DISTRIBUTION OF FRESHWATER SNAILS IN THE FIELD DITCHES (ABU ESHREENS) AND THEIR ROLE IN THE TRANSMISSION OF SCHISTOSOMIASIS IN GEZIRA IRRIGATED SCHEME

By

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DEDICATION

To whom I love and they do too

Tahani

ABSTRACT

This work was carried out in the abu eshreens of three minor canals, Gad El Ain, Wad El Magdi and Hassaballa, in addition to two special abu eshreens, one irrigating the gardens of Abu Usher Hospital and the other irrigating the Inspectors Houses' in Abu Usher, in the northern part of Gezira Irrigation Scheme (the Scheme). The main objective of the study was to determine the distribution of freshwater snails in abu eshreens, and the different factors that might have affected the snail populations.

Five genera of fresh water snails were found in the study abu eshreens. Three of them belong to the order Pulmonata. These were *Biomphalaria pfeifferi*, *Bulinus truncatus* and *Bul. forskalii*. The first two species are the intermediate host snails for the intestinal and urinary forms of schistosomiasis respectively. The last one is of no medical importance in the Sudan. The remaining two genera belong to the order Prosobranchata. These were *Cleopatra* and *Melanoides* snails.

The intermediate host of human schistosomes were not widely distributed in the study area. This is probably due to the dredging of the three minor canals under the study just before the start of the study. Dredging not only deepened the canal and increased the water velocity, but also removed the vegetation that usually supports large populations of the snails.

The distribution of the snails in abu eshreens was found to be affected by the physical characteristics of each canal. The ecological conditions prevailing in the canalisation system during the rainy season affect all freshwater species negatively. However, The ecological conditions and the physical characteristics of the canals, together, determine the distribution of freshwater snails in abu eshreens. It was concluded that abu eshreens do not play any role in the transmission of schistosomiasis in the Scheme.

Bulinus forskalii snails were found widely distributed in the abu eshreens and it dominated all other species. The snail was found in an abu eshreen where it was reported to exist 30 years ago. This indicated that certain abu eshreens are having optimal conditions and under such conditions, freshwater snails establish colonies of populations that can survive for several years. A laboratory experiment indicated that the snail is still refractory to infection with *S. haematobium* miracidia. The possibility to use the snail as a biological agent was discussed.

The crop in the field and the presence of water in the field ditches for a long time affected the distribution of snails in abu eshreens. They were abundant in abu eshreens irrigating vegetables and cotton respectively and were few in abu eshreens irrigating groundnuts/sorghum and wheat plants.

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ABBREVIATIONS, DEFINITIONS AND GLOSSARY

The following abbreviations, definitions and words are used in the text.

a. ABBREVIATIONS

ANOVA:	Analysis of Variable
BNHP:	The Blue Nile Health Project
Bio. pfeifferi	*Biomphalaria pfeifferi*
Bul.forskalii	*Bulinus forskalii*
Bul.truncatus	*Bulinus truncatus*
Cleo	*Cleopatra* snails
Mel	*Melanoides* snails
S.	*Schistosoma*
Spp	Species
SPSS:	Statistical Package for Social Science
WHO:	World Health Organisation

b. DEFINITIONS AND GLOSSARY

Feddan:	Equivalent to 1.04 acres= 4200 square metres
Managil:	Managil extension
Percentage Distribution:	Percentage of the total catch of the individual genera/species in aparticular season, or in abu eshreens irrigating a particular crop or due to ecological factors, from the total yearly catch of that particular genera/species.
Relative Abundance:	The percentage of the monthly catch of the individual species/genera out of the total monthly catch of all snails.
The Scheme:	Gezira Irrigation Scheme.

CHAPTER ONE

GENERAL INTRODUCTION

1. INTRODUTION

The Sudan lies between latitudes 4° N and 21° N. It is the largest country in Africa (one million square miles). The country is a flat land with few mountains in the eastern, mid-west and far-west States. The climate is dry hot in the north and wet hot in the South. The Blue and White Nile Rivers traverse the country before they join at Khartoum, the capital, to form the River Nile that runs down through the desert to Egypt. Agriculture dominates Sudan's economy. It contributes over 60% of the development projects and 90% of the exports are agricultural products (Babiker, personal communication).

For development purposes, irrigation schemes have been constructed along the three rivers and their tributaries *e. g.* the Gezira and the Rahad Agricultural Schemes and Ginaed, El Girba and Kinana Sugar Cane Farms. Different crops are cultivated in these schemes. The main crops are cotton, wheat, sorghum, groundnuts and sugar cane. Economic development in the Sudan has been intimately linked to the agricultural productivity of the irrigated schemes. But the development of the irrigation schemes has resulted in certain undesirable consequences. In creating the large net work of the irrigation canals, the engineers also provided an ideal habitat for the breeding of the intermediate host snails of schistosomiasis as well as large water surfaces for the mosquito breeding. In all agricultural schemes in the Sudan, schistosomiasis is now believed to be endemic (Babiker, personal communication). The oldest and largest scheme in the country is Gezira Irrigation Scheme (the Scheme).

1. 2. SCHISTOSOMIASIS

Schistosomiasis is a parasitic disease of man and mammals in tropical and sub-tropical areas. Human schistosomiasis is one of the most wide spread parasitic diseases. It is second only to malaria in terms of public health importance. It imposes its hazardous impact on health and the economy through the ease with which it is rapidly disseminated without giving rise to alarming signs and symptoms. It was estimated that 200-300 million persons are, world wide, infected with schistosomiasis; and another 500-600 million persons are at risk of infection (Gold-Smith, 1991; WHO, 1993). Data obtained from various endemic countries have clearly indicated that the increase in the prevalence of schistosomiasis is closely related to water resources development (Barbosa *et al*., 1981; Ndamba *et al*., 1994). The increase in the prevalence of schistosomiasis is not necessarily confined to areas where irrigation is expanding but is apt to occur in any relatively dry area where man increase the amount of the natural water held (Mc Mullen, 1973).

Human schistosomes are blood flukes that belong to the digenetic trematodes in the super-family Schistosomatidae (Jordan *et al*., 1993; Cited by Mohammed, 1999). Six species of schistosomes are known to infect man. These are: *Schistosoma haematobium* (Bilharz, 1853), *S. japonicum* (Katsurada, 1904), *S. mansoni* (Sambon, 1907), *S. intercalatum* (Fisher, 1934), *S. mekongi* (Voge *et al*., 1978, cited by WHO, 1993) and a new intestinal Malaysian *Schistosoma* species (Greer *et al*., 1980 & 1989). There are other species that infect mammals and are of economical importance such as *S. mattheii* and *S. bovis* (Jordan *et al*., 1993; Cited by Mohammed, 1999).

1. 2. 1. The Life Cycle

Schistosomes are unisexual trematode worms. The life cycle of human schistosomes is a complicated one. The embryonated eggs voided from the final host in excreta, in either urine (*S. haematobium*) or stool (*S. mansoni*, *S. intercalatum* and *S. japonicum*). In fresh water, the eggs hatch to liberate the miracidia. These swim freely in water to locate, penetrate an appropriate snail host (intermediate snail host) and transform into mother sporocysts at the site of penetration. By asexual multiplication, each mother sporocyst gives rise to a number of daughter sporocysts. Each daughter sporocyst divides asexually to give a large number of free-swimming bifurcate tailed cercariae, the infective stage. The cercariae infect the final host by direct penetration of the host skin. It loses its tail and transforms into a schistosomulum. The schistosomula are carried passively by the blood to the lungs where they stay for a few days before they are carried again by the blood to the liver where they reach maturity. The mature schistosome worms couple and migrate to their final destination, the mesenteric veins in case of *S. mansoni*, *S. intercalatum* and *S. japonicum* and the veins around the urinary bladder in case of *S. haematobium*. At the final site, they establish themselves and produce thousands of eggs (a female worm produces 300-3000 eggs per day) for a period of 2-8 years during which infected persons continue to initiate new cycles of infection by passing ova into water bodies. The schistosome species are similar in their life cycle and the morphology of the miracidia and the cercariae. They differ in the morphology of the adult worms, the shape and size of the eggs (Jordan *et al*., 1993; Cited by Mohamed, 1999).

1. 2. 2. Schistosomiasis in the Sudan

Archibald (1933) claimed that the disease was more likely to flare up in the Sudan as a result of political and economical relations with Egypt. The disease has increased in distribution and prevalence because of the expansion in water resource development projects and an increased population movements (El-Gaddal, 1985). It is endemic in the White Nile River area (Ahmed *et al*., 1996), in the Northern States, River Nile and North States, (El-Toum *et al*., 1993), and in Eastern Sudan (Abdel Galil, 1980; BNHP, 1980). It is also present in Southern Sudan (Brown *et al*., 1984), in Western Sudan (Daffalla & Sulaiman, 1988), and in all irrigation schemes around Khartoum (Musa, 1998; Taha, 1998). The exact magnitude of schistosomiasis in the agricultural schemes, than the other Scheme (El-Motasim, 1998), is not known. It is believed, however, to be serious.

The disease is endemic in Kenana Sugar Scheme (Ahmed *et al*., 1995), in El Genaid Sugar Scheme (Ahmed, 1998), in New Halfa Scheme (Abdel Galil, 1980), and in Rahad Scheme (Elias *et al*., 1994; Karti & Babiker, 2001, unpublished report).

1. 2. 3. Schistosomiasis in Gezira Irrigation Scheme

The history of schistosomiasis in the Sudan began in 1925 with the opening of the agricultural scheme in the Gezira area. Schistosomiasis was practically unknown in the area except for a few sporadic cases in the vicinity of the Blue Nile River. Spence (1924) suggested that Egyptian labourers with schistosomiasis should either be treated before being allowed to enter Sudan or else be sent back to Egypt. In 1925, it was decided to prohibit the entry of infected labourers. Arrangements were then made either to reject or treat at Wadi Halfa quarantine station, all infected labourers coming to the Sudan. Similar procedures were adopted at Kosti and Dueim quarantine stations for all persons coming from the west of the White Nile River.

Between the years 1928 and 1933 the protective quarantine stations at Wadi Halfa, Kosti and Dueim carried out useful survey work and registered an average *S. haematobium* infection rate of 17.5%. Examinations for *S. mansoni* were not made as the infection was then thought to be uncommon. Annual surveys during the years 1926/29 suggested that the infection rate with *S. haematobium* was generally less than 1%. *S. mansoni* was not detected in stools, but may have been overlooked.

Although the data from the medical institutions continued to indicate an infection rate of approximately 1%, a survey conducted by Stephenson (1947) between 1942/45 revealed some alarming figures. The average *S. haematobium* infection was found to be 21% in adults and 45% in children. He incriminated the minor canals as the main source of infection and pointed out that the prophylactic measures taken had failed.

Greany (1952 a & b) conducted a survey in 1946 and found *Bulinus* and *Biomphalaria* snails equally common in all canals in a density closely related to weed growth. *S. mansoni* infection rate in *Biomphalaria* was twenty times that of *S. haematobium* in *Bulinus* (1.2% compared to 0.06%). He examined 80,000 inhabitants (about 25% of the Gezira population at that time) and the results showed that *S. haematobium* and *S. mansoni* were equally prevalent in 10-15 years old children.

During the early fifties, Sharaf El Din and El Nagar (1955) carried out a pilot trial to control the intermediate snail hosts. El Nagar (1958) reported the success of a large control campaign in the Scheme that covered all canals at that time (5000 kilometres). The methods adopted were: snail habitat destruction by removal of the weeds from the canals (mechanically and manually), destruction of snails by copper sulphate, prevention of snail re-invasion by means of mechanical traps and chemical barriers and treatment of infected persons using antimony-based drugs. The results indicated that the campaign was successful and that it could be implemented in other irrigated schemes. However, that campaign was the only trial carried out on a large scale to control the disease in the Gezira area for a very long period.

In 1971 a Bilharzia Project was established in the Scheme with the long term objective to control the disease. Amin (1972 a) found that the infection rate of *S. haematobium* was less than 1% in villages of the northern region of the scheme. He found the infection rate of *S. mansoni* in the same area to be 25% by direct faecal smears and the following year by the stool digestion technique he found a prevalence of 60%.

In 1974 a routine snail control regimen was introduced, which consisted of five aerial sprays with the molluscicide N-trityl morpholine over the main, major and minor canals in the most northerly 80,000 feddans of the Scheme (Amin & Fenwick, 1975 & 1977). The regimen continued for three years and its effects were regularly monitored: (a) by surveillance and sampling of snails, and (b) by parasitological examinations in pre-school children and school-age children. The results suggested that the objective of keeping the minor canals virtually snail free had been achieved, but the incidence data gave equivocal results since in some villages there was evidence that transmission was as high as in a nearby untreated area (Amin *et al*., 1982). Also the cost of aerial application was very high and so the regimen was abandoned.

The Blue Nile Health Project (BNHP) was established in 1979. The 10-year project aimed at control of the major water associated diseases prevalent in the agricultural communities along the Blue Nile River. These diseases are: diarrhoea among children, malaria and schistosomiasis. Twenty-eight villages were randomly selected from the villages in the Scheme for monitoring. The first epidemiological survey showed that the prevalence of schistosomiasis was 51% with a range from 30% to 70%, indicating a rather even distribution geographically. The exceptions were villages on the edge of the Scheme situated close to the Blue Nile River, which had a low prevalence (< 15%) (BNHP, 1981). The BNHP implemented a comprehensive control strategy and was able to reduce the prevalence to less than 5% in the Scheme (BNHP, 1990) in 10-years time.

1. 3. THE SCHISTOSOME INTERMEDIATE SNAIL HOSTS

The intermediate snail host is an essential link in the schistosome life cycle. Knowledge of its ecology, bionomics and population dynamics are required for a proper understanding of the disease transmission, or as a basis for planning and evaluation of measures directed against snails in the control of the disease (WHO 1993).

Despite the ability of schistosome species to develop in a variety of definitive mammalian hosts, the range of snail, that serves as intermediate hosts, is limited (Rollinson & Southgate, 1987). Pulmonate snails of the family Planorbidae are the intermediate snail hosts for human schistosomes in Africa, the Middle East, the Caribbean islands and South

America. *Biomphalaria* snails are the intermediate hosts for *S. mansoni* and certain *Bulinus* species are intermediate hosts for *S. haematobium* and *S. intercalatum*. The intermediate snail hosts of *S. japonicum, S. mekongi* and *S. malysiensis* belong to the prosobranchs family pomatiopsidae. *S. Japonicum* is transmitted by *Onchomelania hupensis*. *Tricula aperta* transmits *S. mekongi* while *Robe rtsiella Kaporensis* transmits *S. malaysiensis* (Jordan *et al*., 1993; Cited by Mohamed, 1999).

Biomphalaria and *Bulinus* snail species are aquatic hermaphroditic snails, that are found in all types of freshwater bodies, ranging from small temporary ponds or streams to large lakes and rivers. Man-made water bodies are, in particular, excellent habitats for snails (Brown, 1980). *Biomphalaria* and *Bulinus* snails have a well-developed ability to self-fertilise, but cross-fertilisation is the most common and copulation is unilateral, *i. e*. one snail acts as a male and the other as a female (Vianey-Liaud *et al*., 1989).

The reproductive capacity of *Biomphalaria* and *Bulinus* snails is high. Eggs are deposited in masses on plants or solid objects in water. Under optimal temperatures, hatching takes place after 7-10 days. Juvenile snails reach sexual maturity after 4-6 weeks (Madsen, 1982). Growth and egg lying are influenced by environmental conditions and population density (Milward *et al*., 1978) as well as by age of snails and certain enzymes *e. g*. phenoloxidase (Bai *et al*., 1996 & 1997). The average longevity of the snail varies among the species and with the local environmental conditions (Madsen, 1982).

1. 3. 1. Distribution in the Sudan

Archibald (1933) described *Bul. forskalii* as occurring in the Blue Nile, in springs of Nuba Mountains in Kordofan province. As for the genus *Biomphalaria*, he reported finding *Bio*. *alexandrina* and *Bio*. *pfeifferi* in the Blue Nile, *Bio*. *Biossyi* and *Bio*. *pfeifferi* in the White Nile. Buchanan (1937) recorded the occurrence of *Biomphalaria* in a focus in Berber region in the Northern Province. Working in Gezira, Stephenson (1947) found both

Bulinus and *Biomphalaria* well established and more numerous in the area practising night storage of water than in those with continuous flow. Greany (1952) found that water courses in the Scheme were heavily populated with the intermediate hosts of both species. He reported the occurrence of *Bul*. *truncatus*, *Bul*. *globosus*, *Bul*. *forskalii*, *Bul*. *africanus* and *Bio*. *alexandrina* in different canals in the Scheme.

Malek (1958) conducted an intensive survey of the snail intermediate hosts in the Sudan. He found *Bul*. *ugandae* to exist in the southern provinces, the White Nile and in the West of Sudan. He reported a wide range of distribution for *Bul*. (*Bulinus*) snails in all regions of the Sudan. He claimed that *Bul*. *globosus* occurs only in the extreme south of the Sudan. He also stated that *Bul*. *forskalii* has a wide distribution in the Sudan in slowly flowing water with plenty of aquatic vegetation. In the south, *Bul*. *forskalii* was found in (Khors) leading to Bahr-El Jebel, in the sudd region, in Bahr-El Gazal, on the swampy banks of the White Nile, in the Nuba mountains and in some island rain pools in Darfur. The snail is rare in the Blue Nile and in irrigation canals of the Gezira.

1. 3. 2. Ecological Factors Affecting the Intermediate Host Snails

Madsen (1992) stressed the importance of ecological studies of the intermediate snail hosts to optimally apply existing control measures. There are several ecological factors which influence the snail population and hence the transmission of schistosomiasis. Among these factors are physical, chemical and biological factors.

1. 3. 2. 1. Physical factors

1. 3. 2. 1. 1. Habitat

The schistosome intermediate snail hosts are found in fresh water habitat. Water resource development projects result in marked increases in ideal snail habitat, leading to horizontally expand and vertically intensified transmission of the disease (WHO, 1993).

Usually snails appear and colonise the canalisation system after a short period from the construction of these schemes (Madsen & Frandsen, 1989). This was observed in the Scheme (Humphreys, 1932), Rahad Scheme (Tamiem *et al*., 1985) and Volta Lake (Scott *et al*., 1982). Snails are spread by water currents (Rahaman & El Din, 1961), by mammals (Madsen & Frandsen, 1989) or by birds (Boag, 1986) to new areas free from the snails, and thus creating a potential situation for the spread of the disease.

1. 3. 2. 1. 2. Geology

The distribution of snails is influenced by geological factors. In South Africa, snails survive in flowing habitat only when rock formations are heterogeneous in hardness (Appleton & Stiles, 1976). The type of substratum normally associated with pulmonate snails is a firm mud substratum, rich in decaying organic matter that provides support for aquatic plants giving protection, egg-laying sites and food for snail populations (De-Clercq *et al*., 1994). In contrast, eroded sediments consisting of coarse gravel and stones, in running water, are more favourable habitats for prosobranchs (Thomas & Tiat, 1984).

1. 3. 2. 1. 3. Temperature

Temperature affects directly the metabolic activity of the snails and indirectly their distribution and growth. It affects rates of photosynthesis, rates of bacterial decomposition and amount of oxygen in water (Madsen, 1982). It also affects the reproduction rates of the intermediate snail hosts (Ichii *et al*., 1990). All intermediate snail hosts of human schistosomes show tolerance to a considerable range of temperature fluctuations. This ranges between 18° and 32° C, with an optimum range between 22° and 26° C. Higher and lower temperatures can be tolerated for limited periods (Klumpp *et al*., 1985).

Temperature was shown to affect the distribution and growth of snail populations in a given area. Low temperatures in winter reduce breeding or stop it completely in tropical and subtropical zones; and it is resumed when temperatures increase. In Egypt, *Biomphalaria* snails have two distinguished periods of growth, the autumn and the spring periods. Daily mortality rate of snails was highest in the hot season (June-September) and lowest in the cold months (December-April). Continuous breeding of *Biomphalaria* snails occurs throughout the year with highest rates of reproduction from November to March. These observations were attributed to variation in temperature between seasons (Yousif *et al*., 1993). Similar results were reported from the Sudan (Hilali, 1992). Appleton (1977) considered the absence of *Bio. pfeifferi* from certain shallow permanent water bodies of north eastern Zulu land to be due to high temperature. Pimentel-Souza *et al*. (1990) evaluated the reproduction of *Bio. glabrata* under laboratory conditions by measuring egg production, number of eggs oviposited, and hatching rate at five different temperatures. Egg production and spawning rates were higher at temperatures between 20° and 27.5° C. The number of eggs per spawning and hatching rate did not vary with temperature.

Raut *et al.* (1992) studied the effect of temperature on survival, growth and fecundity of newly hatched *Indoplanorbis exustus* snails. Snails were cultured at 10°, 15°, 20°, 25°, 30° and 35° C and at room temperature (17.5°-32.5° C). Snails exposed to 10° C died within 3 days. Those reared at the other temperatures and the room temperature survived for a period ranging between 6 and 17 weeks, and the weight and the shell diameter of the individual snails increased weekly. Snails cultured at 15° C died before sexual maturity. There was a positive correlation between temperature and eggs produced by snails.

Temperature is also a factor in the infection of snails by miracidia and subsequent development. In Iran the incubation period was found to be shortest in August (summer) and longest in November (winter) and in the laboratory the cercariae positive rate in exposed *Bulinus truncatus* was found to be highest at 20° to 30° C (Chu *et al*., 1966). In Sudan, Babiker (1980) found that the development from miracidia to daughter sporocyst stage in the snail *Bio. pfeifferi* took eleven days in summer and up to eighteen days in winter.

The developmental time of *S. haematobium* in *Bul. truncatus* snails was determined in the laboratory at different constant temperatures, between 18° and 32° C. The shortest prepatent period was 17-19 days at 30°, 31° and 32° C. At 18° C, cercarial development required at least 16 weeks. No schistosomes reached maturity at 17° or 33° C. The cercarial release per snail showed a maximum at 25° C and the lowest release was at 18° C and 32° C (Pfluger *et al*., 1984). Muhoho *et al.* (1997) observed that the presence of cercariae in natural water depended on the water temperature, and that the intensity and duration of sunlight did not affect the presence of cercariae in water.

