, and which filled up during flood periods were the main source of host snails and schistosomiasis transmission in the lower Volta during the pre-Volta dam period. He reported however that schistosomiasis was not very common in these communities. This was because the conditions which prevailed then could not support the establishment of aquatic weeds or snails on the river beds, thus the Volta River was not the major source for the transmission of schistosomiasis even though a lot of fishing activities took place in it.

McCullough (1965), referring to the prevalence and distribution of intestinal schistosomiasis in Ghana, explained that the disease was confined to Tarkwa and Bogoso in the South-western part of the country and to a few areas in the North-East (now Upper East region) around Bawku and at Wiaga near Navrongo. He also stated that the disease could be found at Nyive and Atikpui villages near Ho in the Volta Region and Wa in the North West (now Upper West Region). The general prevalence of the disease can be attributed to the following factors:

a. Lack of complete knowledge about the disease.

b. Human activities that enhance water contact; this includes occupational, recreational, domestic and transport.

c. Creation of suitable habitats for the snail hosts of the *Schistosoma* parasite.

d. Lack of social infrastructure such as latrines and pipe-borne water.

Water Resources development projects

A number of dams that have been established for economic development such as production of hydroelectricity and irrigation scheme pose health hazards. There have been reports of the prevalence of schistosomiasis associated with these projects. The Tono irrigation scheme constructed in 1977 in the North Eastern part of Ghana, was an example of a Agricultural developmental programme which resulted in a rise in the prevalence rate of schistosomiasis in the Kassena Nankana District. Amankwa et al (1994) reported that the Tono scheme area represented an area of high endemicity for both intestinal and urinary schistosomiasis. They also reported that even though urinary schistosomiasis was already endemic in the area before the construction of the scheme, the prevalence of intestinal schistosomiasis was related to the irrigation scheme creating suitable habitats for intermediate host snails.

McCullough (1965) suggested that habitats of *Biomphalaria* and other molluscs had been found in a series of burrow pits, bordering a road that was constructed 10 years earlier. He also stated that in the North-Eastern and North-Western part of Ghana, *Biomphalaria* have established in dams and fish ponds, many of which had been recently constructed. Odei (1983) explained that the outbreak of schistosomiasis after the construction of the Akosombo and Kpong hydroelectric dams, could be attributed to a decrease in the flow of the river and also decreased turbidity enhancing penetration of sun rays and thus giving rise to the proliferation of submerged and rooted aquatic macrophytes with which the snails are associated. The intensive water-contact activities of the riparian communities, who are mainly fishermen and clam-diggers have resulted in the establishment and transmission of urinary and intestinal schistosomiasis. Some of the inhabitants depend on the river for

transport to other communities, while the children enjoy swimming in the water for recreational purposes.

The absence of piped water in these communities make them depend on the river for their domestic source of water. They also lack social infrastructure such as toilet facilities and therefore continue to contaminate the water bodies with parasite eggs through defaecation and micturition. In addition, the inhabitants have not yet received enough education on the mode of spread of disease. However, in almost all the affected communities along the Volta River a lot of education by both the Volta Basin Research Project (V.B.R.P.) and the health research sector of the Akosombo Hospital has been going on, together with chemotherapy and focal molluscicide. Some amount of success is being achieved with regards to reduction of prevalence of the disease.

1.3. BIOLOGY OF THE SCHISTOSOME PARASITE

All the species of *Schistosoma* have a life cycle characterised by alternation of generations, with the sexual generation taking place in the definitive or human host and the asexual development occurring in the snail intermediate host.

Some of the schistosome eggs laid by the adult wormsin the definitive host reach the environment through faeces or urine, depending on the type of infection . Many the eggs are however retained in the tissues of the definitive host where they provoke an inflammatory reaction. It is this reaction that is responsible for the disease. Although the presence of the adult schistosomes in the definitive host does not give rise to a pathological response, the severity of morbidity and intensity of infection is determined by the number of the adult worms present the eggs they produce in the host tissue. On reaching freshwater, the schistosome eggs hatch into miracidia which swim freely in the water but are relatively short-

lived. When they encounter the appropriate snail host, the miracidia penetrates the head-foot region, tentacles or mantle collar of the snail host and transform into mother sporocysts. These then produces large numbers of daughter sporocysts which migrate to the hepatopancreas of the snail and subsequently give rise to cercariae, which are free-swimming larval forms. The cercariae are infective to human. After successful penetration of intact human skin, the cercariae transform into schistosomula, which migrate in the blood stream to the liver via the lungs, and subsequently developing into young male and female worms in the hepatic portal vessels. Four to six weeks after cercarial penetration worms move to their final destinations where they mature. In the case of *S. haematobium*, causal agent of urinary schistosomiasis, the vessels of the bladder, and for *S. mansoni* (intestinal form), the mesenteric veins of the intestines.

1.4 THE INTERMEDIATE HOST

In Africa the freshwater snails transmiting shcistosomiasis are pulmonate snails belonging to the family Planorbida in the genera: *Biomphalaria* and *Bulinus*. Some of the snail hosts of schistosomes are capable of surviving for up to six months in their habitats by aestivating in the bottom sediments when the freshwater habitat they live in dry out. They do this by lowering their metabolic rate considerably and survive well in aerobic sediments. The aestivating snails resume activity when the habitat refills with water. Being hermaphrodites the pulmonate snails can store sperm from earlier copulation, to use for either cross or self-fertilization. The average life span is about 1.5 years for both *Bulinus* and *Biomphalaria.* Under favourable conditions they reach maturity in about 6 weeks but egg laying can sometimes be delayed until the fourth month depending on environmental conditions. The eggs laid are flat oval packets of between 5-30 eggs arranged in one layer, and glued together

with a yellowish jelly. The eggs are laid mostly on stems and leaves of submerged macrophytes, decaying plants and fallen leaves.

Bulinus and *Biomphalaria* are active during the day as well as at night. They crawl on the bottom, on plants and on various objects immersed in water, scraping their surface with the radulae and swallowing the food which may be animal microorganisms and organic debris. They also eat all kinds of decaying plants. The snails are tolerant of water varying widely in its physical and chemical characteristics, but the optimal temperature is about 25 °C, conductivity about 300 $uscm^{-1}$ and pH 6-8. They are not found in water flowing faster than 0.3 ms^{-1}.

In their aquatic habitats, the snails are mostly found in association with macrophytes (Madsen, 1995). Witenberg and Saliternik (1957) reported that in Israel the favoured plant of *Bulinus* and *Biomphalaria* was the decidous *Potamogeton sp.* Others include *Ceratophyllum demersum, Nitella translucans, Potamogeton pectinatum, Cynodon dactylon,* and *Panicum sp.* These plants serve as a source of food for the snails and also provided shelter, ovipositon sites and aeration. In a study of aquatic weeds in the Volta Lake of Ghana, Paperna (1969) reported that *Ceratophyllum* and to a lesser extent *Pistia* and *Scirpus* supported large populations of *Bulinus truncatus rohlfsi* and that the number of snails greatly declined when the weeds disappeared from many sites in the lake. In another study involving Lake Kariba in Zambia, Mugomba et al (1995) reported that the presence of vegetation in general, was favourable to the snail intermediate host. In another study involving Lake Kariba in Zambia, Mugomba et al (1995) reported that the presence of vegetation in general, was favourable to the snail intermediate host. They noted that the snails were more abundant in patches with vegetation than in barren ones. Thomas (1995), has suggested that because of the close mutualistic linkages between certain pulmonate snail hosts of schistosomiasis and

macrophytes, bioengineering measures aimed at snail control should include those directed at macrophytes.

1.5. PATHOLOGICAL EFFECTS OF SCHISTOSOMIASIS

The effect of the disease is related to the stages of infection, worm burden and previous exposures. Schistosomiasis may be associated with a variety of symptoms which include cercarial dermatitis, katayama fever and tissue damage as a result of egg depositions. Heavy primary infections associated with initiation of egg production leads to katayama fever which is characterised by high fever, lymphadenopathy, eosinophilia, hepatosplenomegaly, and dysentry. Increased deposition of eggs in the host tissue causes an immune reaction (T-cell mediated hypersensitivity to parasite eggs) which subsequently leads to the formation of granulomas (which inflame, thicken and cause the walls of urinary bladder and intestines to become fibrotic). Some of these granulomas are formed on the periportal tissues of the liver which lead to its enlargement and acute liver disease.

Schistosomal egg deposition can also occur in the other organs of the host such as the lungs, brain, pancreas, spinal chord and myocardium. Those trapped in the brain may cause seizures and cerebral atrophy. There is a relationship between heavy infections in children and impaired growth and psychological development. According to the WHO(1993) anthropological studies indicate that the disease may have significant social impact such as stigma associated with haematuria in women.

1.6. CONTROL OF SCHISTOSOMIASIS

Several approaches have been used to control schistosomiasis. The use of molluscicides or biocontrol methods have been used to kill snails thereby reducing the of snail intermediate hosts and the infective cercaria. Chemotherapy or drug treatment is used to eliminate the worms present in infected individuals. Health education and the provision of piped water and toilet facilities can reduce water contact by the people living in the communities (Morgan, 1977). Morgan (1977), reported that in St. Lucia, when clean piped water was supplied to five villages where prevalence of schistosomiasis was high, human water contact was reduced by 82% and there was a corresponding reduction in the prevalence and incidence of the disease. Liese (1986) suggested that strengthening of the Public Health Service (P.H.S.) of national health care systems responsible for epidemiological surveillance implementation of disease control strategies will help reduce the disease burden due to schistosomiasis. In Ghana the control of schistosomiasis has been largely by use of mass chemotherapy (Ansa, 1999).

The drug mostly used in Ghana is praziquantel. It has been found to be effective on other helminth parasites such as *Ascaris* and hookworms. WHO (1993) report indicates that treatment with praziquantel resulted in 60-90% egg clearance in infected people and in a reduction in egg loads of more than 95% among those who remained with patent infection after treatment. Chemotherapy is however expensive especially in terms of personnel and logistics cost (Webbe and Jordan, 1982). There is therefore the need to identify cheaper means of control. Other control measures such as the application of molluscicides, manipulation of the environment and also through biological have been tried in many countries. According to the WHO (1983) report on Tropical Diseases Research, snail control

has limited the transmission of schistosomiasis in some places notably in China, but has failed to do so everywhere, partly because it is expensive and difficult to sustain.

Methods of environmental manipulation include increasing the current speed, fluctuating water levels in canals or reservoirs (including drying them out completely), possible reconstruction and removal of aquatic plants (Madsen 1997) and manipulation of the biological environment of the vector snails may involve the introduction of competitor snails, predators, parasites, and micro pathogens into its environment. Several hundred species ranging from fish to fungi have been considered as potential competitors or predators, but their efficiency has rarely been tested outside laboratory model systems (McCullough, 1981). Biological control demands regular inspection of sites, as well as mass production of the control agents and thus viewed as labour intensive and expensive.

It has been observed that human behaviour patterns encouraging the transmission of schistosomiasis could be curtailed and replaced with patterns which restrict or completely break the transmission. Songs and visual aids have been used in attempts to educate people who live in endemic areas to desist from habits which bring them into close contact with infected waters. (Kpikpi, 1998). Complementary methods which can be used toward this end include provision of alternative sources of water for domestic use, and provision of toilet facilities for the hygienic disposal of human urine and excreta.

1.7 RATIONALE AND OBJECTIVE OF STUDY

There is the increasing understanding that the environment is a giant "living thing" with complex interrelationship and interdependence of all living things. Consequently it has been argued that the environment may be far more fragile than was previously thought. This has led to the current domination of most scientific issues by concern for the environment which

can rightly be described as an "environmental revolution" (Kpikpi, 1998). There is the need for the development of a control method with low environmental pollution, low cost and high efficacy, for reducing or eliminating snail host populations in freshwater habitats. Research teams working for the Volta River Authority observed that dredging of the Lower Volta estuary at Ada wiped out the snail populations as a result of influx of seawater.

The present study was therefore undertaken with the following objectives:

a. To investigate the effect of salinity on the survival, growth and development of bBulinus truncates and Biomphalaria pfeifferi. snail intermediate hosts of schistosomiasis in Ghana .

b. To evaluate the use of salinity as a possible tool in the control of schistosomiasis.

c. To provide baseline data for future intervention programmes.

CHAPTER 2

EFFECT OF SALINITY ON THE SURVIVAL OF *BULINUS TRUNCATUS* AND *BIOMPHALARIA PFEIFFERI*

2.1 INTRODUCTION

The control of the molluscan intermediate host of schistosomes forms a major aspect of any integrated program for schistosomiasis control. Snail-directed control strategies result in the elimination of the snail hosts or modification of the snail habitats rendered them inhabitable (Odei, 1965). To do this effectively without threat to the other freshwater fauna and flora in the habitat, a good knowledge of the ecological characteristics of the freshwater environment is required (Ferguson et. al., 1968).

According to Odei (1965) the factors that influence snail survival in a habitat include temperature, light, pH, organic pollution, dissolved chemicals, oxygen, aquatic macrophytes, seasons and climate, parasites, predators and other fauna. There is the need to fully understand ecological conditions in tropical Africa, particularly in areas of freshwater snail habitats where schistosomiasis is transmitted. Studies on the distribution, population dynamics, and mortality of snails have centred around the effect of climate, season and rainfall on the snails. Extensive studies on the ecology of the schistosome snail intermediate host have indicated that climate and season affect distribution, population and mortality of the molluscan host of *Schistosoma* (McCullough, 1962; Anya et. al., 1991; Witenberg and Saliternik, 1957; Webbe, 1964 and Odei, 1967). However, very little is known about the effects of the effects of salinity on the snails. In this chapter, the extent salinity influences survival of adult and juvenile of *Biomphalaria*. and *Bulinus spp* was investigated. The implications for future snail control are discussed.

2.2 MATERIALS AND METHODS

2.2.1 Snail Sampling

Snail sampling was done along the banks of the Weija Lake, a schistosomaisis endemic area near Accra. The samples were taken with a handnet and the snail species *Biomphalaria pfeifferi* and *Bulinus truncatus* were collected, sorted and stored in two separate 10 litre plastic buckets and brought to the laboratory for use in the planned experiment.

2.2.2 Snail Culture

Cultures were set up to raise snails of uniform size, weight and age. The snails were cultured in ten glass aquaria filled with tap water, eight of these measured 49cm x 36cm x 19.5cm, while the other two measured 61cm x 25cm x 25cm. Twenty adult snails were introduced into each of six glass aquaria together with some macrophytes *(Ceratophyllum demersum)* which served as aerators, shelter and points of attachments for the snail (Witenberg and Saliternik, 1957) (Plate 1 and 2). These snails were kept in the aquaria for two weeks to allow enough time, for them to lay eggs. After the two-week period, the adult snails were transferred into new aquaria without snails, leaving behind some eggs and freshly hatched juveniles on the macrophytes and walls of the aquaria. The snails were fed on the leaves of fresh lettuce *(Latuca sativa)*. Feeding was done every fourth day to ensure adequate supply of food. The water in each aquarium was changed once a week. The pH, conductivity, temperature, dissolved oxygen, and salinity of the water were measured daily(Table 2.9,,2.11,2.13 and 2.15) over a six-week period using the Hach kit and the average taken as follows:

Aquaria	Average pH	Average Salinity (%)	Average conductivity ($umscm^{-1}$)	Dissolved oxygen mgl^{-1}
49cmx36cmx19.5cm	9.4±1	0.00	0.089±0.10	2.02± 0.1
61cmx25cmx25cm	9.54±1	0.00	0.088± 0.10	2.92± 0.1

PLATE 1: Glass aquaria containing snails, macrophytes and lettuce.

