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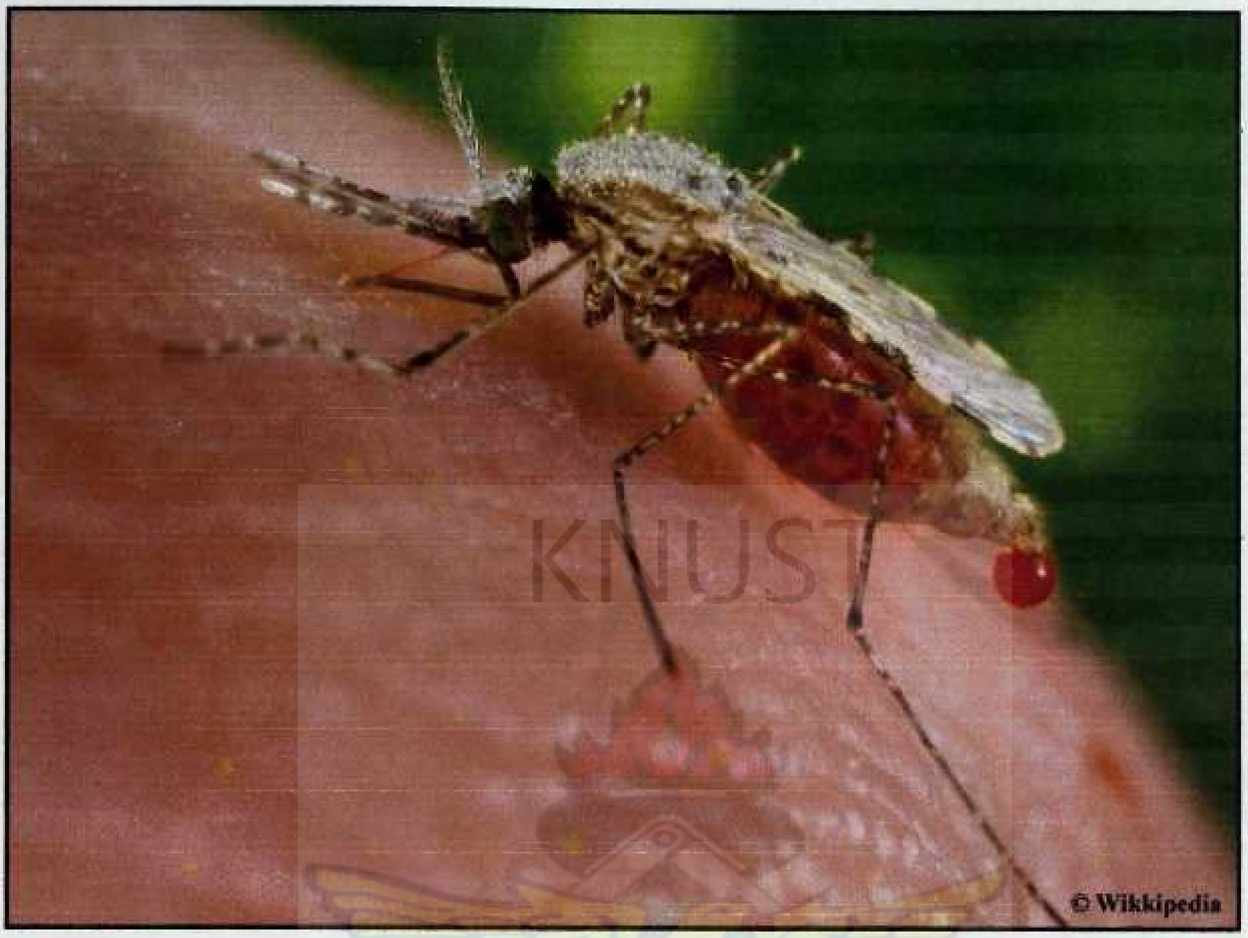

EFFECTS OF RESERVOIR CHARACTERISTICS ON MALARIA AND ITS VECTOR ABUNDANCE: A CASE STUDY OF THE BONGO DISTRICT

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KUMASI-GHANA

Enoch Ofosu
MSc. Thesis
April, 2009

Kwame Nkrumah University of
Science and Technology

WRESP – KNUST

Water Resources and Environmental Sanitation Project in cooperation with UNESCO-IHE

Faculty of Civil and Geomatic Engineering
Department of Civil Engineering

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KNUST

Master of Science Thesis
By
Enoch Ofosu

Supervisors
Prof. Mrs. Esi Awuah
Mr. Frank Ohene Annor

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EFFECTS OF RESERVOIR CHARACTERISTICS ON MALARIA AND ITS VECTOR ABUNDANCE: A CASE STUDY OF THE BONGO DISTRICT

By

Enoch Ofosu, BSc. (Hons.)

DISSERTATION

Submitted in Partial Fulfilment of Requirements of

the Board of Graduate Studies of KNUST

For the Degree of

MASTER OF SCIENCE

in

Water Resources Engineering and Management

April, 2009

CERTIFICATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Enoch Ofosu **(20064399)**	Signature	09/05/2009 Date
Certified by: Prof. Dr. Esi Awuah **(Supervisor)**	Signature	29/04/2009 Date
Mr. Frank Ohene Annor **(Second Supervisor)**	Signature	08/05/09 Date
Prof. S.K. Ampadu **(Head of Department)**	Signature	10/05/2009 Date

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To God be the Glory

Dedicated to

Mr. & Mrs. Adjei- Amoako
(Suhum)

"For the vision awaits an appointed time; it speaks of the end and will not prove false. Though it lingers, wait for it; it will certainly come and will not delay.'

(Habakkuk 2: 2-3)

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ABSTRACT

In the seven (7) administrative zones of the Bongo District of the Upper East Region of Ghana the occurrences of malaria and relative abundance of the principal malaria vector, Anopheles species, were studied as a function of the presence and characteristics of reservoirs during the rainy season. Case studies in the sub-Sahara Africa show that malaria transmission may increase decrease or remain largely unchanged as a consequence of reservoir presence. There was a weak negative correlation between distance from reservoir to settlement and adult anopheles abundance. Also there was a very weak correlation between surface area of reservoirs and adult Anopheles mosquito abundance. Percentage of inhabitants using insecticide treated nets, livestock population density, human population density and Anopheles mosquito abundance affected the occurrence of malaria. The results suggest that vector control targeted at reservoir characteristics and larval control would be an effective approach for malaria control in the Bongo District.

KEY WORDS: *Bongo District, Reservoir, Anopheles species, Malaria, Vector abundance,*

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List of Abbreviations

ANOVA	Analysis of Variance
FGD	Focus Group Discussion
GIDA	Ghana Irrigation Development Authority
GLOWA	Globaler Wandel des Wasserkreislaufes (Global Change and the Hydrologic Cycle)
BDHA	Bongo District Health Administration
ITN	Insecticide Treated Net
KII	Key Informants Interview
LT	Light Trap
OPD	Out Patient Department
WUA	Water Users Association

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I also thank my family for all the support during this period.

CHAPTER ONE

1. INTRODUCTION

Reservoirs have been constructed throughout the world, for water harvesting, storage and irrigation. Most of these reservoirs serve multiple purposes, such as drinking water supply, fishing and watering of animals, and are very well adapted to the environment. Apart from the economic benefits of irrigation and livestock rearing, improved access to water contributes to better health by increased nutritional status, improved hygiene and reduced water-washed diseases, notably infectious skin and eye diseases, however, there are also significant negative impacts associated with reservoirs, specifically increased transmission of water-related diseases, such as malaria (Ijumba & Lindsay 2001). As the planning, construction or rehabilitation of these dams is usually undertaken by communities themselves, health impact assessments are not carried out systematically. However, the total health impact of tens or even hundreds of reservoirs in a country cumulated over time can be quite substantial with positive and negative impacts affecting different population groups (Hunter et al. 1993). The added value of studying reservoirs in West Africa is that they seem to contribute very positively to rural development, and this study would help to identify means of minimizing potential negative impacts.

A number of studies conducted in East and Central Africa suggest that an increase of areas of water reservoirs could negatively affect the health of local populations (Oomen et al. 1990). The construction of reservoirs, water distribution systems and drainage can increase the number of breeding sites for mosquitoes, stretch the duration of their breeding season, and extend the average longevity of mosquitoes. It can therefore affect the transmission intensity and incidence rate of malaria. Similarly, hydrological changes induced by reservoir development can result in outbreaks of other water-related vector-borne diseases such as schistosomiasis, liver flukes, filariasis, onhocerciasis, dangue fever, yellow fever, chikungunyan fever, Rift valley fever and encephalitis (Oomen et al. 1990).

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Poor health is an obstacle to agricultural and other developmental aspirations in the rural areas of West Africa, and can counter potential benefits derived from the reservoir development. It demands therefore that an assessment of the health risk associated with these water retaining structures are made and also come out with strategies to minimize such risks for vulnerable groups. This study makes a comparative assessment of the effects of reservoir characteristics on malaria and its vector abundance in the Bongo District of Ghana.

1.1. Justification

It is now widely recognized that if sub-Saharan Africa is to meet the poverty reduction and food security targets of the Millennium Development Goals, the decline in investment in agriculture must be reversed through the building of reservoirs and other water retaining structures (FAO 2002). The New Partnership for Africa's Development (NEPAD) has called for $US37 billion of new investment in the agriculture sector by 2015 (NEPAD ,2003) and the paper of the Commission for Africa proposed a doubling of the area of arable land under irrigation by 2015, with an estimated cost of $US2 billion per year (Commission for Africa ,2005). The World Water Development Paper calls for "substantial increases in investment in rural areas, where water management plays a central role in raising the productivity of agriculture through reservoir development" (United Nations, 2006).

Recent World Bank corporate strategies identify the need for a "reengagement in agricultural water management," particularly in sub-Saharan Africa (World Bank, 2006).

It is therefore to be expected that investments in reservoir projects and their possible impact on vector population will increase substantially in the near future. However, should this happen, there is a great need for an assessment of the possible effects (if any) of these reservoir on malaria and its vector abundance disease vector in the sub-Sahara Africa. In West Africa, several studies tried to determine the impact of irrigation on the transmission of vector-borne diseases such as malaria. Inland valleys with irrigated rice cultivation turned out to not always increase the risk of malaria because of the complicated interactions between mosquitoes, people and health seeking behaviour (e.g. Ijumba & Lindsay 2001, Briët *et al.*,2003, De Plaen *et al.*,2003). Less information is available on the impacts of small dams, though schistosomiasis was reported to spread with the development of hundreds of small agro-pastoral dams in Cameroon (Ripert & Raccurt 1987), Côte d'Ivoire (Le Guen 2000), in Ghana (Hunter 2003), and Burkina Faso (Poda *et al.* 2003). The impact on malaria was much less clear, as *Anopheles* mosquitoes were found mainly in cattle hoof prints near the reservoirs, rather than in the dam and related infrastructure itself (Cecchi, 2004).

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1.2. Research Hypothesis

1. The study hypothesizes that:

the presence of reservoirs does not significantly contribute to increase in vector abundance and subsequent incidence of malaria (Mutero et al. 2004).

2. The study again hypothesizes that the type of water management and drainage systems of the small dams are potential reason for variation in the occurrence of malaria vectors.

1.3. Main objectives

The main objective of the study is to make a comparative assessment of the effects of reservoirs on malaria and its vector abundance in the sub-districts of Bongo.

The specific objectives are:

1. To assess the relative abundance of *Anopheles species* in the Sub-districts of Bongo in relation to presence of reservoirs.
2. To assess the contribution of various reservoir characteristics to *Anopheles* population abundance.
3. To find out the relationship between the incidence of malaria and their corresponding disease vector population abundance.

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2. LITERATURE REVIEW

2.1. Malaria

Malaria in man is a state of infection by one of four parasites known as plasmodium, *Plasmodium vivax*, *Plasmodium falciparum*, *Plasmodium malariae* and *Plasmodium ovale* (Goma,1966). According to (Kettle ,1990), malaria is the most widespread and persistent disease of mankind. Even today, many tens of millions of the world's population each year suffer from malaria. Malaria is ancient disease recognized by Hippocrates about 400B.C. who described three characteristics stages of an attack as chilly, vigour, high fever and profuse sweating. Mortality from malaria can be high and more than a million infants and young children in the tropical Africa still die from malaria every year. According to (WHO, 1982), malaria is said to be responsible for high infant mortality rates among many population in Tropical and subtropical climates of the world. Also a great concern is its chronic effect of debility and general impairment of well-being. Thus it hinders the economic and social progress of communities where malaria is widespread. Malaria is considered a global problem: it is most persistent and most deadly in poorer areas of the tropics.

