SPATIAL DISTRIBUTION AND *SCHISTOSOMES* INFECTION PREVALENCE OF *BIOMPHALARIA* SNAILS ALONG LAKE VICTORIA SHORELINE OF MBITA - HOMA-BAY COUNTY-KENYA

BY

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DECLARATION

I declare that this thesis is my original work and has not been presented to any institution of higher learning for the award of a degree or any other award.

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DEDICATION

It is with a lot of humility that I dedicate this work to my family for the patience they have given me throughout my study. My wife Irene and children Steve, Jim and Sharon were very encouraging.

ABSTRACT

Intestinal schistosomiasis caused by *Schistosoma mansoni* remains a major public health problem responsible for morbidity and mortality in sub-Saharan Africa despite availability of control programs. It is estimated that more than 6 million people in Kenya are suffering from schistosomiasis. Several species of *Biomphalaria* snails are obligatory intermediate hosts for transmission of *S. mansoni.* Mbita sub-county in Homa Bay County is one of the regions along the Lake Victoria basin in which *schistosoma mansoni* infection prevalence in school going children is high at 76.8%, despite the existence of mass chemotherapeutic control programs in primary schools. Identification of exposure sites is therefore necessary in order to integrate and direct intervention to the area. This was a cross sectional study that aimed to determine the abundance of *Biomphalaria* snails in 16 purposively selected sites, assess the vegetation type associated with population of *Biomphalaria* snails and determine *schistosomes* infection prevalence of *Biomphalaria* snails along the shoreline of Mbita. Sampling of *Biomphalaria* snails was done once in each of the selected sites using 30 minutes scooping technique. The sampling sites were mapped using geographical global positioning system (GPS). The vegetation types at each sampling location was collected and identified at Kenya Marine and Fisheries Research Institute (KMFRI),-Kisumu. *Schistosomes* infection of collected snails was determined by their shedding of cercariae at Nagasaki University Laboratory at Mbita. Generated data was analyzed using analysis of variance (ANOVA) and significant differences in mean number of snails collected per site and vegetation types was determined using Tukey's post hoc test. Chi-square test was used to determine significant differences in proportions of cercariae positive snails between sites. A total of 3135 *Biomphalaria sudanica* snails were collected. The number of snails collected differed significantly between the 16 sites ($F=11.735.df=15; 836: p<0.001$). The lowest snail collection was realized at Bau ($M=0.73$) and the most at Orundu ($M=11.87$), with Tukey's post hoc test indicating that the mean number of snails collected at Orundu differed significantly from all other sites ($p<0.001$). Significant mean differences (MD) was also observed in number of snails collected per vegetation type ($F=7.899. df=5; 846: p<0.001$). The mean number of snails collected in *Cyprus gracilis* was significantly higher than from *Enydra fluactuants* ($MD= 2.032: p< 0.001$), *Eichhornia crassipes* ($MD=4.149: p=0.010$) and *Enydra* fluactuants mixed with *Eichhornia crassipes* ($MD=2.516): P=0.010$). *Eichhornia crassipes* alone ($MD=4.634: p=0.009$) and *Enydra fluactuants* mixed with *Eichhornia crassipes* ($MD=4.777: p=0.002$). However, only 21 (0.67%) of snails sheded human cercariae despite all the 16 sites having human feces contamination except Bau and Kosata, and no significance difference was found in the proportion of snails positive for cercariae between the sites (χ^2 $(60)= 64.00; p<0.338$). These findings suggest that *Cyprus gracilis* is the main vegetation type associated with abundance of *Biomphalaria* snails. Although *schistosomes* infection prevalence of the snails is low, these 16 sites may still be important exposure sites due to abundance of snail and fecal contamination found at the sites. A molecular technique like PCR is necessary for verification of positive snails with human schistosomes. Cercariometry should be done alongside snail sampling.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
CG	*Cyprus gracilis*
EC	*Eichhornia crasssipes*
EF	*Envydra fluctuants*
HDSS	Health Demographic Surveillance System
GPS	Global Position System
H/C	Human Cercariae
MDA	Mass Drug Administration
NH/C	Non Human Cercariae
PCR	Polymerase Chain Reaction
WH	Water Hyacinth
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

Schistosomiasis is a parasitic disease infecting over 243 million people worldwide and is endemic in 78 countries with over 85% of cases occurring in sub-Saharan Africa (WHO, 2012). About 779 million people – more than 10% of the world's population are at risk of being infected with schistosomiasis (Brunn *et al*., 2008). In Africa, schistosomiasis is predominantly due to *S. mansoni* which causes intestinal schistosomiasis and *S. haematobium* which causes urinary schistosomiasis (Brooker *et al.,* 2009). Schistosomiasis caused by *S. mansoni* and *S. haematobium* are the two types found along the Kenyan lake Victoria region (Handzel *et al.*, 2003), with the intermediate host being snails of the genus *Bulinus* and *Biomphalaria* respectively (Ofulla *et al.*,2010). *Schistosoma mansoni* infection continues to be one of the most important and widespread of the neglected tropical diseases in Kenya, especially among communities living around the shores of Lake Victoria in western Kenya (Handzel *et al.,* 2003). More than 6 million people in Kenya are suffering from the disease (Mutahi *et al.*, 2005).

Studies carried out by Nagi *et al*., (2014); Odiere *et al*., (2012) and Opisa *et al.,(* 2011) gave the prevalence to be 76.8%, 63.3% and 60.5% respectively among school going children in Mbita and its adjacent islands of Lake Victoria despite the existence of control programs against schistosomiasis. Several species of snails of the genus *Biomphalaria* are obligatory intermediate host for the transmission of *S. mansoni* but the species which are commonly found along the shores of Lake Victoria is *B. sudanica* while *B. chaonomphala* is found in the lake bed (Standly

et al., 2011) . The natural habitat of *Biomphalaria* species except *B. chaonomphala* are shallow stagnated water with little current near the shores of the Lakes, ponds, marshes, streams and irrigation channels (Kazibwe *et al.,* 2006). They live on water plants and mud and are most common in waters where plants are abundant and in waters moderately polluted by organic matter such as urine and feces as is often near human habitation (Kariuki *et al.*, 2004). Within each habitat, their local distribution is usually patchy, and requires examination of different sites (Opisa *et al.,* 2011). Studies have shown that microhabitat factors such as protection from water flow, wave action, availability of food, presence of vegetation and stable surface for attachment influence the presence and abundance of intermediate host snails (Claire *et al.*, 2014). Since *Biomphalaria* snail species act as intermediate host, a clear understanding of the intermediate host snails abundance is required to gain needed perspective that allows for identification of transmission foci (Kazibwe *et al.,* 2006). Information on abundance of *Biomphalaria* host snails along the Lake Victoria shoreline of Mbita -Homa-Bay County is necessary for the integrated approach in controlling the intermediate host vector.

The detection of *Biomphalaria* snails infected with *schistosomes* parasite is usually performed by cercarial shedding and eventual examination of the shed cercariae under a dissecting microscope for species identification (Kariuki *et al.*, 2004). The importance of determining the infection prevalence of *Biomphalaria* snails with *schistosomes* parasite is the identification of transmission foci, which is a sign of impending human infection.

Different species of aquatic vegetation such as water hyacinth (*Eichhornia crassipes*), water lily (*Nyamphea spp*), hippo grass and short grasses have been associated with the presence of the intermediate (Ofulla *et al.*, 2013) Since *Biomphalaria* snail species act as intermediate

host of *S.mansoni*, knowledge on their abundance is an essential prerequisite towards understanding the disease transmission. However the vegetation covers that support abundance of Biomphalaria snail in Mbita has not been described yet it is important in vector control hence reduction of schistosomiasis transmission.