PLATE 2: Experimental set-up

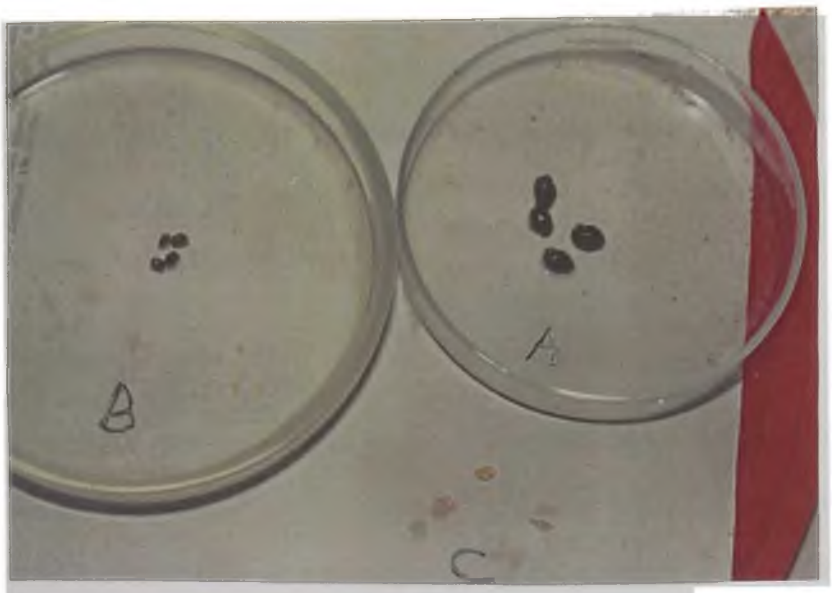


PLATE 3: A: Adult of *Bulinus truncatus B*: Juvenile of *Bulinus truncatus*

C: Egg masses of *Bulinus truncatus*

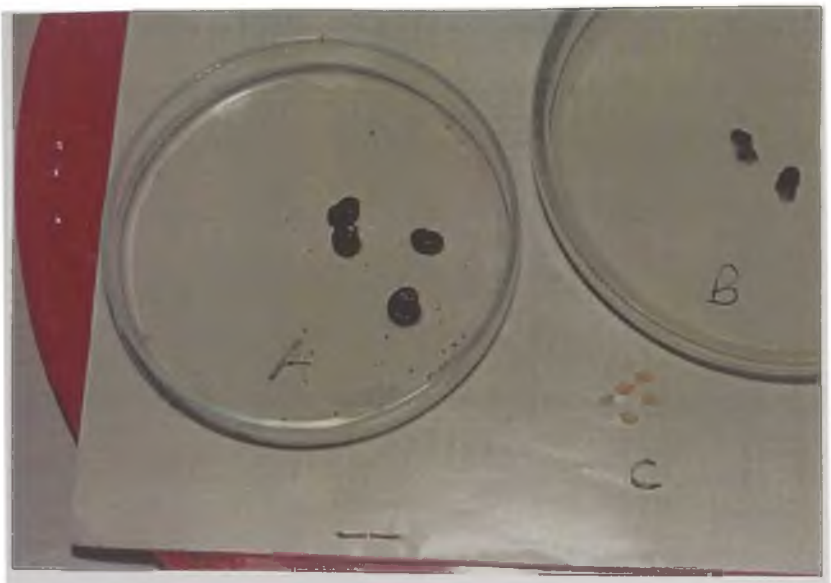


PLATE 4: A: Adult of *Biomphalaria pfeifferi B*. Juvenile of *Biomphalaria pfeifferi*

C: Egg masses of *Biomphalaria pfeifferi*

Biological parameters such as weight, shell length and mortality of the snails were measured. The weight of the snails was determined using a PG 503 Mettler Toledo scale, while the shell length was determined using a whale brand vernier calliper (range 0-200mm). A snail was 'certified' dead if it had shrunk inside the shell and did not respond when touched with a pair of forceps.

2.2.3 Preparation of Materials

Forty litres of seawater was obtained from a rocky beach in Teshie-Nungua (a suburb of Accra), and stored in 10 litre containers in the laboratory. Tapwater was used to make serial dilutions of the seawater. Plastic bowls of volume 720mls were labelled and arranged on shelves in the laboratory. 600mls of the appropriate seawater concentration were poured into each bowl. Tapwater was used as control.

2.2.4 Selection of Snails

Healthy adult and juvenile snails of at least 10 weeks and 4-5 weeks old respectively were selected from the aquaria. (Plate 3 and 4). The weight and shell length of five snails were determined, and put into each bowl, filled with the various concentrations of seawater, and tapwater (control). Each snail was fed on a disc of fresh lettuce (diameter 2.0cm). The adults were fed three times a week and the juveniles were fed twice a week. The snails were monitored daily to determine the number that die each day in the various concentrations of seawater.

2.3 RESULTS.

2.3.1 Mortality of adult and juvenile *Bulinus sp.* in various concentrations of seawater.

The results shown on Table 2.1 and Fig. 2.1 indicate that all the adult *Bulinus* snails kept in solutions containing 30% and above died within one week. Undiluted seawater (salinity,100%) produced 100% mortality of the snails within 0.03 days, and 10% seawater killed 67% of the snails in five days. Table 2.2 and Fig. 2.2 show that 100% seawater killed all the juvenile snails tested within 0.03 days, and 10% seawater killed all the juveniles snails exposed within 5 days. Statistical analysis of the results for both the adult and juvenile snails compared with control, and using chi-square test show significant differences: (Adult: X^2 tab = 1.14.5 while X^2 cal = 70.715; Juveniles: X^2 tab = 1.145 and X^2 cal = 90).

Mortality of adult *Bulinus* in concentrations (10% - 0%) seawater.

Table 2.5 and Fig 2.5 depicts a greater degree of intolerance to high concentrations of saline water as 10%solution recorded 66.67% mortality in one week. Comparatively 9% solution displayed a higher degree of tolerance, as mortality in the first week was only 26.67. This decreased even further as the concentration decreased. It is interesting to note that average mortality of snails in the 7^{th} week were as follows. 100%, 80%, 93.3%, 80%, 53.3% and 40%for 10%, 9%, 8%, 7%, 6%, 5%, and 0% respectively. Showing a general trend of increased mortality with increased salinity. Statistically the results are significant. (X^2 tab = 1.145 and X cal =22.6799).

Mortality of juvenile *Bulinus* in concentration 0% and 5% seawater.

For juvenile *Bulinus* average survival at 7 weeks were 86.67% and 80% respectively for 0% and 5% saline solutions. (Table 2.6 and Fig. 2.5) statistical analysis of the results

show that they are significant. (X^2 tab – 0d.00393, X^2 cal = 0.48). Only two concentrations were used in the set-up because of the low stock of juvenile.

2.3.2 Mortality of adult and juvenile *Biomphalaria sp* in various concentrations seawater.

In the case of *Biomphalaria* snails, 100% seawater killed 100% of the adult snails tested within 0.02 days, and 10% seawater killed 100% of the test adult snails in 4 days (Table 2.3 and Fig. 2.3). Data presented in Table 2.4 and Fig. 2.4 show that 100% of juvenile *Biomphalaria* died in 100% seawater within 0.01days or within 3 days in 10% seawater. Statistical significant differences in mortality were observed between the adult and juvenile *Biomphalaria*:(Adult snails: X^2 tab = 1.145 and X^2 cal = 90).

(Juvenile snails , X^2 tab = 1.145 and X^2 tab = 90)

Mortality of Adult *Biomphalaria* in concentrations (9% - 0%) of seawater.

The percentage mortality after 7 weeks was as follows for 9%, 8%, 7%, 6%, 5% and 0%. Seawater solution: 66.67%, 53.33%, 40%, 60%, 60% and 20% respectively. This shows a general pattern of increased survival with decreased concentration of saline solution, 7% and 6% saline solutions being the exceptions (Table 2.7 and Fig. 2.7). Statistical analysis indicate that the results are significant, (X^2 tab = 1.145 and X^2 cal 8.32).

Mortality of juvenile *Biomphalaria* in concentrations 0% and 5% seawater.

Rather unexpectedly average survival of juvenile *Biomphalaria* was higher 5% seawater solution than 0%saline solutions. Their pattern of mortality over the weeks is similar. (Table 2.8 and Fig. 2.8). Due to the low stock of juvenile *Biomphalaria* snails available only two concentrations were used in the set-up. The results are statistically significant. (X^2 tab = 1.145 and X^2 cal = 3.5294).

TABLE 2.1: WEIGHT, SHELL LENGTH AND MORTALITY OF ADULT *BULINUS* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	**Average initial weight (mg) Of 5 snails**	**Average initial shell length (mm) Of 5 snails**	**Mortality (%)**	**Time taken to attain mortality (days)**
100	45.8	4.39	10	0.03
70	86.67	4.14	100	0.05
50	105.53	4.33	100	0.17
30	77.47	3.71	100	0.17
10	86.80	3.93	66.67	5.00
0	81.87	3.71	0.00	7.00

TABLE 2.2: WEIGHT, SHELL LENGTH AND MORTALITY OF JUVENILE *BULINUS* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	**Average initial weight (mg) Of 5 snails**	**Average initial shell length (mm) Of 5 snails**	**Mortality (%)**	**Time taken to attain mortality (days)**
100	12.3	0.86	100	0.03
70	88.67	0.65	100	0.06
50	15.73	1.45	100	0.08
30	23.13	1.52	100	0.17
10	25.60	1.63	100	5.00
0	16.33	1.01	0.00	7.00

Fig. 2.1 Time period required for achieving 100% mortality for adult Bulinus cultured in varying concentrations of seawater

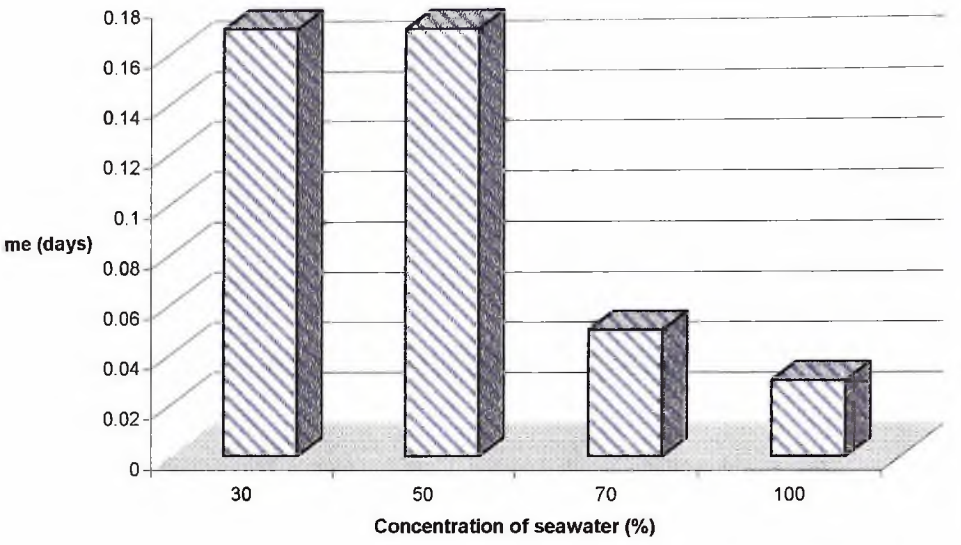


Fig. 2.2 Time period required for achieving 100% mortality for juvenile Bulinus culture in varying concentrations of seawater

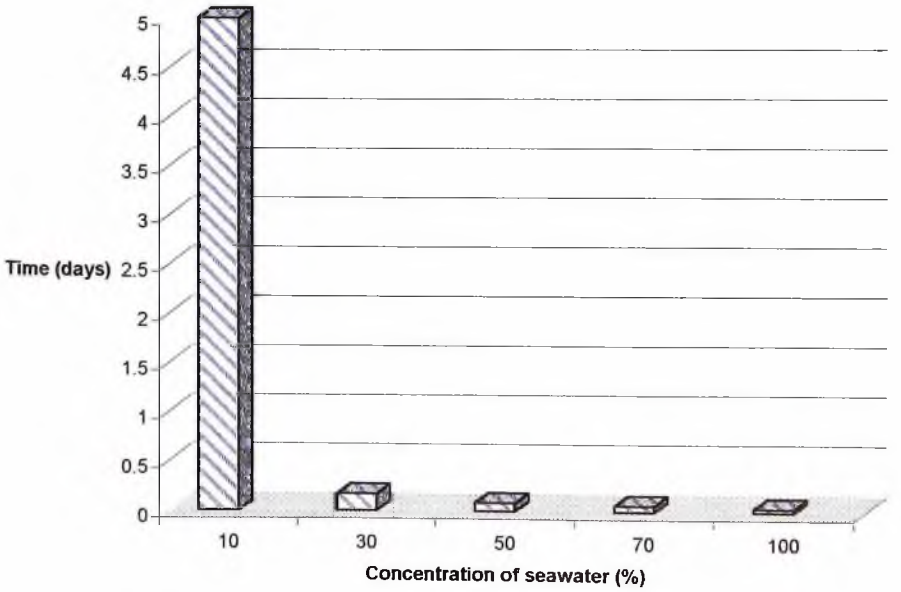


TABLE 2.3: WEIGHT, SHELL LENGTH AND MORTALITY OF ADULT *BIOMPHALARIA* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	Average initial weight (mg) Of 5 snails	Average initial shell length (mm) Of 5 snails	Mortality (%)	Time taken to attain mortality (days)
100	69.47	4.10	100	0.02
70	61.27	3.63	100	0.03
50	71.00	4.21	100	0.08
30	75.07	4.29	100	0.21
10	86.13	4.29	100	4.00
0	55.07	3.43	0.00	7.00

TABLE 2.4: WEIGHT, SHELL LENGTH AND MORTALITY OF JUVENILE *BIOMPHALARIA* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	Average initial weight (mg) Of 5 snails	Average initial shell length (mm) Of 5 snails	Mortality (%)	Time taken to attain mortality (days)
100	12.73	1.81	100	0.01
70	14.00	1.93	100	0.02
50	53.93	3.26	100	0.08
30	35.67	2.19	100	0.17
10	29.13	2.06	100	3.00
0	17.6	1.51	100	7.00