2.2. Malaria morbidity

In its mild form, malaria presents as a febrile illness associated with other non specific signs and symptoms. No clinical syndrome is entirely specific for malaria. The fever may be periodic and interspersed with febrile intervals. In endemic areas, malaria is usually diagnosed clinically and only rarely confirmed by the presence of the parasite in the peripheral blood. However, in endemic countries there are usually many more asymptomatic carriers of the parasite. Hence even parasitological diagnosis does not necessarily indicate that the malaria is the cause of the disease (Greenwood *et al.* 1987). Recent work has provided a quantitative framework for the analysis estimating probabilities that fever episodes are indeed of malaria aetiology as a function of parasite density (Smith *et al.* 1995). Severe life threatening malaria (e.g. cerebral malaria, respiratory distress, severe anaemia, pulmonary oedema, renal failure) and deaths are almost exclusively due to *P. falciparum* malaria. These complications tend to be the main reasons for hospital admission of young children in endemic areas, but pulmonary oedema and renal failure are rare in children. The frequency and pattern of distribution of severe forms of *P. falciparum* malaria vary depending on the level of transmission areas (Snow *et al.* 1994, Trape *et al.* 1987).

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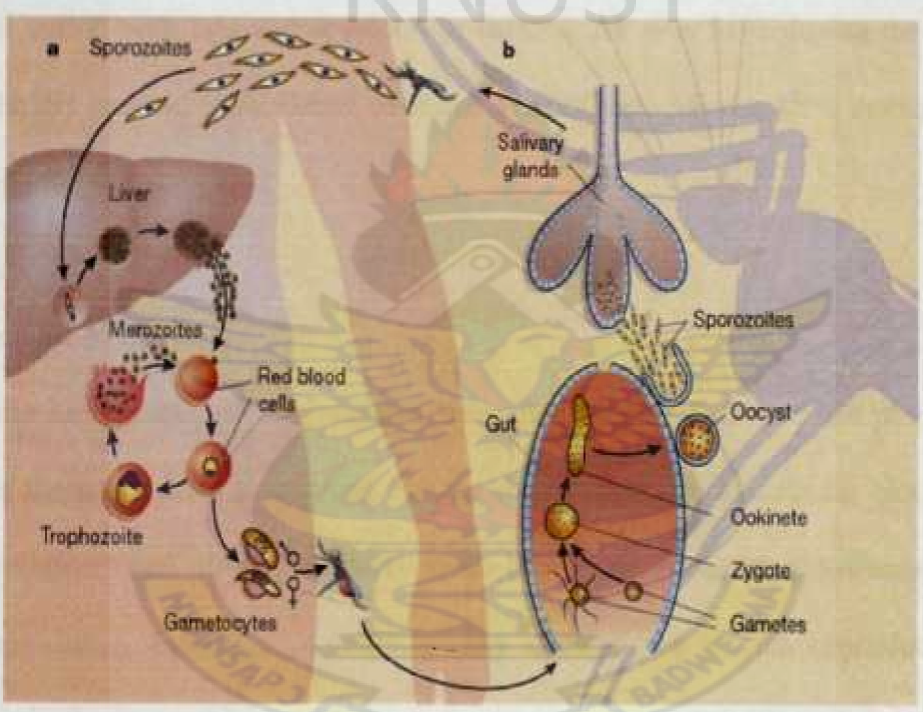

Figure 2.1 : Illustration of life-cycle of *plasmodium spp* in man and mosquito.

2.3. Malaria incidence

The malaria incidence rate can be estimated from a cohort of newborn children by observing the onset of parasitaemia and clinical symptoms and the use of a mathematical model like the model of Bekessy (Gazin *et al.* 1988). Using this logistic regression model of Bekessy in a juvenile population of 2 villages in Burkina Faso (Tago and Kongodjan), the authors have obtained a daily incidence rate of 0.010 from January to July, 0.026 from July to September and 0.004 from

November to May. Using the same model, a study in Idete village infants, Tanzania, found a crude incidence of 0.021 per day (Kitua *et al.* 1996). It is well recognized that, in highly endemic areas, newborn infants are relatively protected against mild clinical malaria and severe malaria, compared to older children (Brabin 1990, Snow *et al.*1998). To determine the true incidence of clinical malaria in this age group, appropriate case definitions are needed. Logistic regression has been used to model the risk of fever as a function of parasite density, to estimate the fraction of fever cases that are attributable to malaria (the attributable fraction, AF), and to estimate the sensitivity and specificity of case definitions using different parasites density thresholds (Smith *et al.* 1994, MacGuinness *et al.* 1998). In a study in southern Ghana, the estimated population AF was 44%, and varied with age and season. For infants, AF was 51% during the wet season and 22% during the dry season; for children over one year of age, AF was 89% during the wet season and 36% during the dry season

2.4. Effects of Malaria

It is one of the key causes of absenteeism from work, school and of the physical and moral degradation of the individual. It destroys lives, reduces agricultural outputs, blocks exploitations of natural resources and thwarts efforts made by many countries towards industrial and commercial expansion. However, equally it may show down human reproduction and hence delay the seemingly inevitable world food shortage as a result of population expansion. The disease constitutes one of the leading causes of mortality and morbidity particularly among infants. (Goma ,1966).

Malaria has caused the abandonment of large areas of eastern countries, Asian-Greece, Mesopotamia empire (Babylon and Assyria) and Roman empire usually the best watered farming land. In South Africa malaria parasite carried by *A. gambiae and A. Funestus* became so sever that some farmers began selling their lands moving away. Malaria remains the world's most devastating human parasitic infection affecting over 40% of the world's population (WHO, 2005). Malaria causes about 400–900 million cases of fever and approximately one to three million deaths annually; this represents at least one death every 30 seconds. The vast majority of cases occur in children under the age of 5 years; pregnant women are also especially vulnerable. It is in sub-Saharan Africa where 85– 90% of malaria fatalities occur. In Ghana, malaria is hyper endemic accounting for more than 44% of reported outpatient visits and an estimated 22% of under five mortality (GHS, 2004).

2.5. The importance of reservoirs

Poverty is widespread in the sub-Sahara Africa and there is a very high degree of household food insecurity among the rural population. Some of the reasons are the dependence of the farmers on a single cropping season for their incomes, low and erratic rainfall which limits the range of crops that can be cultivated and high risk of crop failure (IFAD, 1999). High rainfall intensities exceeding soil infiltration and resulting in high rates of runoff are common. To exploit the runoff potential, reservoirs have been constructed in the region by various agencies. The reservoirs capture surface runoff during the rainy season making water available in the dry season. The reservoirs are for the provision of water mainly for irrigation and for livestock watering, aquaculture, and domestic use. They also serve as habitats for wildlife, a source of recreation and a source of water for construction. Sixty percent of the water in reservoirs is allocated to livestock, domestic and irrigation where as the remaining 40% is allocated to evaporation, dead storage and seepage. For the useful portion of 60%, irrigation constitutes the largest consumer of the water because in the dry season, vegetable gardening is the main activity and as a source of income for the people. Community needs assessment study conducted in the Upper East of Ghana indicates that farmers benefit more from 0.1ha of land in the dry season compared to 0.8ha of land in the rainy season (Gyasi and Schiffer, 2005). Availability of water in the reservoirs in the dry season also reduces livestock theft which is a major occurrence in the dry season when

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animals stray away in search for water. Livestock is another source of income for the inhabitants, inadequate water for watering the animals, impacts significantly on local livelihoods.

The reservoirs have a significant effect on downstream flows as they provide a buffer by delaying and diminishing floods because water can be (temporarily) stored.

They also recharge the groundwater table, thus increasing the base flow in the downstream part of the catchment area, stabilizing the water supply to wells (IFAD, 1999). However reservoirs could also serve as major breeding sites for mosquitoes.

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2.6. Health Impacts of Reservoirs

Recent reviews added to the understanding of the impacts of water resources development, specifically dams, on health (Jobin 1999) and particularly malaria (Keiser et al. 2005a) is that reservoir development can adversely impact health through the extension of water-related vector-borne diseases (such as malaria, schistosomiasis, liver flukes, filariasis, onchocerciasis, dengue fever, yellow fever, Rift Valley fever and encephalitis) (Oomen et al. 1990). A number of complex interlinked factors determine the severity of potential adverse impacts. For example, increasing mosquito-breeding habitats, especially in rice fields, does not necessarily result in increased prevalence of malaria or other mosquito-borne diseases such as lymphatic filariasis (Erlanger et al. 2005) and Japanese encephalitis (Keiser et al. 2005b). Case studies show that malaria transmission may increase, decrease or remain largely unchanged as a consequence of irrigation. In studies in Tanzania, lower malaria prevalence in villages with irrigation, compared to those without, has been attributed to a better socioeconomic status (Ijumba and Lindsay 2001). In West Africa, intensified rice cultivation in the semiarid savanna has led to an increase in *Anopheles* mosquitoes, but because mosquito abundance is high, it has created a demand for bed nets, which farmers can afford through their improved income (Parent et al. 2002). Similar studies in Mwea, Kenya, have suggested that an improved socioeconomic status does not entirely explain the relatively low malaria prevalence in irrigated villages, since poverty and social problems are rampant in both irrigated and non-irrigated villages. The most compelling explanation of low prevalence in the irrigated villages appears to be the tendency by the vector mosquitoes to feed more on cattle than on people (Mutero et al. 2004). Contrary to widespread belief, community-based and small-scale agricultural interventions also have environmental and health impacts (McCartney et al. 2007; Mutero et al. 2004). Currently, these impacts are usually disregarded and, in many instances, there is almost no knowledge of the cumulative environmental and health impacts arising as a consequence of up-scaling. For example, small earth dams are being widely promoted, particularly in Sahelian countries, for multiple uses of water including irrigation and livestock watering. In many places, the creation of small reservoirs has resulted in increased household income through productive agricultural activities upstream and downstream of the dam. However, the potential environmental (e.g., on hydrology) and health consequences (e.g., on malaria and schistosomiasis) are rarely considered and the impacts of many thousands of dams are unclear (Hunter et al. 1993). In Cameroon, the development of hundreds of small agro-pastoral dams has led to a rapid spread of schistosomiasis (Ripert and Raccurt 1987). Similar results have been reported from Côte d'Ivoire (Le Guen 2000; Ghana (Hunter 2003) and Burkina Faso (Poda et al. 2003). In Ethiopia, the construction of small dams in the semiarid northern region of Tigray has led to increased spread of malaria. Seasonal transmission changed to year-round transmission because of the continuous availability of surface water, and children living near small dams had a 7-14 times higher risk of being infected than those living further away (Ghebreyesus et al. 1999). The main health-related costs to households relate to increases in time spent sick and not working, as well as time spent caring for the sick. Disease incidence has also led to reduction in labor allocation to off-farm activities and a decline in non-farm income share, thus adversely affecting the households' ability to cope with risk (Senzanje et al. 2002). Nonetheless, because agricultural yield and farm profit significantly increased in villages close to small dams, even after accounting for health costs, the marginal benefits of investment in water outweighed the costs (Ersado 2005).

2.7. Irrigation and malaria transmission in sub-Saharan Africa

African case studies show that malaria transmission may increase, decrease or remain largely unchanged as a consequence of irrigation (Ijumba and Lindsay, 2001). In West Africa, for instance, intensified rice cultivation in the semi-arid savanna led to an increase in Anopheles, but fewer mosquitoes were infected with malaria. Moreover, mosquito abundance was high, creating a demand for bed nets, which farmers could afford through their improved income. Consequently, malaria transmission did not increase with irrigation development in several. In Mali, malaria transmission changed from seasonal to perennial in irrigated areas, but overall incidence was half that of the rain-fed areas (Sissoko et al., 2004). In Kenya, the presence of livestock appeared to play a crucial role in explaining the differences between irrigated and non-irrigated areas. There were many more head of cattle in the irrigated area and the dominant malaria vector mosquito preferred to feed on cattle rather than on humans (Mutero et al., 2004).