1.2 Statement of the Problem

The prevalence of intestinal schistosomiasis caused by *S. mansoni* is still high (76.8%), among the school going children in Mbita, despite the existence of chemotherapeutic treatment with praziquental in school health de-worming control programs against the disease. Since *Biomphalaria* host snails are the obligatory intermediate vector, their distribution and abundance in an area is an indicator of continuing disease transmission. Since *Biomphalaria* snail species act as intermediate host for transmission of the disease, the information on the abundance of host vector snails and *schistosomes* infection prevalence in this region may help in understanding transmission dynamics. Moreover, the information on the type of vegetation associated with the abundance of vector population would shed more light on the ecological niche of the vector,hence targeted control measures. This study was therefore carried out to determine the abundance of *Biomphalaria* host snail vector, *schistosomes* infection prevalence of the vector snails and asses vegetation types associated with abundance of *Biomphalaria* snails along the Lake Victoria shoreline of Mbita in Homa-Bay county. Such data is essential for the identification of infection sites in order to direct interventions to these areas.

1.3 Objectives

1.3.1 General objectives

To asses spatial distribution and *Schistosomes* infection prevalence of *Biomphalaria* snails along Lake Victoria shoreline of Mbita –Homa Bay County.

1.3.2.Specific objectives

1. To determine the abundance of *Biomphalaria* snails per selected sites along Lake Victoria shoreline of Mbita, Homa Bay County.
2. To determine *schistosomes* infection prevalence of *Biomphalaria* snails along Lake Victoria shoreline of Mbita, Homa Bay County.
3. To determine the vegetation types associated with abundance *of Biomphalaria* snails along Lake Victoria shoreline of Mbita, Homa Bay County.

1.4. Null Hypothesis

1. There are no differences in the abundance of *Biomphalaria* snails per selected site along Lake Victoria shoreline of Mbita, Homa Bay County.

2. There are no differences in the *schistosomes* infection prevalence of *Biomphalaria* snails along Lake Victoria shoreline of Mbita Homa Bay County.

3. There are no difference in vegetation types associated with abundance of *Biomphalaria* snails along Lake Victoria shoreline of Mbita, Homa Bay County.

1.5. Justification and Significance of the study

Schistosomiasis has a great impact on the quality of life of individuals with important implication on the economy (Kariuki *et al.*, 2004) . *Schistosoma mansoni* infection is known to lower cognitive development in children thereby lowering their academic performance in school and reduce work force in adults (Mutahi *et al.*, 2005). Mbita sub-County is an area on the shores of Lake Victoria whose waters are reported to be infected with vector snails of schistosomiaisis (Standley *et al.*, 2011). Residents who live around the Lake Victoria region such as Mbita sub-county regularly come in contact with the Lake water for their recreational activities, domestic use and are likely to be exposed to infection. Documented prevalence of *S. mansoni* in the human population stands high at approximately 76.8% (Nagi *et al.*, 2014) despite the existence of mass drug administration (MDA) programs against schistosomiasis in Mbita. *S. mansoni* infections remains a significant public health threat of residents at Mbita sub-county, especially school children.

A clear understanding of the intermediate host snails abundance and infection prevalence of *Biomphalaria* snails is required to gain needed perspective that allows for identification of transmission sites, in order to direct intervention to these areas. Both the parasite and vector must be targeted in order to break the cycle of transmission so as to achieve success in controlling schistosomiasis. Data obtained from this study can be used to map out possible transmission sites at Mbita sub-county to which prevention and control intervention can be directed.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Schistosomiasis is an ancient disease of man. Eggs were recovered from both Egyptian and Chinese mummies several thousand years showing that the infection was present in civilization of mankind (Nunn & Tapp., 2000). In 1852, Bilharz found *schistosome* trematodes in the urogenital blood vessels during post mortem examination of Egyptian corpses at Kasr-el-Aimi hospital in Cairo. In 1910, Sir Armand Ruffer found calcified eggs in the kidneys of mummies of the twentieth dynasty; however scientific studies of the disease did not start until the middle of the 19th century. Many years passed by and just before the First World War, Japanese scientists Miyairi and Sizuki finally identified amphibious prosobranch snails of the Genus *Oncomelania* as the intermediate host of *Schistosoma japonicum.* Leiper in 1950 showed the aquatic, pulmonate snails of the genera *Bulinus* and *Biomphalaria* as the intermediate host of *S. haematobium* and *S. mansoni* respectively. Schistosomiasis infection stands at more than 200 million people globally and about 600 million people are at risk of getting infection (WHO, 1988)

Biomphalaria snails being intermediate hosts play a bigger role in schistosomiasis transmission. The *schistosomes* parasite requires mollusca-gastropoda intermediate host for its development and therefore it is an essential component of schistosomiasis life cycle. Studying the distribution and prevalence of intermediate host snail vector is of great importance for control intervention. Generally it is true that finding positive vector snails with *schistosomes* is the only

way to confirm diseases transmission, though many other studies have reported very low or none infected snails (Standley *et al*., 2010)

2.2 Transmission of Schistosomiasis

In Africa, schistosomiasis is associated with exposure to contaminated waters where snail vector for *Schistosoma mansoni* are found. Infection prevalence and intensity increases with age and peeks between 10 – 20 years and declines more rapidly with advance in age (Sturrock *et al*., 2001) Transmission occurs when people suffering from schistosomiasis contaminate freshwater sources with their excreta containing parasite eggs. The eggs will hatch on contact with water and release microscopic larvae called miracidia (Sturrock *et al*., 2001) Tiny miracidium must find and penetrate a specific fresh water snails and once inside the snails host, the miracidium transform through an asexual reproduction cycle to produce thousands new cercariae. People become infected when larval forms of the parasite (cercariae) released by freshwater snails penetrate the skin during contact with infested water (Sturrock *et al*., 2001). In the body, the larvae develop into adult *schistosomes.* Adult worms live in the blood vessels where the females release eggs. Some of the eggs are passed out of the body with faeces thereby contaminating the water bodies and the cycle repeats itself.

2.3 Biology, Ecology and Distribution of *Biomphalaria* Snails

Approximately 30 species of *Biomphalaria* snails are recognized and the genus is widely distributed in South America and on the African continent (Brown 1994). *Biomphalaria* is an aquatic snail that acts as a host for the human blood fluke *S. mansoni* that causes intestinal schistosomiasis (Jordan *et al.*, 1993). *Biomphalaria* and *Bulinus* snails are hermaphrodites,

possessing both male and female organs and being capable of self or cross fertilization (Sturrock *et al*., 2001). A single snail can invade and populate a new habitat (Bayne & Loker, 1987). The eggs are laid at intervals in batches of 5-40, each being enclosed in a mass of jelly-like material. The young juvenile snails hatch after 6-8 days and reach maturity in 4-7 weeks depending on environmental conditions. Temperature and food availability are among the most limiting factors. A snail can lay up to 1000 eggs during its life time which is about one year (O'Keefe, 1985)

Biomphalaria and *Bulinus* are the two primary genera of snails capable of harboring infections with *Schistosoma mansoni* and *Schistosoma haematobium*, respectively. Each intermediate snail host species lives in a well-defined habitat (Ofulla *et al.*, 2013). For instance, some are found in running waters, while others occupy still water environments. In Kenya, *Biomphalaria* snails are mainly found in South Western part of the country (Handzel *et al.*, 2003). These regions include: south of central region, Taveta region, Kitui, Machakos, Marsabit and Meru regions, Nairobi area, Baringo, Kericho, Kajiado and Nakuru regions (Kariuki *et al.*, 2004) They are also found in Lake Victoria region and the islands of Lake Victoria although their presence varies from one island to another (Sturrock *et al*., 2001). Biotic as well as abiotic environmental factors are important in the dynamics of schistosomiasis transmission. Biotic factors influencing vector populations include vegetation, food supplies, predators, competitors, and pathogens (Kariuki *et al.*, 2004). Microhabitat factors such as protection from water flow, wave action, desiccation, availability of food, presence of vegetation and stable surface for attachment influences the presence and abundance of intermediate host snails (Claire *et al.*, 2014).

Abundance of phytoplankton and zooplankton also influences species composition and population dynamics of other aquatic organisms including *Schistosomes* vector snails in aquatic ecosystems. Important abiotic factors determining microhabitats of snail populations include physical factors such as water current, temperature, turbidity, transparency and distribution of suspended solids, chemical factors such as ion concentration and dissolved gases in water (Ofoezie, 1999), as well as toxicological factors (Williamson *et al.,* 2004*)* As reported by (Handzel *et al.,* 2003), dense populations of certain species of snails were found in water contaminated by sewerage which has led to the speculation that the snails can be attracted by the increased food supply from organic waste matter. High alkalinity is believed to be associated with organic pollution.

