REGIONAL INSTITUTE FOR POPULATION STUDIES

UNIVERSITY OF GHANA

EXPLORING THE INFLUENCE OF CLIMATE VARIABILITY/ CHANGE ON THE PREVALENCE OF SCHISTOSOMIASIS IN GHANA: A STUDY OF THE GA DISTRICTS

BY

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL POPULATION STUDIES DEGREE

JULY 2013

ACCEPTANCE

Accepted by the Faculty of Social Sciences, University of Ghana, Legon in partial fulfillment of the requirement for the award of MPHIL POPULATION STUDIES.

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DECLARATION

I LARBI, Reuben Tete do hereby declare that, except for the duly acknowledged citations of references and ideas, this work is my original work undertaken at the Regional Institute for Population Studies, University of Ghana, and that neither part nor whole of this work has been presented elsewhere for another degree.

Signed ……………………………

Reuben Tete Larbi

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Date………………………………

DEDICATION

This work is dedicated to my family headed by Elder Nelson Larbi for their invaluable support given me from my infancy till now.

ACKNOWLEDGEMENT

EBENEZER, thus far the LORD has brought us. I would like to acknowledge the Almighty God who is, who was and who is to come, for giving me the enablement to come this far. I also wish to express my heartfelt gratitude to my supervisors; Professor S.N.A Codjoe and Professor George Owusu for helping in making this dream a reality. I cannot also forget the integral role played by Professor Wisdom Akpalu and Dr Joseph Intsiful in the completion of this thesis. Their corrections, directions and guidance are well appreciated. May The Almighty God water them in due season. I am also thankful to the entire RIPS family-Professors Ama de-Graft Aikins, John K. Anarfi, and Francis Dodoo and also Dr Delali Badasu, Dr Naa Dodua.

I would like to also acknowledge the funding received from The International Development Research Centre (IDRC) under the Africa Adaptation Research Centre of excellence at RIPS. The funding has really helped me pursue and complete this course successfully and I want to express my sincerest appreciation to the funders.

I must also appreciate the effort of all the Mphil and PhD students specifically Abu Mumuni, Ernest Afrifa-Anane and also Laud Raphael Sowah, who helped me in my field work

To all of them, I say kudos and may God bless them exceedingly abundantly.

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IAWGCCH-	The Interagency Working Group on Climate Change and Health
UNFCCC-	United Nations Framework Convention on Climate Change
IAMAT-	International Association for Medical Assistance to Travelers
UNECA-	United Nations Economic Commission for Africa
NCCARF-	National Climate Change Adaptation Research Facility
UNDP-	United Nations Development Programme
WHO-	World Health Organisation
IPCC-	Intergovernmental Panel on Climate Change
TAR-	Third Assessment Report
FAR-	Fourth Assessment Report
WHA-	World Health Assembly
EPA-	Environmental Protection Agency
CDC -	Centre for Disease Control
DCPP-	Disease Control Priorities Project
NCAP-	Netherlands Climate Assistance Programme
CHIM -	Centre for Health Information Management
GMet-	Ghana Meteorological Agency
CoV-	Coefficient of Variability