2.8. Mosquito Bionomics

Bionomics deals with the relationship between a given species and its environment. An understanding of mosquito bionomics is therefore of key importance in the epidemiology of mosquito born diseases and in planning methods of mosquito control. Water is an essential component of the mosquito environment and whether is running, standing, clean or polluted sweet or brackish shaded or sunlit, frequently determines which species of mosquitoes breeds in it. (WHO, 1982)

2.9. Mosquito

Mosquitoes are among the best known group of insects, because of their importance to man as pests and vectors of some of the most distressing human diseases (Goma, 1966). Mosquitoes are important vectors of several tropical diseases including malaria, filariasis and numerous viral diseases, such as danque, Japanese encephalitis and yellow fever. In countries with a temperate climate they are more important as nuisance pests than vectors of disease pathogens (Rozendall, 1997). Mosquitoes are small, two-winged insects belonging to the family *Culicidae* of the order *Diptera* (two winged flies). They are distinguished from most flies by a combination of the following characteristics; (i) the presence of scales on the wing veins, (ii) a fringe of scales along the posterior margin of the wing and (iii) a characteristic wing venation, the second, fourth and fifth longitudinal veins being branched. Mosquitoes are distributed widely through out the world; practically no part of the globe that can serve for human existence is free from them. Some species live at altitudes of over 3,700m while others live in mines as far as 1,000m below sea levels. There are about 3,000 species of mosquitoes of which about 100 are vectors of human diseases. Control measures are generally directed against only one or a few of the most important species and can be aimed at the adults or the larvae (Rozendall, 1997). Man has suffered from the activities of mosquitoes from time immemorial. It is believed that as man's most important insect pests, they have influenced and still do influence his selection for living, working and playing site. They have scourged him with their vicious biting attacks and caused him considerable annoyance by the insistent buzzing but more seriously they transmit a number of distressing diseases. Mosquitoes also transmit a number of diseases to domestic animals. In general, therefore, they may be said to affect human welfare by direct annoyance; by transmission of diseases, and by limiting human habitation and consequently reducing land values (Goma 1966).

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Malaria is estimated to be the cause of between 1.5 and 2.7 million deaths each year and the situation is worsening in many parts of the developing world as a result of increasing places of procreation through building of small dams or reservoirs. The most notorious malaria vector for malaria in West Africa is the *Anopheles gambiae*. It is also the vector for *bancroftian filariasis*. In addition *Culex quinquefasciatus* is a considerable nuisance in all tropical and subtropical urban areas, disrupting the inhabitants sleep to the extent of causing fatigue from the lack of rest (WHO, 1988).

2.10. Classification and Identification of mosquitoes.

Mosquitoes are two –winged insects belonging to the order *Diptera*, family *Culicidae* and subfamily *culicinae* and, *Anophelinae* and *Toxorhynchitinae*. The first two are characterised by having long conspicuous needle-shaped mouth parts, comprising the proboscis, which in the female is used in sucking blood (WHO, 1982). There are some 3,100 species of mosquitoes belonging to 34 genera, arranged in three subfamilies: *Toxorhynchitinae, Anophelinae* and *Culicinae.* The most important man biting mosquitoes belong to the genera *Anopheles*, *Culex, Aedes, Mansonia, Haemagogus, Sabethes* and *Psorophora* (Service, 1980). The subfamily *Toxorhynchitinae* includes only one genus *Toxorhynchitinae* that occurs mainly in the tropics and subtropics of the oriental, Neotropical and Afrotropical regions. *Toxorhynchites* are large, metallic colour mosquitoes, which do not suck blood and in which the proboscis is markedly bent. Morphologically they resemble *Culicine* mosquitoes in the structure of the larvae and adult can not bite. They are therefore of no medicinal importance. The small collections of water, such as in tree holes, pitcher plats, bamboo, and cut ends of stumps are their natural habitats. They breed also in man-made containers such as cans and pots. Their larvae are predacious on other mosquito larvae and hence have been introduced in French Polynesia and Samoa to control *A. Aegypti* and *A. Polynesiensi* (Kettle, 1990). Subfamily *Anophelinae* contains the genera

Birronella, *Chagasia* and *Anopheles* but the first two have a restricted distribution and are of no medical importance (Service 1980). About 380 specie of *Anopheles* occur around the world, and 60 of these species are sufficiently attracted to humans to act as vectors of malaria (Rozendall 1997). Anopheles is medically important, being the sole vector of malaria and play a substantial role in transmitting lymphatic filariasis through *Wuchareria bancrofti* (Kettle, 1990). Subfamily *Culicinae* has more than 2,500 species of which the main genera are *Aedes* with over 900 species, *Culex* with nearly 750 species and the medically unimportant *Uranotaemia* with more than 180 species. The *Aedine* genera, *Aedes* and *psorophora* have drought resistant eggs, enabling them to breed in temporary ground pools and containers. The quasi-*sabethine* exhibit both *Aedine* and *Sabethine* characteristics and breed in containers such as bamboo tree holes and leaf exile, and include such genera as *Eretmapodites*, *Haemagogus* and *Armigeres*. A third group is associated with dense aquatic vegetation and include *Ficalbia*, *Coquilletidia* and *Mansonia*. The fourth group is an assemblage of miscellaneous genera of which the largest is *Culex* and *Deinocercites*. They are associated with crab holes in Neoarctic and Neotropical regions. *Culicines* are important vectors of human diseases and are the major vectors of arboviruses and filariasis. These include *A. Aegypti* vector for yellow fever and danque, *C. tarsalis* vector for western equine encephalitis , *C. Quiquefasciatus* vector for *W. bancrofti,* and *Mansonia uniformis* vector for *Brugia Malayi* (Kettle 1990).

2.11. Environment of the immature stage of the Mosquito

The environment of the immature stage of the mosquito is aquatic, with its mobile stage (such as larvae and pupae) dependent on atmospheric air for breathing and therefore typically spending much of their lives on the surface from film of water of the aquatic environment.(WHO, 1982). The temperature of the water in which the mosquito breed is for the most parts moderate, and extreme temperature is inimical to life: though such exceptional extremes are found in the temperate zone during winter, and in the tropics in shallow accumulations of water exposed directly to the sun; as well as in hot springs (Goma, 1966). Temperature is one of the factors that limit geographic distribution of a species. Within optimal ranges, however there is a relationship between temperature and growth. For example mosquitoes breeding in the tropical zone, in water at $23^0C - 27^0C$, usually complete their life cycle within two weeks (WHO,1982). Moderate frequent rainfall usually increases the opportunity for prolific breeding, but repeated and heavy rainfall causes severe flooding resulting in temporary flushing out of breeding places and reduction in mosquito population (Goma,1966).

Some mosquitoes, for example *A. gambiae* show a distinct preference for breeding in exposed sunlit waters; others such as *A. implexus* prefer heavily shaded habitats. A few species are most prevalent in water that is partially shaded for part of the day; for example *A. freeborni* and *A. brunnipes.* Sunlit and shaded habitats may differ from each other in many ways, for example in their water temperature, oxygen contents, microbiota and chemical composition. It might well be that such secondary factors play a controlling role in breeding of mosquitoes rather than sunlight per se (Goma 1966)

The immature stage of some species such as *A. gambiae* is found throughout the entire surface of worm and shallow temporary rainwater pools. Some species for example *A. funestus* breed in clear fresh water with vertical vegetation where as others are adapted to breeding in brackish water such as *A. sundaicus.* Other mosquito species prefer highly polluted water for example *C. quinquefasciatus* and *C. Pipiens.* The aquatic environment of some species is associated with particular plants. For example mansonia larvae are linked with the presence of fresh water lettus (*pistia*) and *A. Simsoni* with auxiliary breeding in banana plants. Other species, for example *A. aegypti* and *Eretmapodite chrysogaster* breed in great numbers in small containers such as old tins, tires and coconut husks.(WHO,1982).

2.12. The environment and habits of the adult mosquito

2.12.1. Mating

Mating is often preceded or accompanied by swarming in which the males associate over markers and fly in a particular manner. Swarming occurs commonly at sunset when the wind tends to die away and the rapidly fading light has a stimulating effect on mosquito activity. Some mosquitoes like *A. aegypti* mate without swarming; with the male responding to the sound of the female's wing beat. Mating usually occurs within 24 – 48h after males seize emergent females entering the swarm and the pairs drop out of the swarm. Female mosquitoes are monogamous. After insemination, the spermatozoa are stored in the female mosquitoes in an organ called the spermatheca and drawn in for fertilization of all the eggs produced throughout the remainder of its life (WHO, 1982).

2.12.2. Biting habit

Blood feeding follows a circadian rhythm with most species of mosquitoes being nocturnal and many including most disease vectors such as *A. gambiae*, *A. minimus* and *A. farauti* have their peak- biting rate after midnight to the early hours of the morning. *A. africanus* is crepuscular (active in twilight) with its biting activity being concentrated into 20-minutes period following sunrise but there is no similar period of activity at sunrise. Species of *A. stegomyia*, including the disease vector *A. Aegypti*, *A. polynesiensis* and *A. scutellaris* are diurnal. *A. aegypti* has two peaks of activity, one just after dawn 06.00 – 07.00 and before sunset 17.00 – 18.00h. (Kettle,1990) . According to Service (1980), *A. albimanus*, a malaria vector in Central and South America, bite mainly outdoors (exophagic) from about sunset to 2100h, whereas in Africa species of the *A. gambiae* complex , which contains probably the world's most efficient malaria vector, bite mainly after 23.00 and mostly indoors (endophagic). The exact feeding pattern of mosquitoes indoors varies with different species and circumstances but usually mosquitoes enter houses to feed in early hours of the night (WHO, 1982).

2.12.3. Host Preference

The favourate environment of the adult female mosquitoes should include a suitable host (WHO, 1982). In some species as *C. Molestus* the first batch of eggs may be matured autogenously without a blood meal but most mosquitoes require a blood meal for ovarian development. The source of the blood meal is a species to be a vector of diseases (Kettle, 1990) .The mosquito's selection is determined by four main factors:

(a) availability of host

(b) climatic conditions and the resting habits of the mosquitoes concerned

(c) Emanations from the host

(d) Visual stimulation (Goma,1966)

According to (Kettle, 1990, Tempelis,1975) basic feeding pattern among mosquitoes are recognized including species that feed:

(a) Almost entirely on mammals such as *A. gambiae*, *culiseta inornata*

(b) Readily on both birds and mammals as *C. Quinquefasciatus*

(c) Almost exclusively on amphibians such as *C. territans.*

(d) Predominantly on reptiles such as *Dernocerites dyari*

(e) A remarkable species, *Uranatoemia lateralis,* which feed on the mud skipper, a fish, which comes out of the water on mud banks with its tail in water (Kettle, 1990).

Species that usually bite man are said to be anthropophilic in their feeding habits, while those that feed mainly on other animals (mammals, amphibian, reptiles or birds) are zoophilic. Mosquitoes

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that feed on birds sometimes are called ornithophilic instead of zoophilic. A no preference mosquito is refered to as an indiscriminate biter. In the absence of the preferred host some species as *An. gambiae* are facultative feeders and will feed readily on another host (WHO, 1982). Females are attracted to hosts by various stimuli such as body odour, carbon dioxide and heat in some species but others are attracted by vision including the silhouette or movement of their hosts (Service, 1980). (Kettle, 1980), commented that Gillies and Wilkes working in West Africa found that a significant number of *Mansonia spp*. Reach their host by flying down wind at low level. Conventional current given off by a worm body enable mosquitoes to orientate to host very effectively over short distances. Other feeding behaviors of the mosquitoes apart from orientation are activation, lading and probing (Kettle, 1990).

2.13. Mosquito Control Measures

Control measures are generally directed against one or few of the most important species and can be aimed at the adult or larvae (Rozendaal, 1997). The control may be taken either to prevent mosquito-borne disease or to protect man and his animals from vicious attacks of the insects. The control measures which can be taken to control mosquitoes depending on particular circumstances may be directed against the immature stages or the adult mosquitoes or simply to prevent contact between man and the insects (Goma 1966).

2.14. The control of the aquatic stage of mosquitoes

This entails both deterring mosquitoes from lying and destroying eggs laid larvae and pupae, which may already be present in the water. The mode of the control may be chemical, biological and mechanical (Rozendaal, 1997).