The abundance of organic matter increases growth of algae which is known to be one of the best types of food for most snails (Rosso & MaCune, 2003). pH is rarely a factor limiting the distribution of the snails, while Pulmonate snail species increased with increase in dissolved oxygen (Ofoezie, 1999). However (Utzinger & Tanner, 2000) concluded that the distribution of freshwater snails is as a result of more complex interactions of different habitat factors. Typically, *Biomphalaria* prefers stagnant or slow moving water with low wave actions. Numerous epidemiological studies have been undertaken focusing primarily on distribution and burden of the disease in human (Tukahebwa *et al.,* 2013) however, information concerning the host vector is needed for control planning. This study presents insights on population abundance of snail intermediate hosts of *S. mansoni* in Mbita. The findings may be useful in designing of schistosomiasis control strategies based on identification of transmission hot spots.

2.4 Development of Trematodes in the Host Vector and Cercarial release

After hatching from the eggs, s*chistosome*s miracidia remain infective for about 8-12 hours in non flowing water and disperse over distance of 5 meters from the source of origin. On locating the host snail, miracidia penetrate tfhe epithelium cells of the snail and development inside the snails depend on the immunity of the molluscs which is both cellular and humoral (Bayne & Loker, 1987). Due to an intricate host- parasite evolutionary interplay, trematodes are highly specific for their mollusc host and miracidia of *S. mansoni* only develop successfully within *Biomphalaria (*Beaver *et al*., 1984*)*. Miracidia develops into primary sporocyts and secondary sporocyts that hence liberate cercariae which are then shaded out from snails when it is sunny and the temperature is warm. In most favorable conditions, the incubation period in vector snails lasts for a minimum of three to four weeks. Once patent, a host snail can shed cercariae for several months, (Fryer & Probert, 1988).

Classical detection is the simple way of detecting snails that shed cercariae. And a number of snails from endemic areas with high schistosomiasis transmission are expected to shed cercariae, however this may not always be the case as reported by other studies. (Kahigi, 2000) found out that in Lake Victoria waters along Kisumu beach there were few snails shedding cercariae. Only 1.04% of snails collected from Lake Victoria basin of Western Kenya shed cercariae whereas studies by (Standley *et al.*, 2010), reported that not a single snail collected from Sesse island of Uganda shed cercariae. The reason as to why this happen has been theorized in many perspectives of which one theory is based on the pre-patent and patent periods of snail host vector infection with cercariae. Mbita area has high prevalence of schistosomiasis Nagi *et al.*, (2014), and therefore detection of cercariae from collected vector snails was very necessary.

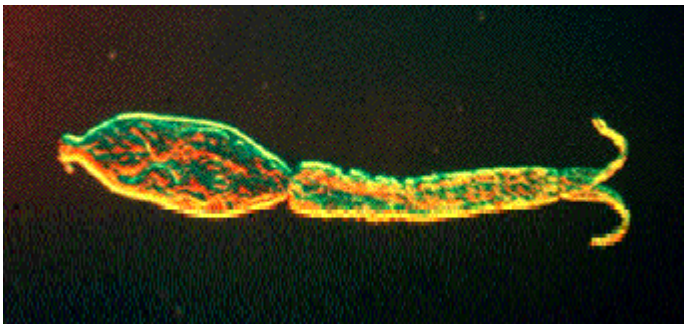

Plate 1: A forked tailed human cercariae

Cercariae are the larval form of the parasite liberated from the snail intermediate host for all trematode parasites. The cercariae of *schistosomes* are characterized by having long tails which are bifurcated at the end (the furcal rami) (plate 1). The tegument is covered with a trilaminate plasma membrane, and on the outer surface with a glycocalyx, and is equipped with spines and sensory papillae. Human *schistosomes* cercariae are released 25 to 30 days after the snail has been infected. They are sexually differentiated male and female, non-feeding stage of the life cycle and their energy requirements are met by stored glycogen in both the tail and the body (Sturrock *et al*., 2006).

As they are non-feeding, their energy stores will become depleted resulting in a reduced infectivity. The energy stores at the tail reserves are utilized first and the cercariae becomes incapable of swimming towards their host (Sturrock *et al*., 2006). Cercariae can remain infective under optimal conditions for between 5 to 8 hours after shedding, although in the field this is probably much less due to such factors as variation in water temperature (Sturrock *et al*., 2006). Like the miracidia, the cercariae exhibits a number of behavioral features that enable it to locate

its definitive host (WHO, 1988). These features include the cercariae show bursts of upwards swimming to bring them to the surface of the water, followed by periods of passive sinking. The cercariae are also affected by other stimuli such as shadows on the water, turbulence and chemicals secreted by the hosts' skin (Hussein *et al*., 2011). On finding the host, the cercariae will penetrate the human skin using secretions from glands in the head region and then sheds its tail to become a *schistosomulum* larva. This commences a migration through the body, until it reaches maturity as an adult worm in the liver. Cercariae from species of *schistosomes* that do not complete their life cycles in man can still penetrate human skin but may undergo a short migration before dying, giving rise to an allergic type of pathology (Fryer & Probert, 1988).

2.5 Life Cycle of *Schistosoma mansoni* in Man

The life cycle of Schstosomiasis in man runs from human to water to snail to water and back to human (Sturrock *et al*., 1994) (Fig.2.1). When man comes in contact with cercariae infested water, the cercariae penetrates the skin. During penetration, the cercariae shade off their tails and become *schistosomulae* which are carried via lymphatic system or blood vessels to the heart and then to the lungs. From the lungs the *schistosomulae* are carried to the liver where they grow and mature with long slender female becoming enclosed within the male *gynaecophoric* canal. Paired worms then migrate to settle in the veins of intestine for *S. mansoni*, *S. intercalatum, S. japonicum and S. mekongi* or in the veins of the bladder in the case of *S. haematobium.* Within 1 - 2 months the production of eggs starts and each female adult worm will produce approximately between 300 - 3000 eggs per day in the tiny vessels of the vesicle plexus in the case of *S. haematobium* and in terminal venules of the mesenteric system for *S. mansoni.* The eggs will work their way either through walls of the venules into intestine or through the

urinary bladder respectively using mechanical or enzymatic means before they are released with the feces or urine to begin the cycle again. Life cycle is completed between 2 – 3 months (Brown 1994).

Intestinal *schistosome* worms reside in the blood vessels lining of the intestine while urinary schistosome worms live in the blood vessels of the bladder. Only about a half of the eggs are excreted in the feces or in the urine, the rest of the eggs stay in the body damaging other vital organs. It is the eggs and not the worm which cause the damages to the liver, intestine, bladder and other organs. The disease has been traditionally tallied in terms of quantifiable morbidities, such as hepatosplenomegaly, hepatic fibrosis, and kidney / bladder inflammation. (Sturrock *et al*., 2006). However, the average persons will not experience all the advanced forms of disease but nonetheless will suffer from subtle morbidities such as anemia, abdominal pain, poor school performance and lowered work capacity (Sturrock *et al*., 2006).