1. 3. 2. 1. 4. Water, substratum and soil

The snail population varied from region to region. Madec and Daguzan (1991) stated that the reproductive variability between snails' populations showed the adaptive flexibility of characters describing reproductive activity and the relative stability of reproductive ability. In a field study in Ghana, Klumpp *et al.* (1985) reared two cohorts of *Bul. truncatus rohlfsi*, one group in lake-water with a mud substratum and the other in lake-water but without mud. Both cohorts were able to tolerate water temperatures ranging from 22° to 35.5° C, but growth and survival were significantly greater for the cohort with mud. Gomot (1998), in the Philippines, stated that the best soils for reproduction of the snails *Onchomelania quadrasi* generally had a pH of 5.6-7.9 and more than 200 mg of CaO/100g of soil. These two soil factors, in addition to shade and moisture, determine the optimum condition for the breeding of *O. quadrasi* in the field as well as in the laboratory.

1. 3. 2. 1. 5. Water level

Klumpp and Chu (1977), working in Lake Volta, studied seasonal fluctuation in population densities and infection rates of *Bul. truncatus rohlfsi*. They reported a positive correlation between fluctuation in the Lake Level, snail population densities and infection rates. Marti *et al*. (1986) studied the ecology of *Bul. globosus* in Tanzania. They showed distinct seasonal fluctuations in pools, with a density peak at the end of the small rainy season. They showed that pH, temperature and conductivity had little effect on the *Bulinus* population. They concluded that rainfall patterns have a distinct influence on snail densities.

Xu *et al*. (2000), working in China, they showed that the general water level in the Yangzte area over a year had a marked effect on the distribution of the intermediate host, *Onchomelania hupensis*, and the prevalence of human schistosomiasis in that year. They reported that disease prevalence showed significant co-relations with the density of the snail hosts, the level of the water table, annual rainfall, yearly evaporation, and altitude.

1. 3. 2. 1. 6. Current velocity

Intermediate host snails have a narrow tolerance range to current velocity (Appleton, 1975). They have strong preference for lentic habitat, and they show marked preference for slow-moving or non-flowing regions, colonised by sub-aquatic plants (Appleton, 1978). The water current affects the nature of substratum, which in turn affects the plants in the habitat (Appleton & Stiles, 1976). Thomas and Tait (1984) stated that snails in flowing waters would have to exhaust a great deal of energy to maintain their position and that flowing water may have a detrimental effect on the snail physiology. They also suggested that stronger currents inhibit the vegetation they use for food, for egg laying and for shelter.

In Nigeria, *Bul. globosus* and *Bul. truncatus* were found in the lakes and the canalisation system. Snails were not found at fall, on exposed shores of large lakes, or irrigation canals with very swift flow. At these conditions the snails are dislodged, a few may be able to survive by attaching themselves to weeds, or by sheltering in quiet pools near the banks where the current is less affective (Emejulu *et al*., 1994).

1. 3. 2. 1. 7. Turbidity

High turbidity levels indirectly affect aquatic vegetation. Algal growth is inhibited when the silt particles settle on it, thus affecting the amount of food available for the snails. Moreover, turbid water exerts a stronger friction than clear water and thus snails can be washed out even at a lower current speed (Madsen, 1986). Some researchers believed that the clarity of water is a necessary condition for the presence of fresh water snails (Meyer-Lassen *et al*., 1994). However, Babiker *et al*. (1985), reported a reduction of *Biomphalaria* snail densities in the Scheme during the rainy season that coincides with a high silt content period in the canalisation system.

1. 3. 2. 1. 8. Rainfall

Rainfall has several distinctive characteristics (Bayomy & Joosse, 1987). Firstly, it determines the amount of water and the water level in a habitat (Klumpp & Chu, 1977). Secondly, heavy rains lead to a rapid increase in the amount of discharged water (Marti, 1986). Thirdly, rainfall, together with temperature, determines the period of desiccation of the habitat (Webbe & Msangi, 1958). Fourthly, the human faeces are flushed into the water bodies during the rainy season, leading to an increase in the infection rates of the intermediate host snails in the dry season (Christie & Upatham, 1977).

Rain stimulates egg lying in snails resulting in peak densities during or shortly after the rainy season (Madsen, 1982; Okeeffe, 1985). This stimulation could be due to a dilution of various chemicals dissolved in water, or it could be due to a drop in water temperature associated with rainfall (Appleton, 1978; Okeeffe, 1985). In contrast, rainfall may result in sharp reductions in population densities where streams and rivers are flushed out (Matri, 1986). However, reduction in snail densities could be due to other factors associated with rain *e. g.* turbidity (Babiker *et al*., 1985) or could be due to a combination of all these factors (Ndifon & Ukoli, 1989; Coulibaly & Madsen, 1990). Upatham *et al*. (1981), in Somalia, reported that *Bul. abyssinicus* snail populations fluctuated in size according to rainfall.

In Kenya, O'Keeffe (1985) studied factors influencing the population dynamics of the snail *Bul. globosus* in two reservoirs in the coastal area. After an exceptionally heavy unseasonal rainfall in August 1980, high snail densities were recorded in September 1980 in both reservoirs. He concluded that rainfall appeared to be the most important factor determining the intrinsic rate of natural increase for this snail species.

Investigations on the distribution of fresh water snails in South Western Nigeria have shown that *Bio. pfeifferi* and *Bul. globosus* were more frequently encountered during the dry season than during the rainy season. It was concluded that dry conditions, which would favour snails, include, among others, low turbidity, reduced currents and substantial growth of algae macrophytes (Ndifon & Ukoli, 1989).

Coulibaly and Madsen (1990) reported that *Bio. pfeifferi*, *Bul. truncatus* and *Bul. globosus*, in two streams (one temporary and one perennial) in Mali, showed great seasonal variations in density following the rainy season with peak densities during the early dry season. The principal factors causing these fluctuations were desiccation in the temporary stream and high temperatures and flushing out of snails as a result of rains in the perennial stream. Transmission was found to be short in the temporary stream, terminated by desiccation of the site, while it was continuous throughout the year, with peak transmission during the dry period in the permanent stream.

Madsen (1982) believed that clarity of fresh water is a necessary condition for presence of snails. In the Sudan, a decline was observed in *Bio. pfeifferi* and *Bul. truncatus* densities in the canals of the Scheme during the rainy season (July-October) due to the increased turbidity during this season. Schistosome infected *Bio. pfeifferi* were found every month of the year except September, *i. e*. period of high turbidity. There was a marked variation in the size of the peak from year to year (Karoum, 1988; Hilali, 1992).

Muhoho *et al*. (1997) studied cercarial density of *S. haematobium* in a river in Kenya. They found that cercarial density was highest in March and April, middle of the rainy season, whereas no cercariae were detected in cool dry season. The snail population peaked late in March, the beginning of the long rainy season, remained high for two months, and decreased rapidly late in May when heavy rain occurred. They did not find any definite correlation between the presence or absence of cercariae and infected snails.

1. 3. 2. 1. 9. Light

There is evidence that planorbid snails may be negatively photo-tactic and that locomotor activity is nocturnal in the case of a variety of aquatic and terrestrial pulmonate (Appleton, 1978). Joy (1971) found that *Bio*. *glabrata* laid its eggs at night. Barbosa *et al.* (1987) showed that the reproductive rate of *Bio. glabrata* was dependent on both intensity of absolute illumination and schedule of illumination exposure.

Gomot *et al*. (1989), studying *Helix aspersa*, showed that there was an interaction between photoperiod and temperature and revealed a predominant effect of photoperiod that compensates for the negative effect of low temperatures. A combination of long day (18 hr L: 6hr D) and temperature of 20° C was the most favourable condition for egg laying as well as for effective functioning of ovitestis and albumen gland.

Gomot (1990) proved that mating of *Helix pomatia* snails was more frequent under long days and rare under short days (8 hr L: 16 hr D) regardless of temperature. The number of eggs laid and the frequency of egg laying were greater in long than in short days. Only long photoperiods brought about cyclic reproduction over a period of 16 weeks, confirming the synchronising role of photoperiod on the neuro-endocrine control of egg laying of the snail.

Biomphalaria snails are attracted to light and negatively affected by darkness. Loreau and Baluku (1991) reported that artificial shading of breeding-site eliminated a population of *Bio. pfeifferi* within six weeks. It was re-colonised eight weeks after the shade was removed. The time taken for re-colonisation suggests that shade acts not only by affecting snail behaviour but also indirectly by removing the diatoms, food for the snails.

Haroun *et al*. (1996) found that the survival and reproductive rates of *Bio. alexandrina* and *Bul. truncatus* snails exposed to sub-lethal doses of X-ray were highly affected by these doses. Maximum survival periods of laboratory bred *Biomphalaria* snails were less than those of field ones. This indicates a high sensitivity of laboratory snails to X-ray. Therefore, the reproductive capacity of irradiated *Biomphalaria* and *Bulinus* snails was highly suppressed. They observed a histological deleterious effect of gametogenesis of the irradiated *Biomphalaria*.

Fujita and Egami (1984) studied changes in the survival rate of adults and embryos of *Physa acuta* after acute gamma irradiation. They reported histological changes in the ovitestis, the number of eggs laid, and the hatchability of the irradiated adult snails. The proportion of immature germ cells was reduced as well as the total number of germ cells.

De Souza *et al*., (1987) studied factors affecting breeding and maintenance of infected snails and the production of *Schistosoma mansoni* cercariae. They showed that snails maintained in incubator at constant temperature and total darkness produced maximum shedding when submitted to brightness and high temperature (about 30° C).

1. 3. 2. 1. 10. Pollution

There is an apparent association between concentration of snails and polluation of the habitat (Babiker *et al*., 1985 a). Field observations indicated that the different species of *Biomphalaria* snails are social snails occurring in lottic or lentic habitats that tend to be heterogeneous in space and time. Both species live in regions of streams or ponds that are intermittent in character (volume changes) and therefore, several successive generations will be found in the same location (Thomas *et al*., 1975).

1. 3. 2. 2. Chemical factors

Researchers concluded that the intermediate host snails are tolerant of water differing widely in the chemical contents and it is apparently not usually possible to predict colonisation of a particular habitat through chemical analysis of water content (Williams, 1970 a & b). Interesting results have been obtained by measuring salinity (total concentration of electrolytes). Salinity often shows seasonal fluctuations as a result of abnormal rainfall or influx of more fresh water, or it increases if rains are particularly light or the influx of water is particularly salty. It was found that certain snail species fail to maintain adequate salt balance when the concentration of a particular ion falls below a particular value (cited by Jordan & Webbe, 1982).

1. 3. 2. 2. 1. Calcium

This is one of the most obvious chemical factors to focus on when dealing with snails since it is the major component of the shell. The ecological importance of calcium is not clear, but there is certain evidence that it may limit the distribution of snails. The quantity and quality of snail food substances may be affected by calcium levels (Madsen, 1986). Exogenous chemicals of snail origin could have longer-term primer effect manifested by growth enhancement of snails (Thomas, 1982). Ions of heavy metals such as zinc, iron, copper, cadmium or silver, are toxic to snails at relatively low concentration (Madsen, 1986).

1. 3. 2. 2. 2.Oxygen and pH

Abdel-Rahman *et al.* (1997) reported that water quality parameters *e. g*. pH, salinity and dissolved oxygen, were not correlated with presence of infected snails. Other results indicated that abundance of snails and *S. mansoni* prevalence are related to thermal-hydrology domains associated with surface water and that regional hydrology characteristics (*i. e*. wet, moist, dry or very dry) affect snail host habitat suitability (Abdel-Rahman *et al*., 1997). Snails may alter the chemical composition of their aquatic medium by removing certain components, including oxygen and ferric ions. They may make use of dissolved oxygen in cutaneous respiration through highly vascularised pseudobranch (Madsen, 1986).

The hydrogen ion concentration is dependent on the nature of the surrounding soil and upon CO_2 content of water, which in turn depends on the photosynthetic activity and bacterial decomposition, which are regulated by light and temperature. Accordingly, typical diurnal fluctuations in pH are observed (Cowper, 1971). Oxygen content in the water is closely linked with the CO_2 cycle, being the great complement of metabolism. *Bulinus* snails are rather tolerant to low oxygen tensions compared to *Biomphalaria* snails (Madsen, 1986).

1. 3. 2. 3. Biological factors

1. 3. 2. 3. 1. Aquatic weeds

Aquatic habitats contain rich micro-flora, which provide for the snail, together with decaying vegetable matter, food (Ferguson *et al*., 1968), protection (Thomas & Tait, 1984) and egg-laying substrata (Thomas, 1987). Presence of aquatic weed is a major problem in the irrigation canals and regular removal of vegetation is necessary (Hilali, *et al*., 1985).

Odei (1972) and Klumpp and Chu (1980) reported that, in Lake Volta, large numbers of *Bul. truncatus rohlfsi* were generally found in association with *Ceratophylum dernersum* and that this plant could be taken as an indicator for the presence of the snails. Hilali *et al*. (1985), in the Sudan, claimed that *Biomphalaria* population appeared to multiply with weed more than *Bulinus*. Madsen *et al*. (1988) stated that the density of *Bio. pfeifferi*, *Bul*. *truncatus*, *Cleopatra bulimondes* and *Lanestis carinatus* were positively correlated with the density of the submerged plants *Potamogeton perfoliatus* and *Perispus* in the Scheme. Similarly in Egypt, Dawood *et al*. (1965) and Dazo *et al*. (1966) reported that *Bio*. *alexandrina*, *Bul. truncatus* and *Lymnaea natalensis* preferred *P. crispus*. Other researchers reported a positive association between plants and snails (Hira, 1969; Thomas & Tait, 1984), although this association may not be constant. Chu (1978) showed that, at the contact sites in Lake Volta, control of *Ceratophylum* would reduce the density of infected and uninfected *Bulinus* snails.

1. 3. 2. 3. 2. Aestivation

With the subsidence of water level in the dry season, or following a flood, snails are exposed to desiccation as well as to destruction by terrestrial predators. But the intermediate host snails have a capacity to survive out of water for weeks or even months through their ability to aestivate (Chu *et al*., 1967). They do not, apparently, follow the receding water line, but are stimulated to aestivate before severe changes in the water volume and other characteristics of the breeding site occur. Olivier and Barbosa (1956) and Barbosa (1959) reported that the ability of *Bio*. *glabrata* and *Bul*. *truncatus* to withstand desiccation was a characteristic of their habitat rather than of snails themselves. Barbosa and Dobin (1952), Olivier (1956) and Barbosa and Oliver (1958) reported that survival of *Bul*. *globosus* was dependent on relative humidity. Later, this was emphasised by (Sturrock, 1975). Field observations on bulinid snails by McCullough (1962), Chu *et al*. (1967) and Hira (1968) indicated that medium size (young snails) survive aestivation best. Desiccation will ultimately kill the aquatic snails and their ova, and could be used as a method of control in certain circumstances (Jordan & Webbe, 1982). Cridland (1957) found that infected snails have low resistance to aestivation, thus they did not aestivate successfully. He claimed that infected *Bio. glabrata* snails were able to aestivate successfully when the parasite was in the primary stage. The same observation for *Bulinus* snails were reported by Webbe and Msangi (1958) and by Hira and Muller (1966).

1. 3. 2. 3. 3. Trematode infection

Trematode infections have deleterious effects on snails; mainly due to mechanical tissue damage caused by endoparasite larval stages, consumption of digested food material and toxic excretions from the parasite. Sturrock (1966) demonstrated that eggs laid by infected *Bio. pfeifferi* had a higher sterility rate and a lower hatching rate than normal eggs. Studies on the influence of *S. mansoni* infection on the growth and reproduction of *Bio. pfeifferi* showed that infection causes a shortened life span but a temporary acceleration in growth which is proportional to the cercarial out put of each individual snail (Sturrock, 1966). .*Biomphalaria* and *Bulinus* species infected with *S. manson*i and *S. haematobium*, respectively, were reported to survive infection and become cured (Jordan & Webbe, 1982). Makanga (1981) showed that the number of young *Bio. pfeifferi* emerging from egg masses was reduced with increasing number of miracidia to which the parent snails were exposed, snails exposed to an average of four miracidia were rendered sterile.

Snails exposed to infection with miracidia of *S. margrebowiei*, when immature, showed significant reduction in growth. When infection occurred at the stage prior to egg-laying a significant reduction in growth was seen but only in the group which developed a patent infection (Raymond & Probert, 1993).

1. 3. 2. 3. 4. Competition and predation

Two species of molluscs, *Marisa cornuarietis* and *Melanoides granifera*, have been studied as effective competitors of *Biomphalaria* (Cheng & Combes, 1987) and therefore, reducing the snails populations. Both have been reported to displace *Bio. glabrata* (Ferguson *et al*., 1968; Ferguson, 1977). In Puerto Rico, *M. cornuarietis* has been studied thoroughly in the laboratory and under field conditions because of its observed affects on *Bio. glabrata* population. These studies have demonstrated the ability of *M. cornuarietis* to act as both predator and competitor of *Bio. glabrata.* Under laboratory conditions, *M.*

cornuarietis preys on immature and adult *Bio. pfeifferi* as well as on its egg-masses. Several species of fish were recorded as predators for molluscs (Andrade & Antunes, 1969).

1. 3. 2. 3. 5. Food

One of the most important factors determining the distribution of snail populations is the availability of food (Webbe & James, 1971). Pulmonates are browsing animals, which feed continuously as they move (Berrie, 1970). They feed on periphyton, made up of algae, bacteria and fungi growing on the surface of aquatic plants, on stones and on mud surface (Webbe, 1962).

Decaying aquatic plants, animal remains and fine organic particles are important components of pulmonate nutrition. The quantitative composition of the diet is probably important in conditioning the habitat. Thus, seasonal fluctuation in the quantity of microflora, as a consequence of changes in rainfall and temperature are accompanied by fluctuations in the density of snails (Malek, 1958).

1. 4. TRANSMISSION PATTERN AND DYNAMICS

The schistosome life cycle is a complicated one. Various factors and conditions determine the pattern of transmission of schistosomiasis. Many of these conditions giving rise to high transmission and therefore high prevalence and intensity of infection, may also be of a very temporary nature. These factors could either be factors affecting the snails (Abdel Wahab *et al*., 1993), or related to the parasite (Vercruysse *et al*., 1994) or to the final host (Wang *et al.*, 1994) and/or a combination of all these factors. This result in relatively short periods of intense transmission separated perhaps by longer periods in which transmission remains at a moderate level. Since transmission of schistosomiasis is absolutely dependent on the presence of the correct host species in sufficient numbers, the epidemiology and the distribution of the disease are controlled by the ecology of the snails.

Other factors that may affect the dynamics of transmission include: the probability of eggs being deposited in water containing the intermediate hosts, hatchability of eggs, survival of miracidia while free living in water, probability of locating and penetrating a host snail, probability of establishing an infection after penetration and the survival of and reproduction by larval stages in the snail host (Farooq, 1973).

1. 4. 1. Sociological Factors Affecting the Transmission Patterns

Sociological characteristic of the population is an important factor determining the nature and extent of transmission in the area. Snails may be widely distributed in an area, but there is a tendency for infected snails to be focally distributed due to the focality of human water contact behaviour (Babiker, 1987, Ibrahim, 1987). Focal infection rates with schistosomes may be quite high (Sudomo, 1984). In large irrigation schemes, most infected *Biomphalaria* and *Bulinus* snails are found close to human settlements (Babiker *et al*., 1985 a & b). The extent of the transmission and the prevalence of the disease are greatly influenced by the social behaviour, the characteristic of the community and the standards of hygiene and sanitation in the area (Ahmed, 1998).

There are variations in the rate of water contact and differences in the sites used between age/sex classes, but there is limited information on variations in individual water contact behaviour (Chandiwana & Woolhouse, 1991). The age and sex related prevalence rates and intensities of infection showed typical peaks in children and adolescents. These patterns varied from one area to another and could be related to ecology and water contact (Gryseels, 1991). Males had more exposure and infection than females (Li *et al*., 2000). In Brazil, Marcal-junior *et al.* (1993) reported that the most frequent reason for contact was recreational and the preferential site of contact was the river. In Nigeria, the prevalence rates varied between the different communities and with the year. The prevalence rates were highest in villages very close to lake (Emejulu *et al*., 1994). Urbanisation would facilitate transmission, probably enhancing the intensity of infection and that a low prevalence could hide a highly focal transmission (Soares *et al*., 1995).

1. 4. 2. The Intermediate Host Snails

There is a high degree of host-parasite specificity that exists between the mollusc and the parasite at a sub-specific level. The relationship between the larval schistosomes and their snail hosts is extremely delicate, and in many cases, this is strain specific (Jordan & Webbe, 1982). A *truncatus*-borne and a *globosus*-borne strain of *S. haematobium* occurring in distinct geographical regions were identified in Ghana (Mc Cullough, 1959). Differences in the biological characteristics and host parasite relationship of the *truncatus* and *globosus* strains were re-affirmed, although there are strains of *S. haematobium* which develop in both types of snails (Chu *et al*., 1978). Evidences of similar situations in southern Nigeria (Cowper, 1971) were reported.

Frandsen *et al*. (1978) concluded that the host-parasite relationship is dependant on two variable factors, the schistosome parasite and the snail host. Frandsen (1979) stated that compatibility describes the host-parasite interaction much better than infectivity of schistosome or susceptibility of snails to infection. Productions of cercariae as well as rate of infection, duration of infection and mortality rates in infected snails are important criteria in assessing the degree of compatibility.

Le Roux (1961) claimed that all African species of *Biomphalaria* are potential intermediate host of *S. mansoni*. However, it seems that some local strains do adapt to local snails (Wright, 1962). This was supported by Christensen *et al*. (1986).