Fig. 2.3 Time period required for achieving 100% mortality for adult Biomphalaria in varying concentrations of seawater

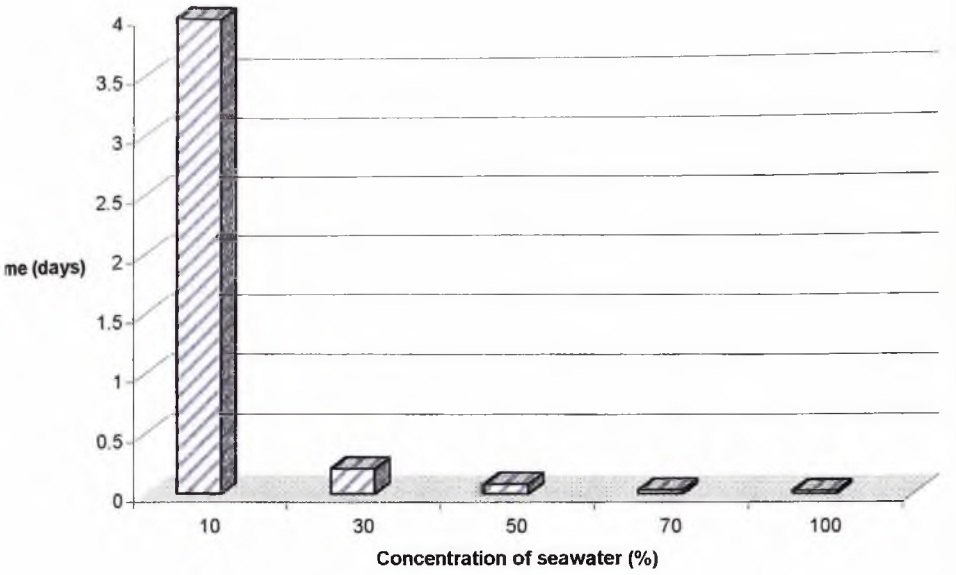


Fig. 2.4 Time period required for achieving 100% mortality for juvenile Biomphalaria in varying concentrations of seawater

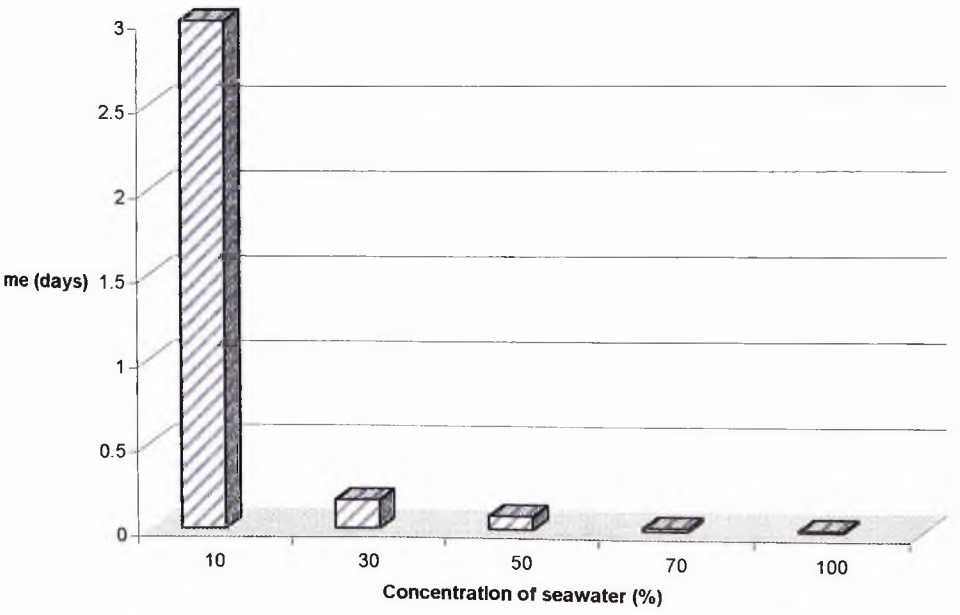


TABLE 2.5: MORTALITY OF ADULT *BULINUS* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER FOR SEVEN WEEKS.

Concentration of seawater	Weekly mortality (%)							Total (%)
	1	2	3	4	5	6	7	
10	66.67	0.00	13.33	13.33	6.67	10.00	0.00	100
9	26.67	6.67	6.67	20.00	0.00	13.33	6.67	80
8	13.33	26.67	6.67	6.67	6.67	13.33	20.00	93.33
7	6.67	6.67	6.67	13.33	6.67	26.67	13.33	80
6	13.33	13.33	0.00	0.00	0.00	13.33	13.33	53.33
5	6.67	0.00	0.00	13.33	13.33	13.33	6.67	53.33
0	0.00	0.00	20.00	6.67	6.67	6.67	0.00	40.00

TABLE 2.6: MORTALITY OF JUVENILE *BULINUS* CULTURED IN 0% AND 5% SEAWATER FOR SEVEN WEEKS

*Concentration of seawater (%)	Weekly mortality (%)							Total (%)
	1	2	3	4	5	6	7	
0	0.00	6.67	0.00	0.00	0.00	0.00	6.67	13.33
5	0.00	0.00	6.67	0.00	0.00	6.67	6.67	20.00

**Only two concentrations were used in set-up because the stock of juvenile snails was not enough.*

Fig. 2.5 Mortality of adult *Bulinus* cultured in varying concentrations of seawater

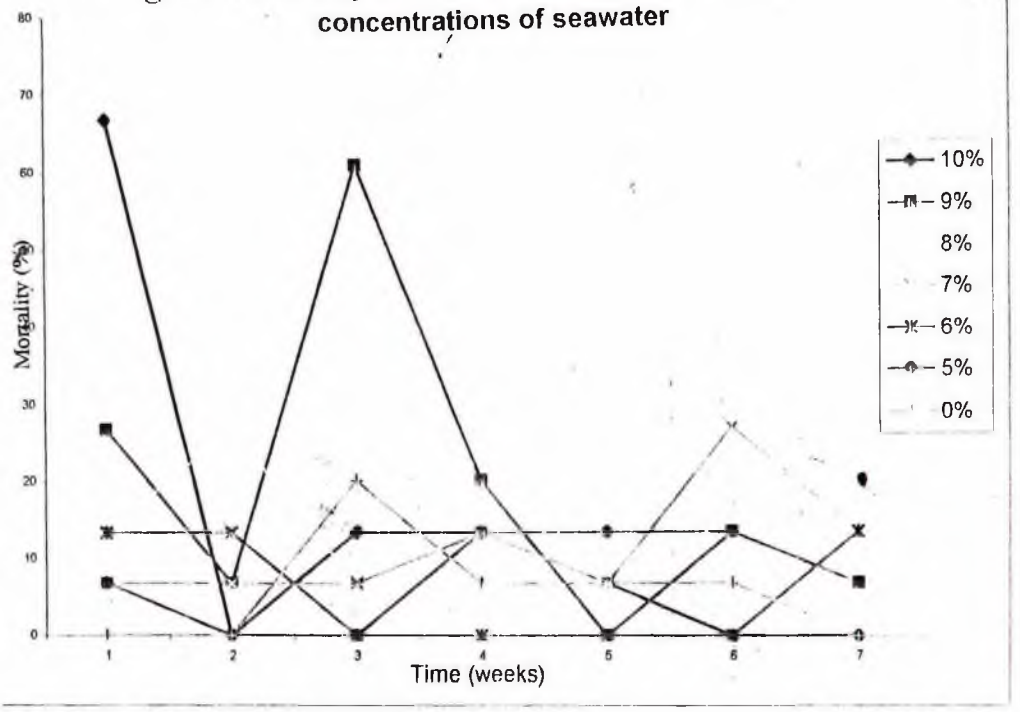
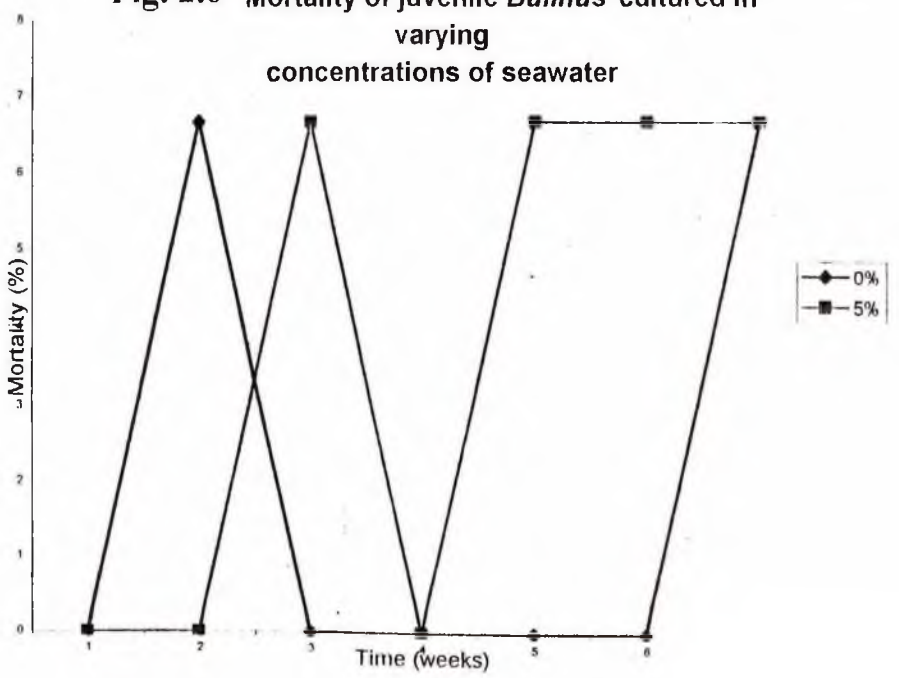


Fig. 2.6 Mortality of juvenile *Bulinus* cultured in varying concentrations of seawater



2.3.3 PHYSICOCHEMICAL FACTORS

pH of (100% - 10%) seawater solution.

The solutions were slightly alkaline in nature, with pH increasing with decreasing concentration, while there was a general increase in pH as the days increased (Table 2.9).

pH of 10% - 0% seawater solution

The solutions were also slightly alkaline in nature and the pH increased with decreasing concentrations of the seawater. In general the pH increased with time (Table 2.10). Statistical analysis showed that across concentrations the pH was significant ($P < 0.0001$) but variations across the weeks were not significant. ($P = 0.939$).

TABLE 2.7: MORTALITY OF ADULT *BIOMPHALARIA* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER FOR SEVEN WEEKS

Concentration of seawater	Weekly mortality (%)							Total (%)
	1	2	3	4	5	6	7	
9	0.00	6.67	0.00	6.67	6.67	13.33	33.3	66.67
8	0.00	6.67	0.00	0.00	6.67	20.00	20.00	53.33
7	6.67	13.33	0.00	0.00	6.67	0.00	13.33	33.33
6	0.00	0.00	6.67	6.67	20.00	6.67	20.00	60.00
5	0.00	0.00	0.00	20.00	6.67	20.00	13.33	60.00
0	6.67	0.00	0.00	6.67	6.67	0.00	0.00	20.00

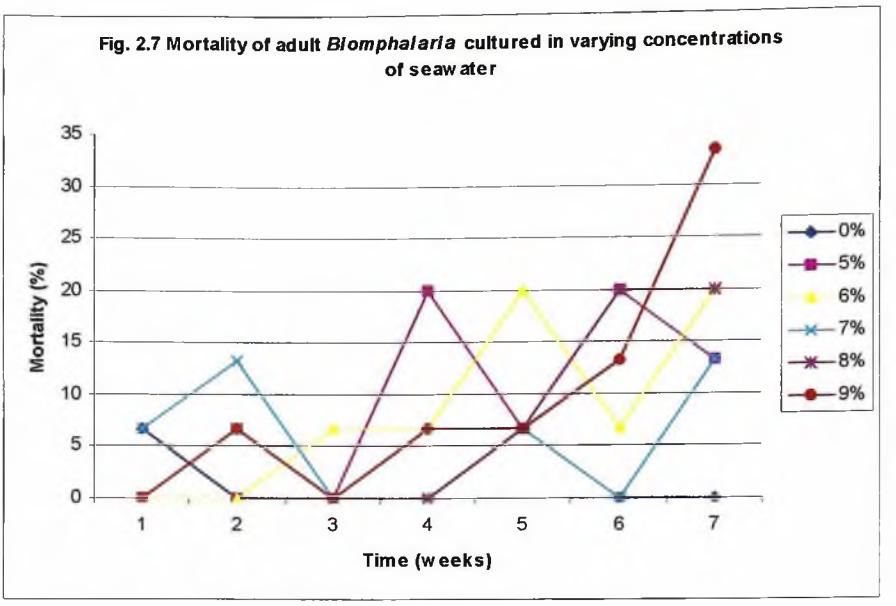
TABLE 2.8: MORTALITY OF JUVENILE *BIOMPHALARIA* CULTURED IN 0% AND 5% SEAWATER FOR SEVEN WEEKS

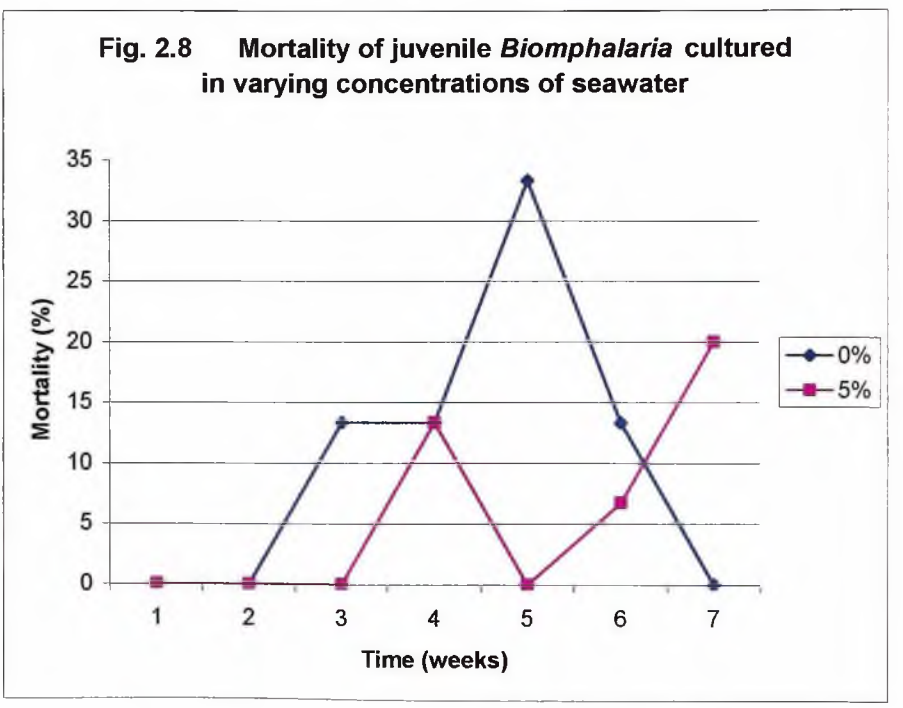
*Concentration of seawater (%)	Weekly mortality (%)							Total (%)
	1	2	3	4	5	6	7	
0	0.00	0.00	13.33	13.33	33.33	13.33	0.00	73.33
5	0.00	0.00	0.00	13.33	0.00	6.67	20.00	40.00

**Only two concentrations were used in set-up because the stock of juvenile snails was not enough*

Temperature of seawater 100% - 10% seawater solution.