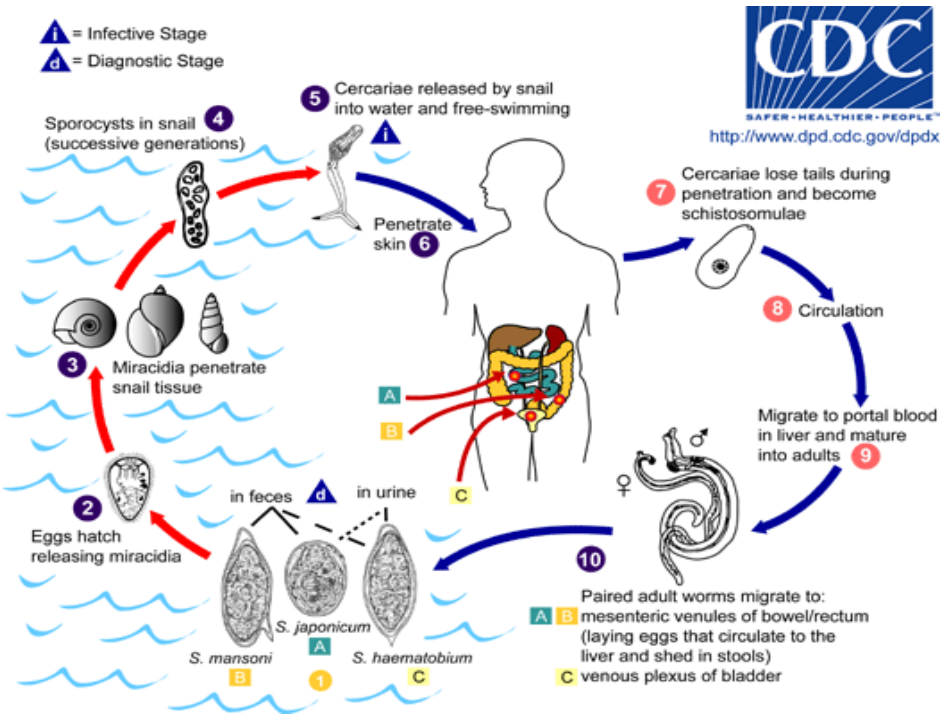

Fig.2.1 Lifecycle of Schistosomiasis (source: CDC)

2.6 Control of Schistosomiasis

According to (Nunn & Tapp., 2000), control programs based on oral drug delivery mostly praziquantel, reducesl morbidity and thereby prevent either contamination of aquatic snail habitat by egg infested human excreta or human exposure to cercariae infested water markedly reduces the chances of transmission. However, educating rural population to prevent human water contact and exposure to potential transmission site has little chance of success without the provision of safe water supplies and acceptable means of excreta disposal. Better progress was reported in stable urban centers where such measures were cost effective and had other many potential benefits (Brown 1994). (Webbe. & Harks., 1990) found that the most successful control program have been those that include mollusiciding even at a reduced level.

2.7 Vegetation Types Associated with *Biomphalaria* Host Snails

Fresh water snails abundance seem to be primarily influenced by vegetation from which snails get food, shelter, deposit their eggs and get protection from the waves (Alves & Blair, 1953; Ofulla *et al.*, 2013). Different species of aquatic vegetation such as water hyacinth (*Eichhornia crassipes*), water lily (*Nyamphea spp*), hippo grass and short grasses have been associated with the abundance of the intermediate snail hosts (Ofulla *et al*., 2013). *Biomphalaria sudanica* occurs close to the lake shore while *Biomphalaria choanomphala* prefers the bottom of the lake and *Biomphalaria pfeifferi* occurs in inland streams (Kariuki *et al*., 2004) . The common vegetation cover found in the collection sites were a combination of *Enydra fluactuants,Eichhornia crassipes* and *Cyprus gracilis*. Water hyacinth was found harboring more *Biomphalaria* host snails than *Bulinus* snail vector, (Kariuki *et al*., 2004). However, Ofulla's finding was that snails were found in the ambatch tree zone, hippo grass / water hyacinth zone and hippo grass zone. The study found out that Ofulla *et al*., (2013) did not report particular vegetation with the highest vector snails abundance neither was, Opisa *et al*., (2011), on a malacological survey and geographical distribution of vector snails for schistosomiasis within informal settlements of Kisumu city, Kenya, found no association between vegetation cover and high snail abundance. No single vegetation type has ever been reported to be harboring many *Biomphalaria* host snail vector or even comparing the snail abundance between different vegetation types.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted at Health Demographic Surveillance System (HDSS) in Mbita sub-county which is one of the five sub-counties of Homa Bay County in western Kenya. The area is located on the shores of Lake Victoria. HDSS Mbita covers an area of 163.28Km^2 and is between latitudes 0^{o}21' and 0^{o}32' South, and longitudes 34^{o}04' and 34^{o}24' East. This HDSS area comprises: Gembe East, Gembe West, Gembe Central, Rusinga East and Rusinga West locations. The HDSS in Mbita follows 11,182 households with a population of 55929 individuals (Keneko *et al.,* 2012). The ethnic group in this area is predominantly Luo (98%). The main economic activities in the area are fishing and subsistence farming. The annual rainfall in Mbita district is between 800-1900 mm. However, the rains are slightly lower in Rusinga Island with an annual range of 800–1200 mm. The long rains start from March to May while the onset of short rains is from September to December. The temperatures in this region ranges from 15^{o}C to 30^{o}C (Mbita Strategic plan 2008-2012).

3.2 Study Design

This was a cross sectional study design. Selected sites were mapped using hand held differential geographical global positioning system (GPS).

3.3 Sampling Procedures

Sixteen (16) sites were purposively selected based on the following: where people had direct water contact due to their routine activities such as swimming, collecting water for

domestic use, bathing, washing and occupational work like fishing or farming (Plate 2 & 3) on pages 18 and 19 shows snail sampling going on while women are using lake water for their domestic use. Plate 4 on page 20 shows a young boy searching for earth worm used as bait for fishing. The surrounding of the selected sites was assessed for the presence of human faeces.

3.3.1 Collection of *Biomphalaria* Snails

Only *Biomphalaria* host snails were collected by the researcher assisted by field assistants using hand held standard flat wire mesh scoop (2 mm mesh size), as per the methods of (Ouma *et al.*, 1986). The sampling period was fixed at 30 minutes per site as earlier described (Ofulla *et al*., 2013, Opisa *et al*., 2011). The sampling site was measured 20 m long, along the lake shore and 2m long into the main water body (plate 2 &3) (Imran *et al.*, 2014). The total area of the site scooped was 40 m^2 and scooping was performed in each and every site between 7.00 am and 9.30 am, the time when cercariae has not started shedding from snails due warmth in the water. The scoop was pushed under the vegetation once, lifted up when still under the vegetation and then shaken three times so that the snails were dislodged from the vegetation roots onto the scoop and then the scoop was withdrawn outside. With the help of a forceps, the vector snails were picked one by one as they were counted and recorded per scoop and then put in a perforated plastic container for transportation to Nagasaki University Laboratory in Mbita. The vegetation from which each scoop was pushed under during sampling was also recorded. The total number of snails collected per site was reported in meters square (m^2). Time of starting and ending collection per every site were noted down.

Plate 2 Snail sampling at one of the selected sites of Mbita shoreline

Plate 3: Snail sampling at one of the selected sites of Mbita shoreline as women are washing and bathing

Plate 4: A boy searching for earth worms at one of the selected sites

3.4 *Biomphalaria* Species Identification

Biomphalaria intermediate host snails which were collected from the selected sites were taken to Nagasaki University Laboratory at Mbita where identification was done up to species level based on shell morphology using the WHO snail identification guide (WHO, 1973) The species of the colleceted *Biomphalaria* snails was identified as *Biomphalaria sudanica.*

Table 3:1 Difference between *B.sudanica* and *B.pfeifferi* based on shell morphology

	B. sudanica	***B.peifferi***
Height	4.2 mm	5.52 mm
Shape of the shell	Large & flat	Discoid
Umbilicus	Occupies 1/2 of the diameter	Occupies 1/3 of the diameter
Diameter	16-17.2 mm	

3.5 Screening of Snails for S*chistosome* Infection

To determine whether the host snails were positive for *schistosome* cercariae, *Biomphalaria* vector snails were singly put in a 24 well culture plates containing 2 mls of clean and clear water (plate 5) and then exposed to bright artificial light for 3 hours (plate 6). After the three (3) hours shedding period was over, the wells containing snails were put under Olympus dissecting microscope (plate 7) and each well with snail inside was checked for shed cercariae which had the tendency of up and down movement using forked coiled tail (Sturrock *et al*., 2001.

Non-shedding snails were returned to the aquaria until the following day when they were again exposed to bright artificial light for 3 hours and were then re-examined under the dissecting microscope before declaring them negative.