1. 4. 3. Contamination

The obvious route for eggs to reach water is defecation directly into water either from latrines built over rivers and canals, (cited by Jordan *et al.*, 1980), or from a bridge over a river as it is common in St. Lucia (Jordan *et al.*, 1980), or more rarely while swimming or bathing. Jordan *et al.* (1980) observed that, in St. Lucia, faeces are frequently found on riverbanks. Another obvious route therefore and possibly that causing the greatest a mount of contamination is form faecal matter deposited near to water, in bushes or in tall grass and subsequently washed into stream. Christie and Upatham (1977) showed that infection rates of sentinel snails' increase with the onset of rains, probably due to wash-in of faeces deposited on the sides of the river. Jordan *et al.* (1980) reported that contamination of snail habitats with *S. haematobium* eggs is due essentially to infected persons urinating directly into water.

Following contamination of water with schistosome eggs, the majority will hatch with the emergence of free-living miracidia. However, the hatching itself is affected by extrinsic factors such as temperature, pH, salinity and light (Pitchford & Visser 1972; Blair & Etges, 1973; Upatham *et al.,* 1976).

1. 5. CONTROL OF SCHISTOSOMIASIS

Measures for the control of schistosomiasis were implemented since the discovery of the life cycle. The results have not been satisfactorily in spite of the technologies and strategies recently developed. The adopted strategy aims to interfere in the complex relationships between man and his bio-social-cultural environment. The measures adopted were either parasite non-specific or parasite specific methods.

1. 5. 1. Non-Specific Measures

Non-specific measures are directed towards prevention of infection. These include provision of adequate save water supply to prevent human contact with water infested by cercariae, improvement of sanitation by provision of latrines to reduce the contamination of water bodies by the schistosome eggs; and health education and community participation to change the human knowledge, attitude and practice.

1. 5. 1. 1. Water supply and sanitation

Improvement of water supply and sanitation are two-control measures that are not specifically targeted against schistosomiasis. They have not been seriously considered as tools of control owing to cost and maintenance difficulties (Jordan *et al*., 1993). However, there is enough evidence indicating that improvement in human environment, provision of water supply and particularly improvement of sanitation, influence the infection rates in the snail intermediate hosts, the transmission of schistosomiasis and the infection rates among man (Pitchford, 1976; Jordan *et al*., 1978). Alone, sanitation and water supply could not control schistosomiasis and an integrated approach was suggested and implemented in many endemic areas e. g. in Zaire (Gryseels *et al*., 1992) and in Sudan (BNHP, 1982-1990), with encouraging results.

1. 5. 1. 2. Health education and community participation

Health education is an important component in the integrated approach to control schistosomiasis. Health education, alone, may have little impact on the control programmes. In any control programme, people should be told about the nature of the work and what it involves. The content of health education programme should include information on the transmission of the schistosome and the ways in which the infection could be prevented or treated (WHO, 1993).

A trial was reported from China to reduce contact with unsafe water sources among school children, using health education. Self-administered questionnaire pre-and post intervention showed a significant increase in knowledge about schistosomiasis in the interventioned schools. This change was associated with a decrease in contact with unsafe water sources (Yuan *et al*., 2000).

1. 5. 2. Specific Measures

The specific are directed against the parasite *e. g*. chemotherapy to eliminate the worms in man and to reduce eggs output, and molluscicides to eliminate the intermediate host snails and therefore, interrupt the life cycle of the parasite. Schistosomiasis control should depend on specific measures against the parasite and the intermediate host snails and supplemented with non- specific measures (Barbosa & Combria, 1992). The combination of chemotherapy, and mollusciciding offers two advantages, elimination of the parasite from the population and reduction of snail population, especially in areas of seasonal transmission (Sturrock, *et al*., 1994; Sturrock, 1995).

1. 5. 2. 1. Chemotherapy

WHO (1980) had warned that schistosome control programmes should not rely on one, but should incorporate a range of control measures Despite this, some programmes have used drugs alone, mainly because of limited resources (Savioli *et al*., 1989; Sturrock *et al*., 1990), or to allow comparisons of different drug delivery strategies (Butterworth *et al*., 1991 & 1994), or used in studies of immunity with the long-term goal of developing vaccines (Butterworth *et al*., 1994).

In Brazil, the national programme was initiated in the mid 1970 s using oxamniquine as the primary weapon for mass or selective population chemotherapy. The various indices of schistosomiasis infection continued to decline but, despite this success, infected snails were still present in 1987 and cases with heavy pathology continued to be reported which indicate continued transmission (Coura Filho *et al*., 1992; Domingues *et al*., 1993; Lima Costa *et al*., 1993).

1. 5. 2. 2. Snail control

Snail control aims to reduce snail populations in water bodies to levels low enough to eliminate risk of schistosomal infection. Different snail control measures were suggested and used to control the intermediate host snails (Combes & Cheng, 1986). These included environmental, biological and chemical control measures.

1. 5. 2. 2. 1. Environmental control

Environmental control measure entails altering in some physical way the water bodies so as to make them unsuitable for snail populations. This could be achieved by complete removal of the snail habitat, by destroying water plants either manually or chemically (Jordan *et al*., 1993); or by engineering techniques, *e. g.* pond filling, drainage and water level fluctuation in irrigation channels (Madsen & Christensen, 1992) and by modification of irrigation practice and water management techniques which include increasing water velocity, stream straightening, canal lining and altering channel design (Mc Junkin, 1970). These engineering methods are usually too expensive and increasingly difficult to implement in new irrigation schemes (BNHP, 1990). In spite of this, new engineering devices are being investigated e. g. shade to control *Bio. pfeifferi* (Loreau & Baluku, 1991).

1. 5. 2. 2.2. Biological control

Although biological control has been suggested from time during the past fifty years, the subject has not attracted serious consideration despite the extensive literature on the subject (Pointier & McCullough, 1989; Madsen, 1990; Sturrock, 1995). Various workers have discussed controlling schistosome-bearing molluscs through the use of turtles, fish and ducks (Sturrock, 1995), and non-targeted snails such as *Marisa cornuarietis* and *Helisoma sp*. (Karoum, 1988). Other methods suggested are introduction of less susceptible or resistant strains of the intermediate host snails to the infection by the local parasite strain *e. g*. *Bio. straminea* in the Caribbean and some Brazilian strains are refractory to the local *S. mansoni* (Michelin & Dubois, 1979; cited by Sturrock, 1995) or *Onchomelania sp*. to *S. japonicum* (Chu *et al*., 1982) and the weak susceptibility of *Bio*.

alexandrina to the infection by the local *S. mansoni* strain in Egypt (Shoukry *et al*., 1997). Much more needs to be understood about the processes determining resistance and susceptibility of snails to schistosomes before seriously considering the introduction of these strains for use as biological control agents (Johnston *et al*., 1993).

1. 5. 2. 2.3. Chemical control

Molluscicides spearheaded the attack on snails. There was a progressive shift from the initial objective of eradication to suppression of snail populations. Research revealed a restricted transmission season in the endemic areas. A logical development was to manage snail populations with molluscicides to suppress transmission, rather than to eradicate snails (Sturrock, 1989). Adequate pre-control studies are essential to define the basic transmission patterns in any given area. Based on the findings, rational decisions can be taken in the subsequent strategy to be adopted for snail control.

The only available chemical for snail control is Bayluscide. It is active against the adult snail and the egg masses in very low concentrations. It has an adverse effect on the aquatic fauna and its cost is high. Tchounwou *et al*. (1992) Studied the influence of selected environmental parameters on the toxicity of Bayluscide to *Schistosoma mansoni* miracidia. Their results indicated that temperature, pH, hardness and salinity of the water exerted profound effects on miracidial survival and that the miracidicidal action of Bayluscide was highly influenced by these factors.

1. 6. THE PRESENT STUDY

Fluctuations in snail population densities have been observed in many parts of the world. These fluctuations have been shown to be associated with variations in temperature and rainfall (Coulibaly & Madsen, 1990) as well as other different environmental factors. The intermediate hosts of human schistosomiasis, *Biomphalaria* and *Bulinus* were widely distributed in the canals of the Scheme. The seasonal variation in the population density of the two species in this area has been studied and it seems to be related to temperature and the agricultural cycle in the Scheme (Manjing, 1978; Fenwick *et al*., 1981; Babiker *et al*., 1985 a; Babiker, 1987; Hilali *et al*., 1995). Today, there are very few snails in the canalisation system although the reason for this decline is not yet known (Babiker, personal comm.). This decline has also been observed in an area where no snail control programme has been implemented (Babiker & Hilali, personal comm.) which suggests that other factors besides Mollusciciding may be having an effect on the snail populations.

The role of abu eshreens, that provide water to crops in the fields, in the transmission of schistosomiasis were studied earlier (Ghandour, 1973, Fenwick *et al*., 1981). The density and the distribution of the different species of snails are believed to have changed. Some of the genera of snails, reported by other researchers in very few numbers, disappeared completely *e. g. Afrogyrus*, *Ceratophyllus* and *Lentorbis*, and other species have started to increase and propagate in the canalisation system of the Scheme *e. g. Bul. forskalii* (Babiker, per. com).

Therefore, the present study was carried out with an overall objective to determine the distribution of freshwater snails in abu eshreens, and the different factors that might have affected the snail populations. The specific objectives were to:

1. Determine the distribution of freshwater snails in the abu eshreens
2. Determine the different factors that might have affected the distribution and caused fluctuation in the density of freshwater snails in abu eshreens
3. Determine the role of abu eshreens in the transmission of schistosomiasis
4. Determine the factors that may affect the transport and invasion of snails to abu eshreens

5. Study the distribution of *Bul. forskalii* in one abu eshreen where it was reported in 1969 that the snail existed.

6. Determine if the local strain of *Bul. forskalii* could play a role in the transmission of schistosomiasis.

CHAPTER TWO

MATERIALS AND METHODS

2. 1. THE STUDY AREA

The present study was carried out in the northern part of Gezira Irrigation Scheme (the Scheme) during the period August 1999 to August 2000.

2. 1. 1. GEZIRA IRRIGATION SCHEME

The Scheme lies in a triangle of land south of the junction of the Blue and White Nile Rivers. The area is almost flat land with clay soil. The idea of developing the Scheme by gravity irrigation followed the success of planting cotton on an experimental area of two hundred and fifty feddans (1 feddan = 1.04 acres) near Tayeba Abdel Bagi in 1913. The administration of this area was entrusted to the Sudan Syndicate at El Zeidab because of its former experience in cotton production. In 1913, construction of a dam at Sennar began, but it was not completed until 1925, having been held up by the 1914/1918 war. Initially the irrigated area was about 250,000 feddans but by 1950 some 0.8 million feddans were irrigated.

Following the nationalisation of the Scheme in 1950, the Syndicate was replaced by the "Sudan Gezira Board", which changed the policy governing the social welfare services rendered to the tenants and inhabitants. The Scheme was greatly enlarged and expanded with the development of the North Western Extension in 1951/52 and the Managil Extension to the south west in 1957/61, which brought the total area to 2.2 million feddans.

Fig.1. For administrative purposes the area is divided into fourteen "Agricultural Groups" and subdivided into one hundred and seven "Agricultural Blocks".

Before irrigation by canalisation, the population was approximately 135,000 (El Nagar, 1958). Following irrigation, there was an influx of people and by 1986 more than 2.6 million people were living there. The total population in the Scheme now is estimated to be over 4.5 millions living in about 2000 villages and 500 registered and numerous unregistered camps (Sudan Census, 1993).

2. 1. 1. 1. The Irrigation Network

The Scheme is irrigated with a network of canals:

a. Main canals

Sennar Dam on the Blue Nile holds three thousand million cubic meters of water. There are two main canals from the dam. One supplies Gezira and the other Managil extension. Water flow is at its maximum from mid September to mid November (32 million meters per day each). Flow is up to three kilometres per hour at the time of maximum agricultural activities. The two canals decrease in size and flow as they pass through the irrigated area. Human water contact is frequent, as the large canals are popular for swimming and bathing. Concrete sluice gates control the passage of water into:

b. Major canals

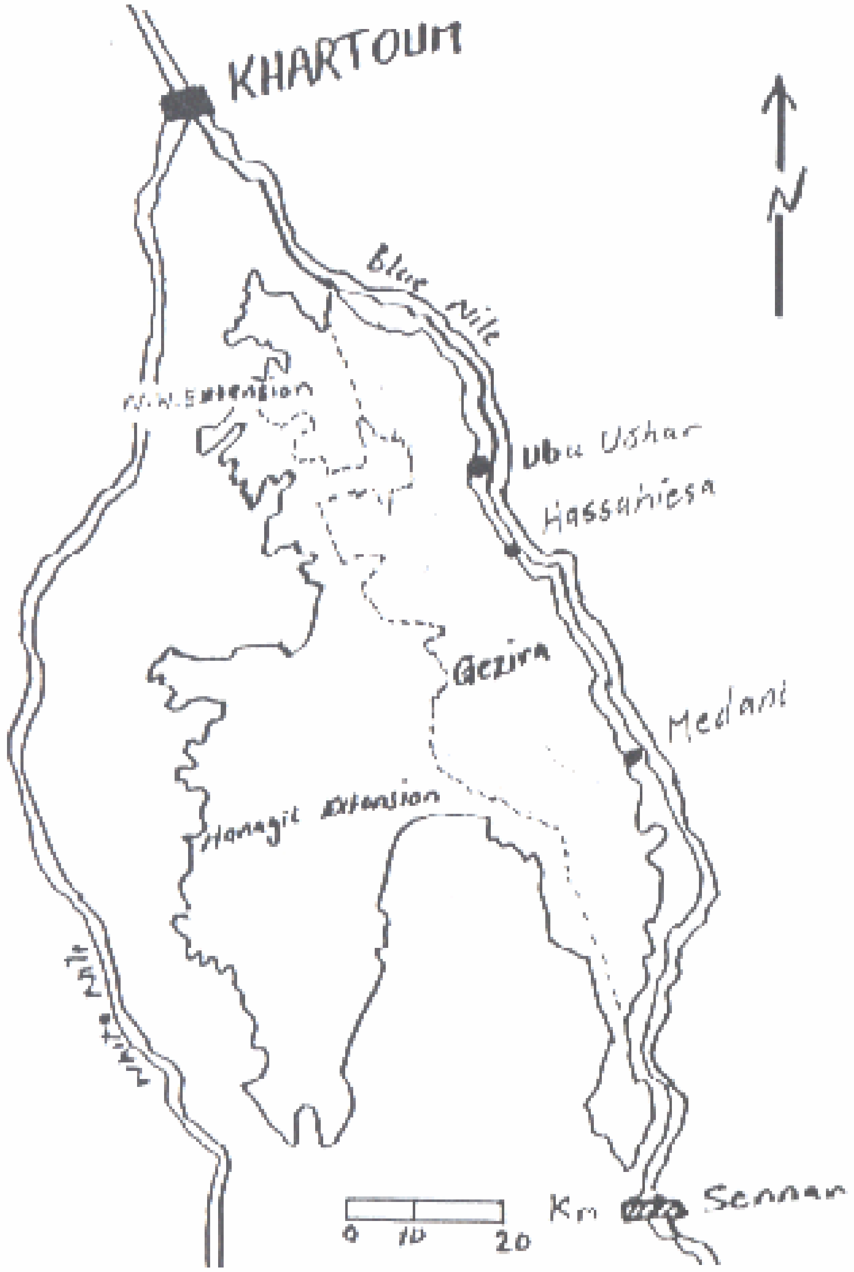
These are smaller but similar to the main canals since they also contain water throughout the year. Flow is greatly reduced outside the peak irrigation period and in early summer (March-May) aquatic vegetation builds up. Snail species found in major canals are *Cleopatra, Melanoides, Biomphalaria* and *Bulinus*. The last two have been found infected in some major canals, especially in sites near to villages where activities for domestic purposes taking place and where the canal banks are used as public latrines

(Babiker, per.Comm). Concrete sluice gates on major canals at 1.5 kilometre intervals lead to:

c. Minor canals

Still smaller canals of uniform 6.0 metres cross section constructed to allow night storage of water. Flow is usually very slow particularly near the tail ends because of the small width of the canal and the dense vegetation particularly in the months of January to April.

Figure 1: The Gezira/Managil Irrigation Scheme



KHARTOUM
N
Blue Nile
N.W. Extension
Ubu Ushar
Hassahiesa
Gezira
Medani
Hanagil Extension
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0 10 20
Km
Sennar

In these months, vegetation builds up along the length of the minor canal. Silting also becomes a problem. The combination results in a reduction of water stored during the night and subsequently the irrigation efficiency is reduced. Minor canals choked with vegetation form a favourable habitat for snails. Agriculturally, the role of the minor canals is to provide a command of water over the fields and the abu eshreens, which are the next canals. These take-off at 300 meter intervals down one or both sides of every minor using under ground pipes that are plugged with mud when not in use.

d. Abu eshreens

Smaller field channels, running at right angle to the parent minor canal. Each abu eshreen is 1.4 km in length and serves one ninety-feddans field. Under the design condition of irrigation, water flows through abu eshreens from 6 a.m. to 6 p.m. for a period of seven to nine days until the whole field has been flooded. The cycle is repeated every fortnight. Night irrigation has become popular of late, leading to abu eshreens remaining open twenty-four hours per day. This results in a decrease in the fluctuation, a drop in overall water level in minor canals and consequently slower flow in abu eshreens. The time required to irrigate the ninety feddans is therefore greatly extended, sometimes leading to a continuous flow in abu eshreens. Under these conditions, abu eshreens usually become clogged with vegetation consisting of submerged and emergent plants as the agricultural season progresses. They play a limited role in the transmission of schistosomiasis, unless they are near a village (Ahmed, 1999). On each abu eshreen, temporary mud dams at regular intervals lead water into nine:

e. Abu sittas

Even smaller channels, 300 meters in length, which cross the fields and carry water for one or two days per irrigation cycle. They are unimportant in the transmission of schistosomiasis because the only human water contact involves the opening and closing of abu sitta. They do not support snails. Each abu sitta serves a ten feddans plot (Hawasha) into which the water is led by breaking the earth into:

f. Gadwals

Smaller ditches which lead the water into the field. They receive water for a few hours each cycle, but may remain wet several days until the fields dry up. No snails are found in them and the human contact with water in the gadwals in negligible.

2. 1. 1. 2. The Agricultural Cycle

The land in the Scheme is used to cultivate five crops viz. Cotton (20%), wheat (20%), fodder (20%), sorghum (10%) and groundnuts (10%), with small areas producing vegetables, citrus fruits and *Eucalyptus*. The remaining 20% of the land is left fallow. There is a standard five-year rotation in each field for the main crops, namely cotton to wheat to sorghum/groundnut to fodder to fallow. However, animal fodder is usually not planted in the Scheme and the area designated for it is used to produce sorghum, groundnuts and vegetables. The agricultural year may be summarised as follows:

The fields designated for cotton are ploughed and irrigated in February and again in June to kill any weeds. Cotton is planted in early August and the fields are irrigated regularly until December when the first crop of cotton is hand picked in January. After subsequent irrigation, two further crops are picked during February, March and April. In May after no further watering, the bushes die, uprooted and burned. Sorghum and groundnuts are planted in July and harvested in October/ November and in December/January respectively. Vegetables (onions, tomatoes, peppers and aubergines) are planted in small plots within the sorghum/groundnut field in June. The crops are harvested in October, November and December. Wheat is planted early November and the crop is mechanically harvested in March/April (Babiker, 1987). The agricultural season ends in May when the cotton bushes are burned. Thereafter, most of the minor canals are closed and left to dry out completely until the next season. However, certain minor canals, designated as summer canals, are having water at a reduced level to provide water over the summer months to villages without water supply. Refilling of the canals, in the Scheme, occurs towards the end of June. The rainy season starts in July and continues until the end of September. This coincides with the flood of the Blue and White Niles.

2. 1. 2. THE CANALS OF THE STUDY

All abu eshreens of three minor canals, in addition to two abu eshreens irrigating gardens in the northern part of the Scheme, were studied.

2. 1. 2. 1. Gad Elain Minor Canal

This canal receives water from Talbab major canal in Doulga Agricultural Block. It is about 5.867 km in length and irrigates about 2012 feddans. Flow in this canal is usually very slow particularly near the tail ends because of the small width of the canal and the dense vegetation particularly in the months of January to April. There was no human settlement near this canals. It provides water to 20 abu eshreens. Each abu eshreen is 1.4 km long, 1.2 m wide and 78 cm deep, with different water speed depending on the crop in the field.

2. 1. 2. 2. Wad Elmagdi minor canal

The canal receives water directly from the main canal at Um Dagarsi Agricultural Block. The length of the canal is 9.951 km and it irrigates 3831 feddans through 36 abu eshreens. There was no human settlement near this canals. Flow of water in the canal is affected by the growth of aquatic weeds and vegetation as the agricultural season progresses. The physical characteristics of abu eshreens are similar to those of Gad Elain.

2. 1. 2. 3. Hassabala Minor Canal

Similar to Wad Elmagdi Minor Canal, water is supplied from the main canal directly in Um Dagarsi Agricultural Block.. It is about 12.299 km in length and irrigates

3273 feddans. Flow of water in this canal is affected the length of the canal particularly in the months of January to April. In these months, vegetation builds up along the length of the minor canal. There was a human settlement near this canals. The canal supplies water to 46 abu eshreens thoughout the year. The physical characteristics of abu eshreens are similar to those of Gad Elain and Wad Elmagdi Minor Canals.

2. 1. 2. 4. Abu eshreen Irrigating the Gardens of Abu Usher Hospital

This abu eshreen was studied 30 years ago by Gandour (1973). It receives water from the main canal directly at Abu Usher area to irrigate the gardens of the houses of Abu Usher hospital. Water is available throughout the year. It is about 169 m in length, 50-80 cm wide and 30-50 cm deep with stagnant water and dense vegetation. The channel runs under trees and hedges of the houses, thus, most of it is shaded (75%-95%).

2. 1. 2. 5. Abu eshreen Irrigating The Gardens of the Houses

This is an abu eshreen that receives water from the main canal in Um Dagarsi Agricultural Block to irrigate gardens of the houses of the Agricultural Inspectors in the block, and then proceed to irrigate fields. It is about 9.870 km long , 50-80 cm wide and 30-50 cm deep with almost stagnant water and dense vegetation at the take-off. The part that irrigates the houses was running under trees and hedges, similar to the abu eshreen irrigating the Hospital's gardens, and most of it was shaded (50%-75%).