2.15. Environmental Management for Vector Control

WHO defines Environmental Management for Vector Control as the planning, organization, carrying out and monitoring of activities for the modification and/or manipulation of environmental factors or their interaction with man with a view to preventing or minimizing vector propagation and reducing man-vector-pathogen contact. It may entail one of two options (or both): environmental modification (permanent infrastructural changes of a capital-intensive nature) and environmental manipulation (recurrent actions aimed at achieving temporary unfavorable conditions for vector breeding). Many insect vectors of the most important parasitic diseases are linked to aquatic ecosystems. Three important categories can be distinguished: natural water bodies, man-made water bodies and water bodies in the human settlement and household environment. The creation of man-made water bodies often results in hydrological changes that favour intensified vector breeding, or shifts in local vector species composition. Many are linked to project of an infrastructure development nature.

2.16. Mosquito net use and malaria

A close association has been observed between people's perception of the cause of malaria and the type of protective measure used. In a longitudinal cohort study in Kenya, 8.5% of the women reported using a bednet regularly, 17,5% burned mosquito coils, 2.7% used an insecticide spray, and 12.1% reported burning dung or leaves. Overall, 67% of the women reported not taking protective measures on a regular basis, and only 5% reported using more than one method regularly (Bloland *et al*. 1999) The level of mosquito nets use has been found to be low in communities where bednets were previously unknown. In their studies in Zimbabwe, (Vundule and Mharakura 1996) observed a 9% use of mosquito bednets among the respondents studied. This contrasts significantly with a rate of 47% found in Malawi (Ziba *et al*. 1994) In West Africa, the use of bednets was found to be high in The Gambia. A study conducted in 73 randomly selected villages in the Gambia found 86% of respondents to be using bednets (Aikins *et al.* 1993). In the same study, 98% of bednet users were reported to have seen their parents using them in their childhood (Aikins *et al.* 1993). The use of mosquito nets has also been found to be higher in urban areas than rural areas. In a KAP study in Douala, Cameroon, mosquito nets were found in 47% of households visited, with 65% of the inhabitants using them. In rural areas, very few mosquito nets were identified (Chambon *et al.* 1997)

An intervention trial conducted in young children (1-9 years) in a rural area of The Gambia to assess the impact of the traditional use of bed nets on malaria morbidity has found no significant difference in the incidence of clinical attacks of malaria or in any other malariometric measurements between the 2 groups of children (one group sleeping under bednets and the second without bednets). Thus, bed nets were considered not very effective in reducing malaria morbidity in this group of children (Snow *et al.* 1988).

Several studies on Insecticide Treated Nets (ITN) undertaken in different African and Asian countries have consistently documented significant reduction in the rate of malaria parasitaemia and malaria morbidity (Ranque *et al.* 1984, Graves *et al.* 1987, Rozendaal *et al.* 1989, Nevill *et al.* 1988, Bradley *et al.* 1986, Campbell *et al.* 1987, Snow *et al.* 1988). A major controlled community trial was subsequently carried out in The Gambia (a country with a seasonal malaria transmission pattern and a relatively low malaria transmission intensity of 4-24 infective bites per person per year). In this trial, sleeping under a bednet was associated with 63% reduction in overall mortality and a 70% reduction in mortality attributed to malaria in young children (Alonso *et al.* 1991). These impressive results have paved the way for the establishment of a National Impregnated Bednet Program in The Gambia. An effectiveness evaluation of this program documented again an overall 25% reduction in all cause mortality in children aged 1-9 year (D´Alessandro *et al.* 1995). The results from three further major trials conducted in African regions of very different malaria transmission intensity were published later. The first one has been carried out at the Kenyan coast among a rural population of children under 5 years of age (10-30 infective bites per person per year). Protection with ITNs was associated with a reduction in all-cause childhood mortality by 33% and severe malaria cases were reduced by 44% (Nevill *et al*. 1996). The second large study took place in rural northern Ghana (100-1000 infective bites per person per year). Here, the use of ITNs was associated with 17% reduction in all-cause mortality in children aged 6 months to 4 years (Binka *et al*.1996).

A third study, which was carried out in rural Burkina Faso in which 300-500 infective bites per person per year were uncounted, was different from the others as impregnated curtains were used instead of bednets. The reduction in all-cause mortality was 15% over the two years of follow up period in children aged 6-59 months, but significant differences were only sees during the first year of the intervention (Habluetzel *et al*. 1997).

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CHAPTER THREE

3. STUDY AREA AND METHODOLOGY

3.1. Study area

The study area is the Bongo district which is one of the eight districts in the Upper East Region of Ghana. As of now the districts on the Region are nine but the current map is not yet out. The Bongo district shares boundaries with Burkina Faso to the North, to the East, Kassena-Nankana District, to the west Bawku west and Bolgatanga District to the South. It is the smallest district in the Upper East Region in terms of space.

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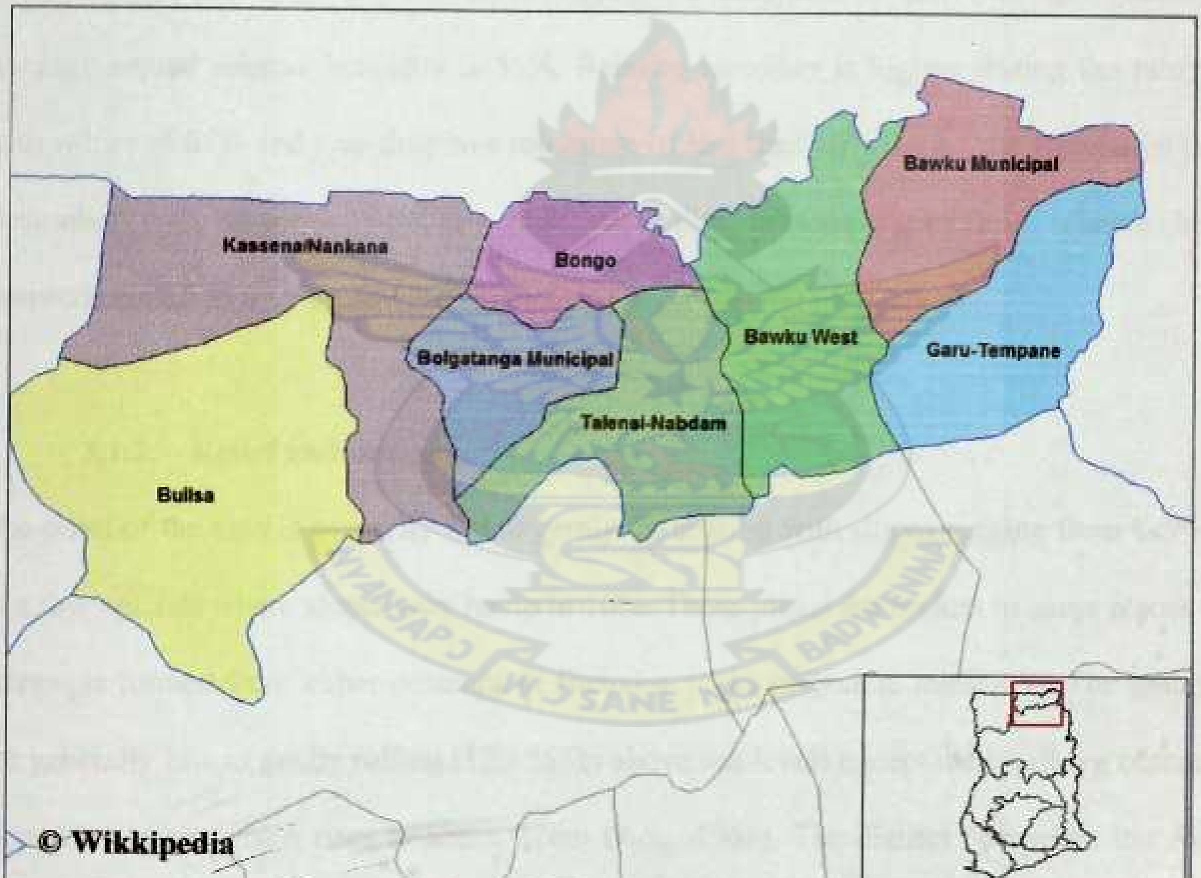

Figure 3.1: A Map showing the districts of the Upper east Region of Ghana.

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3.1.1. Climate

The region falls within the Inter-tropical Convergence Zone whose climatic boundary oscillates annually between the south coast of Ghana and 20° north. As the boundary moves north and south it draws with it the associated weather zones. The effect of this on the region provides a uni-modal rainfall regime lasting from 5-6months which is characterized by low and erratic rainfall and a dry period of 6-7months. Considerable variations exist between successive rainy seasons with respect to time of onset, duration and amount of rainfall received (Walker, 1962). With an average of 28.6°C, temperatures are consistently high. Monthly averages range from 26.4°C at the peak of the rainy season in August to a maximum of 32.1°C in April (Liebe, 2002). Average annual relative humidity is 55%. Relative humidity is highest during the rainy season with values of 65% and may drop to a minimum of less than 10% during the Harmattan period in December and January. With this high variability in temperature and relative humidity, evapotranspiration as expected is high that may affect drying of reservoirs.

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3.1.2. Relief and drainage

The relief of the area is generally flat to gently undulating with slopes ranging from 1-5% except in a few uplands where slopes may be up to 10%. These plains are broken in some places by hills or ranges formed from either outcrops of Birimian rocks or granite intrusions. The granite areas are generally low to gently rolling (120-255m above sea level) except the inselberg outcrops near Bongo township which rises to about 326m (Adu, 1969). The district comprises the Atankuidi Yaragatan- Atanure and the Red Volta drainage basins. The area is drained by the Red Volta and were endemic to the River blindness disease

These rivers overflow their banks in the main rainy season (April to October) and dry up soon after the season leaving disconnected pools of water in their beds, separated by dry stretches of sand and rock.

During the rainy season the streams and rivers are liable to sudden fluctuations in water level, suggesting that there is considerable surface run-off within their catchments during heavy rainfall. The district has one large dam at Vea, and small dams and dugouts located in Bongo, Zorko, Adaboya, apaatanga, Namoo and Soe Yidongo.

3.1.3. Vegetation

The vegetation is Sudan savannah consisting of short drought and fire resistant deciduous trees interspersed with open savannah grassland. Grass is very sparse and in most areas the land is bare and severely eroded. (Needham ,1993) who investigated the natural resources and livelihood systems in the region stated that it is no more possible to find examples of natural vegetation due to the exploitation of the natural resource base for several hundred years. The natural vegetation has been much modified by human activities, particularly agriculture which is almost entirely in the hands of smallholder cultivators, who combine bush farm cultivation of distant fields with permanent cultivation of nearby compound farms. Overgrazing is evident in some areas particularly near ponds and dams, since the region has the highest density of cattle (IFAD, 1991). Common grasses include *Andropogon gayanus* in the less eroded areas and *Hyperrhenia spp.*, *Aristida spp.* and *Heteropogon spp.* in the severely eroded areas. Common trees include *Anogeissus spp.*, *Acacia spp.* and *Triplochiton spp.*

3.1.4. Geology

Granite rocks underlie the entire Bongo District. The rocks have outcrops, which are visible throughout the area. They have well-developed fractures, which makes borehole and drilling of wells possible. The granite rocks, which obtrude all over the landscape, could be a source of material for the construction of industry. These granite are coloured pink, coarse grained and potassium rich. Hornblende and a little biotite are some of the constituent primary minerals (Adu, 1969). The granite has a rectangular jointing and weathers into large upstanding masses and blocky-perched boulders. The hill near Bongo rises several hundreds of metres above the surrounding land with steep and craggy sides (Adu, 1969).

3.1.5. Soils

The Bongo group of soils is developed over Bongo granites. They are characterized by numerous groves of baobab trees. The parent materials of the soils have been known to be very productive due to the high potash and phosphate content of the parent rock. Human population densities on these soils are high. Owing to long periods of intensive farming accompanied by mismanagement of the land, soil exhaustion and erosion are prevalent. Over wide expanses, very severe erosion has resulted in the formation of lithosols (Quansah, 2005). The series of soils are moderately well drained coarse texture soils occupying larger tracts of land on middle and upper slopes and less frequently on summits. Lower slopes soils comprise Yorogo and Zorko series. The Yoroko series are ground water Laterites consisting of shallow, pale coloured and very coarse sands (colluvia) overlying gritty seepage iron-pan. The Zorko series are poorly drained; eroded lithosols occurring near valley edges and usually expose partly weathered rock on round surface (Quansah, 2005). Generally, the Bongo soils consist of about 3 inches of very slightly human-stained, crumbly coarse sandy loan overlying reddish brown, fine blocky, very coarse sandy loam containing occasional incompletely weathered feldspar particles. It grades below into red, mottled pink and yellow coarse sandy clay loam of partially decomposed granite.