Plate 5: Snails are singly put in the wells for shedding in the laboratory

Plate 6: Snails are exposed to artificial light for 3 hours for cercariae shedding

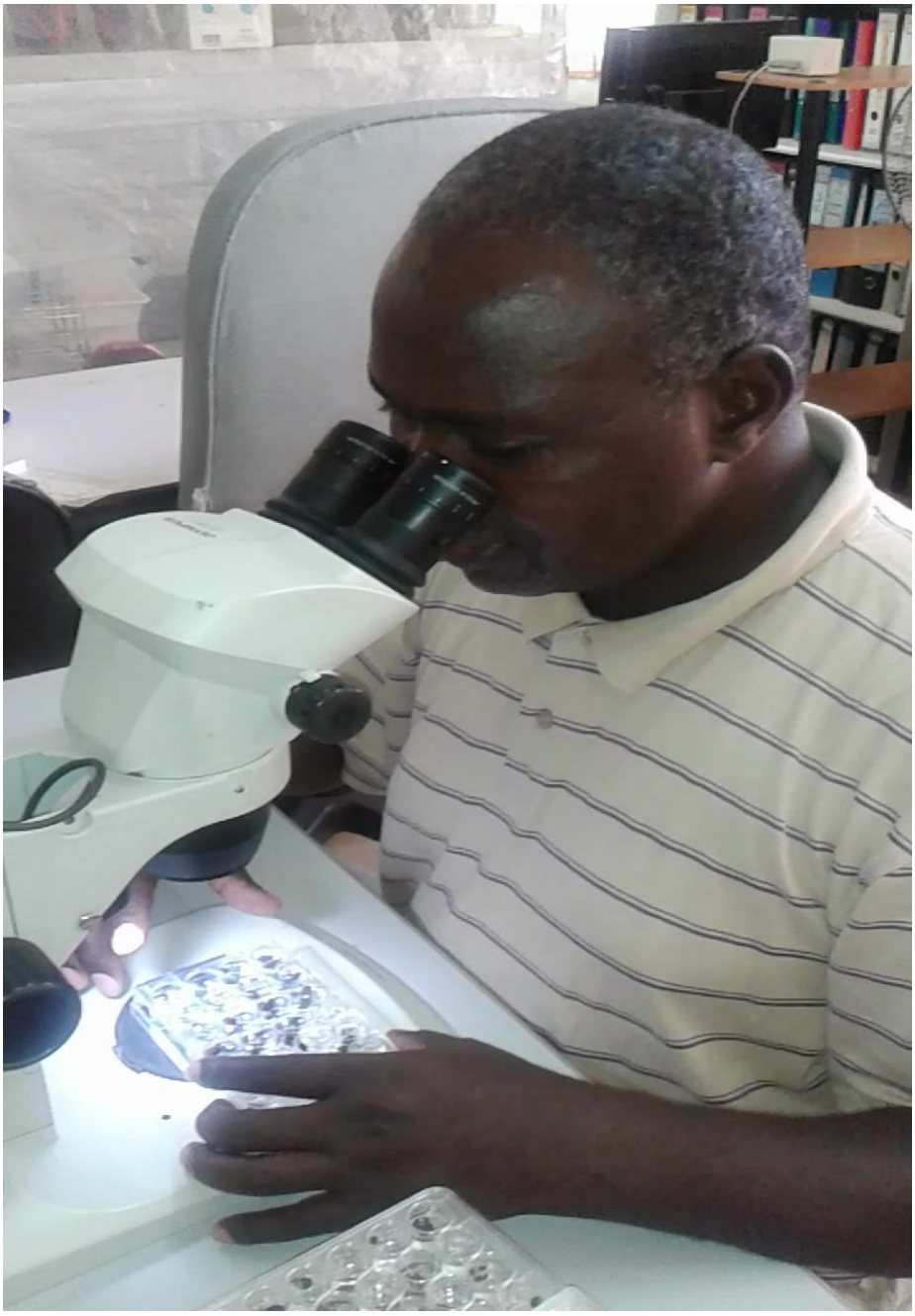

Plate 7: Examination of shed cercariae

3.6 Vegetatation Associated with Distribution of *Biomphalaria* Snails

A sample of vegetation types at each sampling site was collected and taken to Kenya Marine and Fisheries Research Institute (KEMFRI), Kisumu, for identification. The vegetation types from which the snails were scooped were: Buffalo spinach (*Enydra fluactuants*), water hyacinth (*Eichhornia crassipes*) and Sedge (*Cyprus gracilis*). Collected snails were labeled at the site and were then transported in separate perforated plastic containers to Nagasaki University laboratory in Mbita where shedding of *Biomphalaria* snails for cercariae took place. Plates 8 and 9 show vegetations *Eichhornia crassipes / Cyprus gracilis* and *Enydra flactuants* respectively

Plate 8 : Eichhornia crassipes / Cyprus gracilis

Plate 9: Enydra fluactuants

3.7 Data Management and Analyses

Generated data was initially entered and stored in Microsoft Excel and analysis conducted using SPSS. Analysis of variance (ANOVA) was used to compare mean differences in snail abundance between different sites and associated vegetation type. Significant differences in mean number of snails collected per site and associated vegetation type was determined using Tukey's post hoc test. Chi-square test was used to determine significant differences in proportions of cercariae positive snails between sites. All tests were two- tailed and a probability value of ≤ 0.05 was considered as statistically significant.

3.8 Limitations of the current study

Few potential limitations are noted in this study: Snails were sampled on a single day at each site, but due to seasonal variation in snail abundance in their natural habitat, (Kahigi, 2000) future surveys may be enhanced by sampling snails twice a month with an interval of two weeks for more precise snail abundance determination. Similarly, identification of snails in our study was based on morphological characteristics alone. Future studies may benefit from use of more sensitive molecular techniques to verify identity of snails and their averted positivity.

3.9 Study approval

Permission to conduct this study was obtained from the School of Graduate Studies (SGS) of Maseno University. Ethical approval was obtained from Maseno University Ethical and Review Commmittee (MUERC)

CHAPTER FOUR

RESULTS

Sixteen (16) selected sites were mapped using hand held differential geographical global positioning system (GPS). The sites were Uyoga, S-00.41838; E- 034.20200, Kombe A, S-00.43660; E-034.21940, Nyagina, S-00.41091; E-034.20896, Wakodo, S-00.43124; E-034.17620, Wath-Bur A, S-00.41004; E-034.21102, Bau, S-00.41023; E-034.21009, Wath-Bur B, S-00.41020; E-034.17989, Orundu, S-00.43404; E-034.17155, Ngou, S-00.43142; E-034.17587, Kombe B, S-00.43730; E-034.22158, Kobara, S-00.42356; E-034.18288, Koguna,S-00.45644; E-034.19313, Kalea, S-00.43682, E-034.21813, Kosata, S-00.413899, E-034.20616,Kigoda, S-00.41838, E-034.20200 and Kochola, S-00.42845; E-034.17155 (Table 4:2).

Table 4:2. Selected sites and their GPS co-ordinates

S/N	SITES	CO-ORDINATES	CO-ORDINATES
1	Uyoga	S-00.41838	E-034.20200
2	Kombe A	S-00.43660	E-034.21940
3	Nyagina	S-00.41091	E-034.20896
4	Wakodo	S-00.43124	E-034.17620
5	Wath Bur A	S-00.410004	E-034.21102
6	Bau	S-oo.41023	E-034.21009
7	Wath bur B	S-00.41020	E-034.17989
8	Orundu	S-00.43404	E-034.17155
9	Ngou	S-00.43142	E-034.17587
10	Kombe B	S-00.43730	E-034.22158
11	Kobara	S-00.42356	E-034.18288
12	Koguna	S-00.45644	E-034.19313
13	Kalea	S-00.43682	E-034.21813
14	Kosata	S-00.41389	E-034.20616
15	Kigoda	S-00.41838	E-034.20200
16	Kochola	S-00.42845	E-034.17155

4.1. Abundance of *B. sudanica* Snails per Site

A total of 3135 *Biomphalaria sudanica* snails were collected from 16 different sites. Analysis of Variance done on snails sampled from these sites showed a significant difference between the groups ($p<0.001$) (Table 4.3) below.