ABSTRACT

Climate change is projected to have an impact on disease abundance and a geographic shift in the prevalence of many vector borne diseases like schistosomiasis and malaria. Schistosomiasis is one of the 13 diseases that the WHO has classified as Neglected Tropical Diseases (NTDs) which currently affects some 200 million people and another 600 million people are at risk globally. Despite the high prevalence and its associated effects like anaemia and bladder cancer, it receives less attention and little is currently known about the pattern of spread and the potential links to climate change. This study examined the influence of climate variability/change on schistosomiasis prevalence in endemic communities. Also, community knowledge and perceptions of schistosomiasis infection, as well as coping strategies were examined. The study employed a mixed method involving qualitative and quantitative methodologies. Schistosomiasis epidemiological data from the Centre for Health Information Management (CHIM) and climatic data the Ghana Meteorological Agency were used. The primary data collection involved focus group discussion, in-depth interviews and participant observation in two communities. The results of the quantitative data analysis showed a significant positive correlation between total rainfall and schistosomiasis ($r=0.410$, $p<0.05$). The correlation between rainy days and schistosomiasis is not significant ($r=0.263$, $p>0.138$). Minimum and maximum temperatures correlated negatively with schistosomiasis ($r=-0.717$, $p<0.05$) and ($r=-0.631$, $p<0.05$) respectively. Moreover, there was no significant difference between the effect of moderate rainfall and high rainfall on schistosomiasis prevalence ($X^2=2.098$, df=3, $p>0.5$). It was also found that the maximum temperature Granger-causes a reduction in schistosomiasis. Also, the knowledge and perceptions of climate change was consistent with the empirical data and that for schistosomiasis was similar to biomedical explanations. There had been control and prevention interventions such as school-based education, screening and treatment which were mainly targeted towards school children to the neglect of the other vulnerable groups. The study recommends that community members be involved in prevention and control programmes, so that their knowledge and perceptions can be integrated into the implementation strategies.

CHAPTER ONE

Introduction

1.1 Background of the study

Climate has an intense influence on the existence of humans and other living organisms on earth. This is because climatic factors are essential for health, food production and livelihood in general (Intergovernmental Panel on Climate Change (PCC), 2001; United Nations Development Programme (UNDP), 2007). While weather is the current atmospheric condition at a given place and is characterised by variables like temperature, rainfall and relative humidity, climate refers to the average weather (IPCC, 2001; Hansen, Sato and Ruedy, 2011). Naturally, the earth's climate varies by seasons, years and even on much longer periods (IPCC, 2001). Depending on latitude, the vegetation type, the distance from the sea and other geographical factors, the climate may also vary from place to place (Hansen et al., 1988; Adejuwon, 2006). According to the IPCC Third Assessment Report (TAR), any statistically significant variations of the mean state of the climate or of its variability, typically persisting for decades or longer time periods, are referred to as climate change (IPCC, 2001).

Climate change poses significant direct and indirect risks to human health through bush fires, heat waves, floods, transmission of vector-borne and other infectious diseases (Hunter; 2003; Haines et al, 2005). Infectious disease vectors that do not regulate their internal temperatures are sensitive to external temperature changes (IPCC, 2001). Climate change may therefore affect the distribution of these vector species by increasing or decreasing their loads depending on whether or not the conditions provide favourable conditions for breeding (Hunter, 2003; WHO 2009). The effect of climate change on emerging diseases will be based on the effects of temperature and rainfall on all life stages of both hosts and parasites (Paull and Johnson, 2011). In the case of schistosomiasis, changes in temperature and rainfall patterns would directly affect the reproductive behaviour and could result in a geographical distribution of the snail host and the development of the parasites. It could also affect the infection rate indirectly by influencing environmental factors like vegetation and the availability of breeding sites (Medical Ecology, 2012; Martens et al., 1995). For instance, whiles cercaria infection does not occur at all at temperatures below 9^{o}C, the infection rate increases from 15^{o}C to a maximum of 27^{o}C beyond which thermal death begins for both parasites and the snail intermediate host (Martens et al., 1995; Mangal, Paterson and Fenton, 2008). Rainfall on the other hand can create seasonal standing ponds for the breeding of the schistosomes; however, excess rainfall resulting in floods creates turbulence in the habitat and thereby dispersing the snails, and killing the schistosome parasites. Droughts too could eliminate the breeding sites by causing the snail habitats to dry up (Dazo et al; 1966; Barbosa, 1989; Paull and Johnson, 2011).