The temperature readings recorded did not follow a set pattern. The variations across concentrations were minimal; the variations across the days however increased slightly compared to that across the concentration. Statistical analysis showed that the variations across concentrations and days were not significant. (P = 0.393 across concentrations and p = 0.421 across the days) (Table 2.11).





Temperature of 10% - 0% seawater solution.

Temperatures recorded did not follow a set pattern. Even though temperature variations across concentrations were minimal, the variations were greater across the weeks. (Table 2.12) ($P = 0.07$ across concentrations and $P < 0.0001$ across weeks). This shows that temperatures were statistically non-significant across concentrations while they were significant across weeks.

Dissolved oxygen of concentrations 100% - 10% seawater solution.

Dissolved oxygen values ranged from 2.28 mg/l to 4.45 mg/l. These values did not follow a set pattern, (Table 2.13). The results were statistically significant across concentrations and across days CP = 0.013 across concentrations and $P < 0.0001$ across days).

Dissolved oxygen of concentrations 10% - 0% seawater.

Dissolved oxygen recorded for the solutions did not follow a set pattern and ranged from 2.73 mg/l to 4.2 mg/l. (Table 2.1, $P=0.001$ across weeks and $P<0.0301$ across concentrations) thus the results were statistically significant.

Conductivity of 100% - 10% seawater concentration.

Table 2.15 shows that ionic conductivity values recorded for the various solutions decreased with decreasing seawater concentration. Daily variations recorded were minimal. Statistically, the results were significant across concentrations and not significant across days. ($P < 0.0001$ across concentrations and $P = 1.000$ across days).

Conductivity of 10% - 0% seawater solution.

In Table 2.16, it is observed that conductivity increased with increasing seawater concentrations. The weekly variations recorded were minimal and statistically insignificant ($P = 0.139$). In contrast the variations recorded across the concentrations were statistically significant. ($P < 0.0001$).

Salinity of 100% - 10% seawater solution

As expected salinity of seawater decreased with decrease in seawater concentration. Also in general, seawater salinity increased over time (Table 2.17). Increase of salinity with time, however was not statistically significant, ($P = 1.000$). In contrast the variations across concentrations were statistically significant. ($P < 0.0001$).

Salinity of 10% - 0% seawater

From Table 2.18 it is observed that the salinity of the solutions generally with increasing seawater concentration, the variations across the weeks did not follow a set pattern and was not statistically significant. ($P = 0.858$). However the results obtained across concentrations were statistically significant ($P < 0.001$).

TABLE 2.9: pH READINGS RECORDED FOR VARYING CONCENTRATIONS OF SEAWATER DURING THE 14-DAY PERIOD.

Concentration of seawater (%)	Daily pH														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100	8.84	8.92	8.96	9.02	9.00	-	-	9.02	8.99	8.97	8.98	8.93	-	-	8.95
70	8.86	8.88	8.91	8.98	8.95	-	-	9.01	8.96	8.94	8.95	8.91	-	-	8.92
50	8.88	8.90	8.90	8.96	8.98	-	-	8.99	8.96	8.92	8.99	8.92	-	-	8.93
30	8.93	8.91	8.92	8.93	8.96	-	-	8.98	8.97	8.95	8.99	8.94	-	-	8.96
10	8.93	8.90	8.85	8.98	9.97	-	-	8.99	8.90	8.91	9.06	8.86	-	-	8.90
0	9.77	9.79	9.59	9.52	9.47	-	-	9.21	9.25	9.13	9.23	9.20	-	-	9.23

TABLE 2.10: pH READINGS OF DIFFERENT CONCENTRATIONS OF SEAWATER TAKEN AT WEEKLY INTERVALS FOR SEVEN WEEKS

Concentration of seawater (%)	Initial (^{0}C)	Weekly pH						
		1	2	3	4	5	6	7
10	8.93	8.99	8.90	9.14	-	8.81	8.98	9.06
9	9.06	9.14	-	8.78	9.06	9.22	9.09	9.08
8	9.06	9.13	-	8.88	9.06	9.20	9.09	9.07
7	9.09	9.11	-	8.90	9.05	9.12	9.04	90.4
6	9.08	9.15	-	8.80	9.03	9.12	9.09	90.4
5	9.34	9.05	9.04	9.29	-	8.98	9.21	9.08
0	9.77	9.21	9.23	9.84	-	9.39	9.80	9.78

TABLE 2.11: TEMPERATURE READINGS FOR VARYING CONCENTRATIONS OF SEAWATER DURING THE 14-DAY PERIOD.

Concentration of seawater (%)	Daily Temperature (^{0}C)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100	27.2	27.7	27.2	27.4	27.4	-	-	26.9	27.5	28.1	28.2	27.5	-	-	27.1
70	27.4	27.5	27.2	27.2	27.2	-	-	26.9	27.7	28.1	28.2	27.3	-	-	27.0
50	27.0	27.5	27.2	27.2	27.2	-	-	26.7	27.4	28.1	28.2	27.3	-	-	27.0
30	26.9	27.4	27.2	27.2	27.2	-	-	26.6	27.4	28.1	28.2	27.1	-	-	27.2
10	27.0	27.4	27.3	27.3	27.2	-	-	26.6	27.5	28.1	28.2	27.0	-	-	27.2
0	27.1	27.6	27.3	27.3	27.3	-	-	26.6	27.4	28.0	27.8	27.0	-	-	27.1

TABLE 2.12: TEMPERATURE OF VARYING CONCENTRATIONS OF SEAWATER TAKEN AT WEEKLY INTERVALS.

Concentration of seawater (%)	Initial (^{0}C)	Weekly Temperature (^{0}C)						
		1	2	3	4	5	6	7
10	27.0	26.6	27.2	27.0	-	27.5	28.3	28.3
9	27.9	26.8	-	27.3	28.2	28.3	28.0	27.5
8	28.0	26.7	-	27.4	28.2	28.2	28.0	27.7
7	28.0	26.7	-	27.4	28.2	28.3	28.0	27.6
6	28.1	26.6	-	27.5	28.1	28.3	27.9	27.6
5	27.3	28.1	28.2	26.5	-	27.5	28.2	28.2
0	27.1	26.6	27.1	27.1	-	27.4	28.4	28.3

TABLE 2.13: DISSOLVED OXYGEN READINGS FOR VARYING CONCENTRATIONS OF SEAWATER FOR THE 14-DAY PERIOD.

Concentration of seawater (%)	Daily Dissolved oxygen (mgl^{-1})														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100	3.60	4.45	3.35	2.54	2.80	-	-	2.90	3.13	2.31	2.29	2.28	-	-	3.37
70	3.26	4.21	3.45	2.84	3.34	-	-	2.80	3.35	3.35	2.20	2.28	-	-	3.18
50	1.85	4.10	3.53	3.05	3.39	-	-	2.72	3.45	2.92	2.45	2.49	-	-	3.29
30	2.75	4.10	3.55	3.39	3.32	-	-	3.59	3.55	3.00	2.39	2.30	-	-	3.30
10	3.35	3.85	3.87	4.20	3.34	-	-	3.11	3.39	3.03	2.65	2.50	-	-	3.23
0	3.50	4.42	3.68	4.15	3.62	-	-	3.56	3.68	3.85	3.85	3.65	-	-	3.57

TABLE 2.14: DISSOLVED OXYGEN FOR CONCENTRATIONS OF SEAWATER TAKEN AT WEEKLY INTERVALS.

Concentration of seawater (%)	**Initial Dissolved Oxygen ($mgt-^{1}$)**	**Weekly Dissolved Oxygen (mgl^{-1})**						
		1	2	3	4	5	6	7
10	3.35	3.39	3.32	2.80	-	3.96	2.92	2.79
9	4.00	2.80	-	3.21	2.98	3.01	2.94	3.47
8	3.81	2.85	-	3.60	2.95	2.82	3.11	3.10
7	3.82	2.55	-	3.02	2.85	2.76	3.01	3.13
6	3.10	2.73	-	3.39	3.10	3.11	2.98	3.00
5	4.20	3.67	3.75	3.37	-	3.49	3.71	2.93
0	3.50	3.68	3.57	3.94	-	3.29	3.22	3.46

TABLE 2.15: CONDUCTIVITY READINGS VARYING CONCENTRATIONS OF SEAWATER DURING THE 14 DAY PERIOD.

Concentration of seawater (%)	Daily Conductivity (umscm^{-1})														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100	52.80	52.90	53.10	53.40	53.90	-	-	55.20	55.50	55.50	55.90	55.90	-	-	55.98
70	41.80	41.60	41.80	42.10	43.40	-	-	44.60	44.70	44.90	45.20	45.50	-	-	46.20
50	29.40	29.60	29.70	29.80	30.10	-	-	30.90	31.00	31.00	31.60	31.70	-	-	32.21
30	19.00	19.30	19.40	19.40	19.40	-	-	20.00	20.20	20.00	20.20	20.20	-	-	20.46
10	6.30	6.50	6.60	6.60	6.60	-	-	6.62	6.61	7.38	7.50	7.50	-	-	7.76
0	1.08	1.10	1.12	1.17	1.18	-	-	1.06	1.06	1.08	1.15	1.21	-	-	1.24

TABLE 2.16: CONDUCTIVITY READINGS FOR VARYING CONCENTRATIONS OF SEAWATER TAKEN AT WEEKLY INTERVALS

Concentration of seawater (%)	Initial Conductivity	Weekly Conductivity (mscm^{-1})						
		1	2	3	4	5	6	7
10	6.30	6.62	7.76	6.25	-	6.58	7.55	7.23
9	5.77	6.60	-	6.00	5.92	5.84	5.88	5.87
8	5.18	5.98	-	5.05	5.06	5.26	5.41	5.20
7	4.64	5.34	-	4.91	4.55	4.66	4.71	4.63
6	3.99	4.59	-	4.12	4.04	4.00	4.10	4.03
5	3.39	3.64	3.64	3.40	-	3.52	3.48	3.41
0	0.11	0.11	0.12	0.15	-	0.13	0.13	0.12

TABLE 2.17: SALINITY READINGS FOR VARYING CONCENTRATIONS OF SEAWATER DURING THE 14-DAY PERIOD.

Concentration of seawater (%)	Daily Salinity (%)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
100	34.90	34.80	34.90	34.90	35.20	-	-	36.50	36.70	36.90	37.10	37.12	-	-	37.15
70	24.90	25.00	25.00	25.20	25.30	-	-	25.60	25.60	25.70	25.90	26.00	-	-	26.10
50	18.10	18.30	18.30	18.30	18.50	-	-	19.00	19.30	19.20	19.32	19.40	-	-	19.45
30	11.10	11.30	11.30	11.50	11.60	-	-	11.90	12.10	11.90	12.10	12.10	-	-	12.12
10	3.46	3.46	3.50	3.47	3.50	-	-	3.50	3.50	3.58	3.62	3.63	-	-	3.80
0	0.00	0.00	0.00	0.00	0.00	-	-	0.00	0.00	0.00	0.00	0.00	-	-	0.00

TABLE 2.18: SALINITY READINGS OF CONCENTRATIONS OF SEAWATER TAKEN AT WEEKLY INTERVALS.

Concentration of seawater (%)	Initial Salinity (%)	Weekly Salinity (%)						
		1	2	3	4	5	6	7
10	3.46	3.50	3.80	3.60	-	3.46	3.56	3.52
9	3.00	3.20	-	3.10	3.10	3.00	3.11	3.10
8	2.70	3.10	-	2.70	2.60	2.70	2.70	2.70
7	2.40	2.80	-	2.50	2.30	2.40	2.40	2.35
6	2.00	2.30	-	2.10	2.00	2.10	2.00	2.10
5	1.70	1.80	1.80	1.70	-	1.70	1.70	1.70
0	0.00	0.00	0.00	0.00	-	0.00	0.00	0.00

2.4 DISCUSSION

2.4.1 Effect of salinity on mortality of adult and juvenile *Bulinus* and *Biomphalaria* cultured in (100%-0%) seawater solution.

Conductivity, pH, salinity and dissolved oxygen, and temperature significantly contributed to the mortality of both adult and juvenile snails. The snails are freshwater species and the primary physiological requirement of freshwater molluscs is the capacity for osmoregulation. Osmotic regulation may be defined as the maintenance of the total particle concentration of body fluids at levels different from those of the external medium. All freshwater molluscs show hyperosmotic regulation, maintaining higher concentrations of ions in the blood than those of the medium. This type of regulation is a steady type in which energy is expended (Wilbur and Young, 1964). Prosser and Brown (1961) have indicated that to lessen their osmotic work, freshwater molluscs produce hypo-osmotic urine.

Furthermore it has been shown that oxygen consumption of aquatic molluscs is usually found to be influenced by the salinity of the medium, for example the freshwater mussel *Hydridella* shows a progressive decrease in oxygen uptake when kept in media of increasing salinity (Histcook, 1953b). Odei, (1983) also stated that the influx of seawater into the Volta estuary did not favour the establishment of snails due to its high salinity and the absence of aquatic macrophytes. The above evidence suggests that in media of high salinity the osmoregulatory and respiratory mechanisms of the snails are adversely affected, this accounting for the high mortalities observed in cultures 100%-10% seawater solution for both species. For the lower concentration that is 10%-0% seawater solution there was a general increase in mortality as seawater concentration increased. These findings agree with that of Picquet et. al (1996) who have reported that there is a progressive elimination of gastropod species at salinity above one

part per thousand. The lowest seawater concentration used in the experiment was 5% seawater solution, which had a salinity of about 1.7 parts per thousand.

The intermediate hosts prefer alkaline medium, the higher the alkalinity the more favourable the environment. (Picquet et. al. 1996). The media in which the snails were bred was only weakly (pH = 9.4) and must have adversely affected the snails. While Fritsch (1993) has reported that the snails tolerate water temperature ranges of 26^0C – 28^0C, Appleton (1977) reported greater survival, growth, and reproduction for *Biomphalaria pfeifferi* at 25^0C with a marked fall in all these parameters at higher temperatures.

In Ghana the two snails studied are usually found in the same habitats and have similar ecological niches, therefore they will have similar preferences as far as temperature, ionic conductivity, salinity etc. are concerned. Appleton's work therefore suggests that the snails prefer lower temperatures than those temperatures under which the experiment was conducted and the temperature effect even though not directly accounting for the fatalities observed, must have been a contributing factor. The ionic conductivity effect on the survival of the snails is not precisely known, but it is the view of the investigator that since trend observed in salinity was similar to the trend observed for ionic conductivity, the two factors may have had similar effect on the survival of the snails, that is high ionic conductivities have a negative effect on the snails, and the higher the conductivity the more negative the effect.