Table 4.3: ANOVA table showing the distributions of *B.sudanica* snails between groups

Number of snails	Sum of squares	df	Mean square	F	*P*-value
Between groups	1219.098	5	242.820	7.899	<0.001
Within groups	26114.427	846	30.868		
Total	27333.525	851			

Table 4.3: Statistical analysis based on abundance of *B. sudanica* between sites was done using Analysis of variance (ANOVA). *P*-value was considered significant at $P<0.005$

The number of snails collected differed significantly between the 16 sites ($F=11.735.df=15; 836$: $p<0.001$) (Table 4:4). Koguna, Orundu and Kombe-B had over three hundred *B. sudanica* snails collected from each site while W.Bur-B, Wakondo and W.Bur-A had over two hundred snails collected from each site. The rest of the sites had over one hundred *B. sudanica* snails collected from each site .The lowest snail collection was realized at Bau ($n=59$: $M=0.73$) and the most at Orundu ($n=356$: $M=11.87$), with Tukey's post hoc test indicating that the mean number of snails collected at Orundu differed significantly from all other sites ($P<0.001$).

Table 4.4: Abundance of *Biomphlaria* snails per site and the *P* values

Study site	Total Snail Collected per site	Mean Snail Collection	Mean Difference	ANOVA Between Groups	Tukey's Post hoc Significance
ORUNDU	**356**	11.87		*P*<0.001	
UYOGA	**118**	2.57	9.301*		*P*<0.001
KOMBE-A	**116**	2.07	9.795*		*P*<0.001
NYAGINA	**175**	3.37	8.501*		*P*<0.001
KIGODA	**121**	1.95	9.915*		*P*<0.001
WAKODA	**151**	3.78	8.092*		*P*<0.001
W. BUR (A)	**286**	6.22	5.649*		*P*<0.001
BAU	**59**	0.73	11.138*		*P*<0.001
W. BUR (B)	**238**	3.61	8.261*		*P*<0.001
KOCHOLA	**177**	3.22	8.648*		*P*<0.001
NGOU	**187**	4.07	7.801*		*P*<0.001
KALEA	**171**	3.42	8.447*		*P*<0.001
KOMBE- B	**339**	6.65	5.220*		*P*<0.001
KOBARA	**139**	2.14	9.728*		*P*<0.001
KOSATA	**174**	2.76	9.105*		*P*<0.001
KOGUNA	**328**	7.63	4.239		*P*= 0.051
TOTAL	**3135**				

Table 4.4: The number of snails collected differed significantly between the 16 sites (F=11.735.df=15; 836: p<0.001). The lowest snail collection was realized at Bau (M=0.73) and the most at Orundu (M=11.87).

4.2 *Schistosomes* Infection Prevalence of *B. sudanica* Snails per Site

The numbers of snails infected with human and non-human cercariae per site were determined (Table 4.5). Wath Bur-A had 286 *B. sudanica* snails collected 3 (1.05%) snails were positive with human cercariae while 6 (2.1%) snails shed non-human cercariae. In addition, Koguna had 328 *B. sudanica* snails of which 5 (1.52%) snails had non-human cercariae. From Wath Bur-B, 238 *B. sudanica* snails were collected with 4 (1.68%) snails shading non-human cercariae. Furthermore, Orundu had 356 snails with only 2 (0.56%) snails shedding human cercariae. Out of 177 *B. sudanica* snails collected from Kochola, 3 (1.7%) snails shed non-human cercariae. Additional analysis revealed that Ngou had 187 *B. sudanica* snails with 2 (1.06%) snails shedding non-human cercariae. The *B. sudanica* snails collected from Wakodo were 151 with 3 (0.20%) snails shed human cercariae. Uyoga had a total of 118 *B. sudanica* snails out of which 4 (3.34%) snails shed human cercariae while 2 (1.68%) snails shed non-human cercariae. Out of the 174 *B. sudanica* snails collected from Kosata, 3 (1.72%) snails shed non-human cercariae while from Kombe A, out of the 116 *B. sudanica* snails collected, 5 (4.31%) shed human cercariae. Nyagina had 175 *B. sudanica* snails, 4 (2.3%) snails shed human cercariae while 2 (1.1%) snails shed animal cerariae. Overall, a total of 21 (0.66%) shed human cercariae and 27 (0.86%) snails non-human cercariae. Moreover, human feces were seen in all the sites except Bau and Kosata.

Table 4.5: Number of *B. sudanica* snails and their *schistosomes* infection prevalence

Site	No. snails	Human *schistosome* Detected	Non-human *schistosome detected*	Human *Schistosome%*	Non- human *Schistosome %*	Presence of Human Feaces +/-ve	χ^2 square for proportion of +ve cercariae Snails between Sites.*P*<0.338
Koguna	328	0	5	0%	1.52%	+	
W. Bur-B	238	0	4	0%	1.68%	+	
Orundu	**356**	**2**	**0**	**0.56%**	**0%**	+	
Kochola	177	0	3	0%	1.70%	+	
Ngou	187	0	2	0%	1.07%	+	
Wakondo	**151**	**3**	**0**	**1.99%**	**0%**	+	
Uyoga	**118**	**4**	**2**	**3.39%**	**1.69%**	+	
Kosata	174	0	3	0%	1.72%	_	
Kobara	139	0	0	0%	0%	+	
Kombe –B	339	0	0	0%	0%	+	
Kalea	171	0	0	0%	0%	+	
Nyagina	**175**	**4**	**2**	**2.3%**	**1.14%**	+	
Kombe –A	**116**	**5**	**0**	**4.31%**	**0%**	+	
Kigoda	121	0	0	0%	0%	+	
Bau	59	0	0	0%	0%	_	
W. Bur-A	**286**	**3**	**6**	**1.05%**	**2.10%**	+	
Total	3135	21	27	0.67%	0.86%		

Table 4.5: 21 (0.67%) of *B. sudanica* snails sheded human cercariae and 27 (0.67%) sheded non- human cercariae, but no significance difference was found in the proportion of snails positive for cercariae between the sites (χ^2 (60)= 64.00; p<0.338).

4.3 Number of *Biomphalaria sudanica* Snails collected per Pure Vegetation and Mixed Vegetation

The distributions of *B. sudanica* snail host vector based on vegetation were analyzed (Table 4:6). *Enydra flactuants* had 1650 (52%) snails while *Cyprus gracilis* had 997 (32%) snails and *Eichhornia crassipes* had a paltry 24 (1 %) snails. Analysis of mixed vegetation snail abundance showed that *Enydra flactuants* mixed with *Cyprus gracilis* had 352 (11%) snails whereas *Eichhornia crassipes* mixed with *Cyprus gracilis* had 85 (3%) snails while *Enydra flactuants* mixed with *Eichhornia crassipes* had 27 (1%) snails

4.4 Abundance of *Biomphalaria sudanica* Snails based on Vegetation types

Significant mean differences (MD) was observed in number of *B. sudanica* snails collected per vegetation type ($F=7.899$. $df=5;846$; $p<0.001$). Significant differences in abundance of *B. sudanuca* snails based on different vegetation types in the 16 sites were determined using Tukey's post hoc test (Table 4:6). The mean number of *B. sudanica* snails collected from *Cyprus gracilis* was significantly higher than from *Enydra fluactuants* alone (MD= 2.032): $p<0.001$), *Eichhornia crassipes* (MD=4.19: $p=0.010$) and *Enydra fluactuants / Eichhornia crassipes* combination. *Cyprus gracilis / Enydra fluactuants* combination also gave higher mean number of snails than *Enydra fluactuants* alone (MD=2.516: $p=0.010$). *Eichhornia crassipes* alone (MD=4.634: $p=0.009$) and *Enydra fluactants / Eichhornia crassipes* combination (MD= 4.777: 0.002).

Table 4:6 Number of *B.sudanica* snails collected per pure and mixed vegetation and Tukey's post hoc test analysis

Vegetation Type		**Total Snail Collected per vegetation**	**Mean Snail Collection**	**Mean Difference**	**ANOVA Between Groups**	**Tukey's Post hoc test; *P* -value**
CG		997	5.19		P<0.001	
	EC	24	1.04	4.149*		*P*<.010
	EF	1650	3.16	2.032*		*P*=.000
	EFCG	352		-0.485		*P*=.991
	ECCG	85		1.497		*P*=.827
	EFEC	27		4.293*		*p*<.001

Table 4.6: *Cyprus gracilis* and *Enydra fluactuants*, were the main vegetation types associated with abundance of *Biomphalaria* snails.