The soils are well drained, friable, and porous and possess good filth. Consequently, they have good water holding capacity. They are inherently fertile but for the most part farmed more or less continuously so that they are lacking in organic matter and nitrogen. The soils are rich in phosphate and support crops like millet, sorghum, rice, maize, groundnut, cowpea, bambara beans and vegetables. However, the high pressure of population and farming activities on the land have rendered the carrying capacity of the soil very low resulting into low soil fertility, low water holding capacity and susceptible to sheet erosion during the rainy season (Quansah, 2005).

3.2. Methodology

Qualitative and quantitative data were collected. The quantitative data collection technique was used mainly in the entomological data acquisition while both quantitative and qualitative technique were employed for the collection of information about health and water - related infrastructure and also in key informant interviews.

3.2.1. Site selection

The seven administrative zones of the Bongo District (namely Soe, Namoo, Zorko, Bongo, Valley, Beo and Bongo) were selected as the study area. A reservoir was selected from each of these zones except Balungu where there was no reservoir due to the total collapse of the Balungu dam since the year 2005. This zone however was used as a control. One settlement each within each zone was selected for entomological data collection. The settlements which were situated at varying distances from their corresponding reservoirs were all within 2 kilometres (2Km) away from the reservoirs. The control community (Balungu) was 3.5km away from the nearest reservoir (Bongo). It is generally assumed that the flight range of *Anopheles specie* is within 1-2 km from suitable breeding sites (Birley 1989;Thomson *et al.* 1995; Dolo 1996.) All selected settlements ~~had a health centre each~~ where treatment of malaria and other diseases were reported for treatment by the inhabitants. All these selections were done after careful and thorough recognisance surveys.

3.2.2. Data Sources

The research employed both primary and secondary data. The primary data was obtained from the field using instruments and methods like interview schedules, questionnaires, focussed group discussions and observation guide. Standard mosquito trapping for both adult and larvae was carried out. The secondary sources consisted of a desk study of books and the internet to extract information and statistics on malaria, reservoir, mosquitoes and related topics.

3.2.3. Data Collection Procedure

Data collection season

Malaria occurrence is at its peak during the months of September and October. The period of data collection was however scheduled within this period. This season is the peak for the rainy season in the region and as such mosquito presence is relatively high.

Figure 3.2 shows the monthly malaria trends in the Bongo District from 2003 to 2007.

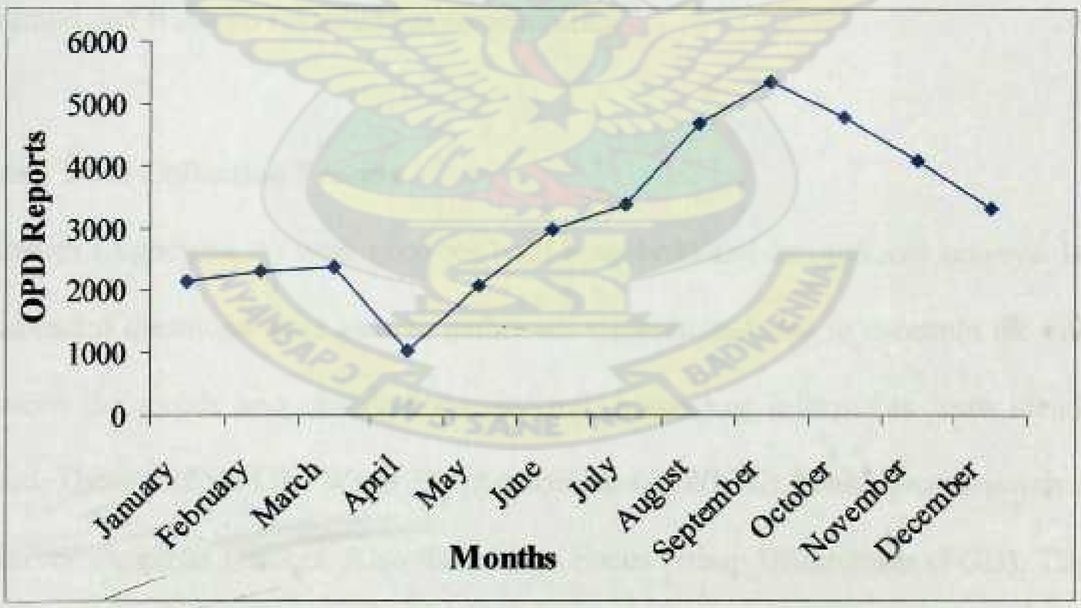

Figure 3.2 Monthly malaria trends in the Bongo District: (2003-2007).

3.2.3.1.Community Data Collection

Sampling Method

Clustered sampling technique (dividing the community into zones so that a specified number from each zone is selected to prevent bias) was used together with Stratified sampling technique (choosing population according to age, gender, sex etc) in addition to simple random sampling technique to select respondents for the household survey. The combination of these three techniques was to ensure an even selection of the respondents giving each respondent an equal chance of being selected. Purposive sampling on the other hand was used to select institutions and key informants.

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Sample Size

A sample size of 30 households for each of the seven (7) zones was taken for the purpose of this research. This was made up of 30 households each from Vea, Beo Apataanga, Soe, Bongo, Zorko, Namoo and Balungu resettlement communities.

Community Data Collection Process

Questionnaires (Appendix A) were used for both household and institutional surveys. Both open and closed ended questions were used to gather information and also to ascertain the information gaps between the trends and observations realized. Some key informants were identified and interviewed. These included the Water Users associations (WUA.), health professionals and users of the reservoirs such as farmers. Also there were Focus Group Discussions (FGD). The District Health Administration was contacted for heath data

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3.2.3.2. Entomological Data Collection

Adult mosquito sampling

One standard adult collection methods; light traps (LT) was used over three nights in each of the six (6) dam settlements and the non-dam settlement, Balungu which served as a control. Five households were selected at each of the zones for sampling. It was ensured that the selected households had not used any form of insecticide or mosquito repellants over the past two weeks. Household sizes of the selected houses were between five (5) and ten (10). The households were located at different locations within the villages or the towns where the sampling were done. They were at different distances from the reservoirs. Both the rooms and the compounds of all the selected houses were sampled. A 60cm × 30cm light trap with an input voltage of 220V and rated power of 30W and rated frequency of 50Hz with two fluorescent tubes to attract mosquitoes and powered by mini electrical power generator were hanged in rooms and the compounds from 1800GMT to 0600GMT for nocturnal anopheles sampling. Thus mosquito collections were made with five (5) traps/night for three (3) nights. The mosquitoes obtained by this method were classified and counted.

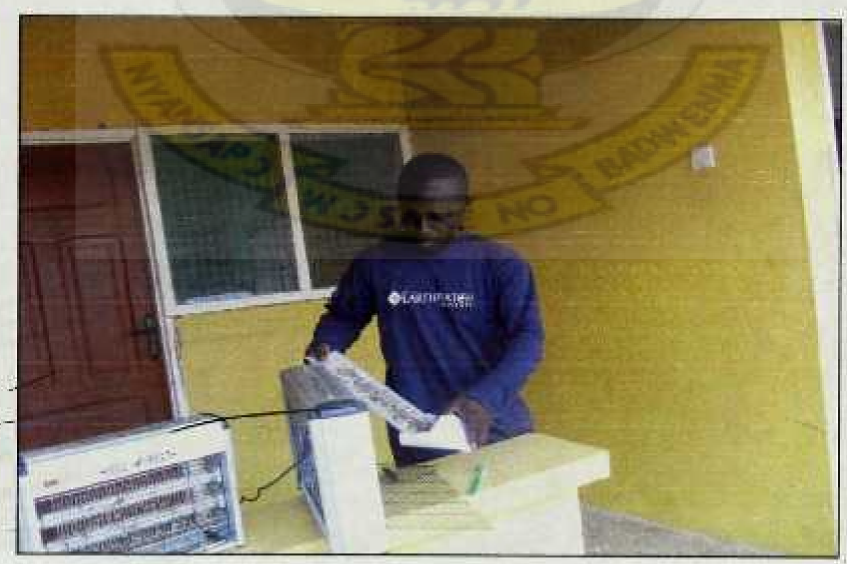

Plate 3.1: Entomological Sampling: Emptying mosquitoes from light trap into an envelope.

Larval Sampling

After a thorough recognizance survey the larvae were known to be found at the peripheries of the reservoirs (within one meter (1m) from the shoreline into the reservoir) ,within the spillways, canals , laterals, livestock drinking spots and water that seeps from the dam walls. Plates 3.2 to 3.5 show the pictures of these larval niches. At the peripheries of the reservoir three (3) sampling plots 1m×1m size each were randomly laid for larvae collection. Within each plot a 15cm diameter dipper was used to make five (5) random fetches into a plastic container. The larvae collected by the random fetches were identified and counted. These processes were repeated for the spillways, canals and the laterals and also the seepage water from the dam walls and the livestock drinking spots. In the case of the canals and the laterals one canal and one lateral each from all the reservoirs were selected and the plots were laid.

Plate 3.2: Livestock drinking point

Plate 3.3: Peripheries of reservoir

Plate 3.4: Spill ways as a mosquito breeding habitat

Plate 3.5: An irrigation lateral as a mosquito breeding habitat

3.2.4. Data Analysis

In the analysis, both qualitative and quantitative methods were used to measure the research objectives. The qualitative technique was in the form of comprehensive statements and analytical descriptions. This helped to consider several realities. The quantitative technique was mainly base on diagrams like graphs and percentages. Microsoft Excel computer application software and Statistical Package for Social Sciences (SPSS) were used to aid the quantitative analysis of the primary data. A one way Analysis of Variance (ANOVA) which assumes that the data from the different groups come from populations where the observations have a normal distribution and the standard deviation is the same for each group was used to determine which means amongst the set of means (from the various sampling zones) differ from the Control (Balungu).

The one-way analysis of variance (ANOVA) was used to evaluate whether there is any evidence that the means of the mosquito populations differ. This was carried out after data on the number of mosquitoes from the various zones was transformed (cube root transformation) to meet assumptions of normality of the distribution of the data. Relationships between parameters were examined by means of correlation.

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4. RESULTS AND DISCUSSION

The first specific objective of the study is to assess the relative abundance of *Anopheles species* in the seven (7) administrative zones of Bongo with respect to the presence of reservoirs. In pursuance of this *Anopheles* mosquitoes trapped in the various sampling zones were compared. Also Analysis of Variance (ANOVA) was carried out to ascertain whether the differences in *Anopheles* mosquito abundance in each sampling zone and the control (Balungu) were significant or not. Figure 4. 1 below shows the number of *Anopheles* mosquitoes trapped (Vector abundance) in all the seven (7) administrative districts. The lowest vector abundance was recorded at Balungu the control community, the administrative zone without reservoir. The valley zone however had the highest vector density.