2. 2. MATERIALS

2. 2. 1. BREEDING AND MAINTENANCE OF SNAILS

Snails used in the laboratory and field experiments were laboratory-bred snails collected from the study canals. The snails were screened in the laboratory and any snail shedding *S. haematobium* or any other cercariae was discarded. The un-infected snails were kept in groups of 30-40 in plastic bowls containing tap water. Thin sheets of polythene were put on the surface of water to act as an egg-laying substratum. The snails were fed with fresh lettuce or dry gergare. Water in the bowls was changed twice a week.

2. 2. 2. SOURCE AND PRODUCTION OF MIRACIDIA

Urine samples were collected from patients, visiting Abu Usher hospital. The urine was collected from patients with high *S. haematobium* egg counts and living in the Scheme, into urine sample bottles. The collected samples were then transferred to the laboratory. The samples were transferred to centrifuge tubes and centrifuged for 3 minutes at 1000 RPM. The supernatant was discarded and the sediment containing the ova was transferred to urine flaskes, topped with normal saline and stored in a refrigerator for a maximum of 3 days before use as required.

When miracidia were needed to infect snails, the supernatant, in the urine flask, was discarded and replaced by warm water (22º-27º C). The urine flask was then put under light. Twenty minutes later, the egg began to hatch and the miracidia emerged and swam to the surface where they could be seen and collected by a fine Pasteur pipette.

2. 3. METHODS

2. 3. 1. SNAIL SURVEYS

2. 3. 1. 1. The Scoop

Snails tend to be unevenly distributed in habitats due to different physical, biological and chemical factors. Several semi-quantitative techniques have been developed to measure the population density in a habitat (Dazo *et al*., 1966; Williams & Hunter, 1968). In this study, a deep scoop described by Amin (1972) and used by other researchers (Hilali, 1992; Ahmed, 1998) was used. The deep scoop was made of metal square frame 30 cm x 30 cm on which a steel gauze was soldered and coverrd on one side by a lighter gauze of one millimetre mesh. The frame was soldered to a long metal bar to act as a handle.

2. 3. 1. 2. Technique for Snail Collection

The technique for using the scoop was to start at the edge of water in the canal, push away the scoop, scraping the canal bed and the vegetation to a distance of about 1.0 metre towards the middle of the canal, and then firmly lift the scoop upwards vertically. This action, with a slight shake through the water on the vertical lift, collected both vegetation and snails without picking up too much bottom mud which would make finding snails impossible.

2. 3. 1. 3. Collection of Snails

Monthly snail surveys were carried out in all abu eshreens with water at the time of the survey. In each abu eshreen, snails were collected from three sites. These were: (1) the 10 metres at the take-off, (2) 10 metres at the middle and (3) the tail end of the channel. Twenty scoop was taken at each site as described above. The collected vegetation and snails, from each site, were put seperately into a labelled plastic bowl. The collected snails were then transported to the laboratory. They were then washed several times with clean water and sorted into species.

2. 3. 1. 4. Identification of Snails

Collected snail species were identified to the genera level using the field guide for the identification of north-east African fresh water snails prepared by the Danish Bilharziasis Laboratory (1983). *Bulinus* and *Biomphalaria* were identified to the species level using the same field guide. The collected *Biompharaia* and *Bulinus* snails were then counted and measured to the nearest millimetre. They were categorized into three size groups: young (3-6 mm), adult (7-9 mm) and old (10+ mm).

2. 3. 1. 5. Examination of Snails for Natural Schistosome Infection

Collected *Bulinus and Biomphalaria* were washed several times with clean water to remove dirt and mud. They were seperated into species. Each species was then placed in clean water in several half filled 100 ml beakers, under light, and observed continuously. The water in the beakers was examined with a hand lens for schistosome cercariae.

2. 3. 1. 6. Measurements of Physical Factors

During the monthly malacological surveys, temperature and water flow were recorded. Temperature of water was obtained by a thermometre. Water flow was determined as the time required by a floating object to travel a distance of 25 m. Flow was then recorded as m/second. It was categorized into four groups as follows: (stagnant=0, slow < 30, good (31-50) and fast >50). Also the water level and density of vegetation were estimated visiually. Water level was considered high when the canal was full, shallow when it was half full and pools when the water was vey low in the canal. The density of vegetation was estimated as dense when the vegetation covered the whole canal, and as light when the vegetation was patchy in distribution.

2. 3. 1. 7. Management of the Snails' Data

The data from the monthly surveys were used to determine the monthly relative abundance of each species and/or the percentage distribution. The relative abundance of a particular species was calculated as the percentage of the total catch of the individual species out of the total monthly catch of all snail species:

$$\text{Relative abundance of the species} = \frac{\text{Monthly total catch of individual species}}{\text{Monthly total catch of all snail species}} \times 100$$

The percentage distrrbution of a particular genera/species was calculated as the percentage of the total catch of the individual genera/species found in a particular season, or in abu eshreens irrigating a particular crop, or due to a particular ecological factor, from the total yearly catch of that particular genera/species.

To determine the distribution of the snails, in the different seasons, the data on the snail distribution were categorized into 3 groups: rainy season (July-October), hot season (March-June) and cold season (November-February).

2. 3. 2. LABORATORY EXPERIMENTS

2. 3. 2. 1. Determination Snail's Movement in the Field

In order to determine the movement of snails under field condition, a field experiment was conducted in two abu eshreens, one with dense vegetation and the other without vegetation. Preliminary laboratory and field tests suggested that *B. pfeifferi* snails with a shell diametre of at least 7 mm. can survive the process of drying the shell, marking with nail varnish to dry and returning the snails to water (Fenwick & Amin, 1982).

Therefore, Laboratory bred *Bul. forskalii* , *Bio. pfeifferi* and *Bul. truncatus* snails, 7-9 mm. were laid out on a filter paper to dry. Any dirt, mud or algae were carefully removed using a soft cloth and forceps. A daily colour code was then prepared for each species. The snails were marked on one side with a small dab of the nail varnish colour specified for the day. When the varnish was dry, the snails were placed on a plastic bowl to recover before using them in the experiment.

The marked snails were divided into two groups: group (1) placed on a plastic bowl and kept in the laboratory as a control, and group (2) transferred to the pre-selected abu eshreen. They were gentely place at the take off of the selected abu eshreen. The next day extensive scooping was carried out in search for the snails placed the previous day along the whole length of abu eshreen. The distance from the release point at which any recaptured coloured snail was found was recorded. At the end of the search for the coloured snails, a new patch of coloured snails, pre-prepared was placed at the take-off. The experimenrt was repeated on 3 successive days.

2. 3. 2. 2. Infection of *Bulinus forskalii* snails with *S. haematobium* Miracidia

It is known that *Bul. forskalii* is the intermediate host snails for *S. haematobium* and *S. bovis* in certain foci in East and Central Africa. In the Sudan, Ghandour (1969) stated that they could not be infected with *S. haematobium* miracidia. The present experiment was carried out to determine if the present populations of *Bul. forskalii* still do not take the infection.

Four groups of laboratory bred *Bul. forskalii* snails were prepared. Each group consisted of 20 snails. Each snail was placed individually into a 2.5 cm x 7.5 cm glass tube. Each snail of the 1st, 2nd, 3rd and 4th groups was exposed individually to 0, 1, 2, and 4 *S. haematobium* miracidia respectively. The required number of the miracidia was collected from the stored urine as described above. The glass tubes containing the snails with the miracidia were kept over night to allow penetration of the miracidia. The next day, the snails of each group were pooled and transferred to a separately labelled bowl containing canal water. The four groups of the exposed snails were kept in the laboratory and maintained at room temperature. On days 20 post exposure, all surviving *Bul. forskalii* snails were screened for patent cercariae. Thereafter, they were examined daily for cercariae.

2. 4. STATISTICAL ANALYSIS

The data collected during this study were analysed using the (Statistical Package for Social Science) SPSS (Nei *et al*., 1975) and a microcomputer PC. Snails do not follow normal distribution in nature, therefore non-parametric tests were applied (Siegle, 1965) for the analysis of the data. The means of the snails collected were categorized by month, crop in the parent field, site of collection, season, water velocity, water level, vegetation density and shade and compared statistically using Kruskal-Wallis one-way ANOVA. The snail data in the abu eshreens of the three minor canals, in relation to the different variables, were analyzed by Friedmann two-way ANOVA to determine whether there were any significant differences between the three canals.

CHAPTER THREE

RESULTS

3. 1. THE MOLLUSCAN FAUNA

The following snails were collected from the abu eshreens under study during the period August 1999-August 2000:

Biomphalaria pfeifferi: the intermediate host snail of *Schistosoma mansoni*

Bulinus truncatus: the intermediate host snail of *S. haematobium*

Bulinus forskalii: of no known medical importance in the Sudan

Cleopatra species: of no known medical importance

Melanoides species: of no known medical importance

3. 2. DISTRIBUTION SNAILS

3. 2. 1. MONTHLY DISTRIBUTION OF SNAILS

In this section (3. 2. 1.), the data on the distribution of the snails are presented in Tables to show the monthly relative abundance of snails, whereas the total of the columns in the Tables shows the percentage distribution of a particular species during the study period. Table 1 shows the total number of snails collected during the study period.

3. 2. 1. 1. All Abu eshreens

The total number of the monthly distribution of snails in the abu eshreens is summarized in Table 1 and Figure 2.

The populations of *Bio.pfeifferi* and *Bul. truncatus* snails were affected by the rainy season (July/September). The number of snails found during that period was very small. Both *Bul. truncatus* and *Bio. pfeifferi* started to increase in the following months. *Bio. pfeifferi* reached a peak in mid March 2000, after that there was a sharp decline in the

Table 1: Monthly Distribution of Snails, all abu eshreens, August 1999-August 2000

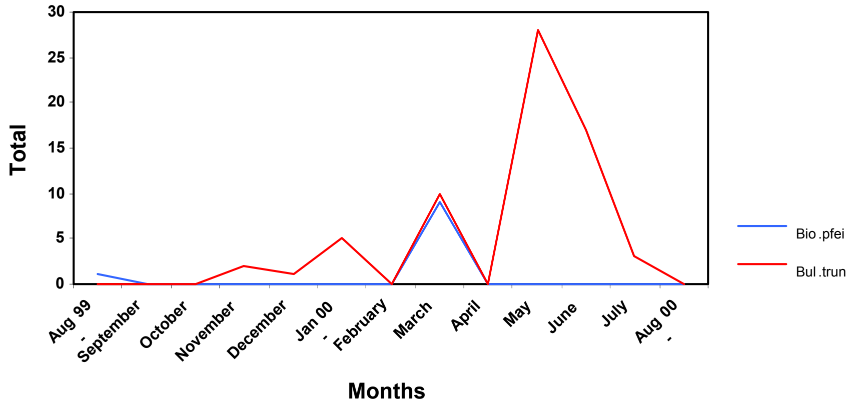
Month	No. of Abu 20	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.spp*	*Mel.*
Aug 1999	47	1	0	28	0	0
Sep	47	0	0	19	0	3
Oct	47	0	0	77	0	0
Nov	47	0	2	20	0	2
Dec	47	0	1	136	7	2
Jan 2000	47	0	5	90	4	3
Feb	32	0	0	29	0	0
Mar	17	9	10	8	0	0
Apr	0	* *	* *	* *	* *	*
May	17	0	28	17	134	0
Jun	47	0	17	11	0	0
Jul	47	0	3	1	0	0
Aug 2000	47	0	0	0	0	0
Total	489	10	66	436	145	1[illegible]
significance		$P > 0.05$	$P > 0.05$	$P < 0.05$	$P < 0.05$	$P >$ [illegible]
	$P > 0.05$					

* * Canals were dry

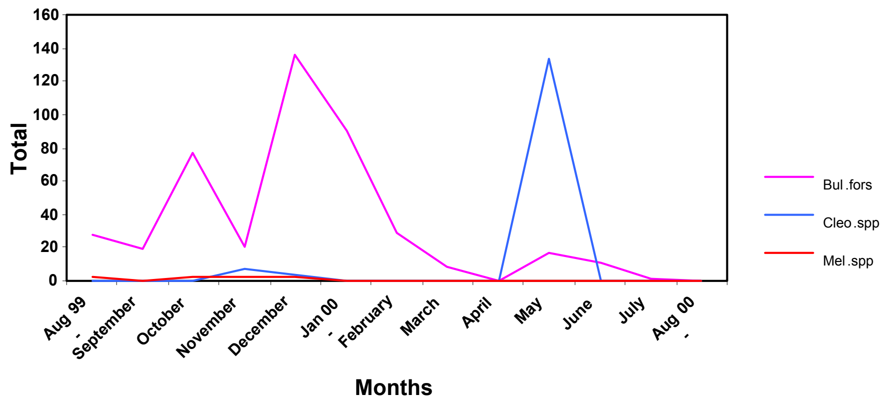
Fig. 2: Monthly Distribution of the Snails, all

abu eshreens, August 1999-August 2000.

One. Schistosome Intermediate Host Snails



Two. Other snails



density of this species. *Bul. truncatus* reached a peak in May 2000 and declined in the following months. The monthly density of *Bio. pfeifferi* during the whole observation

period was very low in comparison with that of *Bul. truncatus*. There were no significant differences ($P > 0.05$) in their monthly distribution through the year.

In most monthly surveys, *Bul. forskalii* snails dominated all snail species in the abu eshreens. There was a significant difference ($P < 0.05$) in its monthly distribution through the year. The populations of the species, in the different abu eshreens, were affected by the rainy season. They started to increase in the following months and reached a peak in December, before they declined again.

Cleopatra snails were found in the surveys during December 1999, January 2000 (4 & 7 snails respectively) and in May 2000 (134 snails). There was a significant difference ($P < 0.05$) in its monthly distribution through the year. *Cleopatra* snails were also affected by the rainy season. Only 10 *Melanoides* snails were found during the whole period of observation. There was no significant difference ($P > 0.05$) in its monthly distribution through the year.

The statistical analysis between the minor canals (Friedmann two-way ANOVA) did not indicate a significant difference ($P > 0.05$) between the abu eshreens of the three minor canals under investigation.

3. 2. 1. 2. Abu eshreens of the Minor Canals

Tables 2-4 shows the monthly relative abundance of snails collected from abu eshreens of Gad El Ain, Wad El Magdi, and Hassaballa Minor Canals respectively. Tables 5 and 6 show the monthly relative abundance of snails in the two abu eshreens irrigating the hospital’s and the inspectors’ houses respectively.

Table 2: Monthly Relative Abundance of Snails, abu eshreens Of Gad El Ain Minor Canal, August 1999-August 2000

Month	No. of Abu 20	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.sp*
Aug 1999	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Sep	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Oct	15	0.00 (0)	0.00 (0)	93.75 (30)	0.00 (0)
Nov	15	0.00 (0)	0.00 (0)	77.77 (14)	22.22 (4)
Dec	15	0.00 (0)	0.00 (0)	85.71 (30)	8.57 (3)
Jan 2000	15	0.00 (0)	0.00 (0)	100.00 (2)	0.00 (0)
Feb	10	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Mar	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Apr	0	* *	* *	* *	* *
May	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jun	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jul	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Aug 2000	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Total	155	0.00 (0)	0.00 (0)	84.44 (76)	7.77 (7)
significant		P >o.o5	P >0.05	P <0.05	P >0.05

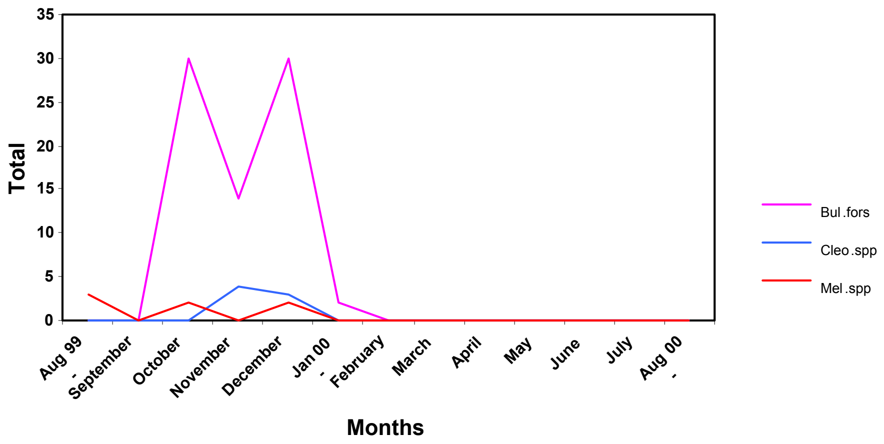
(): Total number of snails
* *: Canals were dry

Table 3: Monthly Relative Abundance of Snails, abu eshreens Of Wad El Magdi Minor Canal, August 1999- August 2000

Month	No. of Abu 20	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.sp*
Aug 1999	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Sep	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Oct	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Nov	15	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (1)
Dec	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jan 2000	15	0.00 (0)	0.00 (0)	100.00 (12)	0.00 (0)
Feb	10	0.00 (0)	0.00 (0)	100.00 (25)	0.00 (0)
Mar	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Apr	0	* *	* *	* *	* *
May	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jun	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jul	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Aug 2000	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Total	155	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)
significant		P >o.o5	P >0.05	P <0.05	P >0.05

(): Total number of snails
* *: Canals were dry

Fig. 3: Monthly Distribution of the Snails, abu eshreens Of Gad El Ain Minor Canal, August 1999-August 2000.



No *Bio. pfeifferi* and/or *Bul. truncatus* snails were found in the abu eshreens of Gad El Ain Minor Canal (Table 2 & Figure 3) during the observation period. *Bul. forskalii* appeared and dominated all snail species immediately after the rainy season (October 1999 to January 2000) before the disappeared. This species constituted 84% of the snails found in the abu eshreens. There was a significant difference ($P < 0.05$) in its monthly distribution throughout the year. The monthly relative abundance of *Cleopatra* and *Melanoides* snails was 16% during and after the rainy season ($P > 0.05$).

The distribution of the snails in the abu eshreens of Wad El Magdi Minor Canal (Table 3 & Figure 4) was very similar to that in Gad El Ain Minor Canal. No *Bio. pfeifferi* and/or *Bul.truncatus* snails were found in the abu eshreens.

Table 4: Monthly Relative Abundance of Snails, abu eshreens Of Hassaballa Minor Canal, August 1999-August 2000

Month	No. of Abu 20	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.sp*
Aug 1999	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Sep	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Oct	15	0.00 (0)	0.00 (0)	100.00 (2)	0.00 (0)
Nov	15	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (2)
Dec	15	0.00 (0)	0.00 (0)	100.00 (79)	0.00 (0)
Jan 2000	15	0.00 (0)	25.00 (3)	75.00 (9)	0.00 (0)
Feb	10	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Mar	5	0.00 (0)	50.00 (3)	50.00 (3)	0.00 (0)
Apr	0	* *	* *	* *	* *
May	5	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jun	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Jul	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Aug 2000	15	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)
Total	155	0.00 (0)	5.94 (6)	92.07 (93)	1.98 (2)
significant		P >o.o5	P >0.05	P <0.05	P >0.05

(): Total number of snails
* *: Canals were dry

Table 5: Monthly Relative Abundance of Snails, Abu eshreen Irrigating the Gardens of Abu Usher Hospital, August 1999 August 2000

Month	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.spp*	*M*
Aug 1999	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Sep	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Oct	0.00 (0)	0.00 (0)	100.00 (45)	0.00 (0)	0.00
Nov	0.00 (0)	20.00 (2)	60.00 (6)	0.00 (0)	20.00
Dec	0.00 (0)	0.00 (0)	83.33 (5)	16.66 (1)	0.00
Jan 2000	0.00 (0)	3.07 (2)	96.92 (63)	0.00 (0)	0.00
Feb	0.00 (0)	0.00 (0)	100.00 (4)	0.00 (0)	0.00
Mar	42.85 (9)	33.33 (7)	23.80 (5)	0.00 (0)	0.00
Apr	* *	* *	* *	* *	* *
May	0.00 (0)	15.64 (28)	9.49 (17)	74.86 (134)	0.00
Jun	0.00 (0)	60.71 (17)	39.28 (11)	0.00 (0)	0.00
Jul	0.00 (0)	75.00 (3)	25.00 (1)	0.00 (0)	0.00
Aug 2000	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Total	2.40 (9)	16.29 (59)	43.37 (157)	37.29 (135)	0.55
significant	P >o.o5	P <0.05	P <0.05	P <0.05	P

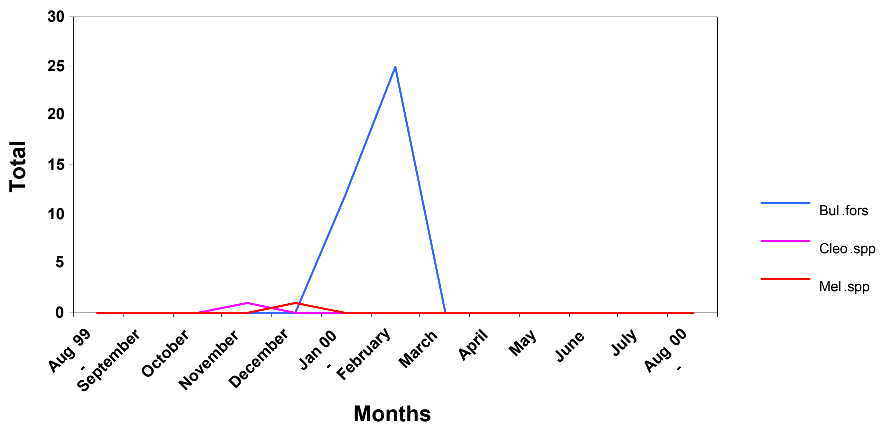
(): Total number of snails
* *: Canals were dry

Bul. forskalii appeared and dominated all snail species during January 2000 and February 2000 before they disappeared. This species constituted 95%

of the snails found in the abu eshreens. There was a significant difference ($P <$ 0.05) in its monthly distribution.