Key: CG-*Cyprus gracilis*, EF-*Enydra fluactuants*, EC-*Eichhornia crassipes*, EFEC-*Enydra fluactuants/Eichhornia crassipes*, ECCG-*Eichhornia crassipes/Cyprus gracilis*

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CHAPTER FIVE

DISCUSSION

Fresh water snails abundance is primarily influenced by vegetation from which snails get food, shelter, deposit their eggs and get protection from the waves(Ofulla *et al.*, 2013). The study reported that a total of 3135 *Biomphalaria sudanica* snails were collected from the 16 purposively selected sites. Of the 16 sites, Orundu had the highest snail collection 356 (11.2%) while the lowest was Bau with 59 (1.9%). The results of the current study demonstrated high abundance of *Biomphalaria sudanica* host snail vectors of *S. mansoni* from the selected sites along the Lake Victoria shoreline of Mbita. The data showed that majority of the selected sites had many host vector snails of which three (3) sites had over 300 snails, two (2) sites over 200 snails and eleven (11) sites over 100 snails collected. This study results concur with that of Standley *et al*.,(2011) on the distribution of *Biomphalaria* (Gastropoda: Planorbidae) along the shoreline of Lake Victoria of Kenya, Uganda and Tanzania that showed not only are *Biomphalaria sudanica* snails widely found around the shoreline of Lake Victoria, but also their distribution is heterogeneous on a local scale. However, the result is inconsistent with that of Opisa *et al*., (2011) who found out that of the 25 sites sampled along the Lake Victoria shoreline of informal settlement of Kisumu city, 17 sites (68%) yielded only 11-50 snails. Furthermore the study showed that the number of snails collected after 30 minutes of scooping in an area of 40 m^2 from the selected sites was more compared to other studies. The low figures from other studies could be due to improper snail sampling, lack of proper identification of vegetation preferred by snails or the area of the site covered. The study therefore reported that, since *Biomphalaria sudanica* vector snails are found in the vegetation along the shoreline next to the open beaches

where people frequent, such places may be important transmission points taking into account that human feces were also found around the selected sites. Therefore, any human activity around those places will enhance the chances of schistosomiasis infection. As in plate 4 where the young boy is searching for earth worms in an almost stagnant water near the shoreline, he stands a high risk of getting infected if the cercariae are present so will be farmers who irrigate their farms with waters from such places or any person who might come in contact with such waters.

Meanwhile the study further observed that, of the 3135 snails collected only 21 (0.67%) shed human cercariae and 27 (0.86%) shed non-human cercariae. The result shows that very low percentage of *B. sudanica* host snails shed human cercariae and again there was no significance difference on the proportion of *schistosomes* positive snails per site even though all the sites except two had human feces around them. Although human feces were seen around some of the selected sites no test was done on them to determine their positivity and also to ascertain the viability of the *Schistosoma mansoni* eggs. It would be important that future study includes collection of such feces to be tested for the positivity and viability of *S.manssoni* eggs. Taken into account that the area of study is a high schistosomiasis transmission foci (Nagi *et al.*, 2014), it may raise some questions that very few vector snails shed human cercariae. However, the findings of this study is consistent with other previous study results from endemic areas with high transmissions where snail vector infection with cercariae were low and even some places had no single snail shedding cercariae. (Kahigi, 2000) on host snail vectors of *S. mansoni*: Dynamics, infection and re-infection rates in individuals occupationally exposed to Lake Victoria waters a long Kisumu beach observed that the cercarial shedding was low in the vector snails. The study further concurred with the findings of (Steinauer *et al.*, 2008) who found out

that in the Lake Victoria basin in Western Kenya, only 1.04% of the total collected vector snails from different sites shed cercariae. Furthermore (Standley *et al.,* 2010) , reported that there was not a single snail collected from the shoreline of Sesse island of Lake Victoria which shed cercariae.

Many researchers have come up with different explanation concerning these findings: First, the development of parasite inside the vector snails has stages (O'Keefe, 1985). After penetration of the miracidium into the host snail, it develops into primary and secondary sporocysts that hence liberate mature cercariae and this takes approximately four weeks (Sturrock *et al*., 2001), so it depends at what stage the vector snail was collected. Secondly, in pre-patent period very few snails will shed cercariae (Sow *et al.,* 2011), therefore identification of vector infection cannot be performed by classical detection (shedding) (Kariuki *et al*., 2004). Although classical detection is routinely used in the laboratories for identification of human *schistosomes* infected vector snails (Ouma *et al.,* 1986) few snails are always found shedding human cercariae and it is worth noting that molecular techniques could be the most accurate method in determining positive *Biomphalaria* host snails both in their pre-patent and patent stages of infection.

In determining the abundance of snails based on the vegetation types**,** the results revealed that there was significant difference in the abundance of *Biomphalaria* snails between *Cyprus gracilis* vs *Eichhornia crassipes, Cyprus gracilis* vs *Enydra flactuants* and *Cyprus gracilis* vs *Enydra flactuants* mixed with *Eichhornia crassipes.* Using vegetation *Eichhornia crassipes* as reference, the study found out that there was significant difference in the abundance of *Biomphalaria* snails between *Eichhornia crasipes* vs *Enydra flactuants* mixed with *Cyprus*

gracilis. On comparing *Enydra flactuants* vs *Eichhornia crassipes* mixed with *Cyprus gracilis* and *Enydra flactuants* vs *Enydra flactuants* mixed with *Cyprus gracilis*, the results showed significant difference in the abundance of *Biomphalaria* snails between *Enydra flactuants* vs *Enydra flactuants* mixed with *Cyprus gracilis*. The results further pointed out that, there was significant difference in *Biomphalaria* snail's abundance between *Enydra flactuants* mixed with *Cyprus gracilis* vs *Enydra flactuants* mixed with *Eichhornia crassipes*. Comparing the difference between two mean values of two different vegetations, Tukey's honestly significance difference showed that the number of snails collected from two different vegetation was statistically different. Therefore the result of this study is important when malacological survey is carried out.

The findings of the study compare positively to those of Teckla *et al.,* (2014) whom in a study on population abundance and disease transmission potential of snail intermediate host of human schistosomiasis in fishing community of Mwanza found out the common vegetation cover found in the collection sites were combination of water hyacinth and grass $p<0.001$. However, Teckla and his colleagues did not find snails from other vegetations around the Lake Victoria shoreline of Mwanza. The study results compare negatively to those of Ofulla *et al.,* (2013) who found out that more snails were collected from hippo grass mixed with *Eichhornia crassipes* along the shoreline of Lake Victoria. Furthermore no information is available on comparison of vegetation types associated with high population of *B. sudanica* vector snails. On the contrary, this study reported how snails were distributed in different vegetation types which are useful for future malacological survey. On descriptive statistics the study noted that *Enydra flactuants* had the highest snails (1650), followed with *Cyprus gracilis* (997) and *Eichhornia crassipes* having the least (24) snails. This could be due to the fact that many scoops were

pushed under the *Enydra flactuants* which means that it was the vegetation covering large areas of the sampled sites. It is also true that *Enydra fluactuants* are not thick and compact like *Eichhornia crassipes* and therefore many snails were found under them. Furthermore green algae which is snail's best food was found growing on the stems of the vegetation. However, Tukey's post hoc statistical analysis showed that *Cyprus gracilis* is the vegetation of choice for the vector snails. This finding is inconsistence with that of Ofulla *et al*.; (2013) and Opisa *et al*., (2011), who found out that *Eichhornia crassipes* and hippo grass harbors many *Biomphalaria* snails. As in the findings from other research work, snails get shelter and protection from various vegetation but like any other animal, food takes center stage. Rather than feeding directly on higher plants, snails are known to feed by grinding the decaying plants matter, microflora, algae and bacteria that covered it (Klumpp & Chu, 1980). Therefore, *Cyprus gracilis* being soft grass, the rate of drying and decaying is high and the growth of algae and other microflora on the decaying materials will be on the increase. Due to the availability of food -especially algae, the population of vector snails is most likely to rise. This study therefore noted that *Cyprus gracilis* and *Enydra fluactuants* are the vegetation of choice for vector snails and therefore future sampling should be directed at these vegetation types for better results. The finding of this study showed preferential habitation of some vegetation by *Biomphalaria* snails.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

The study found out that there was differential presence of *Biomphalaria sudanica* host snails vector in all the 16 purposively selected sites. Sampled intermediate host vector snails were exposed to artificial light for 3 hours and some were found to be infected with human cercariae. Vegetation cover being a necessity for the presence of snails, *Cyprus gracilis* and *Enydra flactuants* were found to be associated with abundance *of B. sudanica* host snails.