CHAPTER 3

EFFECT OF SALINITY ON GROWTH OF THE SNAILS

3.1 INTRODUCTION

Snail control remains on important component in integrated schistosomiasis control. Control programmes targeted against the snail intermediate should include a profound knowledge of their distribution, population dynamics, growth as well as the factors affecting these patterns. Thomas and Benjamin (1974) have indicated a close correlation between mortality and growth rate of *Biomphalaria glabrata*. Thus, any factor which inhibits snail growth could contribute to its mortality and consequently decrease its population. Most of the work involving snail growth has centred on the effect of crowding on the growth of the snail. Several workers have investigated the inhibitory effects of crowding in molluscan growth and populations (Wright,1960; Chernin and Michelson,1957 a, b; Gazinelli et. al ,1970). Little information however is available on effects of salinity on growth rate of snails.

While observations suggest that infection of the snail may not be dependent on size, the percentage of infection is highest among large sized snails, with more than 7mm-shell length (Anya et. al., 1991). Therefore growth inhibitory factors when present in an environment will decrease the percentage of schistosome infected snails in the population. This chapter seeks to investigate the effect of salinity on growth of the snails and the possible implications for future snail control are discussed.

3.2 MATERIALS AND METHODS

The procedure outlined in sections 2.2.1, 2.2.2, 2.2.3 and 2.2.4 of this thesis were followed and snail growth in the various concentrations of seawater was monitored by weekly measurement of weight and shell length.

3.3 RESULTS

3.3.1 Weight and shell length of adult *Bulinus* cultured in 10% seawater.

From Table 3.1 and Fig. 3.1 it can be observed that even though there was a general increase in weight in the first week, the rate of weight gain decreased with time. At certain times snail weight losses were recorded in the presence of seawater, compared with snails cultured in 0% but the differences were statistically not significant. In contrast, snails maintained in seawater generally significantly increased in shell length over time (P<0.0.5)(Table 3.2 and Fig. 3.2).

3.3.2 Weight and shell length of juvenile *Bulinus* cultured in 0% and 5% seawater

A general increase in weight was observed in the juvenile *Bulinus* as shown in Table 3.3 and Fig. 3.3. The rate of weight gain decreased in weeks 2,5,6, and 7 for snails in 5% seawater solution while for that of 0% seawater the rate of weight gain decreased in weeks 2,5 and 7 respectively. Statistically the results were significant, (P <0.0001).

Similarly a general increase in shell length was observed also observed in juvenile *Bulinus* snails maintained in seawater ((P <0.0001, Table 3.4 and Fig. 3.4).

TABLE 3.1: WEEKLY AVERAGE GROWTH RATE OF ADULT *BULINUS* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER FOR SEVEN WEEKS

Conc. of seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
10	-5.6	-6.6	13.00	-8.00	-7.5	-	-
9	12.76	2.42	-11.53	-7.78	8.78	-0.28	-5.83
8	12.40	0.87	0.68	7.65	0.42	-11.83	-
7	18.6	-8.13	-0.20	-1.49	1.53	-2.62	4.73
6	9.31	1.59	1.57	0.35	3.55	-2.38	3.75
5	-1.27	2.10	1.63	-1.30	-1.30	0.72	-3.50
0	2.60	3.33	5.75	15.10	6.62	9.32	6.08

TABLE 3.2: WEEKLY AEVRAGE GROWTH RATE OF ADULT BULINUS CULTURED IN VARYING CONCENTRATIONS OF SEAWATER FOR SEVEN WEEKS

Concentration of seawater (%)	**Weekly change in shell length (mm)**						
	1	2	3	4	5	6	7
10	0.08	0.00	-0.17	-0.05	-0.07	-	-
9	0.32	0.05	0.04	-0.08	-0.02	-0.03	-0.18
8	0.22	0.02	0.09	0.02	0.11	-0.07	-
7	0.22	0.18	0.05	0.01	0.01	0.17	0.07
6	0.23	0.28	0.01	0.02	0.01	0.07	-0.02
5	0.09	0.16	0.10	0.08	0.04	0.24	-0.03
0	0.21	0.19	0.14	0.31	0.06	0.28	0.07

Fig. 3.1 Growth (weight) of adult Bulinus in varying concentrations of seawater

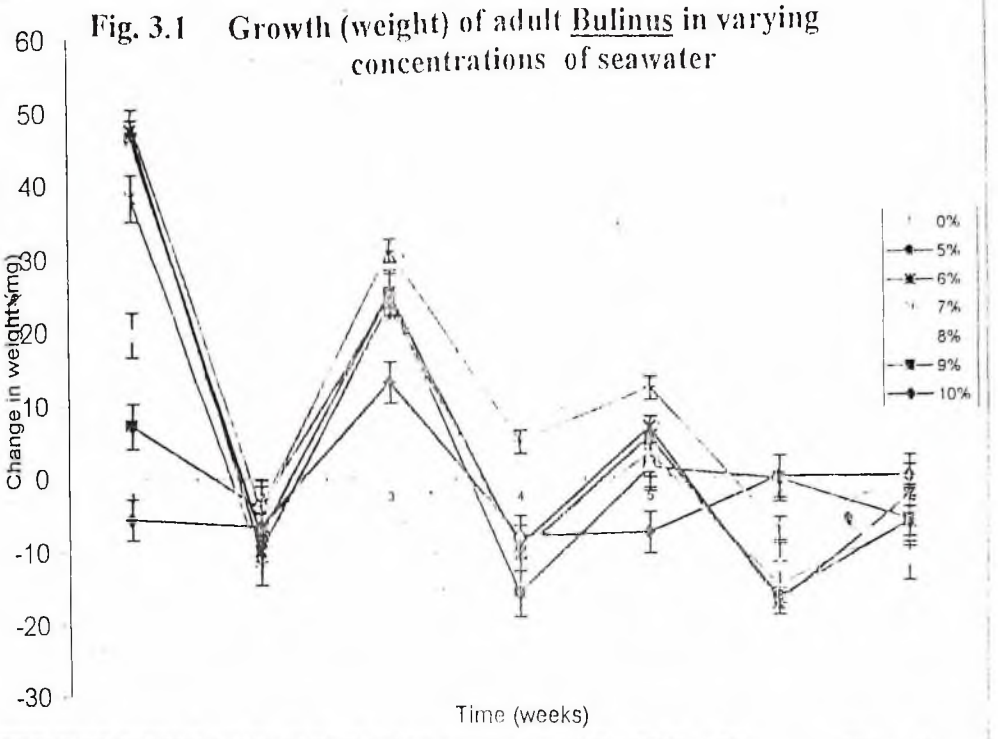


Fig. 3.2 Growth (Shell length) of adult Bulinus in varying concentrations of seawater

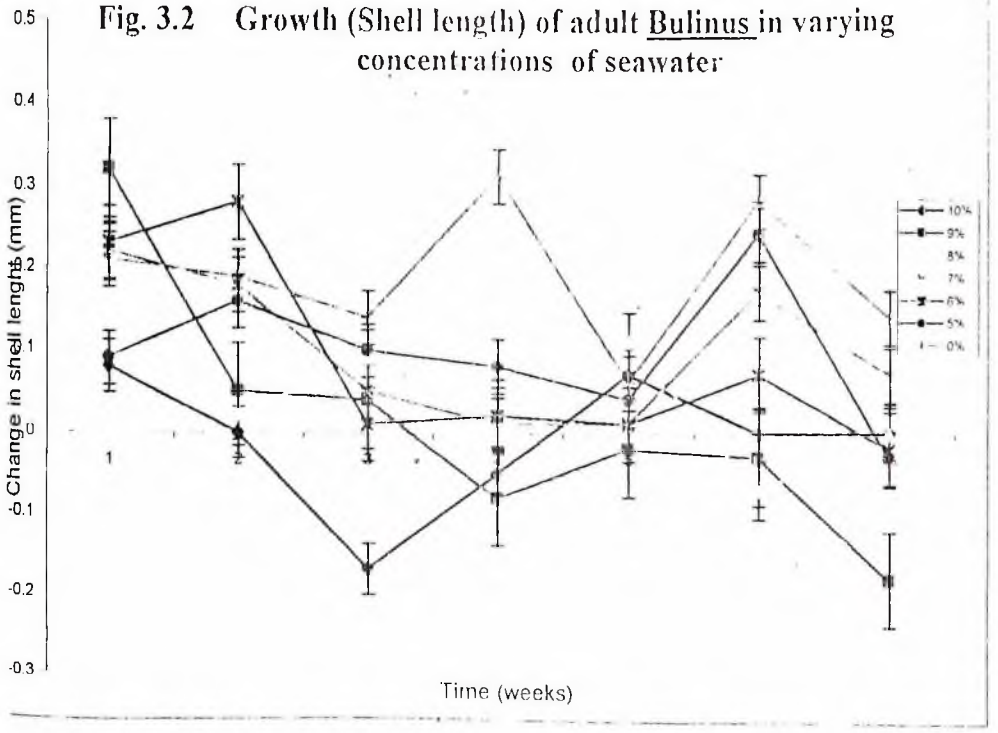


TABLE 3.3. WEEKLY AVERAGE GROWTH RATE OF JUVENILE *BULINUS* CULTURED IN 0% AND 5% SEAWATER FOR SEVEN WEEKS.

Concentration seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
0	7.65	7.02	9.73	9.75	5.30	6.40	4.35
5	7.00	3.33	7.15	9.57	5.55	2.87	2.30

TABLE 3.4 WEEKLY AVERAGE GROWTH RATE OF JUVENILE *BULINUS* CULTURED IN 0% AND 5) SEAWATER FOR SEVEN WEEKS

Concentration seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
0	0.46	0.35	0.57	0.44	0.09	0.19	0.14
5	0.61	0.35	0.41	0.48	0.14	0.13	0.08

TABLE 3.5 WEEKLY AVERAGE GROWTH RATE OF ADULT *BIOMPHALARIA* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
9	4.60	-3.98	-2.58	4.42	-11.9	1.33	-3.25
8	6.40	-1.06	-6.70	-4.40	2.20	-2.40	-2.30
7	5.08	0.95	-4.50	2.58	2.28	2.72	-2.47
6	9.86	-1.00	-1.88	-5.67	-4.82	6.19	-4.53
5	0.15	0.46	4.00	-1.85	-1.53	4.77	4.60
0	2.13	9.28	6.05	2.88	7.38	1.86	2.72

Fig. 3.5 Growth (weight) of adult Biomphalaria in varying concentrations of seawater

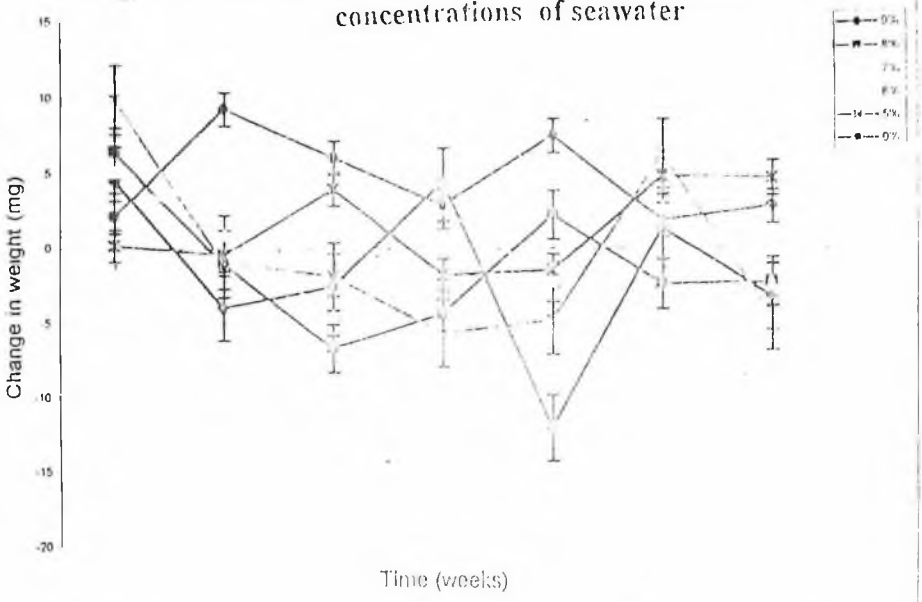


Fig. 3.6 Growth (Shell length) of adult Biomphalaria in varying concentrations of seawater

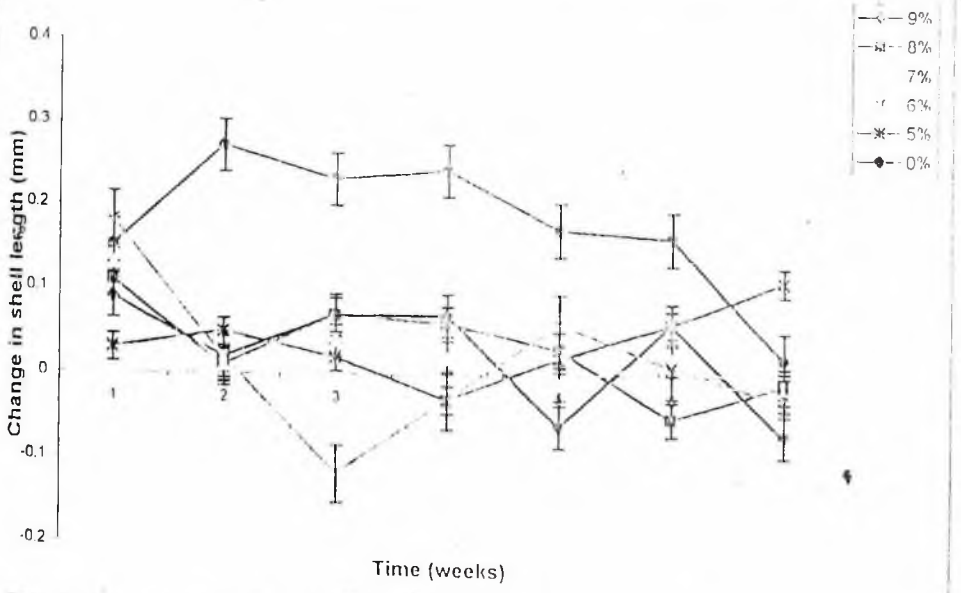


TABLE 3.6: WEEKLY AVERAGE GROWTH RATE OF ADULT *BIOMPHALARIA* CULTURED IN VARYING CONCENTRATIONS OF SEAWATER FO RSEVEN WEEKS

Concentration of seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
9	0.09	0.02	0.07	0.07	-0.06	0.06	0.07
8	0.11	0.01	0.07	0.06	0.03	-0.05	-0.10
7	0.13	0.01	0.04	0.02	-0.01	0.02	-0.02
6	0.18	0.02	-0.12	-0.03	0.06	0.01	-0.13
5	0.03	0.05	0.02	-0.03	0.02	0.06	0.11
0	0.15	0.27	0.23	0.24	0.17	0.16	0.02

TABLE 3.7: WEEKLY AVERAGE GROWTH RATE OF JUVENILE *BIOMPHALARIA* CULTURED IN 0% AND 5% SEAWATER FOR SEVEN WEEKS

Concentration seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
0	11.60	8.26	4.00	1.45	4.73	-3.85	9.17
5	6.13	7.67	0.07	-0.70	2.25	1.30	2.14

TABLE 3.8: WEEKLY AVERAGE GROWTH RATE OF JUVENILE *BIOMPHALARIA* CULTURED IN 0% AND 5% SEAWATER FOR SEVEN WEEKS

Concentration seawater (%)	**Weekly change in weight (mg)**						
	1	2	3	4	5	6	7
0	0.42	0.31	0.31	0.21	0.00	0.16	0.12
5	0.34	0.11	0.15	-0.02	0.17	0.30	0.12

3.3.3 Weight and shell length of adult *Biomphalaria* cultured in 9% - 0% seawater

A general increase in weight in weeks 2, for the adult *Biomphalaria* snails maintained in the various concentrations of seawater. However, this weight increase declined after two weeks, relative to that for the snails. Even though the weights fluctuated considerably, the snail weights were generally much lower than initial snail weights at the end of the expereriment, 7 weeks later (Table 3.4 and Fig 3.4). However, this decline in weight was not significant, $P>0.925$.