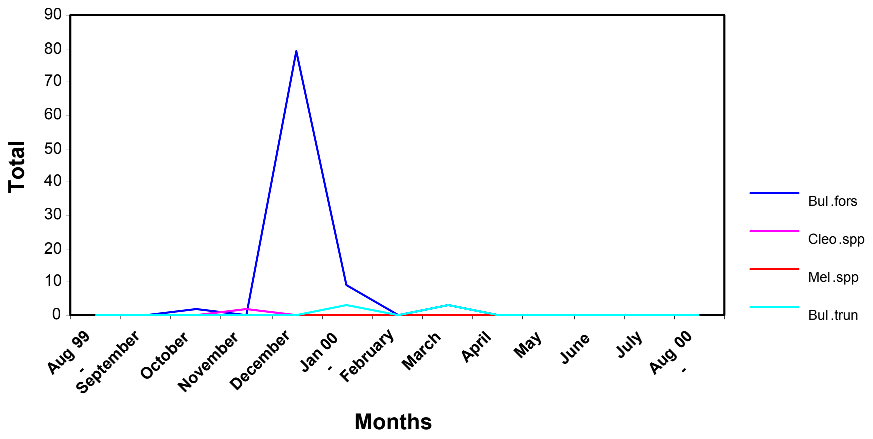
Cleopatra and *Melanoides* snails were found during November and December 1999 in a low relative abundance 6% , $P > 0.05$.

Fig. 4: Monthly Distribution of the Snails, abu eshreens Of Wad El Magdi Minor Canal, August 1999-August 2000.



Unlike the situation in the abu eshreens of Gad El Ain and Wad El Magdi Minor Canals, *Bul. truncatus* was found in the abu eshreens of Hassaballa Minor Canal (Table 4 & Figure 5), but no *Bio. Pfeifferi* or *Melanoides* snails were found during the study period. *Bul. truncatus* snails were found only in January and March 2000. Its monthly distribution was not significant ($P > 0.05$).

Fig. 5: Monthly Distribution of the Snails, abu eshreens Of Hassaballa Minor Canal, August 1999-August 2000



Bul. forskalii represented a high percentage of the snails collected (92%) and was found from October 1999 to March 2000. There was a significant difference ($P < 0.05$) in its monthly distribution.

Cleopatra snails, found during November 1999, were only 2% of the monthly catch. There was no significant difference ($P > 0.05$) in its monthly distribution through the year.

In the abu eshreen irrigating the gardens of the hospital in Abu Usher (Table 5 & Figure 6), *Bio. pfeifferi* snails were found only in March 2000.

Bul. truncatus snails were first found after the rainy season (July-September). During the following months, they were found intermittently. They reached a peak in May, though their monthly relative abundance was only 16%. There was a significant difference ($P < 0.05$) in its monthly distribution.

On the other hand, *Bul. forskalii* was found throughout the year except during the rainy season (July- September). There was a significant difference (*P*

< 0.05) in its monthly distribution. During May 2000, 75% of the total monthly catch were *Cleopatra* snails.

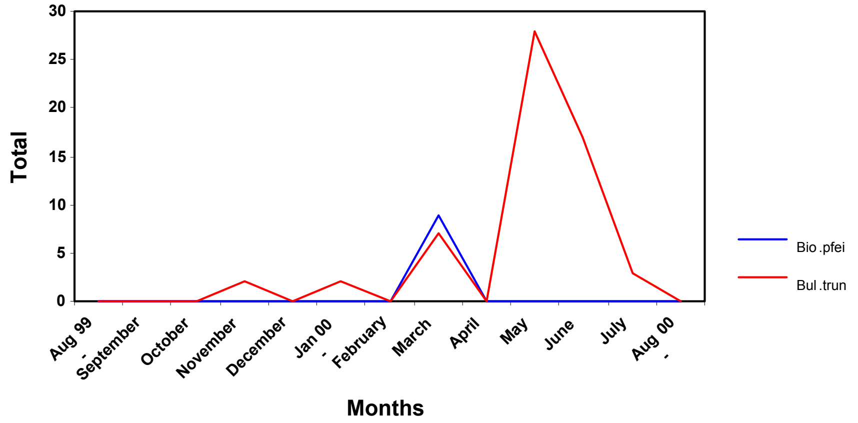
Table 6: Monthly Relative Abundance of Snails, Abu eshreen Irrigating the Inspectors' House, August 1999- August 2000

Month	*Bio.pfei*	*Bul.trun*	*Bul.fors*	*Cleo.spp*	*M*
Aug 1999	3.44 (1)	0.00 (0)	96.55 (28)	0.00 (0)	0.00
Sep	0.00 (0)	0.00 (0)	100.00 (19)	0.00 (0)	0.00
Oct	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Nov	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Dec	0.00 (0)	4.34 (1)	95.65 (22)	0.00 (0)	0.00
Jan 2000	0.00 (0)	0.00 (0)	100.00 (4)	0.00 (0)	0.00
Feb	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Mar	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Apr	* *	* *	* *	* *	* *
May	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Jun	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Jul	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Aug 2000	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00
significant	P >o.o5	P >0.05	P <0.05	P >0.05	P

(): Total number of snails
* *: Canals were dry

Fig. 6: Monthly Distribution of the Snails, abu eshreen
Irrigating the Gardens of Abu Usher Hospital, August 1999-August 2000

One. Schistosome Intermediate Host Snails



Two. Other Snails

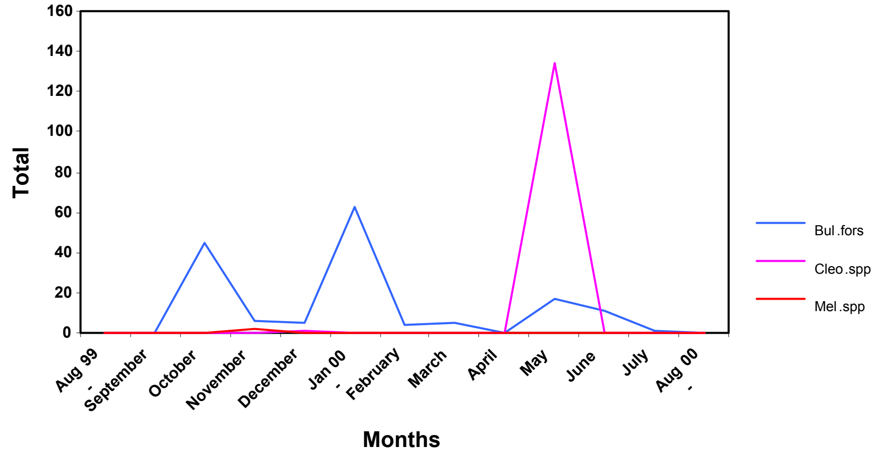


Table 7: Percentage Distribution of snails by crop

Crop	No. of Abu 20	*Bio.pfeif*	*Bul.trun*	*Bul.fors*	*Cleopa. pp*	*M*
Cotton	165	0.00 (0)	9.09 (6)	29.36 (128)	4.83 (7)	20
Wheat	135	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Ground/Sor	165	0.00 (0)	0.00 (0)	17.88 (78)	2.07 (3)	60
Vegetables	24	100.00 (10)	90.90 (60)	52.75 (230)	93.10 (135)	20
Total	489	1.50 (10)	9.90 (66)	65.36 (436)	21.74 (145)	1

(): Total number of snails

Melanoides snails were found in this abu eshreen only during November 1999, and they constituted only 0.55% of total catch of the snails.

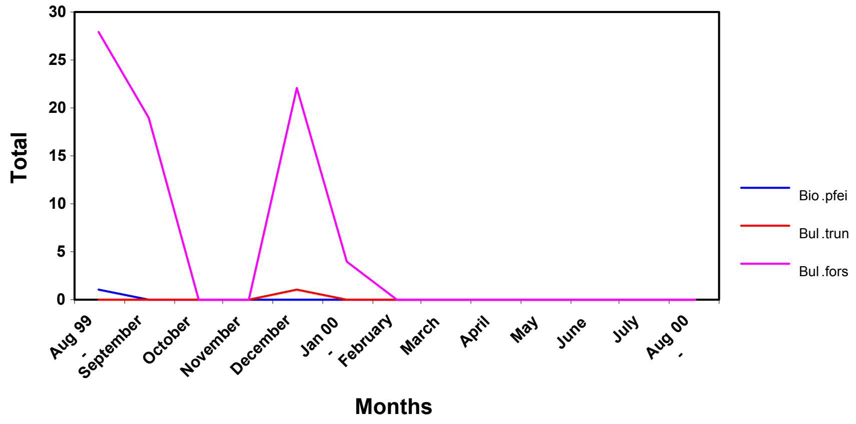
In the abu eshreen irrigating the inspectors' houses, 1% of the total catch were *Bio. pfeifferi* snails and another 1% were *Bul. truncatus* snails.

Bul. forskalii snails were found intermittently during the year of study. There was a significant difference ($P < 0.05$) in its monthly distribution.

The prosobranch snails, *Cleopatra* and *Melanoides*, were not found in this abu eshreen, (Table 6 & Figure 7).

The statistical analysis between the different crops and the snail data from the abu eshreens of the three minor canals (Friedmann two-way ANOVA) did not indicate a significant difference ($P > 0.05$) between the abu eshreens of the three minor canals.

Fig. 7: Monthly Distribution of the Snails, abu eshreen Irrigating the Inspectors' Houses, August 1999-August 2000



3. 2. 2. PERCENTAGE DISTRIBUTION OF SNAILS BY CROP

The data presented in the Tables on the distribution of the snails in this section and the following sections show the percentage of the total catch of the individual snail species found in abu eshreens from the total yearly catch of that particular species. The Figures show the number of snails found in abu eshreens.

In all abu eshreens investigated, (Table 7 & Figure 8), *Bio. pfeifferi* snails were not found in abu eshreens irrigating cotton, wheat, and groundnut/sorghum. They were found in abu eshreens irrigating vegetables and gardens (100%).

Bul. truncatus tended to accumulate in abu eshreens irrigating vegetables (91%) and few were found in the channels irrigating cotton (9%). They were not found in channels irrigating wheat and groundnuts.

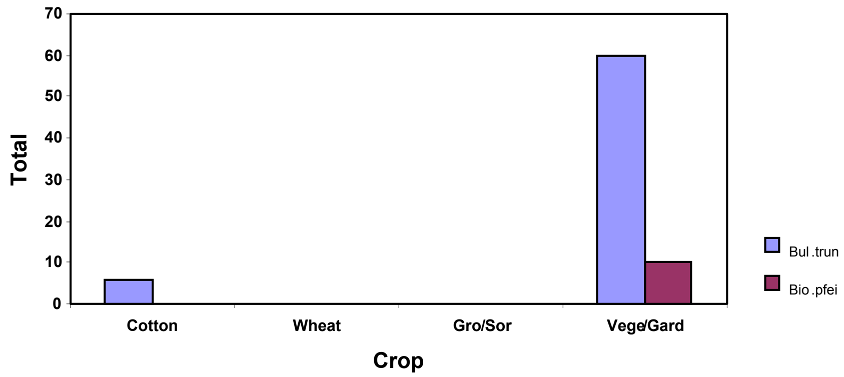
Bul. forskalii snails were more abundant in abu eshreens irrigating vegetables (53%) and less in cotton (29%) groundnuts/sorghum (18%) and they were not found in abu eshreens irrigating wheat.

Cleopatra snails were more abundant in abu eshreens irrigating vegetables (93%) followed by those irrigating cotton (5%) and groundnuts (2%) and they were not found in abu eshreens irrigating wheat.

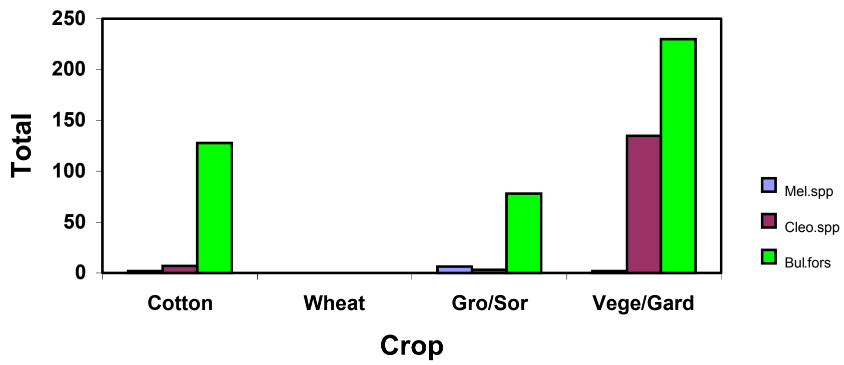
Melanoides snails were more abundant in abu eshreens irrigating groundnuts/ sorghum (60%) followed by those irrigating cotton and vegetables (20%) and they were not found in abu eshreens irrigating wheat. There were significant differences ($P < 0.05$) in the monthly distribution of all snails' species except *Melanoides.*

Fig. 8: Distribution of Snails by Crop , all abu eshreens,
August 1999-August 2000

One. Schistosome Intermediate Host Snails



b.Other Snails



3. 2. 2. 1. Percentage distribution of snails abu eshreens of Gad El Ain Minor

Canal, by crop

The percentage distribution of the snails in the abu eshreens taking water from Gad El Ain Minor Canal is shown in Table 8 and Figure 9.

The total number of snails collected from abu eshreens taking-off from this canal during the whole period of study was 90 snails. This did not include any *Bio. pfeifferi* or *Bul. truncatus* snails. The total percentage of the prosobranch snails of the two genera,

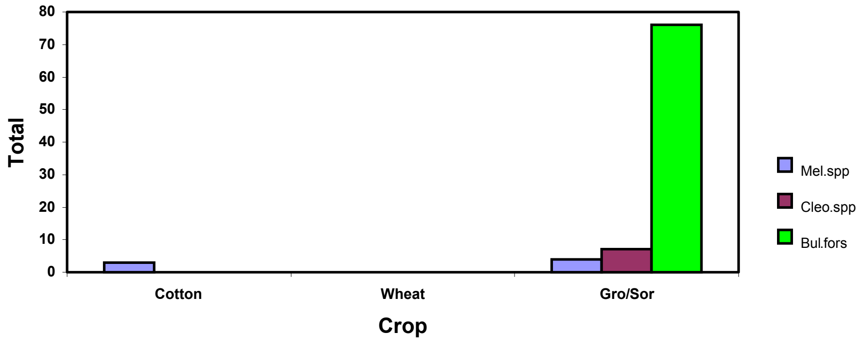
Cleopatra and *Melanoides*, was 16%. These were found in abu eshreens irrigating cotton and groundnuts/sorghum fields. The remaining 84% were *Bul. forskalii* found in abu eshreens irrigating Groundnuts/Sorghum.

Table 8: Percentage Distribution of Snails by crop, abu eshreens Of Gad El Ain Minor Canal, August 1999-August 2000

Crop	No. of Abu 20	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mela. spp*	Total
Cotton	55	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	33.33 (3)	3
Wheat	45	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Gr/Sor	55	0.00 (0)	0.00 (0)	100.00 (76)	100.00 (7)	66.67 (4)	87
Total	155	0.00 (0)	0.00 (0)	84.40 (76)	7.80 (7)	7.80 (7)	90

(): Total number of snails

Fig. 9: Distribution of Snails by Crop, abu eshreens of Gad El Ain Minor Canal August 1999-August 2000



3. 2. 2. 2. Percentage distribution of snails abu eshreens of Wad El Magdi Minor

Canal, by crop

The percentage distribution of the snails in the abu eshreens taking water from Wad El Magdi Minor Canal is shown in Table 9 and Figure 10.

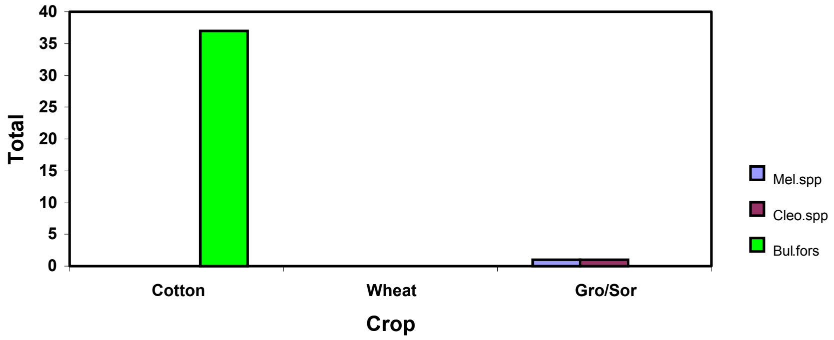
Table 9: Percentage Distribution of Snails by crop, abu eshreens Of Wad El Magdi Minor Canal, August 1999-August 2000

Crop	No. of Abu 20	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. Spp*	Total
Cotton	55	0.00 (0)	0.00 (0)	100.00 (37)	0.00 (0)	0.00 (0)	37
Wheat	45	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Gr/Sor	55	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (1)	100.00 (1)	2
Total	155	0.00 (0)	0.00 (0)	94.88 (37)	2.56 (1)	2.56 (1)	39

(): Total number of snails

The intermediate hosts of schistosomiasis, *Bio. pfeifferi* and *Bul. truncatus* snails were not found in any abu eshreen providing water to any crop in Wad El Magdi Minor Canal. Almost 95% of the total catch of the snails were *Bul. forskalii* and all of them were

Fig.10. Distribution of Snails by Crop, abu eshreens of Wad El Magdi Minor Canal August 1999-August 2000



found in abu eshreens providing water to cotton. *Cleopatra* and *Melanoides* snails constituted only 5% of the total catch of the snails were found in abu eshreens irrigating Groundnuts/ Sorghum.

3. 2. 2. 3. Distribution of snails in abu eshreens of Hassaballa Minor Canal, by crop

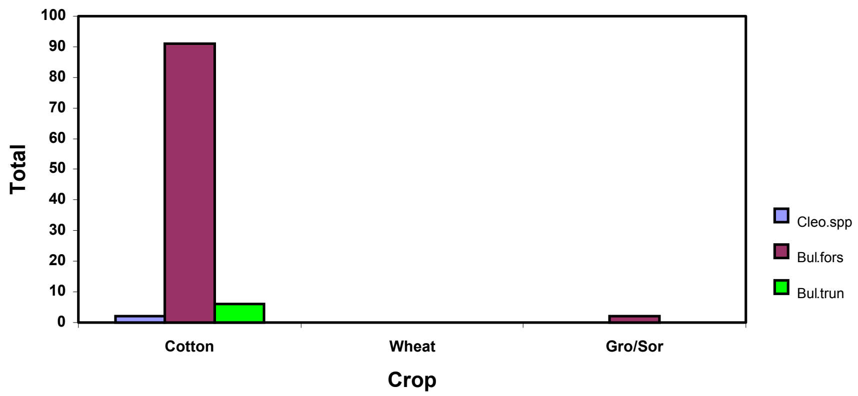
The percentage distribution of the snails along abu eshreens taking water from Hassaballa Minor Canal is shown in Table 10 and Figure 11.

Table 10: Percentage Distribution of Snails by crop, abu eshreens Of Hassaballa Minor Canal, August 1999-August 2000

Crop	No. of Abu 20	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. Spp*	Total
Cotton	55	0.00 (0)	100.00 (6)	97.85 (91)	100.00 (2)	0.00 (0)	99
Wheat	45	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Gr/Sor	55	0.00 (0)	0.00 (0)	2.15 (2)	0.00 (0)	0.00 (0)	2
Total	155	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101

(): Total number of snails

Fig.11: Distribution of Snails by Crop, abu eshreens of Hassaballa Minor Canal August 1999-August 2000



Similar to the situation in abu eshreens of the other two minor canals, *Bio. pfeifferi* and *Melanoides* snails were not found in any abu eshreen. Few *Bul. truncatus* and *Cleopatra* snails were found in abu eshreens of this canal and they were found only in abu eshreens irrigating cotton. 97.85% of the *Bul. forskalii* snails were found in abu eshreens irrigating cotton.

3. 2. 3. PERCENTAGE DISTRIBUTION OF SNAILS BY ECOLOGICAL FACTORS

The percentage distribution of the different species of snails in the abu eshreens of the study canals according to the different ecological factors is shown in Table 11-16.

In all abu eshreens (Table 11), *Bio. pfeifferi*, *Bul. truncatus*, *Bul. forskalii*, *Cleopatra* and *Melanoides* snails were found in large numbers in water bodies with stagnant water flow and shallow water level. *Bio. pfeifferi*, *Bul. truncatus*, and *Cleopatra* snails were found in large numbers in areas with dense vegetation and shade. *Bul. forskalii* snails were found in large numbers in areas with dense vegetation and absent shade while *Melanoides* snails were found in large numbers in areas with light vegetation and absent shade. The majority of the different snail species were found in the shallow water. There was a significant difference ($P < 0.05$) in the distribution of all snails by water level and vegetation, except *Melanoides* and *Bio. pfeifferi* ($P > 0.05$).

3. 2. 3. 1. Percentage distribution of Snails by Ecological Factors, Gad El Ain Minor

Canal

Bio. pfeifferi and *Bul. truncatus* snails were not found in the abu eshreens throughout the observation period, Table 12. *Bul. forskalii, Cleopatra* and *Melanoides* snails were found in large numbers in abu eshreens with zero water flow and shallow water levels. *Bul. forskalii* snails found in large numbers in areas with dense vegetation, while *Cleopatra and Melanoides* were found in large numbers in areas with light vegetation. *Bul. forskalii, Cleopatra* and *Melanoides* snails were found in large numbers in areas with absent shade.