6.2 Conclusion

1. The findings from this study indicates that *Biomphalaria sudanica* host snail vectors were found in all the 16 selected sites and a total of 3135 snails were collected. This confirms that the population of host snail vector along the Lake Victoria shoreline of Mbita is high.
2. The study has shown that of the 3135 *Biomphalaria* snails collected, 21 (0.66%) shed human cercariae with 27 (0.85%) shed non-human cercariae.
3. Statistically, *Cyprus gracilis* had the highest number of vector snails followed with *Enydra flactuants* while *Eichhornia crassipes* had the least number of *Biomphalaria* snails.

6.3 Recommendation for the Study

1. The high abundance of *Biomphalaria* snails and confirmation of human cercariae shed from snails collected along the shoreline of Mbita calls for malacological survey for identification of more transmission sites.
2. Public Health Education to the community around Mbita as well as prospective control intervention to complement school based mass drug administration (MDA) program in reducing transmission and re-infection- is necessary.
3. The county government should put up pit latrines near the beaches with high human activities for proper human waste disposal in order to reduce water contamination with human feces.
4. Sign post should be erected on the sites where *Biomphalaria* snails with human cercariae are found directing people not go beyond the safe place.

6.4 Recommendation for Future Research

1. More sensitive molecular techniques like PCR should be used to verify the positivity of *Biomphalaria* snails with human *schistosomes* instead of relying on routinely done classical detection.
2. Cercariometry should be done alongside snail sampling to confirm whether the site from where the sampling is done has cercariae already shed in the water or not.
3. Human feaces found around the sampling sites should be sampled to a certain the viability of *schistosomes* eggs by doing hatchability test for miracidium recovery.

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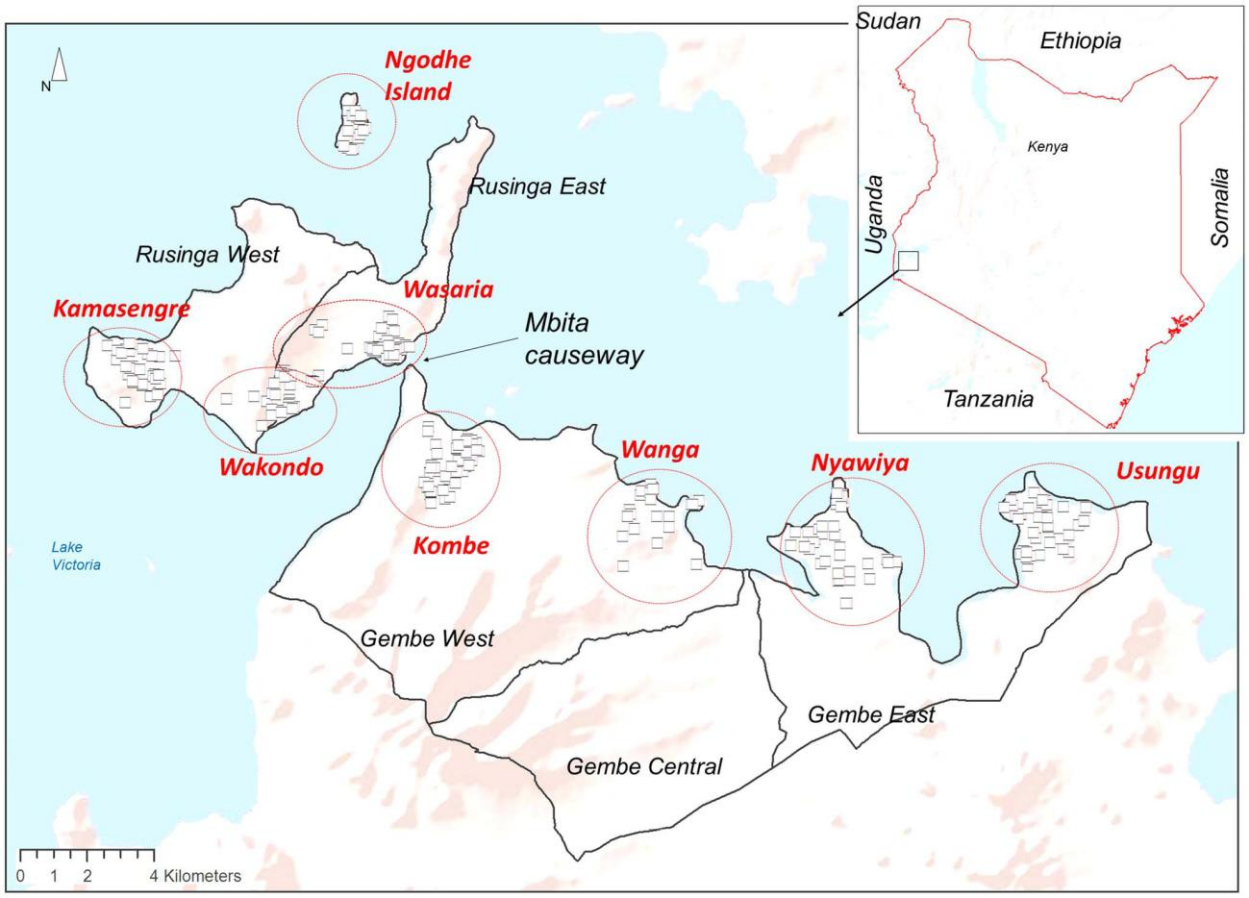
APPENDICES

APPENDIX 1

Map of proposed study area



MASENO UNIVERSITY ETHICS REVIEW COMMITTEE

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Private Bag – 40105, Maseno, Kenya
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FROM: Secretary - MUERC

DATE: 18th December, 2015

TO: Sabiano Odero Obonyo
PG/MSc/PH/00061/ 2013
Department of Biomedical Sciences and Technology
School of Public Health and Community Development, Maseno University
P. O. Box, Private Bag, Maseno, Kenya

REF: MSU/DRPI/MUERC/00256/15

RE: Spartial Distribution and Schistosomes infection Prevalence of *Biomphalaria* Snails along Lake Victoria Shoreline of Mbita, Homabay County, Kenya. Proposal Reference Number MSU/DRPI/MUERC/00256/15

This is to inform you that the Maseno University Ethics Review Committee (MUERC) determined that the ethics issues raised at the initial review were adequately addressed in the revised proposal. Consequently, the study is granted approval for implementation effective this 18th day of December, 2015 for a period of one (1) year.

Please note that authorization to conduct this study will automatically expire on 17th December, 2016. If you plan to continue with the study beyond this date, please submit an application for continuation approval to the MUERC Secretariat by 18th November, 2016.

Approval for continuation of the study will be subject to successful submission of an annual progress report that is to reach the MUERC Secretariat by 18th November, 2016.

Please note that any unanticipated problems resulting from the conduct of this study must be reported to MUERC. You are required to submit any proposed changes to this study to MUERC for review and approval prior to initiation. Please advice MUERC when the study is completed or discontinued.

Thank you.

Yours faithfully,

DIRECTORATE OF RESEARCH PUBLICATION & CONSULTANCIES 18 DEC 2015 MASENO UNIVERSITY

Dr. Bonuke Anyona,
Secretary,
Maseno University Ethics Review Committee.

Cc: Chairman,
Maseno University Ethics Review Committee.