Generally, the adult *Biomphalaria* snails also increased in shell length (Table 3.5 and Fig 3.5) even though the rate of shell length increase was statistically not signicant ($P>0.0.5$).

3.3.4 Weight and shell length of juvenile *Biomphalaria* cultured in 0% and 5% seawater solution

A general but statistically significant weight gain was observed for the juvenile *Biomphalaria* snails maintained in seawater, relative to the controls maintained in 0% seawater, ($P>0.05$ Table 3.6 and Fig. 3.6). However, the shell lengths of juvenile *Biomphalaria* significantly increased with time, $P<0.05$.

3.4 Discussion

3.4.1. Effects of salinity on growth rate of adult *Bulinus* and *Biomphalaria* in (10%-0%) seawater solution.

Major differences were observed between the growth rates of both *Bulinus* and *Biomphalaria* snails cultured in seawater solution and in normal freshwater (0% seawater). Marked weight losses were observed for snail cultured in 10%-5% seawater solution relative to control groups (0% seawater), for snail species.

Data presented in Table 1 in the Appendix shows that *Bulinus* snails with average weight size 89.6 mg – 106.2 mg and maintained in seawater had average weights below their initial average weight at the end of the experiment, 7 weeks later. Similarly, adult *Biomphalaria* snails generally had lower average weights than initial average weights by the seventh week, regardless of weight range (see Table 5 in appendix). These results imply that the negative effect of salinity is on the adult *Biomphalaria sp.*, and large sized bulinid snails. This may be good for the malacologist interested in using salinity as a snail control measure, because high salinity will retard the growth of the snails, thereby reducing their susceptibility to schistosome infection as susceptibility to infection is usually high among large sized snails (as stated in chapter 1 of this thesis). In contrast salinity generally increased shell length for both the adult *Bulinus* and *Biomphalaria spp.* Thomas et. al., (1974) stated that snails obtain nearly all their calcium for shell growth and development from the external medium. Since seawater contains a substantial amount of calcium (about 0.410 g/l of seawater) the snails absorbed the calcium ions present in the seawater, thereby enhancing shell growth.

Anya et. al., (1991) however, observed that habitats with high magnesium to calcium ratio were usually snail free and habitats with moderately high pH, high bicarbonate and high calcium ions had high snail densities. Therefore, when using salinity as a control measure, the

magnesium ion content of the habitat could be increased to counteract the positive effect of calcium on the snails. The amount of ions dissolved in seawater could be described in the order, chloride>, sodium>, magnesium> sulphate>, calcium>, potassium>, bicarbonate (Table 6.1).

Seawater has the right chemical composition to destroy *Bulinus* and *Biomphalaria* snails. It is the view of the investigator that application of seawater to small pool ponds and streams could render the habitats inhabitable by the schistosome-transmitting snails thereby effectively controlling schistosomiasis in areas where such bodies of water serve as transmission sites. The dredging of sandbars at estuaries to enhance the entry of seawater into rivers can also be a very effective tool for snail control. This is actually being carried out at the mouth of the Volta River at Ada.

3.4.2 Effects of salinity on growth rate of juvenile *Bulinus* and *Biomphalaria* in 0% and 5% seawater solution

In the present study it was observed that salinity of 5% or less increased average weights and shell lengths of juvenile *Bulinus*. Similar salinity concentrations only slightly increased average weights, but significantly increased shell lengths of juvenile *Biomphalaria* snails. These results suggest that salinity concentrations below a value of 5% increase growth rate of juvenile *Biomphalaria* and *Bulinus* snails. Therefore, it is the view of the investigator that the salinity concentrations which inhibit growth in the adult snails will also inhibit growth in the juvenile snails. If the magnesium to calcium ratio is taken into consideration during modifications of snail habitats, then the snail populations may be wiped out completely in the habitats, thereby effectively breaking the schistosomec transmission cycle.

CHAPTER 4

EFFECT OF SALINITY ON HATCHING OF EGGS

4.1 INTRODUCTION

Bulinus and *Biomphalaria* both have a life span of about $1^1/_2$ years; under favourable conditions they reach maturity in about 6 weeks and start laying eggs, though egg laying may be delayed till the 4^{th} month of life (Witenberg and Saliternik, 1957). The snails are hermaphrodites and can self fertilise their eggs, though cross fertilisation is usually favoured. Furthermore they breed throughout the year even though breeding is usually maximum from about September to the end of January, this period embracing the heavy rains and the first part of the dry season (McCullough, 1962). *Bulinus* snails may lay up to 50 egg masses in its lifetime, with each egg mass containing about 5-20 eggs, while *Biomphalaria* species lay about 5 egg masses in its lifetime with each egg mass containing at least 30 eggs. (Witenberg and Saliternik, 1957)

The life span of the two species when compared with its reproductive potential (egg laying ability) suggests that they have high repopulating potential. Therefore control measures aimed at reducing snail population should include measures aimed at reducing egg "hatchability". This chapter investigates the effect of salinity on hatching of eggs and the possibility of using salinity as a reproductive control measure is discussed.

4.2 MATERIALS AND METHODS

Procedure outlined in sections 2.2.1, 2.2.2, 2.2.3 and 2.2.4 of chapter 2 of this thesis were followed and in order to obtain eggs, eight adult snails were placed in labelled plastic bowls, filled with aerated tapwater, one week before the experiment began.The snails were fed on fresh lettuce leaves. The snails were removed from the bowls when at least five egg masses were laid in each bowl. The tapwater was then poured out of the bowls, and replaced with appropriate concentrations of seawater. The eggs were monitored daily to determine the time of hatching and whether or not the eggs would hatch. The water in the bowls was changed once a week.

4.3 RESULTS

4.3.1 Hatching of eggs of *Bulinus* in various concentrations of seawater.

All the eggs, which were incubated in seawater of concentrations 100%, 70%, 50%, 30% and 10% failed to hatch within a fourteen-day period. At lower concentrations of seawater however, egg hatching was as follows: 16.67%, 0%, 37.5%, 50% and 100% at 9%, 8%, 7%, 6%, 5% and 0% seawater solution respectively. Egg hatching usually began 7^{t} to 9 days after exposure to seawater (Table 4.1 and Fig 4.1). Chi-square analysis of the results indicated a statistical significance were statistically significant (X^2 tab=3.940 X^2 cal= 46.18405).

4.3.2 Hatching of *Biomphalaria* eggs in various concentrations of seawater.

Table 4.2 indicates that with the exception of a hatching rate of 16.67% observed in a 10 % solution of seawater on the 9th day none of the eggs incubated in 100%, 70%, 50% and 30% seawater solution hatched during the 14 day incubation period. In contrast all the eggs incubated in the 5% and 0% seawater solution hatched with 87.5% and 12.5% of the eggs hatching on the 8th and 9th day for the 5% seawater, and 20% and 80% of the eggs hatching on the 6th and 7th day respectively for the 0% seawater solution. Hatching records for 6%, 7%, 8% and 9% seawater solutions were as follows: 25%, 28.57%, 14.28% and 50%, respectively with the eggs hatching on the 6th or 7th day. The results obtained were statistically significant by Chi-square analysis (X^2 tab =3.940 X^2 cal = 46.1992).

TABLE 4.1: HATCHING OF EGGS *OF BULINUS* IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	**No. of eggs laid**	**Number of eggs hatched over 14 days (%)**														Total (%)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
100	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	6	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67
8	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	8	0.00	0.00	0.00	0.00	0.00	0.00	31.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.5
5	6	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67
0	6	0.00	0.00	0.00	0.00	0.00	0.00	50.00	16.67	33.33	0.00	0.00	0.00	0.00	0.00	100

TABLE 4.2: HATCHING OF EGGS OF *BIOMPHALARIA* IN VARYING CONCENTRATIONS OF SEAWATER

Concentration of seawater (%)	No. of eggs laid	Number of eggs hatched over 14 days (%)														Total (%)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	
100	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
70	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
50	7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
30	9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.67	0.00	0.00	0.00	0.00	0.00	0.00
9	6	0.00	0.00	0.00	0.00	0.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.00
8	7	0.00	0.00	0.00	0.00	0.00	0.00	14.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.28
7	7	0.00	0.00	0.00	0.00	0.00	0.00	28.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.57
6	8	0.00	0.00	0.00	0.00	0.00	0.00	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25
5	8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.5	12.5	0.00	0.00	0.00	100
0	5	0.00	0.00	0.00	0.00	0.00	0.00	20.00	0.00	80.00	0.00	0.00	0.00	0.00	0.00	100

Fig. 4.1 Hatching of eggs of *Bulinus* cultured in varying concentration of seawater

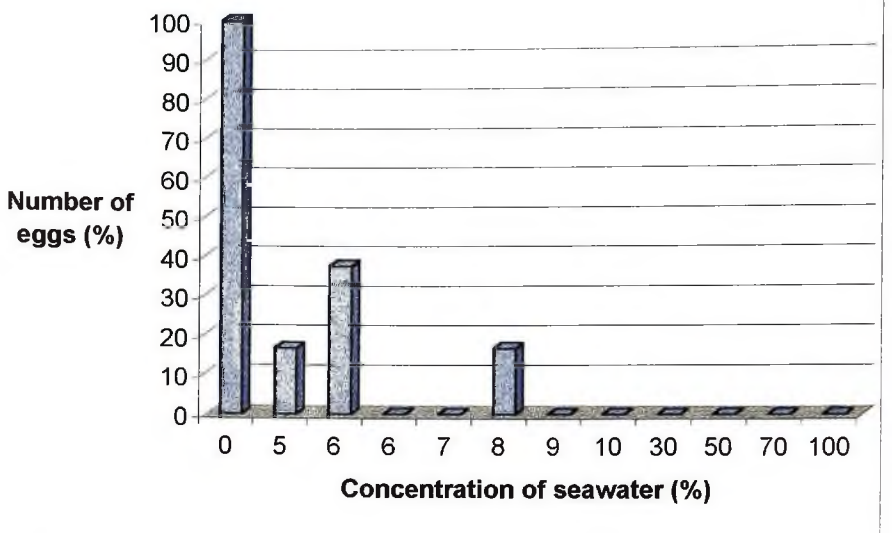
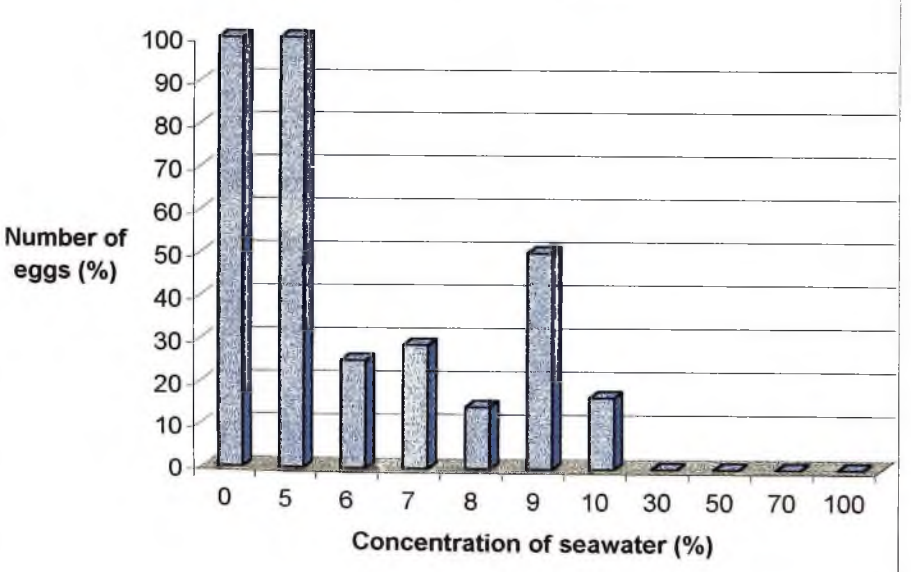


Fig. 4.2 Hatching of eggs of *Biomphalaria* cultured in varying concentration of seawater



4.4 DISCUSSION

4.4.1 The effect of salinity on the hatching ability of eggs of *Bulinus* and *Biomphalaria spp.* in 100%-10% seawater solution

The findings reported in this chapter lend further support to the conclusions of Chapter 2 that high salinity adversely affects survival of *Bulinus* and *Biomphalaria* snails. Generally, no hatching was recorded when the eggs were incubated in 100%-10% seawater solution. Furthermore, the eggs did not show any sign of development when observed with a magnifying glass, implying that high salinity affected the viability of the eggs.

In contrast, even though egg hatching was generally low at seawater concentrations of 10%-5% for both *Bulinus* and *Biomphalaria* species, the unhatched eggs showed signs of development when examined with a magnifying glass, neonate snails were seen inside the egg capsules of the unhatched eggs, implying that the egg viability was unaffected. It was also expected that the eggs would show a progressive decrease in hatching with increasing seawater concentration, but this did not occur in all the cases. This may be due to the fact that some of the eggs had developed to some extent before the experiment began, and so were not adversely affected by the culture medium. As stated earlier in Chapter 2, the adult snails were placed in bowls containing tapwater untill five eggs were laid, usually 3 days elapsed before five eggs were laid. The eggs laid on day one would have therefore developed to some extent before the later eggs were laid.

These findings are confirmed by Donnelly et. al (1983) who have demonstrated that the ability of eggs to hatch and the fecundity and survival of adult *Bulinus africanus* a close relation of *Bulinus truncatus* was adversely affected by salinity as low as one part per thousand with significant reductions occurring between 3.5 parts per thousand (about 10% seawater) and 4.5 parts per thousand (about 13% seawater).