Table 11: Percentage Distribution of Snails by Ecological Factors, all abu eshreens, August 1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. Spp*	*Mel.Spp*	Total
Stagnant	100.00 (10)	100.00 (66)	91.74 (400)	95.86 (139)	90.00 (9)	624
Slow	0.00 (0)	0.00 (0)	8.26 (36)	0.69 (1)	0.00 (0)	37
Good	0.00 (0)	0.00 (0)	0.00 (0)	2.76 (4)	0.00 (0)	4
Fast	0.00 (0)	0.00 (0)	0.00 (0)	0.69 (1)	10.00 (1)	2
Total	0.15 (10)	9.90 (66)	65.37 (436)	21.74 (145)	0.15 (10)	667
Water Level						

Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	100.00 (10)	100.00 (66)	96.33 (420)	95.86 (139)	70.00 (7)	642
High	0.00 (0)	0.00 (0)	3.67 (16)	4.14 (6)	30.00 (3)	25
Total	0.15 (10)	9.90 (66)	65.37 (436)	21.74 (145)	0.15 (10)	667
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	39.39 (26)	42.66 (186)	45.52 (66)	80.00 (8)	286
Dense	100.00 (10)	60.61 (40)	57.34 (250)	54.48 (79)	20.00 (2)	381
Total	0.15 (10)	9.90 (66)	65.37 (436)	21.74 (145)	0.15 (10)	667
Shade						
Absent	0.00 (0)	9.09 (6)	47.25 (206)	6.90 (10)	80.00 (8)	230
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	30.30 (20)	11.24 (49)	40.69 (59)	0.00 (0)	128
Dense	100.00 (10)	60.61 (40)	41.51 (181)	52.41 (76)	20.00 (2)	309
Total	1.50 (10)	9.90 (66)	65.36 (436)	21.74 (145)	1.50 (10)	667

(): Total number of snails

Table 12: Percentage Distribution of Snails by Ecological Factors, Abu eshreens of Gad El Ain Minor Canal, August 1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Stagnant	0.00 (0)	0.00 (0)	78.95 (60)	57.14 (4)	85.71 (6)	70
Slow	0.00 (0)	0.00 (0)	21.05 (16)	14.29 (1)	0.00 (0)	17
Good	0.00 (0)	0.00 (0)	0.00 (0)	28.57 (2)	0.00 (0)	2
Fast	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	14.29 (1)	1
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90
Water Level						
Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	0.00 (0)	0.00 (0)	81.58 (62)	57.14 (4)	57.14 (4)	70
High	0.00 (0)	0.00 (0)	18.42 (14)	42.86 (3)	42.86 (3)	20
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	0.00 (0)	21.05 (16)	57.14 (4)	100.00 (7)	27
Dense	0.00 (0)	0.00 (0)	78.95 (60)	42.86 (3)	0.00 (0)	63
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90
Shade						
Absent	0.00 (0)	0.00 (0)	100.00 (76)	100.00 (7)	100.00 (7)	90
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Dense	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90

(): Total number of snails

3. 2. 3. 2. Percentage distribution of Snails by Ecological Factors, Wad El Magdi Minor Canal

Bio. pfeifferi and *Bul. truncatus* snails were not found in the abu eshreens of Wad El-Magdi Minor Canal throughout the observation period, Table 13. *Bul. forskalii* and *Melanoides* snails were found in abu eshreens without water flow, while *Cleopatra* snails were found in fast water flow. *Bul. forskalii* and *Melanoides* snails were found in shallow water level, while *Cleopatra* snails were found in high water level. *Bul. forskalii, Cleopatra* and *Melanoides* snails were found in areas with light vegetation. *Bul. forskalii, Cleopatra* and *Melanoides* snails were found in large numbers in areas without shade.

3. 2. 3. 3. Percentage distribution of Snails by Ecological Factors, Hassaballa Minor Canal

Bio. pfeifferi and *Melanoides* snails were not found in the abu eshreens of Hassaballa Minor Canal, Table 14, throughout the observation period. *Bul. truncatus* and *Bul. forskalii* snails were found in large numbers in abu eshreens without water flow, while *Cleopatra* snails were found in water bodies with good water flow. *Bul. truncatus* and *Bul. forskalii* snails were found in large numbers in water bodies with shallow water level, while *Cleopatra* snails were found in water bodies with high water level. *Bul. truncatus*, *Bul. forskalii* and *Cleopatra* snails were found in large numbers in areas with Light vegetation. *Bul. truncatus*, *Bul. forskalii* and *Cleopatra* snails were found in areas without shade.

3. 2. 3. 4. Distribution of Snails by Ecological Factors, Abu eshreen Irrigating the Gardens of Abu Usher Hospital

Biomphalaria pfeifferi, Bulinus truncatus, Bulinus forskalii, Cleopatra and *Melanoides* snails were found in the abu eshreen irrigating the gardens of Abu Usher's hospital (Table 15). These species of snails were found in large numbers whenever water was stagnant and shallow and the vegetation was dense with shade.

Table 13: Percentage Distribution of Snails by Ecological Factors, Abu eshreen of Wad El Magdi Minor Canal, August 1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Stagnant	0.00 (0)	0.00 (0)	100.00 (37)	0.00 (0)	100.00 (1)	38
Slow	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Good	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Fast	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (1)	0.00 (0)	1
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39
Water Level						
Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	0.00 (0)	0.00 (0)	100.00 (37)	0.00 (0)	100.00 (1)	38
High	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (1)	0.00 (0)	1
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	0.00 (0)	100.00 (37)	100.00 (1)	100.00 (1)	39
Dense	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39
Shade						

Absent	0.00 (0)	0.00 (0)	100.00 (37)	100.00 (1)	100.00 (1)	39
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Dense	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39

(): Total number of snails

Table 14: Percentage Distribution of Snails by Ecological Factors, Abu eshreens of Hassaballa Minor Canal, August 1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Stagnant	0.00 (0)	100.00 (6)	78.49 (73)	0.00 (0)	0.00 (0)	79
Slow	0.00 (0)	0.00 (0)	21.50 (20)	0.00 (0)	0.00 (0)	20
Good	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (2)	0.00 (0)	2
Fast	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101
Water Level						
Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	0.00 (0)	100.00 (6)	97.85 (91)	0.00 (0)	0.00 (0)	97
High	0.00 (0)	0.00 (0)	2.15 (2)	100.00 (2)	0.00 (0)	4
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	100.00 (6)	91.40 (85)	100.00 (2)	0.00 (0)	93
Dense	0.00 (0)	0.00 (0)	8.60 (8)	0.00 (0)	0.00 (0)	8
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101
Shade						
Absent	0.00 (0)	100.00 (6)	100.00 (93)	100.00 (2)	0.00 (0)	101
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0

Dense	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101

(): Total number of snails

Table 15: Percentage Distribution of Snails by Ecological Factors, Abu eshreen Irrigating the Gardens of Abu Usher Hospital, August1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Stagnant	100.00 (9)	100.00 (59)	100.00 (157)	100.00 (135)	100.00 (2)	362
Slow	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Good	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Fast	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362
Water Level						
Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	100.00 (9)	100.00 (59)	100.00 (157)	100.00 (135)	100.00 (2)	362
High	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	33.90 (20)	29.30 (46)	43.70 (59)	0.00 (0)	125
Dense	100.00 (9)	66.10 (39)	70.70 (111)	56.30 (76)	100.00 (2)	237
Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362
Shade						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	33.90 (20)	31.21 (49)	43.70 (59)	0.00 (0)	128
Dense	100.00 (9)	66.10 (39)	68.79 (108)	56.30 (76)	100.00 (2)	234

Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362

(): Total number of snails

3. 2. 3. 5. Distribution of Snails by Ecological Factors, Abu eshreen Irrigating the Inspectors' House

In this abu eshreen (Table 16), *Biomphalaria pfeifferi, Bulinus truncatus* and *Bulinus forskalii* snails were found in large numbers when water was stagnant and the water level was shallow and when the vegetation and shade were dense. *Cleopatra* and *Melanoides* snails were not found in this abu eshreen throughout the observation period.

Table 16: Percentage Distribution of Snails by Ecological Factors, Abu eshreen Irrigating the Inspectors' House, August 1999-August 2000

Water Flow						
	Bio. pfei	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Stagnant	100.00 (1)	100.00 (1)	100.00 (73)	0.00 (0)	0.00 (0)	75
Slow	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Good	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Fast	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75
Water Level						
Dry	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Pools	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Shallow	100.00 (1)	100.00 (1)	100.00 (73)	0.00 (0)	0.00 (0)	75
High	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75
Vegetation						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	0.00 (0)	2.74 (2)	0.00 (0)	0.00 (0)	2
Dense	100.00 (1)	100.00 (1)	97.26 (71)	0.00 (0)	0.00 (0)	73

Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75
Shade						
Absent	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Light	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Medium	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Dense	100.00 (1)	100.00 (1)	100.00 (73)	0.00 (0)	0.00 (0)	75
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75

(): Total number of snails

3. 2. 4. PERCENTAGE DISTRIBUTION OF SNAILS BY SITES OF COLLCETION

The percentage distribution of the snails collected from three sites in each abu eshreen in the study area is shown in Table 17 and Figure 12.

27% (177 snails) of the total snails catch were found at the tail ends of the abu eshreens, 44% (295 snails) were collected from the middle of the ditches and 29% (195 snails) were found at the head.

The percentages of distribution of the snails at the take-off (head) of abu eshreens were as follows: *Bul. forskalii* (51%), *Cleopatra* (33%), *Bul. truncatus* (13%) and *Melanoides* (3%). At the middle of abu eshreens the percentages were: *Bul. forskalii* (56%), *Cleopatra* (27%), *Bul. truncatus* (14%) and *Bio. pfeifferi* (3%). The percentages at the tail of abu eshreens were: *Bul. forskalii* (98%) and *Melanoides* (2%). *Bio. pfeifferi, Bul. truncatus* and *Cleopatra* snails were not found at the tail ends of abu eshreens. There were no significant differences ($P > 0.05$) among the distribution of all species by site of collection except the distribution of *Bul. truncatus* ($P < 0.05$).

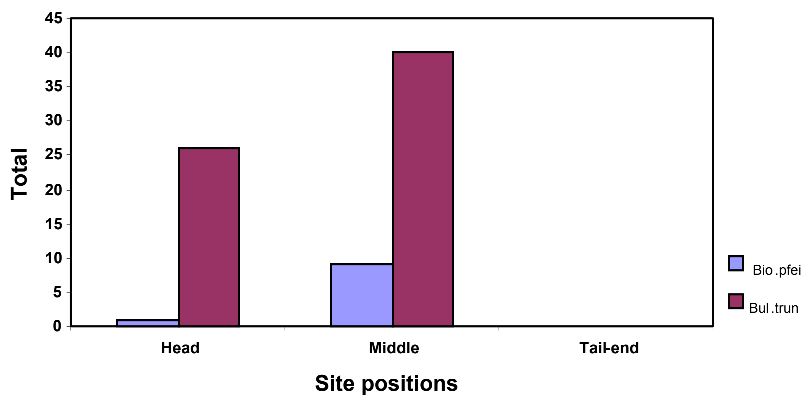
Table 17: Percentage Distribution of Snails by site positions, all abu eshreens , August 1999-August 2000.

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. Spp*	Total
Head	10.00 (1)	39.39 (26)	22.71 (99)	44.14 (64)	50.00 (5)	195
Mid	90.00 (9)	60.61 (40)	37.39 (163)	55.86 (81)	20.00 (2)	295
Tail	0.00 (0)	0.00 (0)	39.90 (174)	0.00 (0)	30.00 (3)	177
Total	1.50 (10)	9.90 (66)	65.36 (436)	21.74 (145)	1.50 (10)	667

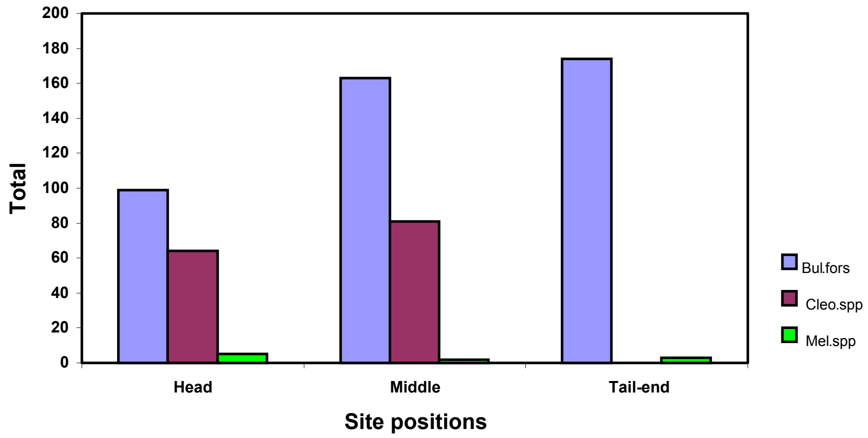
(): Total number of snails

Fig. 12: Monthly Distribution of the Snails by site positions, all abu eshreens, August 1999-August 2000

a. Schistosome Intermediate Host Snails



b. Other Snails



3. 2. 4. 1. Abu eshreens of Gad El Ain Minor Canal

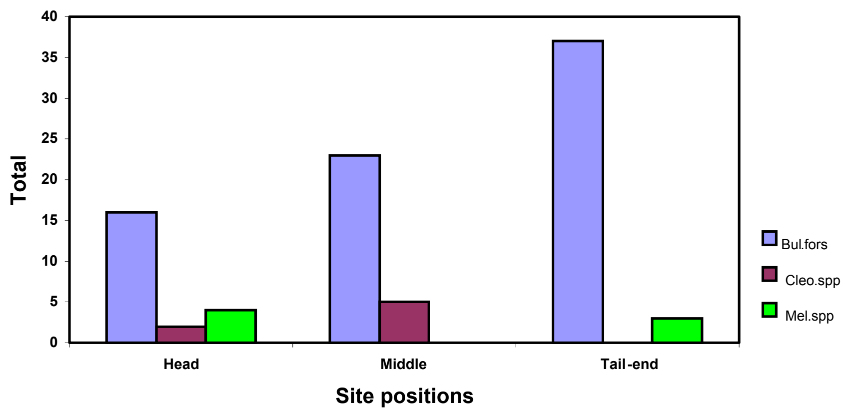
Forty snails (44%) of the total snails catch were found at the tail ends of abu eshreens of this minor canal, 28 snails (31%) were collected from the middle and 22 snails constituting 24% were found at the heads of abu eshreens, Table 18 and Figure 13.

Table 18: Percentage Distribution of Snails by site positions Abu eshreens of Gad El Ain Minor Canal, August 1999-August 2000

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Head	0.00 (0)	0.00 (0)	21.05 (16)	28.57 (2)	57.14 (4)	22
Mid	0.00 (0)	0.00 (0)	30.26 (23)	71.43 (5)	0.00 (0)	28
Tail	0.00 (0)	0.00 (0)	48.68 (37)	0.00 (0)	42.86 (3)	40
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90

(): Total number of snails

Fig.13: Monthly Distribution of the Snails by site positions abu eshreens of Gad El Ain Minor Canal, August 1999-August 2000



The snails found at the take-off were *Bul. forskalii* (73%), *Melanoides (*18%) and *Cleopatra* (9%). The snails found in the middle of abu eshreens were *Bul. forskalii* (82%) and *Cleopatra* (18%). The snails found at the tail of abu eshreens were *Bul. forskalii* (93%) and *Melanoides* (7%). *Bio. pfeifferi and Bul. truncatus* snails were not found at any of the three sites of collection along the abu eshreens in this canal.

3. 2. 4. 2. Wad El Magdi Minor Canal

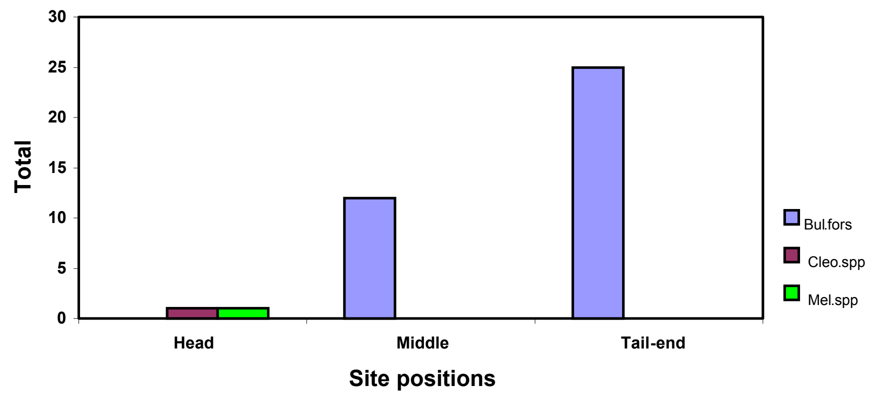
Table 19 and Figure 14 show the percentage distribution and the number of snails found at the sites of collection respectively. 64% (25 snails), 31% (12 snails) and 5% (2 snails) of the total snails catch were found at the tail ends, the middle and the take-off of abu eshreens respectively.

Table 19: Percentage Distribution of Snails by site positions Abu eshreens of Wad El Magdi Minor Canal, August 1999-August 2000

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Head	0.00 (0)	0.00 (0)	0.00 (0)	100.00 (1)	100.00 (1)	2
Mid	0.00 (0)	0.00 (0)	32.43 (12)	0.00 (0)	0.00 (0)	12
Tail	0.00 (0)	0.00 (0)	67.57 (25)	0.00 (0)	0.00 (0)	25
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39

(): Total number of snails

Fig. 14: Monthly Distribution of the Snails by site positions abu eshreens of Wad El Magdi Minor Canal, August 1999-August 2000



The two Prosobranchs genera, *Cleopatra* and *Melanoides* were found in equal percentages (50%) at the take-off, but only two snails were found. Only *Bul. forskalii* snails were found at the middle and the tail ends of abu eshreens. The intermediate snail hosts of schistosomiasis were not found along any abu eshreen.

3. 2. 4. 3. Abu eshreens of Hassaballa Minor Canal

The majority of the snails, 64% (65 snails) of the total snails catch was found at the tail ends of the abu eshreens, 26% (26 snails) were collected from the middle and 10% (10 snails) were found at the head, Table 20 and Figure 15.

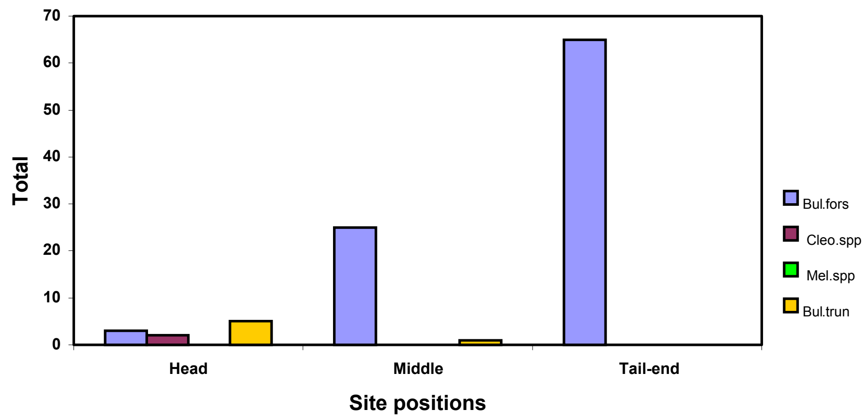
The snails found at the take-off (head) of the abu eshreens of this canal were *Bul. truncatus* (50%), *Bul. forskalii* (30%) and *Cleopatra* (20%). At the middle of abu eshreens, *Bul. forskalii* constituted the majority of snails (96%) and *Bul. truncatus* (4%). At the tail of all abu eshreens along this canal, only *Bul. forskalii* snails were found. *Bio. pfeifferi* and *Melanoides* snails were not found at any of the three sites of collection.

Table 20: Percentage Distribution of Snails by site positions Abu eshreens of Hassaballa Minor Canal, August 1999-August 2000

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Head	0.00 (0)	83.33 (5)	3.23 (3)	100.00 (2)	0.00 (0)	10
Mid	0.00 (0)	16.67 (1)	26.88 (25)	0.00 (0)	0.00 (0)	26
Tail	0.00 (0)	0.00 (0)	69.89 (65)	0.00 (0)	0.00 (0)	65
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101

(): Total number of snails

Fig. 15: Distribution of the Snails by site positions abu eshreens of Hassaballa Minor Canal, August 1999-August 2000



3. 2. 4. 4. Abu eshreen Irrigating the Gardens of Abu Usher Hospital

13% (47 snails) of the total snails catch were found at the tail end of this abu eshreen, 63% (229 snails) at the middle and 24% (86 snails) at the head, Table 21 and Figure 16.

The snails found at the take-off (head) were *Cleopatra* (69%), *Bul. truncatus* (23%) and *Bul. forskalii* (8%). *Bio. pfeifferi and Melanoides* snails were not found at the head of the abu eshreen. In the middle of the abu eshreen, *Bul. forskalii* (45%), *Cleopatra* (33%), *Bul. truncatus* (17%), *Bio. pfeifferi* (4%) and *Melanoides* (1%) were found. At the tail of the channel, only *Bul. forskalii* snails were found.