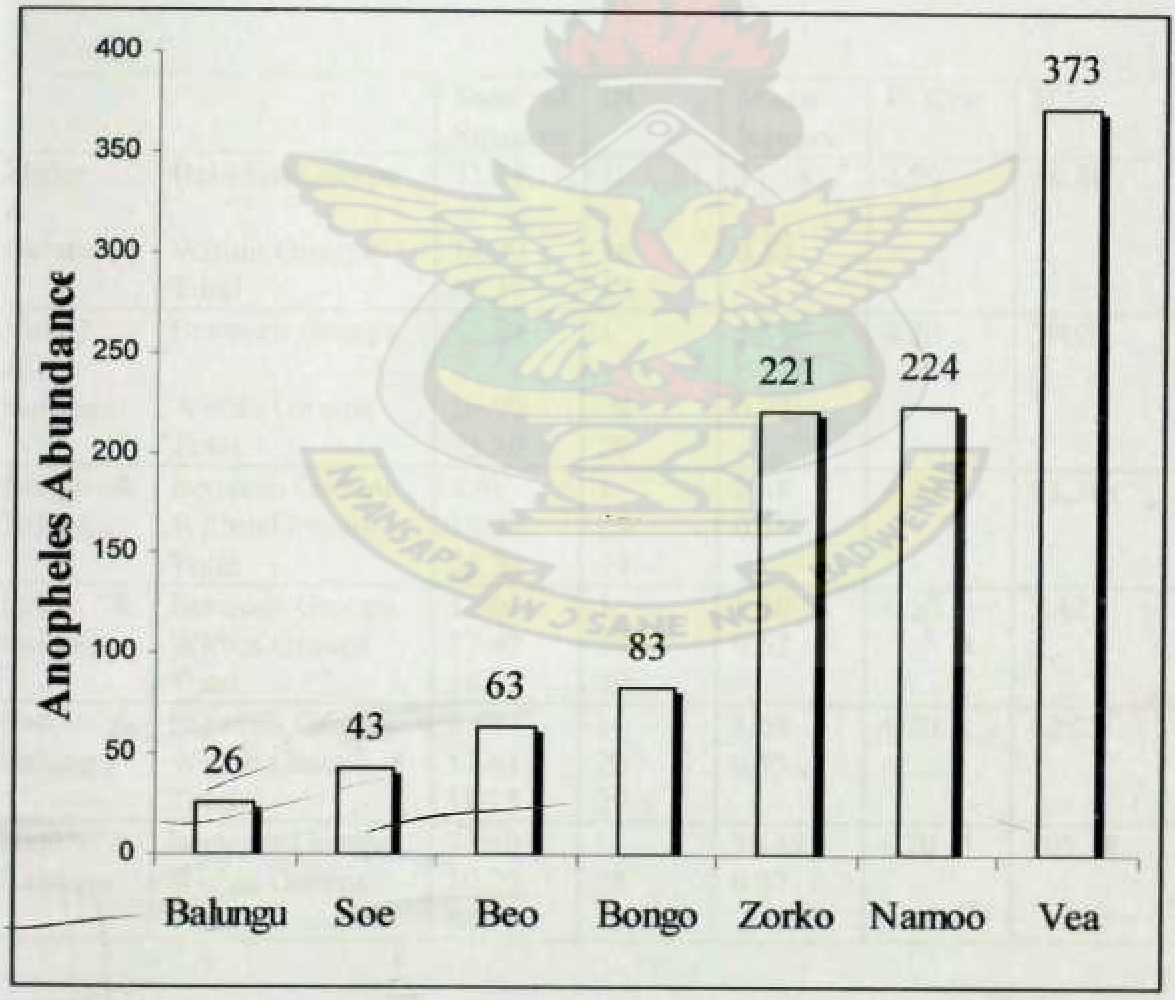

Figure 4.1: *Anopheles* mosquitoes trapped in the various zones.

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Table 4.1 below shows the summary of the results of the Analysis of Variance (ANOVA). It compares the population means of the various sampling zone with that of the control community at 95% confidence level. All the sampling zone but Soe (with P = 0.131) had their population means significantly different from that of the control community. The results confirms the earlier findings by Oomen et al. 1990 that the construction of reservoirs can increase the number of breeding sites for mosquitoes, stretch the duration of their breeding season, and extend the average longevity of mosquitoes. *Anopheles* mosquitoes were found to be relatively abundant at areas with reservoirs than the control community which has no reservoir.

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Table 4.1: ANOVA comparing the population means of the entire sampling zone with the control.

		Sum of Squares	Df	Mean Square	F- Crit	F	P-Value
Zorko & Balungu	Between Groups	31.58	1	31.58	4.20	59.80	2.01157E-08
	Within Groups	14.79	28	0.53			
	Total	46.37	29				
Valley & Balungu	Between Groups	52.89	1	52.90	4.20	70.90	3.71689E-09
	Within Groups	20.90	28	0.75			
	Total	73.80	29				
Bongo & Balungu	Between Groups	7.48	1	7.48	4.20	13.30	0.001075482
	Within Groups	15.76	28	0.56			
	Total	23.23	29				
Soe & Balungu	Between Groups	1.50	1	1.50	4.20	2.42	0.131334565
	Within Groups	17.42	28	0.62			
	Total	18.92	29				
Beo & Balungu	Between Groups	5.64	1	5.64	4.20	12.53	0.001423166
	Within Groups	12.61	28	0.45			
	Total	18.25	29				
Namoo & Balungu	Between Groups	38.50	1	38.49	4.20	105.38	5.38002E-11
	Within Groups	10.23	28	0.37			
	Total	48.73	29				

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The second specific objective of the study is to assess the contribution of reservoir characteristics to *Anopheles* mosquito abundance. The reservoir characteristics considered (as shown in Appendix C) in the study were distance from the reservoir to settlements and reservoir surface area. From (Figure 4.2) it is obvious that there was a very weak correlation between reservoir surface area and vector abundance. Data collection season (the rainy season) could have influenced this as mosquitoes could come from some breeding sites order than the reservoirs. Also presence of extra structures of the reservoirs (such as canals and laterals) could have contributed to this. Figure 4.4 gives more evidence in support of this claim. There was a weak negative correlation (R^2= 33%) between the distance from community to reservoir and vector abundance (Figure 4.3). The results of the study show a limited possibility for settlements which are closer to the reservoirs to have more mosquito abundance than those farther away. This confirms earlier findings by (Faye *et al.* 1993; Lindsay *et al.*1995) that highest mosquito densities are found close to breeding sites such as irrigation schemes. The rather weak correlation could stem from the fact that the mosquito sampling took place within the rainy season. This implies that there was a high possibility of mosquitoes coming from breeding sites order than the reservoirs.

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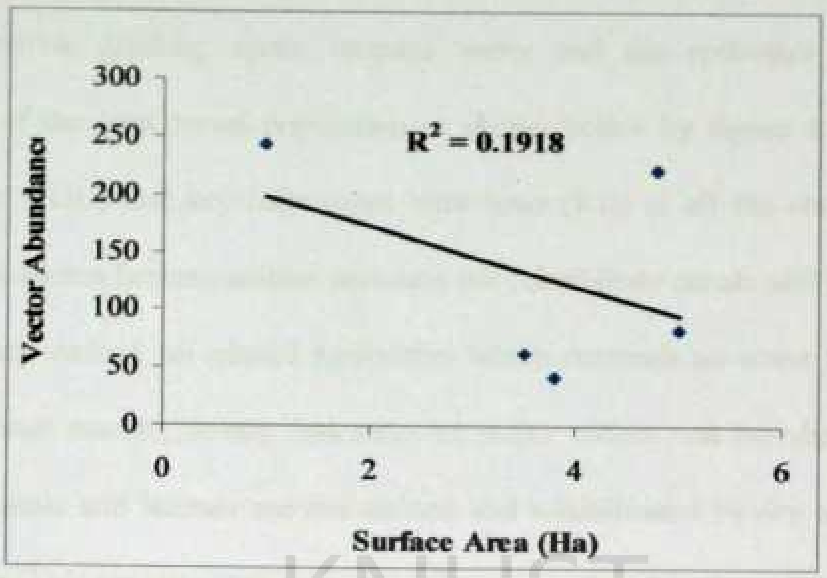

Figure 4.2: Correlation between Surface area and vector abundance

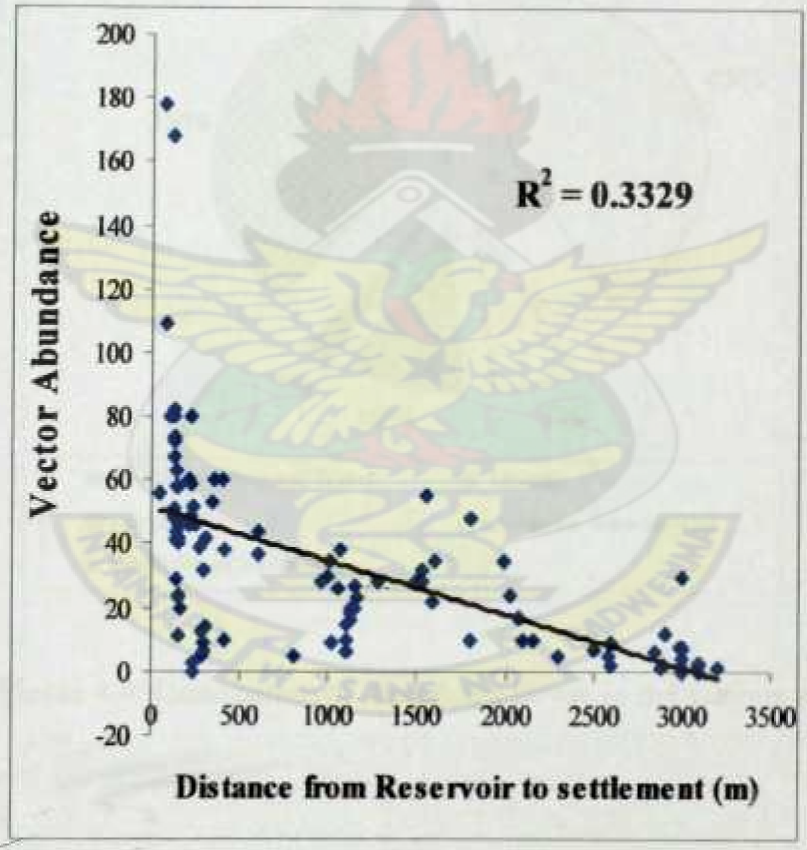

Figure 4.3: Correlation between distance from community to reservoir and vector abundance

Larval abundance in the various *Anopheles* larval niches or breeding places (spillways, seepage water, laterals, canals, peripheries of reservoir and livestock drinking points) were assessed.

Laterals and canal of the reservoirs accommodated 35% and 45% respectively while the peripheries, livestock drinking spots, seepage water and the spillways accounted for the remaining 20% of the total larval population as shown below by figure 4.4. Results of focus group discussion (FGD) and key informants interviews (KII) in all the reservoir communities revealed that wet season farmers neither maintain nor rehabilitate canals and laterals of irrigation schemes since they embark on rainfed agriculture which demands no water from the reservoirs. They are as a result muddy, weedy and serve as major niches and breeding sites for malaria vectors. These canals and laterals are maintained and rehabilitated by dry season farmers who make use of them. This explains why majority of larvae are found in the canals and laterals.

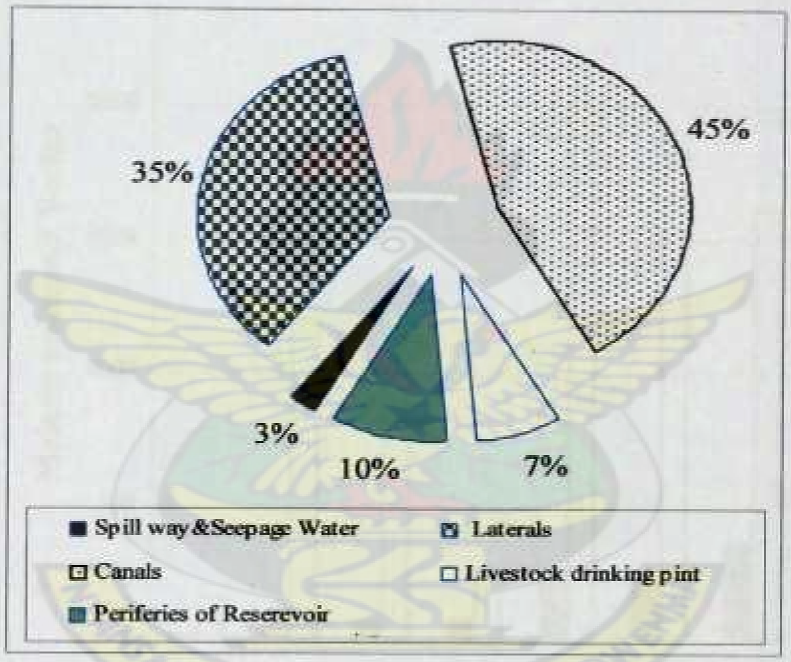

Figure 4.4: Distribution of *Anopheles* larvae in the various ecological niches.

The third specific objective is to find out the relationship between the incidence of malaria and their corresponding disease vector abundance. Figure 4.5 below shows the malaria incidence and the corresponding disease vector abundance compared at the various sampling zones. High vector abundance resulted in high malaria cases. It is also obvious from the graph that Beo with a higher mosquito abundance did not have a relatively higher malaria cases when it is compared with Soe. There is a similar situation when Zorko, Namoo and Vea (Valley) are compared. According to (Dolo *et al* 2000) high mosquito densities do not necessarily result in high transmission of malaria. This seemingly unusual trend could be explained by the individual relationships between the following parameters: livestock population density, human population density and percentage of inhabitants at the sampling zone using insecticide treated nets (ITN) on one hand and malaria cases on the other.