With regard to temperature optimum egg laying and hatching have been observed for *Bulinus alexandrina* and *Bulinus truncatus* at 25^0C (El Hassan, 1974). Other known parameters influencing egg production by snails and egg hatching are water, temperature, volume of water available per snail and diameter of the shell (Pereka and Deslandes, 1964). Infact, Pimentel-Souza et. al., (1990) have shown that the highest fertility of the snail *Biomphalaria glabrata* a close relative of *Biomphalaria pfeifferi* occurred at temperatures between 20^0C and 27.5^0C, with maximum egg laying occurring at 22.5^0C, and maximum hatching occurring at 25^0C. The temperatures observed in the present work ranged from 26.6^0C to 28.3^0C. The effect of pH, dissolved oxygen and ionic conductivity on the eggs of the snails, are not known, and it is the view of the investigator that further in-depth study on the effect of these parameters on the production and hatching of eggs of the snails should be undertaken.

CHAPTER 5

FIELD STUDY

5.1. INTRODUCTION

The salinity of most ocean water is within the range of 34-36%. The relative proportions of the major ionic constituents in ocean water remain virtually constant despite some variation in total salinity (Tait, 1981). The major ions in seawater are sodium and chloride with magnesium sulphate and calcium present in substantial amounts.

TABLE 5.1: COMPOSITION OF SEAWATER

Ion	Amount per litre of seawater (g)
Sodium	10.83
Magnesium	1.303
Calcium	0.410
Potassium	0.389
Chloride	19.440
Sulphate	2.713
Bicarbonate	0.143

At the mouth of a large river, freshwater dilutes the ocean water. At a river mouth (estuary) the salinity gradient between freshwater and the sea fluctuates continuously with the state of the tide, and varies with the amount of freshwater coming downstream. If the river is large and the tides are large, the estuary extends far up the river.

The Volta River is a large river and the mouth extends up the river (Map 1). The salinity boundary has been held at a minimum 10-15km from the sea and at maximum 20-25km

further downstream at the 10km point from the sea. (People and Rogoyska, 1969). The conditions here are similar to that maintained in the laboratory namely mixing of seawater with freshwater and is described below.

5.2 THE SITE OF THE SURVEY

Azizanya is a village community about 3km from Ada Foah (Fig. 5.1) in the Greater Accra Region. The village is about 4.5km from the mouth of the Volta River estuary. The men in the community are mostly fishermen while the women are fishmongers. Even though there is a stand pipe in the village, the people make use of the river for many domestic, recreational and occupational activities like washing of clothes, bathing, cooking, swimming, fishing and clam digging. The community has no public place of convenience and the people defecate into the river. Most of the houses in the village community are made of coconut leaves with thatch roofs (roofs made with grass). About 1km from the village is a hotel (The Manet Paradise). Visitors to the hotel can swim or have boat rides on the estuary. A number of private properties are near the hotel (Plate 7).

Preliminary studies were carried out along the banks of the Volta river estuary, beginning from one end of the village to the third house after the hotel (A distance of about 3km) to find out the following:

a. The conditions prevailing in the natural environment, which was similar to conditions, maintained in the laboratory during the experiment.
b. The macrophytes exiting in the environment.
c. The snail species exiting in the environment.
d. The kind of ecological interaction existing among the snail species and the macrophytes.

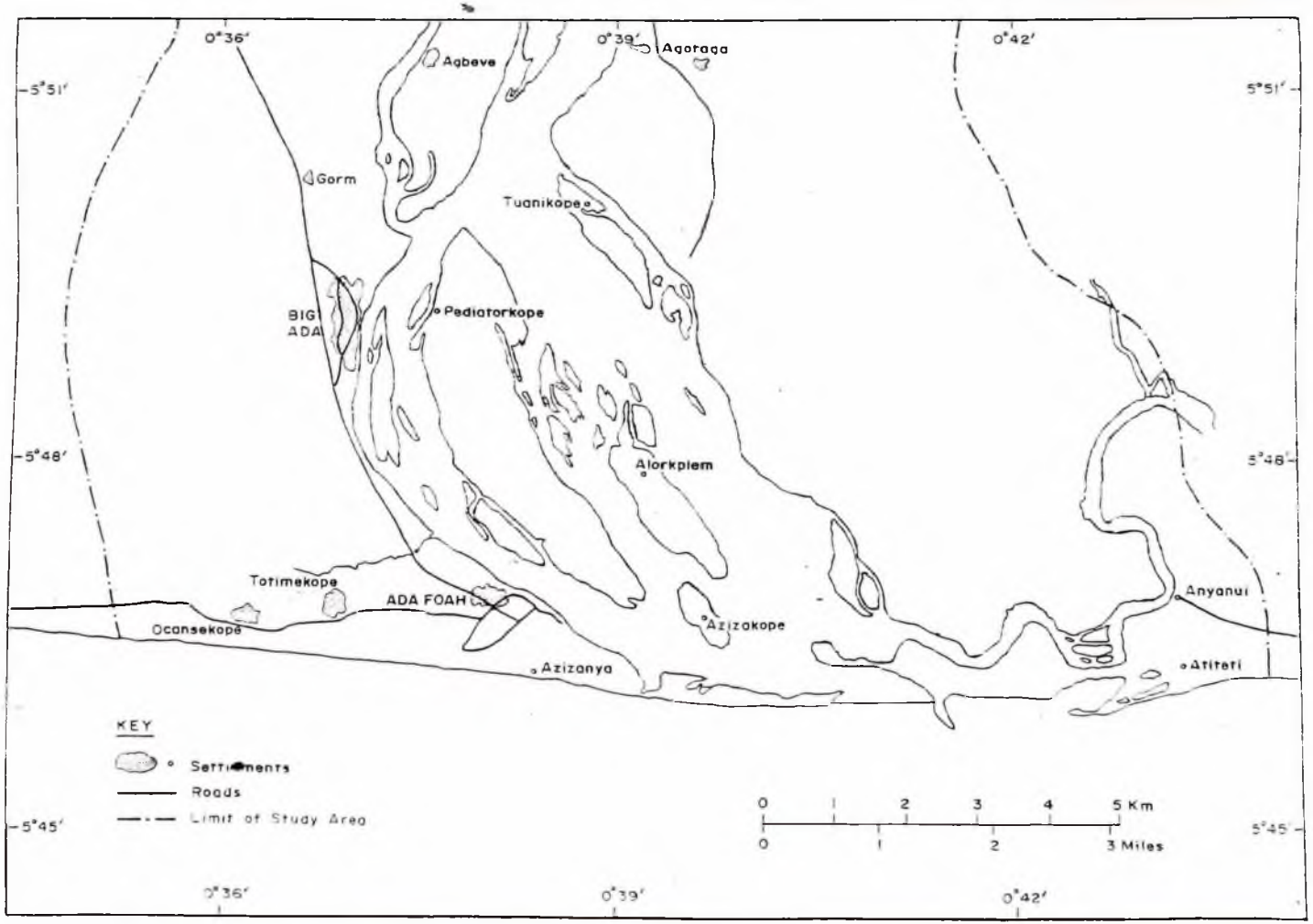


Fig. 5.1 : MAP OF STUDY AREA

5.2.1: SAMPLING PROCEDURE

Sampling was done along the banks of the Volta river estuary. Six sites were selected and each site was a water contact site. The first site was about 4km from the point of entry of river into the sea and the last site (site 6) was closer to the point of entry into the sea. The second site was about 500m from the first site, the third 600m from the second and 500m from the fourth. The fifth site is 500m from the fourth and 800m from the sixth and last site. At each site a quadrat measuring 4m x 6m was marked out using a tape measure and wooden pegs. Eight scoops were made per quadrat using a hand net (Plate 5).

5.2.2: Characteristics of the study site

In addition to the sampling, the physicochemical and biological characteristics of each of the sites were noted as these play a major role in the ecology of the snails.

Physicochemical characteristics

The physicochemical parameters noted were the nature of the sediments, the pH, temperature, conductivity, and salinity, with the exception of sediment type, the other parameters were taken twice a day, at low tide, i.e. from 6-7 hrs GMT, and high tide from 16-17 hrs GMT.

Biological characteristics

The biological factors noted were the aquatic macrophytes present at the sites and the molluscan species available.

PLATE 5: SAMPLING AT SITE 1

PLATE 6: TYPICAL HOUSING UNIT IN THE SETTLEMENT

PLATE 7: SAMPLING SITE 6, IN FRONT OF A PRIVATE PROPERTY

PLATE 8: SAMPLING SITE AT MANET PARADISE

PLATE 9: FISHING ACTIVITIES ON VOLTA RIVER

PLATE 10: RECREATIONAL ACTIVITY (CHILDREN SWIMMING IN RIVER)

5.3 RESULTS

5.3.1: Nature of the sediment

The sediment type was the same in all six sites, being sandy. The banks sloped slightly in sites 1-4, but sloped deeply in sites 5 and 6.

5.3.2: Physicochemical factors

Table 5.2 shows that, salinity increased at high tide and decreased at low tide the highest salinity recorded being 13.5% (about 38.57% seawater), and lowest salinity recorded was 1.8% (about 5.14% seawater), the conductivity also increased at high and decreased at low tide. The highest conductivity recorded was 22.3ms/cm and the lowest recorded was 3.62 ms/cm. The pH did not vary widely even though it was higher at low tide and lower at high tide, the pH ranged from 8.70 to 9.04. High tide usually occurred in the afternoons where temperatures generally increased, thus temperature were usually higher at high than low tide. The temperature ranged from 26.6 ^{0}C to 30.6 ^{0}C.

5.3.3: Biological Characteristics

The organisms obtained in the sampling were hermit crabs and newly hatched fish. No macrophytes were found at the sites and no snail species were found either. These results agree with the findings of a survey conducted by (V.B.R.P, 1996).

TABLE 5.2: PHYSICO-CHEMICAL PARAMETERS READINGS RECORDED AT THE SIX SURVEY SITES AT HIGH AND LOW TIDES FOR FOUR DAYS.

Time (days)	Site	Salinity (%)		Conductivity (ms/cm)		pH		Temperature (^{0}C)	
		High tide	Low tide	High tide	Low tide	High tide	Low tide	High tide	Low tide
1	1	3.8	-	7.12	-	8.74	-	30.6	-
	2	6.0	-	10.60	-	8.72	-	29.1	-
	3	5.0	-	9.08	-	8.71	-	29.2	-
	4	6.2	-	11.00	-	8.70	-	28.8	-
	5	7.3	-	12.70	-	8.71	-	28.6	-
	6	9.7	-	16.50	-	8.71	-	28.4	-
2	1	7.3	3.2	12.70	6.10	8.75	8.80	29.2	27.0
	2	8.3	4.0	14.40	7.46	8.73	8.81	29.1	27.5
	3	9.0	5.1	15.40	9.20	8.74	8.80	29.2	27.6
	4	10.9	5.4	18.40	9.70	8.73	8.79	28.6	27.3
	5	11.0	5.2	18.50	9.40	8.73	8.80	28.5	27.3
	6	11.5	5.6	19.30	10.10	8.73	8.81	28.5	27.6
3*	1	2.4	2.5	4.76	4.95	8.86	8.91	27.1	27.3
	2	3.5	2.8	6.54	5.41	8.85	8.86	27.3	27.7
	3	3.9	3.1	7.27	5.85	8.87	8.85	27.2	27.7
	4	2.8	3.6	5.42	6.79	8.80	8.84	27.4	27.7
	5	3.2	4.2	6.12	7.82	8.87	8.83	27.4	27.8
	6	3.0	4.3	5.74	7.90	9.02	8.83	27.1	27.7
4	1	3.8	1.8	7.11	3.62	8.76	8.90	27.8	26.7
	2	10.6	2.3	17.70	4.52	8.75	8.91	27.7	27.0
	3	5.2	2.0	9.40	4.02	8.84	8.90	27.9	26.8
	4	13.5	3.2	22.30	6.12	8.78	8.89	27.3	27.1
	5	9.3	3.2	15.80	6.09	8.76	8.86	27.7	27.0
	6	4.0	2.4	7.38	4.72	8.91	9.04	27.8	26.6

*1: readings could not be taken at low tide on day one because the equipment was not functioning.

*3, *4: there was a heavy rain in the morning on day 3 and light showers on morning of day 4, and high tide is usually in the afternoons, this could account for the low salinity readings recorded.

5.4 DISCUSSION

At the estuary the salinity varies widely thus organisms which survive in such habitats are euryhaline i.e. can tolerate wide ranges of salinity. The snail hosts of *Schistosoma* are stenohaline and can tolerate limited salinity variation thus, they will not survive in the estuary, snails also depend on aquatic macrophytes for shelter, food and egg laying. Witenberg and Saliternik (1957) observed that snails scrape the surface of plants with their radulae and swallow the scrapings rich in vegetable, animal microorganisms and organic debris. They also lay eggs on the leaves of some plants, and plants such as *Ceratophyllum demersum, Potamogeton pectinatum* serve as aerators. They also suggested that snails will not colonize habitats devoid of vegetation. Markowski (1953) discovered that snails were attracted by the algae found of the blades of leaves.

The site of survey was devoid of vegetation and the salinity varied widely, such a habitat is not suitable for both *Bulinus sp.* and *Biomphalaria sp.*, and it was therefore expected that those species would not be found in the habitat. This was confirmed by the sampling done as no snails were found.

CHAPTER 6

GENERAL DISCUSSION

6.1 Effect of salinity on mortality of snails

In chapter 2 the effect of salinity on mortality of *Bulinus truncatus* and *Biomphalaria pfeifferi* was investigated to test the hypothesis that increasing salinity of freshwater snail habitats cause the death of the snails in freshwater systems. The results of the investigations which were discussed in relation to the above hypothesis in section 2.2 show that in snail cultures of 100% - 0% seawater solution, survival of juvenile and adults of *Bulinus truncatus* and *Biomphalaria pfeifferi* was significantly affected. Furthermore the severity of the effect of salinity on mortality increased with increase in seawater concentration. The results of the work therefore suggest that salinity could be an important tool in the eradication of snails from freshwater environments. From the present work it was observed that at 10% seawater solution (about 3.5 $\%_{o}$ salinity), complete elimination of the snails could be achieved within five weeks. Therefore, the salinity of freshwater systems could be increased to 3.5% $_{o}$ to kill the snails, but before this control measure could be implemented, extensive studies on the ecology of the other flora and fauna in such environment will be necessary to ensure that they would not be adversely affected by increased salinity.

Chernin (1970) has talked about the role of miratones in the meeting of parasites and snail. He has reported that miratones reduce infection of snails with miracidia and the majority of miratonal activity and content in *Biomphalaria gabralta* has been traced to the effect of magnesium ion. While it is hard to envisage a biologically significant role for such a common chemical when balanced against the larger factors which bring parasite and snail

into contact, it is worth looking into it since Anya et al (1991) have also reported that habitats with high magnesium to calcium ratios were snail free.