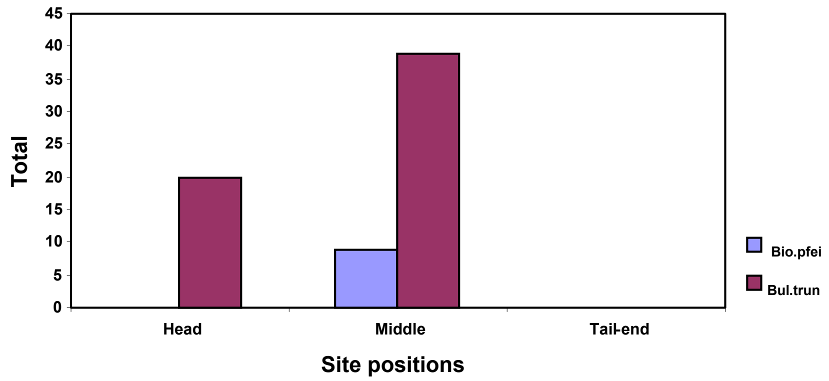
Table 21: Percentage Distribution of Snails by site positions in Abu eshreen Irrigating the Gardens of Abu Usher Hospital

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Head	0.00 (0)	33.90 (20)	4.46 (7)	43.70 (59)	0.00 (0)	86
Mid	100.00 (9)	66.10 (39)	65.61 (103)	56.30 (76)	100.00 (2)	229
Tail	0.00 (0)	0.00 (0)	29.94 (47)	0.00 (0)	0.00 (0)	47
Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362

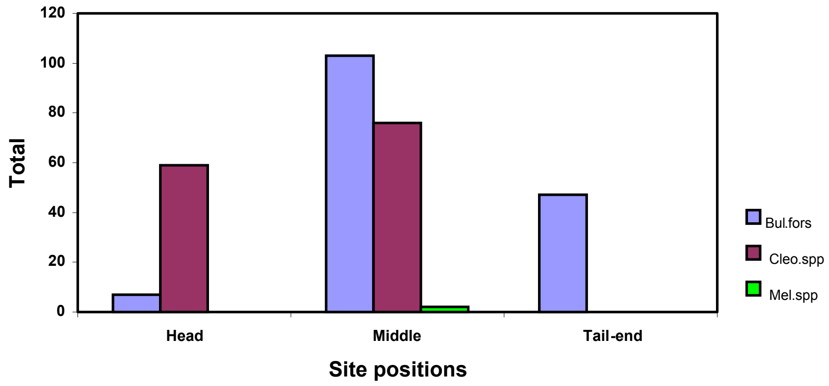
(): Total number of snails

Fig. 16: Distribution of the Snails by site positions in Abu eshreen Irrigating the Gardens of Abu Usher Hospital

a. Schistosome Intermediate Host Snails



b. Other Snails



3. 2. 4. 5. Abu eshreen Irrigating the Inspectors' Houses

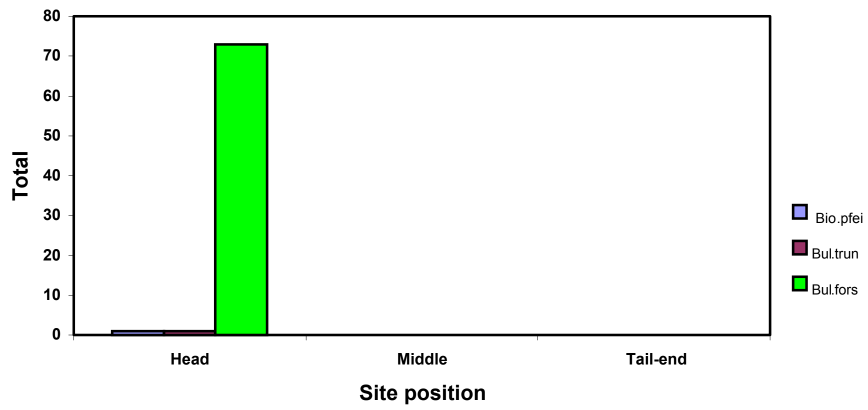
All the snails collected along this abu eshreen (Table 22 & Figure 17) were found at the take-off. 97% (73 snails) of the snails collected were *Bul. forskalii*. The other remaining two snails were *Bul. truncatus* and *Bio. pfeifferi* respectively.

Table 22: Percentage Distribution of Snails by site positions in Abu eshreen Irrigating the Inspectors' House, August 1999-August 2000

Site	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel.Spp*	Total
Head	100.00 (1)	100.00 (1)	100.00 (73)	0.00 (0)	0.00 (0)	75
Mid	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Tail	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75

(): Total number of snails

Fig.17 .Distribution of the Snails by site positions in Abu eshreen Irrigating the Inspectors' House, August 1999-August 2000



3. 2. 5. PERCENTAGE DISTRIBUTION OF SNAILS BY SEASON

The distribution of snails in the different seasons, in all abu eshreens surveyed is shown in Table 23 and Figure 18. High percentages of *Bio. pfeifferi*, *Bul. truncatus* and *Cleopatra* were found during the hot season, while low percentages were found during the rainy season. The distribution of *Bul. truncatus* and *Cleopatra* in the different seasons was significant ($P < 0.05$). *Bul. forskalii* snails were more abundant in the cold season and showed a significant difference ($P < 0.05$) in its seasonal distribution. There were no observed differences in the densities of *Bio. pfeifferi* and *Melanoides* snails with the different seasons ($P > 0.05$).

Table 23: Percentage Distribution of Snails by seasons, all abu eshreens, August1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	90.00 (9)	83.33 (55)	8.26 (36)	92.41 (134)	0.00 (0)	234
Cold	0.00 (0)	12.12 (8)	63.07 (275)	7.59 (11)	50.00 (5)	299

Rainy	10.00 (1)	4.55 (3)	28.67 (125)	0.00 (0)	50.00 (5)	134
Total	1.50 (10)	9.90 (66)	65.37 (436)	21.74 (145)	1.50 (10)	667

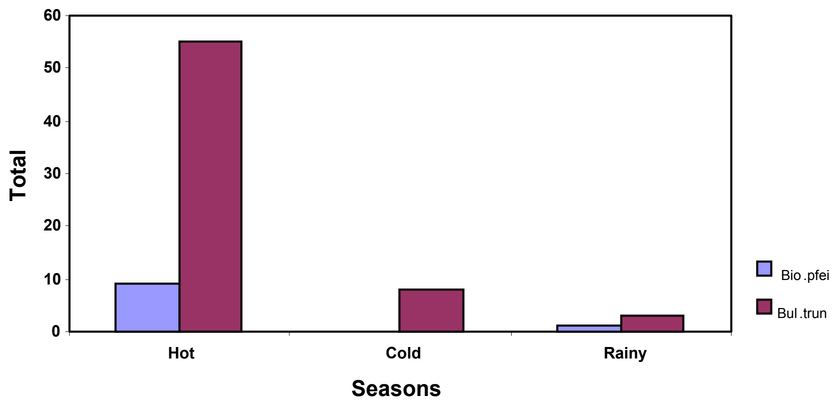
(): Total number of snails

3. 2. 5. 1. Abu eshreens of Gad El Ain Minor Canal

The total number in all the abu eshreens along this minor canal was 90 snails (Table 24 & Figure 19). 61% of the *Bul. forskalii* snails were found during the cold season, 72% *Melanoides* snails were found during the rainy season and all the *Cleopatra* snails were found during the cold season.

Fig.18: Distribution of Snails by seasons, all abu eshreens, August1999-August 2000

a. Schistosome Intermediate Host Snails



b. Other Snails

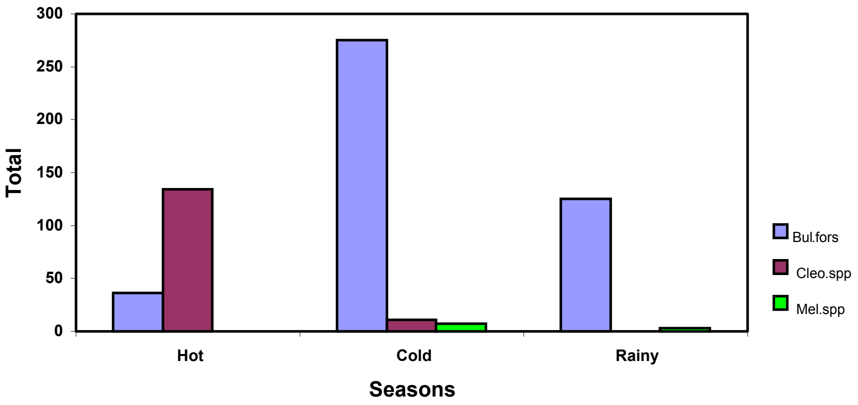
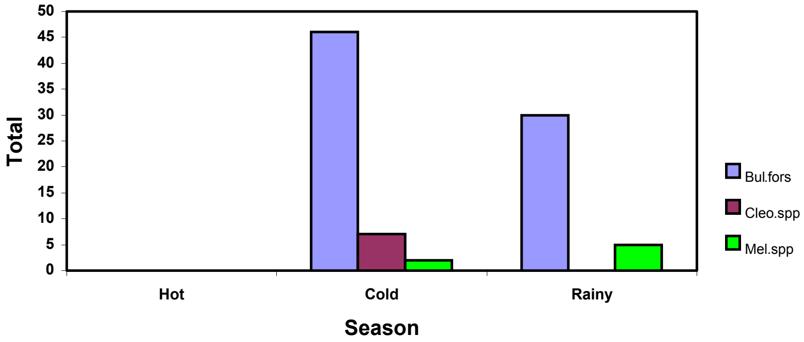


Table 24: Percentage Distribution of Snails by seasons abu eshreens of Gad El Ain
Minor Canal, August 1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Cold	0.00 (0)	0.00 (0)	60.53 (46)	100.00 (7)	28.57 (2)	55
Rainy	0.00 (0)	0.00 (0)	39.47 (30)	0.00 (0)	71.43 (5)	35
Total	0.00 (0)	0.00 (0)	84.44 (76)	7.78 (7)	7.78 (7)	90

(): Total number of snails

Fig. 19: Distribution of Snails by seasons abu eshreens of Gad El Ain Minor Canal, August1999-August 2000



3. 2. 5. 2. Abu eshreens of Wad El Magdi Minor Canal

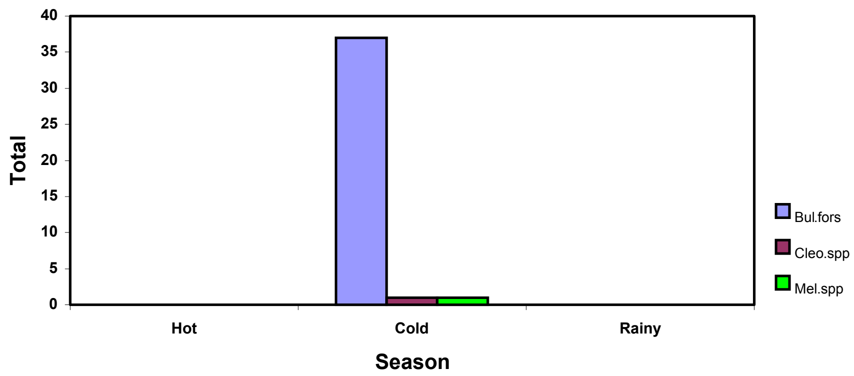
In the abu eshreens taking water from this canal, Table 25 and Figure 20, all the species of snails were found only during the cold season.

Table 25: Percentage Distribution of Snails by seasons abu eshreens of Wad El Magdi Minor Canal, August 1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Cold	0.00 (0)	0.00 (0)	100.00 (37)	100.00 (1)	100.00 (1)	39
Rainy	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Total	0.00 (0)	0.00 (0)	94.87 (37)	2.56 (1)	2.56 (1)	39

(): Total number of snails

Fig. 20: Distribution of Snails by seasons abu eshreens of Wad El Magdi Minor Canal, August1999-August 2000



3. 2. 5. 3. Abu eshreens of Hassaballa Minor Canal

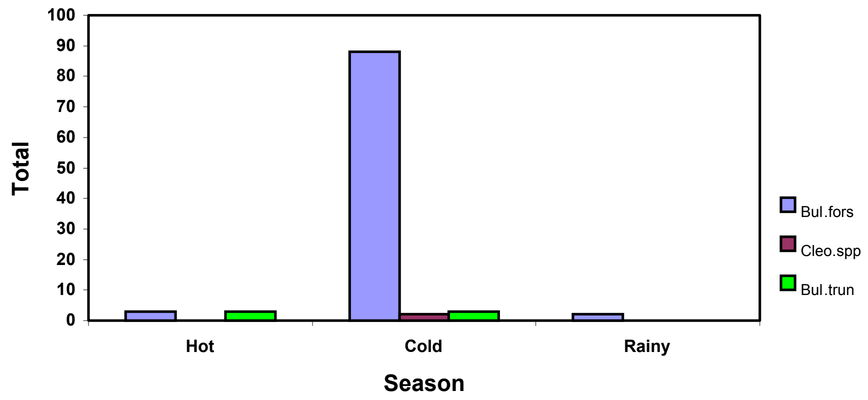
Out of the 101 snails collected from the abu eshreens of this minor canal, only 6 snails were *Bul. truncatus*, found during the hot season and cold seasons respectively (Table 26 & Figure 21). The majority of the snails collected in the abu eshreens were *Bul. forskalii*. 94.6% of these were found during the cold season.

Table 26: Percentage Distribution of Snails by seasons abu eshreens of Hassaballa Minor Canal, August 1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	0.00 (0)	50.00 (3)	3.23 (3)	0.00 (0)	0.00 (0)	6
Cold	0.00 (0)	50.00 (3)	94.62 (88)	100.00 (2)	0.00 (0)	93
Rainy	0.00 (0)	0.00 (0)	2.15 (2)	0.00 (0)	0.00 (0)	2
Total	0.00 (0)	5.94 (6)	92.08 (93)	1.98 (2)	0.00 (0)	101

(): Total number of snails

Fig.21: Distribution of Snails by seasons abu eshreens of Hassaballa Minor Canal, August1999-August 2000



3. 2. 5. 4. Abu eshreen Irrigating the Gardens of Abu Usher Hospital

This abu eshreen harboured mainly *Cleopatra* and *Bul. forskalii* snails (Table 27 & Figure 22). The first genus was abundant during the hot season (99.3%) and the second dominated during the cold season (49.68%). *Bio. pfeifferi* snails were found during the hot season only. 88.14% of the *Bul. truncatus* snails were found during the hot season.

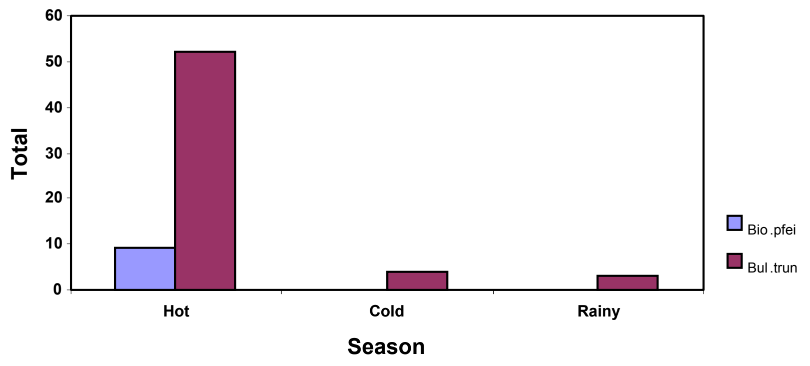
Table 27: Percentage Distribution of Snails by season in abu eshreen Irrigating the Gardens of Abu Usher Hospital, August1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	100.00 (9)	88.14 (52)	21.02 (33)	99.26 (134)	0.00 (0)	228
Cold	0.00 (0)	6.78 (4)	49.68 (78)	0.74 (1)	100.00 (2)	85
Rainy	0.00 (0)	5.08 (3)	29.30 (46)	0.00 (0)	0.00 (0)	49
Total	2.49 (9)	16.30 (59)	43.37 (157)	37.29 (135)	0.55 (2)	362

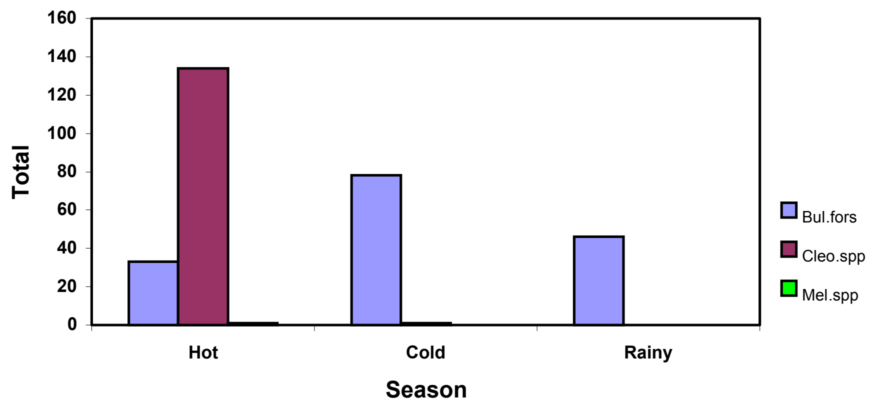
(): Total number of snails

Fig. 22: Distribution of Snails by season abu eshreen Irrigating the Gardens of Abu Usher Hospital, August 1999-August 2000

a. Schistosome Intermediate Host Snails



b. Other snails



3. 2. 5. 5. Abu eshreen Irrigating the Inspectors' House

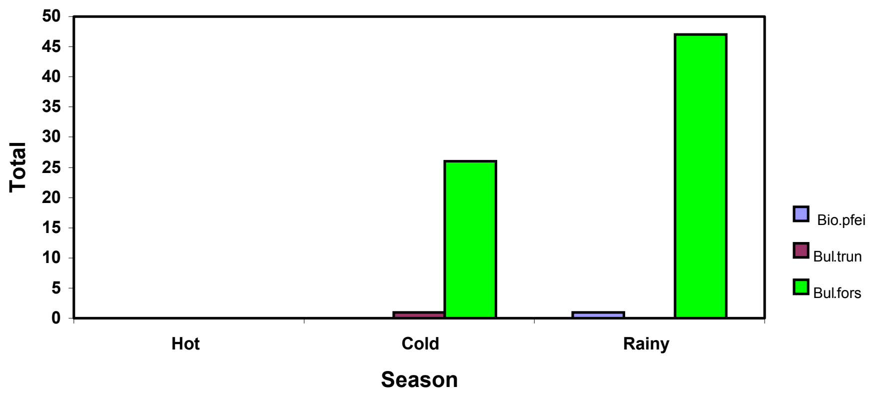
Out of the 75 snails collected in this abu eshreen, 73 snails were *Bul. forskalii* (Table 28 & Figure 23). 64.38% and 35.62% of the total *Bul. forskalii* were collected during the rainy and cold season respectively.

Table 28: Percentage Distribution of Snails by season in abu eshreen Irrigating the Inspectors' House, August 1999-August 2000

Season	*Bio. pfei*	*Bul. trun*	*Bul. fors*	*Cleo. spp*	*Mel. spp*	Total
Hot	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0.00 (0)	0
Cold	0.00 (0)	100.00 (1)	35.62 (26)	0.00 (0)	0.00 (0)	27
Rainy	100.00 (1)	0.00 (0)	64.38 (47)	0.00 (0)	0.00 (0)	48
Total	1.33 (1)	1.33 (1)	97.33 (73)	0.00 (0)	0.00 (0)	75

(): Total number of snails

Fig. 23: Distribution of Snails by season in abu eshreen Irrigating the Inspectors' House, August 1999-August 2000



3. 3. DETERMINATION OF MOVEMENT IN THE FIELD SNAILS

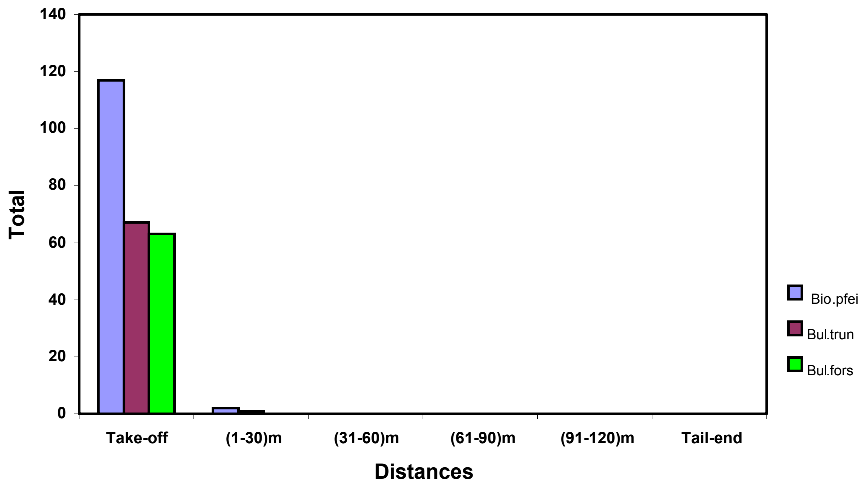
The field experiment to determine the mobility of the different species of snails under natural conditions, indicated that vegetation provide protection for the snails (Table 29 & Figure 24). In the abu eshreen with dense vegetation all the snails were found at the point of release, the take-off. When there was no vegetation in the abu eshreen, the snails were found dispersed at different distances from the point of release.

Table 29: The total catches of the snails in different distances of two types of abu eshreens

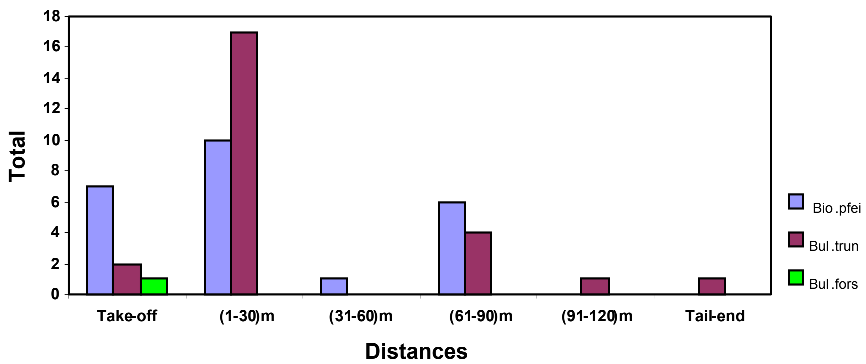
Abu eshreens with vegetation				
Distance (m)	*Bio. pfei*	*Bul. trun*	*Bul. fors*	Total
Take-off	117	67	63	247
1-30	2	1	0	3
31-60	0	0	0	0
61-90	0	0	0	0
91-120	0	0	0	0
Tail	0	0	0	0
Total	119	68	63	250
Abu eshreens without vegetation				
Take-off	7	2	1	10
1-30	10	17	0	27
31-60	1	0	0	1
61-90	6	4	0	10
91-120	0	1	0	1
Tail	0	1	0	1
Total	24	25	1	50

Fig.24: The total catches of the snails in different distances of two types of abu eshreens

a. Abu eshreens with vegetation



b. Abu eshreens without vegetation



3. 4. Infection of *Bulinus forskalii* snails with *S. haematobium* Miracidia

Non of the exposed *Bul. forskalii* snails to *S. haematobium* miracidia was infected *i. e*. no cercariae emerged from the snails after three weeks of exposure, Table 30.