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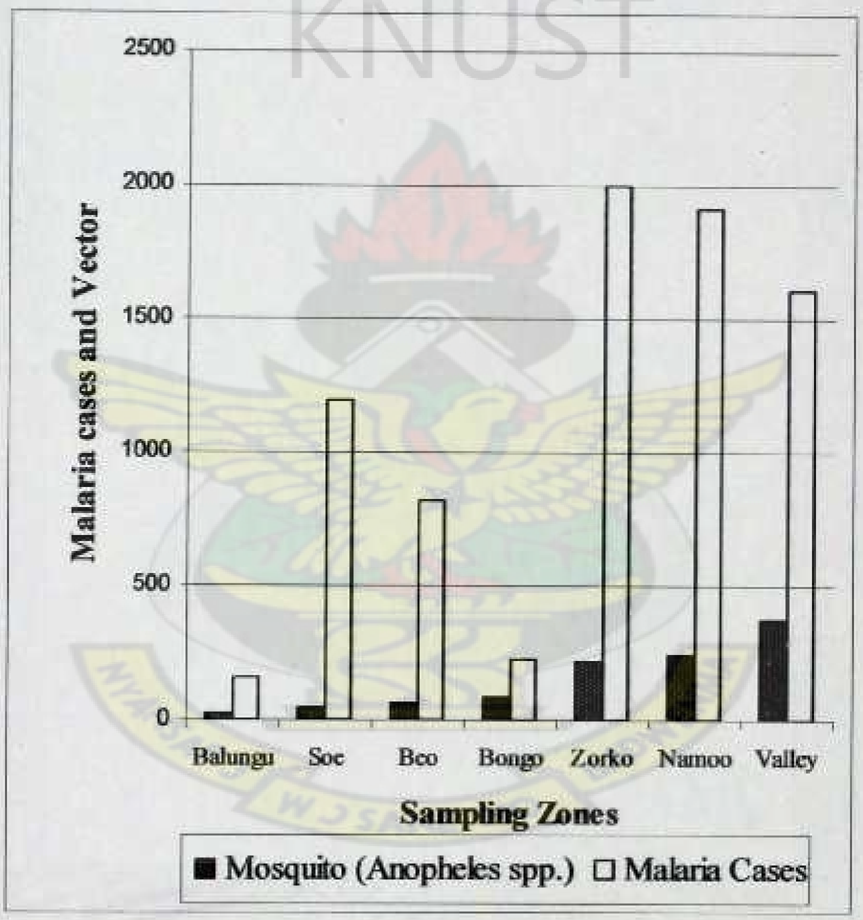

Figure 4.5: Malaria Cases and vector Abundance compared.

abundance resulted in high malaria cases. It is also obvious from the graph that Beo with a higher mosquito abundance did not have a relatively higher malaria cases when it is compared with Soe. There is a similar situation when Zorko, Namoo and Vea (Valley) are compared. According to (Dolo *et al* 2000) high mosquito densities do not necessarily result in high transmission of malaria. This seemingly unusual trend could be explained by the individual relationships between the following parameters: livestock population density, human population density and percentage of inhabitants at the sampling zone using insecticide treated nets (ITN) on one hand and malaria cases on the other.

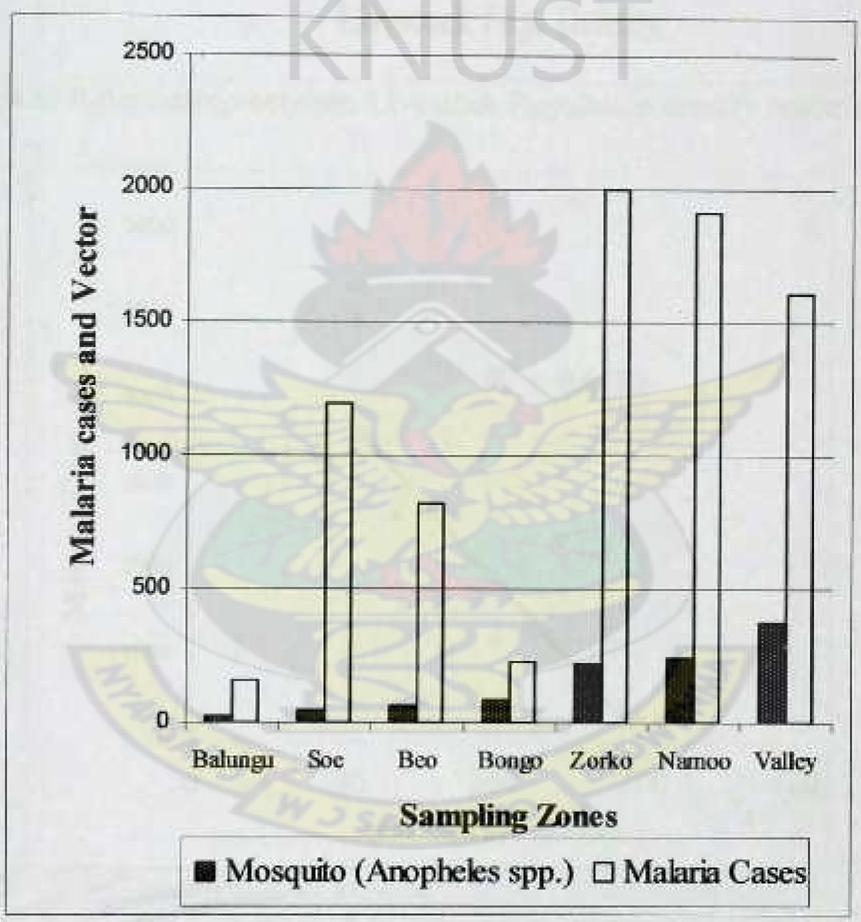

Figure 4.5: Malaria Cases and vector Abundance compared.

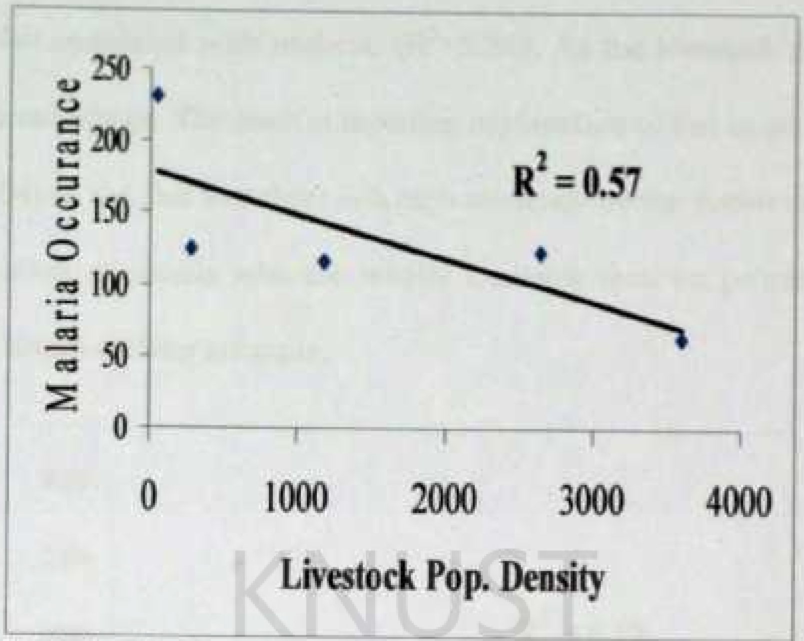

Figure 4.6: Relationship between Livestock Population density malaria cases.

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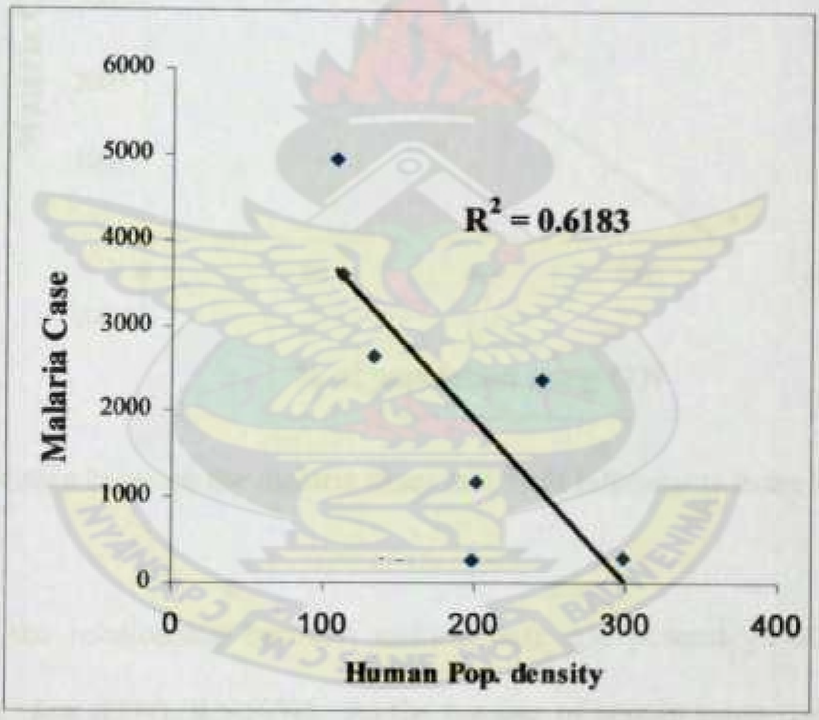

Figure 4.7: Relationship between Human Population density malaria cases.

~~Figures~~ 4.6 and Figure 4.7 show the relationships between livestock population density and the incidence of malaria on one side and human population density and malaria incidence on the other hand. Livestock population density correlated with the incidence of malaria, (R^2= 57%) and human population also correlated with malaria, (R^2=62%). As the livestock population density increases the malaria case drops. The most compelling explanation of this trend has been reported by (Mutero et al. 2004) as the fact that there is a high tendency by the vector mosquitoes to feed more on cattle and other mammals who are readily available than on people who mostly are protected by diverse health seeking attempts.

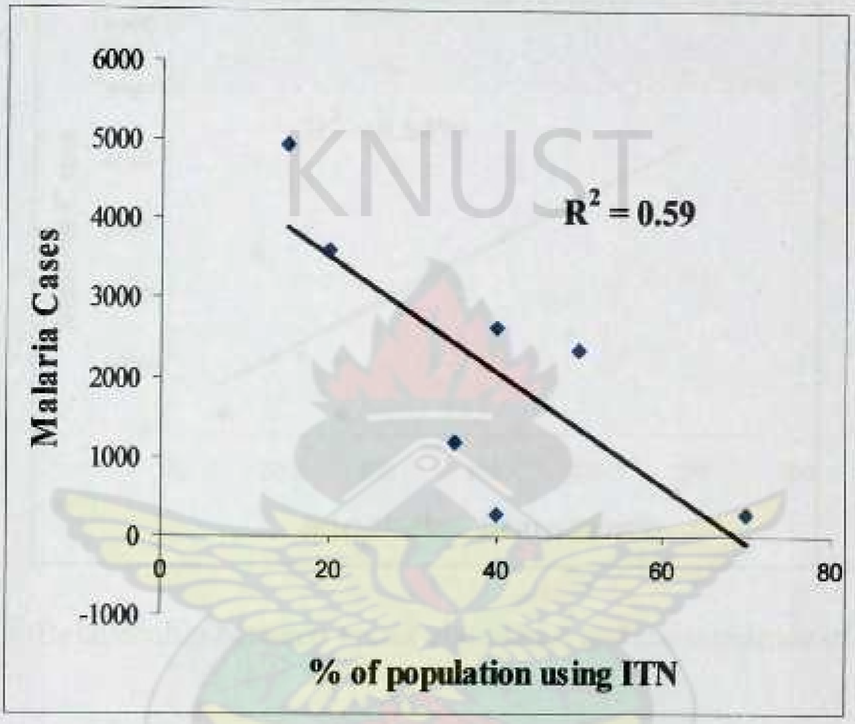

Figure 4.8: Relationship between the malaria cases and % of inhabitants using ITN.

Figure 4.8 shows the relationship between malaria case and percentage of inhabitants using Insecticide Treated Nets (ITN),(R^2=59%). As the number of people using the ITN increases the malaria cases drops. It was found out that the population density was higher at the urban centres than the villages and the cottages. At the urban centres the use of the ITNs and other form of malaria control methods were relatively higher. This is in support of the trends outlined by several studies on Insecticide Treated Nets (ITN) undertaken in different African and Asian countries. A study in Douala, Cameroon by (Chambon *et al.* 1997) reveals that the use of mosquito nets were higher in consistently documented significant reduction in the rate of malaria incidence and morbidity (Ranque *et al*.1984, Graves *et al*. 1987, Nevill *et al*. 1996, Bradley *et al*. 1986, Campbell *et al*. 1987, Snow *et al*. 1994, Snow *et al.* 1988).