6.2 Effect of salinity on growth rate of the snails

The results of the investigations carried out in chapter three were discussed in relation to the hypothesis that increasing salinity in freshwater snail habitats would retard growth of the snails. It was observed that for seawater concentration 100% - 30% snail cultures no growth measurements could be taken since the snails died within a week. However for the lower concentrations of seawater (from 10% - 0%) growth rate with respect to weight was not significantly affected by salinity for the adults of *Bulinus* and adults and juveniles of *Biomphalaria*, but weight gain recorded for juvenile *Bulinus* was significantly affected.

When change in shell length was however used as an index of growth (Fig. 3.1,3.2 and Fig.3.5, 3.6), it was observed that shell length of adults and juveniles of *Bulinus* and juveniles of *Biomphalaria* significantly increased while increase in shell length of adult *Biomphalaria* was not significantly affected. This can be explained in part by the fact that growth during this period was mainly a result of uptake of ions such as calcium, which are essential for the formation of snail shells. Body mass made of protein thus, decreased as a result of loss of water and lack of formation of new protoplasmic material.

6.3 Effect of salinity on hatching ability of the eggs at the snails

In chapter four the effect of salinity on hatching of the eggs was investigated to test the hypothesis that increasing salinity of freshwater snail habitats could decrease or prevent the hatching ability of the snail eggs. The results of these investigations, which were discussed in relation to the hypothesis, stated above in section 4.2 show that salinity

significantly affected the hatching of the eggs of both species. That is the egg showed a progressive decrease in hatching as salinity increased. The precise way in which the eggs were affected is not known, but it is the view of the investigator that the high ionic content of the culture media, caused an osmotic gradient between the membrane of the egg capsule and the culture medium, leading to the movement of certain vital substances within the egg capsule, which were necessary for the development of the embryonic snails into the culture media, thereby killing the embryonic snails. The implication therefore is that when the salinity of freshwater habitats are increased to about 3.5% $_{o}$, the hatching ability of the eggs would be adversely affected leading to the death of the embryonic snails in the egg capsules. Since these snails have a high intrinsic rate of proliferation, one viable egg of *Bulinus* could give rise to between 5 and 20 snails while one viable *Biomphalaria* egg can hatch to give about thirty snails, this discovery may be important because, at 3.5% $_{o}$ salinity, not only will the adult snails in the freshwater habitats be eliminated, but the young snails yet to be hatched would also be killed.

6.4 Conclusions

From the present study it has been established that:

a) Increase in salinity causes increased mortality of the snails; thus a threshold of 3.5‰ will effectively rid freshwater habitats of the snail hosts.

b) Increase in salinity may not be an effective tool in retarding growth of the host snails in freshwater environments.

c) Increase in salinity causes a decrease in hatching ability of the eggs of the snails, therefore increasing the salinity of snail habitats to about 3.5‰ will cause a decrease in the emergence of young snails, in the habitat after the old ones have been killed.

6.5 Implications for snail control

Field studies conducted at Ada (which happens to be the point of entry of the river into the sea) revealed the absence of both macrophytes and intermediate host snails. It was also observed that salinity content of the river increases at high tide and decreases during low tide and this is due primarily to the influx of seawater into the river. Present studies on the effect of salinity on the intermediate host snails confirms the assertion that salinity of about 3.5% or higher, adversely affects the snails has the potential of wiping off snail host of schistosomiasis. This gives credence to the dredging activity of the Volta River Authority. Thus in spite of the high cost of dredging, it is still recommended that dredging should form part of the integrated approach to the control of schistosomiasis in the area.

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TABLE 1

Weight of adult *Bulinus* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mg	Weekly average weight/ mg						
		1	2	3	4	5	6	7
10	114.20	108.6	102.0	115.0	107.0	99.5	-	-
	78.00	-	-	-	-	-	-	-
	68.20	-	-	-	-	-	-	-
9	92.80	111.67	112.0	109.67	90.00	88.00	96.0	101.00
	100.00	105.00	110.67	107.33	105.67	100.33	93.50	81.00
	89.60	104.00	105.25	76.33	74.33	108.0	106.00	96.00
8	74.00	84.20	80.00	78.00	85.00	73.00	76.00	-
	92.60	111.00	121.00	122.50	126.00	120.50	109.00	-
	57.00	65.60	62.40	64.80	77.25	96.00	69.0	63.67
7	82.20	102.20	94.00	91.40	89.60	85.20	82.80	93.25
	76.60	101.00	93.00	98.00	97.00	98.00	-	-
	95.80	107.2	99.0	96.0	94.33	108.33	99.50	94.00
6	86.00	91.40	11.00	89.80	90.00	100.4	95.00	94.00
	53.20	60.33	68.50	66.00	67.00	68.50	68.50	66.50
	69.60	85.00	82.0	81.00	78.75	80.00	78.25	66.00
5	106.20	104.00	105.50	108.50	112	104.00	102.00	95.00
	88.60	80.60	88.20	94.8	91.40	97.50	94.33	93.50
	81.80	88.20	85.40	80.20	77.00	75.00	82.33	79.67
0	75.00	78.00	84.40	84.40	91.60	16.80	109.00	117.75
	78.40	80.20	82.40	85.00	96.67	110.00	130.5	136.50
	92.20	95.20	96.60	111.25	137.67	139.0	134.33	137.33

TABLE 2 :

Shell length *Cadulo Radiatus* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater ‰	Initial average shell length -mm	Weekly average shell length - mm						
		1	2	3	4	5	6	7
10	4.62	4.72	4.72	4.55	4.50	4.43	-	-
	3.82	-	-	-	-	-	-	-
	3.32	-	-	-	-	-	-	-
9	4.74	4.43	4.56	4.59	4.30	4.30	4.30	4.30
	4.36	4.45	4.46	4.50	4.50	4.50	4.45	3.90
	4.00	4.48	4.50	4.56	4.60	4.55	4.50	4.50
8	3.82	3.94	3.55	3.50	3.50	3.70	3.70	-
	4.04	4.43	4.85	5.05	5.05	5.05	4.90	-
	3.04	3.20	3.24	3.36	3.42	3.56	3.50	3.50
7	3.74	3.96	4.18	4.22	4.22	4.25	4.15	4.02
	3.64	4.25	4.20	4.30	4.30	4.40	-	-
	4.28	4.32	4.48	4.50	4.46	4.46	4.70	4.70
6	3.90	4.20	4.24	4.26	4.26	4.28	4.15	4.06
	2.88	3.06	3.60	3.60	3.35	3.65	3.65	3.65
	3.50	3.70	3.95	3.95	3.95	3.90	3.90	3.04
5	4.48	4.38	4.68	4.68	4.70	4.70	4.70	4.50
	4.16	4.16	4.26	4.26	4.26	4.28	4.60	4.45
	3.90	4.26	4.34	4.46	3.83	3.88	3.88	3.88
0	3.06	3.50	3.94	4.06	4.12	4.15	4.53	4.63
	3.88	3.96	4.04	4.33	4.56	4.65	5.05	5.30
	4.20	4.32	4.38	4.40	5.03	5.10	5.16	5.23

TABLE 3:

Weight of juvenile *Bulinus* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mg	Weekly average						
		1	2	3	4	5	6	7
0	18.6	28.00	30.20	38.40	46.80	53.00	59.60	62.50
	3.4	17.75	28.80	40.80	53.40	58.10	63.40	68.8
	20.00	26.20	34.00	43.00	51.25	54.75	62.50	67.25
5	10.00	19.20	20.20	29.00	36.40	41.60	45.00	51.00
	12.00	17.00	21.20	30.25	42.75	52.00	54.0	54.50
	17.00	23.80	28.40	32.0	40.80	43.00	46.20	46.60

TABLE 4:

Shell length of juvenile *Bulinus* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mm	Weekly average shell length /mm						
		1	2	3	4	5	6	7
0	1.06	1.48	1.64	2.24	2.72	2.90	3.18	3.25
	0.76	1.25	1.74	2.42	2.88	2.94	3.02	3.20
	1.20	1.68	2.08	2.53	2.90	2.93	3.13	3.30
5	0.52	1.04	1.44	1.90	2.36	2.40	2.65	3.80
	0.42	1.22	1.52	2.18	2.65	2.88	3.00	3.03
	0.96	1.48	1.82	1.94	2.46	2.60	2.62	2.68

TABLE 5

Weight of adult *Biomphalaria* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mg	Weekly average weight/mg						
		1	2	3	4	5	6	7
9	91.8	95.8	94.8	91.40	98.0	84.75	86.0	82.00
	83.6	95.6	92.3	89.6	92.50	77.25	80.75	78.00
	99.8	96.8	89.25	87.5	91.25	84.0	83.25	80.25
8	102.4	109.8	112.2	104.3	98.8	101.0	100.0	98.00
	100.0	109.8	107.8	97.5	93.5	94.5	90.00	88.50
	94.2	95.8	92.2	89.8	86.6	90.0	88.4	85.00
7	76.0	84.2	83.5	78.5	80.5	79.67	80.34	80.34
	76.0	84.4	81.25	76.0	80.25	78.50	82.5	79.5
	80.6	79.25	80.25	77.0	78.5	74.25	77.75	73.33
6	87.2	96.6	96.60	99.25	89.8	86.67	89.67	84.00
	79.0	83.8	82.8	80.5	79.25	76.25	77.0	73.75
	75.4	90.8	88.8	82.8	76.5	75.0	78.67	74.40
5	81.2	80.8	77.8	82.2	82.0	73.67	88.5	98
	86.8	86.8	84.4	93.2	88.25	98.0	98.7	93.5
	78.0	78.8	82.8	81.6	82.0	76.0	74.8	75.75
0	58.2	61.6	73.4	80.0	78.0	87.40	87.8	88.2
	62.0	63.0	75.8	77.6	83.25	93.0	88.5	90.25
	45.0	47.0	50.25	60.0	65.0	68.0	68.67	74.67

TABLE 6:

Shell length of adult *Biomphalaria* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mm	Weekly average shell length /mm						
		1	2	3	4	5	6	7
9	5.02	5.14	5.18	5.22	5.26	5.00	5.08	5.00
	4.84	4.82	4.82	4.96	4.70	4.78	4.84	4.90
	5.12	5.28	5.29	5.32	5.34	5.34	5.37	5.18
8	5.10	5.24	5.26	5.29	5.32	5.35	5.37	5.40
	5.18	5.26	5.27	5.00	5.10	5.12	4.93	5.05
	5.20	5.30	5.30	5.32	5.36	5.39	5.40	5.18
7	4.50	4.72	4.73	4.76	4.78	4.67	4.70	4.70
	4.52	4.64	4.64	4.70	4.74	4.75	4.76	4.90
	4.86	4.92	4.93	4.95	4.95	5.02	5.05	4.86
6	4.70	4.98	4.99	4.73	4.80	4.96	5.03	4.75
	4.62	4.80	4.82	4.65	4.67	4.67	4.69	4.54
	4.54	4.62	4.64	4.70	4.52	4.54	4.47	4.50
5	4.76	4.88	4.88	4.90	4.67	4.67	5.05	5.60
	4.86	4.70	4.76	4.78	4.90	4.93	5.00	5.00
	4.46	4.58	4.66	4.69	4.71	4.75	4.78	4.57
0	3.44	3.60	4.02	4.22	4.44	4.76	4.88	5.90
	3.82	3.98	4.12	4.32	4.58	4.73	4.78	4.80
	3.02	3.15	0.34	3.70	3.93	3.97	4.28	4.30

TABLE 7:

Weight of juvenile *Biomphalaria* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mg	Weekly average weight /mg						
		1	2	3	4	5	6	7
0	26.40	35.40	44.80	48.50	52.35	56.7	56.00	63.33
	10.80	27.60	35.60	42.40	43.00	49.0	42.00	53.00
	15.60	34.60	42.00	43.50	43.50	-	-	-
5	52.80	55.00	54.60	59.00	53.58	56.3	55.25	58.50
	5.00	16.00	29.60	28.20	32.60	35.8	41.00	38.67
	39.80	45.00	54.80	52.00	51.00	51.75	51.50	56.00

TABLE 8:

Shell length of juvenile *Biomphalaria* in varying concentrations of seawater taken at weekly intervals for seven weeks.

Concentration of seawater/%	Initial average shell length/mg	Weekly average shell length /mg						
		1	2	3	4	5	6	7
0	1.42	2.24	2.56	2.98	3.35	3.35	3.67	3.80
	1.66	1.74	2.94	3.16	3.40	3.40	3.40	3.50
	1.46	1.82	2.65	2.95	2.98	-	-	-
5	3.20	3.48	3.52	3.54	3.40	3.48	3.55	3.60
	0.54	0.98	1.90	2.08	2.28	2.58	2.70	2.86
	2.52	2.82	3.20	3.46	3.35	3.48	3.55	3.70

TABLE 9

Mortality of Adult *Bulinus* cultured in different concentrations of seawater for seven weeks.

Concentration of seawater (%)	Weekly mortality							No. of snails which died in seven weeks	No. of snails alive after seven weeks
	1	2	3	4	5	6	7		
10			2	2	1			5	0
	5							5	0
	5							5	0
9	2			2				4	1
	1	2				1	1	4	1
	1		1	1		1		4	1
8		3	1				1	5	0
	2	1				1	1	5	0
				1	1	1	1	4	1
7					1	1	1	3	2
	1	1		1		2		5	0
			1	1		1	1	4	1
6						1	1	2	3
	2	1					1	4	1
		1				1		2	3
5	1						1	2	3
				2	1	1		4	1
					1	1		2	3
0						1		1	4
			2		1			3	2
			1	1				2	3

TABLE 10

Mortality of juvenile *Bulinus* cultured in different concentrations of seawater for seven weeks

Concentration of seawater (‰)	Weekly mortality								
	1	2	3	4	5	6	7	No. of snails which died in seven weeks	No. of snails alive after seven weeks
0							1	1	4
								0	5
		1						1	4
5						1		1	4
			1					1	4
							1	1	4

TABLE 11

Mortality of adult *Biomphalaria* cultured in different concentrations of seawater for seven weeks.

Concentration of seawater (%)	Weekly mortality								
	1	2	3	4	5	6	7	No. of snails which died in seven weeks	No. of snails alive after seven weeks
9				1	1	1	2	4	1
							2	3	2
		1				1	1	3	2
8					1	1		2	3
		1				1	1	3	2
						1	2	3	2
7		1			1			2	3
		1					1	2	3
	1						1	1	4
6					2		1	3	2
			1		1		1	3	2
				1		1	1	3	2
5				2		1	1	4	1
				1	1	1		3	2
						1	1	2	3
0								0	5
				1				1	4
	1				1			2	3

TABLE 12:

Mortality of juvenile *Bomphalaria* cultured in different concentrations of seawater for seven weeks.

Concentration of seawater (%)	Weekly mortality								
	1	2	3	4	5	6	7	No. of snails which died in seven weeks	No. of snails alive after seven weeks
0			1			1		2	3
				2	1	1		4	1
			1		4			5	0
5				1			1	2	3
							2	2	3
				1		1		2	3