Table 30: Exposure of *Bulinus forskalii* to different numbers of *S. haematobium* miracidia in the laboratory

Bul.fors snails	(0) Miracidium	(1) Miracidium	(2) Miracidia	(4) Miracidia
1st group	(0)	(0)	(0)	(0)
2nd group	(0)	(0)	(0)	(0)
3rd group	(0)	(0)	(0)	(0)
4th group	(0)	(0)	(0)	(0)

() Total number of infected snails

CHAPTER FOUR

DISCUSSION

Abu eshreens in Gezira Irrigated Scheme (the Scheme) proved to be a suitable habitat for all fresh water snails. Five species of snail were found in the abu eshreens. These belong to two orders: (1) Prosobrancha (*Cleopatra*, and *Melanoides* species) and (2) Pulmonata (*Biomphalaria pfeifferi*, *Bulinus truncatus* and *Bul. forskalii*). About two thirds of the snails collected were *Bul. forskalii*.

Freshwater snails, and in particular the schistosome intermediate host snails, are distributed in a highly focal (clumped) manner, *i. e.* they do not occur over the entire habitat but only at certain foci or points. Such focal distribution has been observed in the Sudan by

Hilali (1992) and it seems to be a general feature in the distribution of the schistosome intermediate host species in all other endemic areas (Klumpp & Chu, 1977; WHO, 1985; Doumenge *et al.*, 1987). However, the present study indicates that the distribution of the snails and the relative abundance of a particular species of snails, in abu eshreens, would be affected by the crop in the field. Therefore, snails would not be found throughout the year as the case in the summer minor canals (Taha, 2002).

The population densities of the intermediate host snails are affected by environmental (El-Emam & Madsen, 1982; Marti, 1986), chemical (Williams, 1970 a & b; Appleton, 1975), biological (Hilali *et al.*, 1985) and physical (Babiker, 1984) factors. Studies on the distribution of the schistosome intermediate snail hosts have been made in various parts of Africa, and considerations have been given to factors that may influence the population density. Some workers stated that rainfall is responsible (Hira & Muller, 1966; Klumpp & Chu, 1977; O'Keeffe, 1985), in other areas it is temperature (Demian & Kamil, 1972; Appleton, 1977). It is most probable that these two factors apparently are acting together rather than individually. However, the factors affecting the distribution of non-schistosome transmitting snails, especially those of non medical importance, are not well known.

Most of the studies were carried out on the snail populations in the minor canals. Only one study was carried out to determine the role of abu eshreens in the transmission of schistosomiasis and not the distribution of freshwater snails (Fenwick *et al.*, 1981). That study proved that abu eshreens would play a limited role in the transmission of schistosomiasis provided that the crop in the parent field is irrigated for the greater part of the agricultural season *i. e*. abu eshreens irrigating groundnut/sorghum, vegetables and cotton. Groundnuts/sorghum and vegetables are usually planted in June while cotton is planted in August. The crops are harvested in December/January for the first two crops and the harvest of cotton starts usually in December/January and finishes in April.

Previous studies in the Scheme indicated that the snail populations in the canalisation system are affected by the type of water (Red water) which prevails during the flood season of the Blue Nile, July-October, *i. e*. the rainy season (Babiker *et al*., 1985; Hilali *et al*., 1995). Rainfall affects the amount of silt in the water, which in turn inhibits the algal growth and affect the food available for the snails.

Heavy flooding usually reduces snail populations because of the rapid flow and the high silt content. The decline in the snail numbers during the rainy season (Table1) could be due to a change in the water chemistry (silt content). Another explanation for the low numbers of snails could be due to the excessive water during the rainy season which disperses the snails over a greater water volume resulting in a reduced capture rates of snails (dilution factor). A third explanation could be the indirect effect of the high silt content in reducing light penetration and therefore reducing the amount of algae and aquatic plants, the main source of food for snails. A fourth reason for the reduction in the density of the different species of snails observed during the rainy season could be due to the high turbidity of water that prevents the normal development of the gonads of the snails as well as hatching of the eggs (Webbe & Msangi, 1958; Shiff, 1964). Or it could be due the fact that rain would cause a drop in the temperature of water to levels unsuitable for the breeding of the snails.

The present study shows marked variations in the density of the different species of snails, in abu eshreens, through the year. The density of all snail species, found in the abu eshreens, dropped significantly during the rainy season, July/September. The snail population started to increase in number after the rainy season, October/December. However, Meyer-Lassen *et al*. (1992) reported that the rainy season, in El-Rahad Irrigation Scheme, with high temperature and high water level was the optimal season for breeding and population growth of the intermediate hosts in spite of the high turbidity of the canal water.

Although the snail populations in abu eshreens would be affected by the physical characteristics of the canal, the length of irrigation of the parent field also would affect the distribution and the presence of the snails in abu eshreens. The groundnuts and sorghum are usually planted in June and harvested in December-January, cotton is planted in August and harvested in March-April. Therefore, it would be expected that abu eshreens irrigating cotton, sorghum and groundnuts would harbour large numbers of snails. In fact, most of the snails were found in abu eshreens irrigating vegetables and sorghum/groundnuts, with the prosobranch snails dominating all species (Table 7).

Fenwick *et al*. (1981) stated that *Biomphalaria* snails, infected and non-infected, were found in abu eshreens irrigating cotton and sorghum. In this study, the intermediate host snails for the intestinal schistosomiasis (*Biomphalaria pfeifferi*) were not found in any abu eshreen irrigating cotton (Table7). They were collected from those irrigating vegetables and gardens. On the other hand, *Bul. truncatus* tended to accumulate in abu eshreens irrigating vegetables (91%) and cotton (9%). Both species were not found in channels irrigating wheat and groundnuts.

Bul. forskalii snails were more widely distributed. They were found and collected from abu eshreens irrigating vegetables, cotton and groundnuts/sorghum. They were not found in abu eshreens irrigating wheat. This is most probable because this species before establishing itself in the canal will be faced by the drying of the canal due to the short period for irrigation of the crop (November-March).

The snail populations in abu eshreens are usually affected by the physical characteristics of the canal. These characteristics are the result of the environmental factors existing in these canals. A canal without vegetation would be with good flow and the snails would be flushed away to the tail end of the canal. The snails in a canal with dense vegetation, on the other hand, would be found along the whole length of the canal. The association between the presence of snails in the vegetation, in different freshwater habitats was studied by many investigators (Ferguson, 1978; Klumpp & Chu, 1980; Thomas *et al*., 1983; Hilali *et al*., 1985; Madsen *et al*., 1988).

The present study showed that there is a close significant relationship between the presence of snails and the presence of vegetation in the canalisation system. It seems that snails are attracted to weeds that offer a major source of food, egg-laying substrata, protection and shelter. However, the most important factor is the availability and type of food, as well as availability of minerals, particularly calcium that makes up the snail shell.

Water flow in abu eshreens is affected by the presence and/or absence of vegetation. Abu eshreens without vegetation would be with a good flow of water and snails will be flushed away which explains the absence of snails under such conditions. The majority of snails were found in abu eshreens with dense vegetation. However, for snails to establish colonies and populations, the most important factors would be the availability and type of food, as well as, availability of minerals, particularly calcium that makes up the snail shell. The take-off is the part of the canal where water flow is at its maximum. For the whole period of the study the snails were not found in that part of abu eshreens. Snails were found in large numbers in water bodies with stagnant water flow. They were absent, or found in small numbers, in water bodies with fast water flow. Fast moving water flushes the snails away, destroys the surfaces suitable for egg laying by the snails and removes the source of food available for the snails. *Cleopatra* snails were usually found in large numbers in water bodies with fast water flow. They are morphologically adapted for such a habitat. They have strong muscular head and foot region that can tolerate high water velocities. During the course of this study they were abundant in abu eshreens with slow flow. Their presence, in relatively large numbers, in the slow moving water in the abu eshreens may be due to other factors such as availability of food, since detritus and epiphytic algae, growing on the surface of plants, tend not to occur in fast flowing waters.

The distribution of snails was affected by the water level. It seems that the water level is not an important environmental factor in determining the distribution of the snails, but would interfere in finding the snails. When the water level is high, it is most probable that snails at the bottom would not be reached (Table11). On the other hand, at a low level of water and in the presence of dense vegetation, scooping would be difficult and so some of the snails would be missed. However, when water levels are low, high numbers of snails would be found since the snails, most probably, would be following the receding water. The majority of the snails found in abu eshreens were collected in areas with dense vegetation because, most probably, the vegetation and the shade it provides causes drop in the temperature to levels favourable by the snails. *Melanoides* and *Bul. forskalii* snails they were found in large numbers in areas without shade in the abu eshreens of the three minor canals. In the abu eshreens irrigating the gardens, *Bul. forskalii* was found in relatively large numbers. This could be due to other unknown factors beside shade and temperature.

Another important factor that would affect the distribution of populations of the snails, in abu eshreens, is the physical characteristics of the minor canal, *e. g*. whether the canal is dredged or not, the density of vegetation and the rate of flow in the minor canal. Annual changes in the snail population densities may be related to variation in local conditions as well as variation in ecological factors from one year to another. These conditions include vegetation, water flow and level and shade.

Before the commencement of this study, the three minor canals: Gad El Ain, Wad El Magdi and Hassaballa, were dredged. The silt and vegetation were removed mechanically from both sides of the canals. The effect of dredging was very clear on the snail populations in abu eshreens of the three minor canals. The intermediate host snails of the two schistosomiasis forms, intestinal and urinary, were not found in the abu eshreens of Gad El Ain and Wad El Magdi Minor Canals, and only 6 *Bul. truncatus* snails were found in the abu eshreens of Hassaballa Minor Canal. Even the non-transmitting schistosome snails were affected by the dredging of the minor canals and therefore very few numbers were found.

Dredging seems to be a very effective method for the control of snails. The process involves the removal of silt accumulated in the canal during the flood season. The removal of silt also includes the removal of aquatic weeds from the canalisation system. This has a positive effect on water velocity. It increases water speed and, thus, snails will be carried to the middle part of the abu eshreen, where they are trapped in the vegetation and they survive happily in media rich with food.

During the hot season, abu eshreens will be dry and the snails would be found in the pools at the head of abu eshreens and where the vegetation is dense. Areas with dense vegetation are characterised by high humidity, and therefore most of the snails were found at mid part of abu eshreens. Snail populations would be affected by such adverse conditions. On the other hand, the majority of snails were collected during the cold season (Table 23). This is the season that follows the rainy season. Silt will be settled, vegetation will be growing in the canals, range of temperature will be optimum and food will be available. Thus, the conditions would be in favour for the snails to breed and increase in numbers as the agricultural season progresses.

Different researchers, working in the endemic areas, stated that the favourable range of water temperature for *Bul. truncatus* snails is between 21-26° C (El-Emam & Madsen, 1982; Kamal, 1984; Lewis *et al*., 1986; El-Sheikh *et al*., 1990). Sturrock (1987) stated that cool winters minimise snail growth of all sizes and breeding without seriously affecting survival whereas hot summers minimise breeding and survival. Dazo *et al.*, (1966), studying the ecological factors influencing the distribution of schistosomiasis intermediate hosts in Egypt, reported that low water temperature during winter as well as higher temperatures in summer reduced breeding of *Bio. alexandrina* and *Bul. truncatus* or stopped it completely and therefore snail numbers decreased.

Freshwater snails tolerate a wide range of temperature, with an optimum temperature range for breeding (Appelton, 1977), within the temperature tolerance range. The highest total number of *Bio. pfeifferi*, *Bul. truncatus* and *Cleopatra* snails were found during the hot season *i. e*. March-June. This agrees with the findings reported by other investigators working in the Scheme (Karoum, 1988; Hilali, 1992; Ahmed, 1999) or other irrigation schemes in the Sudan such as Rahad (Elias *et al*., 1994) and White Nile irrigation schemes (Ahmed *et al*., 1996). The difference between these studies and the present study is that the previous studies were carried out in the minor canals and not abu eshreens. However, the conclusion remains the same. It is believed that a combination of higher temperatures, slow moving water, minimal silt content and increasing vegetation, during the hot season would make the habitat suitable for the breeding of the snails in the hot season. *Bul. forskalii* snails were found in a large numbers during the cold season *i. e*. November-February. This would most probably be due to the gradual reduction in the silt content until the water is clear in late November. Concurrently there would be a reduction in water temperature and reappearance of aquatic vegetation in the abu eshreens.

The majority of non-schistosome transmitting snails found in abu eshreens of Gad El Ain and Wad El Magdi minor canals, except *Cleopatra*, were found from October to February, immediately after the rainy season *i. e*. the cold season. This is most probably due to a combination of factors; (1) a drop in temperature, (2) a slow moving water, (3) a minimal silt content and (4) an increasing density of vegetation in abu eshreens.

The majority of *Cleopatra* snails were found during the hot season. During that season, abu eshreens are dry except small pools of water at the take-off. The genus is characterised by the presence of an operculum that provides protection for the snail from drying and protects the soft internal tissues of the snails. The majority of the snails are usually found at the middle of abu eshreen, where the humidity would be rather high due to dense vegetation and the small water pools under the vegetation. The members of this order are usually found in areas with fast moving water or buried in the mud (Babiker, per. com.). However, this does not explain why the *Melanoides* snails, the other member of the order present in the canalisation system, was not found in the same density. The most obvious reason to explain the difference in the density of the two genera, in abu eshreens, would be the dredging of the minor canals that affected the re-invasion of abu eshreens by the *Melanoides* snails since they were removed with the silt from the minor canals.

It worth noting that *Bul. forskalii* snails were more abundant in the abu eshreens than all other species. About one third of the total number collected from this species were found in the abu eshreen irrigating the houses of the hospital in Abu Usher town. Ghandour (1973) found plenty of *Bul. forskalii* in this abu eshreen more than thirty years ago. This indicates that the habitat in this abu eshreen seems to be very suitable for this species. It also proves, generally, that the canalisation system is rather stable and that under such conditions of stability in the habitat the pulmonate snails would propagate and continue to survive for years and years.

On the other hand, the density of *Bio. pfeifferi* and *Bul. truncatus*, in this abu eshreen, was very low. The two species of snails belong also to the pulmonate group. Although, the density of the schistosome intermediate host snails in the canalisation system in the Scheme has dropped drastically during the past few years, this does not explain the reason for the low densities of these two species of snails. Ghandour (1973), following the snail population in this in abu eshreen, did not report the presence of any intermediate host snails. Therefore, one would conclude that the factors affecting the populations of the different species of the pulmonate group could be different. These factors would differ between the different abu eshreens as evident by the comparison between the abu eshreen irrigating the houses of the hospital and that irrigating the houses of the field inspectors. The two abu eshreens run under trees, *i. e.* they are partially shaded, and both of them take water from a canal with high velocity, a main and a major respectively. Another factor could be the continuous irrigation of the gardens of the houses of the hospital. This would not allow the ditch to dry for a long period to eliminate the snails from the channel. The situation is different in the other abu eshreen. The gardens are irrigated irregularly and after long periods of dryness that would affect the snail populations in the field ditch.

The wide distribution of *Bul. forskalii* in abu eshreens raises several questions. Why the distribution of this species was limited in certain foci since the inception of the Scheme and suddenly there is this wide distribution? Could the extrinsic and intrinsic factors, affecting the breeding and existence of the species in the canalisation system, be determined? Could this species be used as a biological agent to control the intermediate host snails in the canalisation system of the Scheme? The answer for these questions requires urgent in-depth studies.

In an attempt to answer the question of how the snail was distributed in the canalisation system, a field experiment on the snail movement was carried out. The scrawl speed of the snails themselves was very slow. *Bul. forskalii* are usually found floating at the surface of the water. Their active movement in the aquatic habitat is almost negligible. Snails suspended on the water would be drifted with the current to different sites in the canals. Similar observations were reported by Zhongguo *et al,* (2002) for moving patterns of *Oncomelania* snails. However, the limiting factor is most probably the physical characteristics of the minor and abu eshreen canals *i. e*. the rate of water flow and the presence and/or absence of vegetation in the two types of canal.

It is known that *Bul. forskalii* does not transmit *S. haematobium* in the Sudan, whereas it does in other parts of Africa (Jordan *et al*., 1993). Ghandour (1973) stated that the snail did not take the infection. The present study shows the same conclusion. If this snail is to be used as a biological agent for the control of the intermediate host snails such a fact has to be monitored regularly to eliminate the possibility of a new vector for urinary schistosomiasis in the Scheme.

The results of the distribution of the intermediate host snails indicated that the two species are very small in number. The reason for this is not known. The same observation reported and observed in the Scheme (Babiker, per. Com). This could be due to a number of reasons. It could be due to the herbicides used in the Scheme, or could be due to an unknown pollution by chemicals used by the farmers in the plots designated for vegetables in the farm, or could be due to changes in the water chemistry in the canals.

The Scheme was reported as a highly endemic area for schistosomiasis (Babiker, 1987; Elmotasim, 1998). It is interesting to note that not a single schistosome intermediate host snail was found infected with human schistosome cercariae. This clearly indicates that, if the area is still endemic, the transmission of schistosomiasis can occur in spite of the low number of snails. Infected snails are generally few in nature, not exceeding 1-2% (cited by Jordan *et al.,* 1993). They are usually found in relatively large numbers at the potential transmission sites. This determines the seasonality and focality of schistosomiasis transmission in the endemic areas, including the Scheme (Babiker *et al.,* 1985, 1987; Hilali *et al,* 1995). The fact that not a single snail was found infected indicates that the transmission rate of schistosomiasis, in abu eshreens, could be negligible, and that they do not play any role in the transmission of schistosomiasis in the Scheme.

The present study highlighted the distribution of snails in abu eshreens in the Scheme. The following conclusion could be drawn from the results

1. Abu eshreens are suitable habitats for the different fresh water snails. However, they are found in a relatively low density. The reasons behind this need further investigation.
2. The environmental conditions and the physical characteristics of any abu eshreen, as well as those of the minor canal providing water to the field ditch, could be important factors in the distribution of freshwater snails in abu eshreens.
3. Dredging of the canals could be an effective tool to remove the snails from the habitat for a long period. Dredging changes the physical characteristics of the canal, and this in turn determines the distribution of the snails in abu eshreens.
4. The snail populations, in any abu eshreen, seem to be affected by crop planted in the parent field. The longer the period for irrigation of that particular, the more suitable abu eshreen will be for the snails.
5. *Bio. pfeifferi* and *Bul. truncatus* are not widely distributed in abu eshreens.
6. It seems that the role of abu eshreens in the transmission of schistosomiasis in the Scheme is rather limited.
7. *Bul. forskalii* is widely distributed in the abu eshreens of the Scheme. The local strain of the snail could not be with the local *S. haematobium* miracidia. Studies are urgently needed to determine the possibilities of using the snail as a biological agent.

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ا لاصة

أجريت هذه الدراسة في أبو عشرينات ثلاثة قنوات جانبية (فرعية) جاد العين، ود الماجدي وحسب الله بالأضافة الي أبو عشرينين معينين أحدهم يروي جنائن مستشفي أبو عشر والاخر يروي منازل المفتشين في منطقة أبو عشر في الجزء الشمالي من مشروع الجزيرة.

الهدف الرئيسي لهذه الدراسة هو تحديد توزيع حلزونات المياه العذبة في أبو عشرينات الدراسة وكذلك تحديد العوامل المختلفة التي يمكن أن تؤثر علي مجتمع الحلزونات.

وجدت خمسة أجناس من حلزونات المياه العذبة في أبو عشرينات الدراسة. ثلاثة منهم ينتمون الي رتبة الرئويات وتضم البايومفلاريا الفيفرابية *Biomphalaria pfeifferi* ، البولاينس المبتور *Bulinus truncatus* والبولاينس فورسكالي *Bulinus forskalii* .

النوعين الأول والثاني يمثلان العائل الوسيط للمنشقة المعوية والبولية علي التوالي.أما الأخير ليس له أهمية طبية في السودان. الأجناس الأثنين الأخري هي الكيلوباترة *Cleopatra* الميلانويدس *Melanoides* وهذه الأجناس ليس لها أهمية طبية. العائل الوسيط للبلهارسيا لا ينتشر انتشارا واسعا في منطقة الدراسة وهذا يعزي الي ازالة الطمي قبل بداية الدراسة من الثلاث قنوات الفرعية تحت الدراسة. ازالة الطمي لا تؤدي الي زيادة عمق القنوات وبالتالي زيادة سرعة تيار الماء فيها فقط بل تتسبب في ازالة الأعشاب التي تحتوي عادة على أعداد كبيرة من الحلزونات.

توزيع الحلزونات في أبو عشرينات يتأثر بالخصائص الطبيعية لكل قناة. الأوضاع البيئية المتوفرة في نظام القنوات أثناء موسم الأمطار تؤثر سلبا على جميع حلزونات المياه العذبة. لذلك وجود الأوضاع البيئية و الخصائص الطبيعية للقنوات معا، تحدد توزيع حلزونات المياه العذبة في أبو عشرينات. و كانت الخلاصة أن الأبو غشرينات لا تلعب أي دور في نقل البلهارسيا في المشروع.

وجدت حلزونات البولاينس فورسكالي منتشرة انتشارا واسعا في الأبوعشرينات . هذه الحلزونات أيضا وجدت في أبو عشرين سجل أنها وجدت به قبل ٣٠ سنة. هذا يوضح أن هنالك أبو عشرينات خاصة لها ظروف مثلي ، حلزونات المياه العذبة التي تتواجد فيها تكون مستمعرات تمكنها من البقاء لسنوات.

أثبتت التجربة المعملية أنه والي الآن لا يمكن اصابة حلزون البولاينس فورسكالي *Bulinus forskalii* بهوادب المنشقة الدموية *Schistosoma haematobium* . وقد نوقشت امكانية استخدام هذا الحلزون كأحد العوامل البيولوجية في المكافحة.

تأثير الموسم الزراعي بدأ واضحا في تواجد الحلزونات حيث أن وجود المحصول في الحقل ووجود المياه في القنوات لمده تؤثر علي توزيع الحلزونات. وجدت الحلزونات باعداد كبيره في أبو عشرينات التي تروي الخضروات والقطن علي التوالي وندرتها في في أبو عشرينات التي تروي محصولي الذره والفول والقمح.