As shown by figure 4.9 below, there is a positive correlation (R^2=65%) between vector abundance and the malaria cases. A greater vector abundance results in a corresponding great malaria incidence.

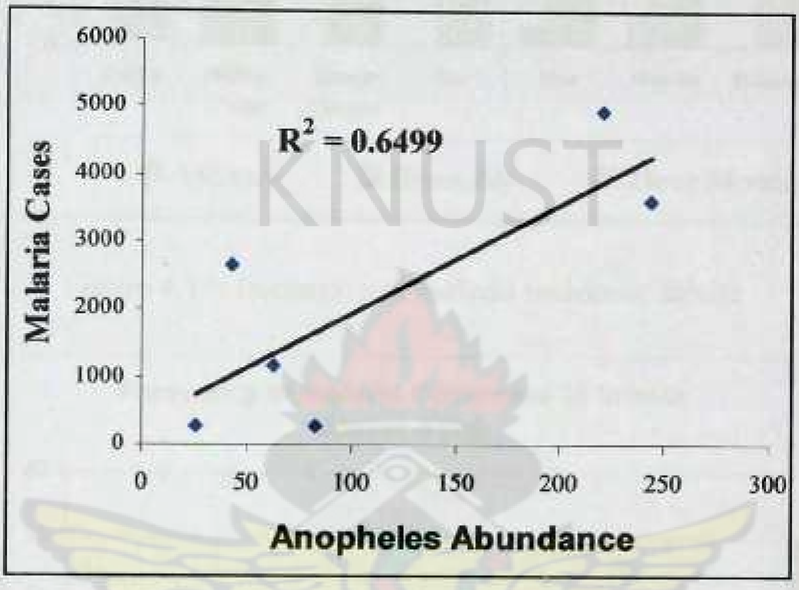

Figure 4.9: Relationship between vector abundance and the incidence of malaria.

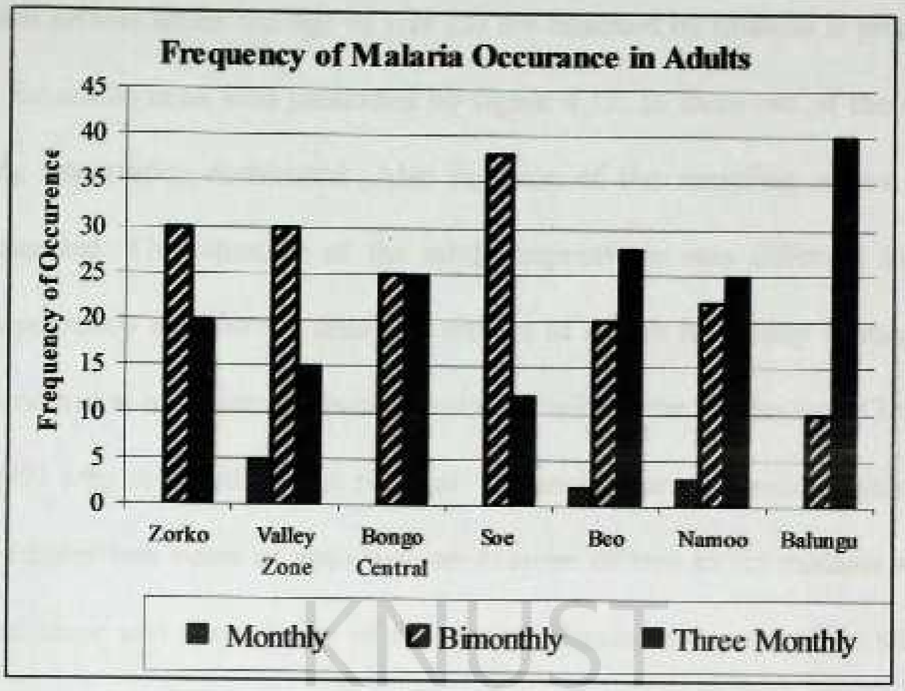

Figure 4.11: frequency of malaria incidence adults

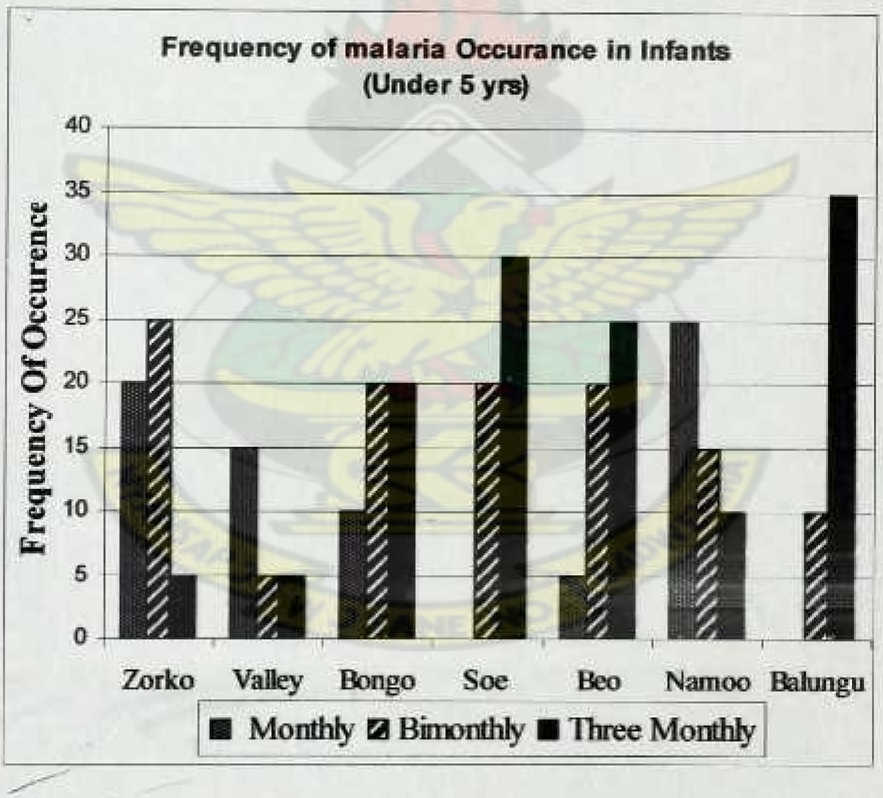

Figure 4.12: frequency of malaria incidence in children under five years

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The rate at which infants under the age of five (5) are attacked by malaria is presented in figure 4.11. The case for adults is as well presented by figure 4.12. In three out of the seven sampling zones bimonthly occurrence dominated .Also in three of the sampling zones three- monthly occurrence dominated. The situation of the adult respondents was different from that of the infants as it is apparently rare for the adults to reports of a high frequency of monthly incidence which was very common in infants. This observation confirms the findings of (Trape *et al*. 1994. Rogier *et al*.1999) who reported that in Senegal the incidence of clinical malaria is highest in young children (under two years of age) with an average of two to six malaria attacks per year and both the incidence and the severity of the disease decreases considerably with age. (Akum Achidi *et al*.1996) explains this trend that by the age of five and above, immunoprotection is reflected by a low rate of malaria attacks despite frequently high parasite densities.

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSSION

The results of the study shows that the presence of reservoirs significantly resulted in an increase in the abundance of disease vector (*Anopheles* Mosquitoes) in all the settlement areas with reservoirs except Soe which had its reservoir farthest away from the community.

Distance from settlement to reservoir and vector abundance had a weak negative correlation. This implies that there is a possibility of people living near the reservoir to encounter more mosquitoes than people living father away. There was a very weak correlation between surface area of reservoir and vector abundance. Canals and laterals of irrigation schemes harboured 80% of the total number of larvae sampled while seepage water from dam, livestock drinking points, peripheries of reservoirs and spillways harboured the remaining 20%.

Adult *Anopheles* Mosquito Abundance correlated with malaria occurrence. This implies there is a possibility of high anopheles mosquito population to result in high malaria cases. Factors accounting for the rather low correlation were: percentage of inhabitants using ITN as well as livestock and human population densities all of which had negative correlation with malaria cases. Thus an increase in these parameters resulted in a decrease in malaria cases. Inhabitants at various areas with reservoirs experienced the symptoms of malaria more frequently (monthly and bi-monthly) than those of the control community (mostly every three months).

5.2. RECOMMENDATION

It is recommended to the Ghana Irrigation Authority (GIDA) to ensure during reservoir designs that a buffer zone of at least five hundred meters (600m) is created around each reservoir within which there shall not be any human settlement.

The functions and mandates of the Water Users Associations (WUA) should be extended to cover the wet seasons so as to mobilize the wet season farmers to maintain sanity in the irrigation canals and laterals. This would ensure that the canals and laterals which are the major breeding sites for the disease vectors are made uninhabitable to them.

The Bongo District Health Administration (BDHA) should intensify their campaign on the use of the Insecticide Treated Nets (ITN). This would lessen the malaria burden with its high mortality rate.

This research should be replicated during the dry season. This would help ascertain the trends outlined in this study. This is due to the fact that the data collection took place in the rainy season where surface waters pools order than the reservoirs could contribute to vector abundance.

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APPENDICES

APPENDIX A: QUESTIONNAIRES

Households Questionnaires

1. Name of respondent (optional) ....Size of household................
2. Do you in any way benefit from the small dam in this area? Yes [ ], No [ ]
3. If yes, in which way? Financial [ ], Food resources [ ], Livelihood [ ], other............
4. Do you suffer any ill health due the presence of the small dams? Yes [ ], No [ ]
5. If yes, specify: Malaria [ ], lymphatic filariasis [ ], others ....
6. How do you treat these diseases? Government Health Service [ ], Self medication [ ], others................
7. How much money do you spend annually for treating theses diseases? ....
8. How do you control mosquitoes in you home? Treated net [ ], spray insecticide [ ], smoke insecticide [ ], others................
9. How often do you experience the symptoms of malaria? Monthly [ ], Bimonthly [ ], Three monthly, others..........
10. How often does your under five year old child experience the symptoms of malaria? Monthly [ ], Bimonthly [ ], Three monthly, others.........

Checklist

1. Name of dam................located in..........of the Bongo District
2. What are the various uses of the reservoir? ....
3. What is the average surface area of the reservoir? ....
4. What is the average depth of the reservoir? ....
5. Name of nearest village or human settlement? ....
6. Name of nearest town or city? ....
7. What is the distance of the reservoir from the human settlement? ....
8. Name of nearest health center or hospital? ....

APPENDIX B: Adult *Anopheles* Mosquitoes trapped in all the sampling zones

Communities	Zorko			Valle (Vea) Zone			Bongo Central			Soe			Beo			Namoo			Balungu (Control)		
Days	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Trap A	21	23	19	28	32	10	9	13	5	18	20	16	4	17	8	56	58	50	2	0	2
Trap B	27	27	20	82	80	72	14	9	19	15	10	15	20	4	7	46	44	40	8	10	5
Trap C	53	48	51	51	48	49	6	11	1	7	9	6	16	20	5	44	63	41	3	10	0
Trap D	83	85	80	73	74	67	30	14	42	0	3	2	23	24	8	60	45	58	2	0	1
Trap E	40	37	46	168	178	109	24	9	39	2	5	1	10	8	16	46	40	42	17	6	9
TOTALS	224	220	216	402	412	307	83	56	106	42	47	40	73	73	44	252	250	231	32	26	17

APPENDIX C: Summary of Reservoir Parameters

Reservoir	Area (Ha)	Mean Depth(m)	Distance to settlement (m)	Larvae Counts	OPD Malaria Cases	Livestock Population Density	Human Population Density	% usage (ITN)
Soe	3.8	5.4	583.3	95	1199	124	133.0	40
Beo	3.5	4	309	29	822	116	202.0	35
Bongo Central	5	3.5	247.1	41	223	125	199.0	70
Zorko	4.8	3	153	491	1997	132	314.0	15
Namoo	1	2.8	146.8	101	1914	64	113.0	20
Valley Zone(Vea)	405	4.2	131.28	988	1613	119	244.0	50
Balungu	None	None	None	None	156	446	199.0	40