Schistosomiasis is a waterborne parasitic disease with the most common symptom being blood in urine or stool (Mafiana, 2004; Tay, et al., 2011). It is also known as *bilharziasis* or “snail fever,” and most commonly affects school-age children (Kvalsvig, 1998; Watts, 2005; Ugbomoiko, 2010; Aboagye and Edoh, 2011). It is one of 13 diseases that the WHO has classified as neglected tropical diseases (NTDs). Untreated schistosomiasis often results in anaemia, stunted growth in children, cognitive malfunctions, and sometimes premature death (Schistosomiasis Fact Sheet, 2010; Carter Centre, 2010). Complicated cases may also result in bladder dysfunction, kidney and liver disease, and sometimes cancer. Two types of schistosomiasis are common in Ghana: urinary and intestinal characterised by blood in the urine and stool respectively (Black et al., 2008; Zheng, 2008). Schistosomiasis is one of the most widespread of all human parasitic diseases, affecting over 200 million people in more than 74 countries (WHO, 1990; Carter Centre, 2010). It is the most prevalent of all water-borne diseases and a great health risk in rural areas (Kamga, 2003).

Concerning the prevalence in Ghana, the WHO epidemiological chart for Ghana indicates prevalence ranging from 1% to 90% depending in the geographical location and the endemicity of the area (WHO, 2009). Also, a study conducted among patients and school children in Sunyani between 2006 and 2009 found that the prevalence rate among the patients at the Sunyani Regional Hospital for 2006, 2007, 2008 and 2009 were 0.24%, 0.55%, 0.55% and 0.75% respectively while that for the school children at the same place in 2008 and 2009 were 60.1% and 60.3% respectively (Tay, Amekudzi and Tagoe, 2012).

1.2 Statement of the Problem

The WHO estimates that NTDs affect over one billion people each year and cause about 570,006 deaths annually. Recent reports indicate that some 200 million people are infected with schistosomiasis. Another 500 to 600 million people exposed to the disease as a result of poverty, poor hygiene and lack of adequate water facilities (WHO, 2009). Agricultural work, domestic chores, and recreational activities tend to expose rural dwellers of endemic communities to infested water. After malaria and intestinal helminthiasis, schistosomiasis is the third most devastating tropical disease in the world, being a major source of morbidity and mortality in developing countries in Africa, South America, the Caribbean, the Middle East, and Asia (WHO, 2010). Within sub-Saharan Africa, Nigeria is the country with the highest number of human schistosomiasis — about 29 million in 2008 (Hotez and Kamath, 2009). A survey of 8,274 people in the Ghana-2101 project showed that 12% were passing ova of *S. haematobium* in the urine, the infection rate rising to a peak of 34% in males 15-19 years of age (Lyons, 2002). In another study conducted by Nsowah-Nuamah et al., (2006) in eight villages in the Ga and Akuapem South districts in Ghana, out of the 2562 who submitted urine samples, the prevalence of *Schistosoma haematobium* infection ranged between 54.8 and 60.0%. These allude to the fact that schistosomiasis is still a major problem in some parts of the country and specifically the Ga District.

Studies have shown that urinary schistosomiasis can lead to iron deficiency, anaemia, cancer of the bladder, protein-energy malnutrition and reduced mental and physiological performance (Cohen et al. 1992; Moji et al, 1998; Ross et al., 2002; el-Mawla, 2001; WHO, 2009; King 2010). It has also been found that urogenital schistosomiasis damages the hymen and clitoris in women leading to bleeding, especially after coitus and could increase the risk of contracting HIV and other STIs (WHO, 2009; Schistosomiasis fact Sheet, 2009). Aside being driven by poverty, schistosomiasis is also found to be poverty –promoting; thus it reduces worker productivity and impair childhood development and consequently, the future productive capabilities of those affected who happen to be predominantly children. The resulting reduction in productivity and hence economic loss tends to worsen already impoverished conditions of the affected populations (Carter Centre, 2010).

However, despite the numbers they affect, and their health and social consequences, schistosomiasis just like the other NTDs attract less than one percent of the total health funding for the developing world (National Health Profile, 2004). Also, the perceptions about hematuria (blood in urine) and their implications for schistosomiasis control in the endemic communities have received very little attention (Takougang et al., 2004). The potential impact of climate variability/ change on the transmission of the schistosomiasis and the other NTDs has received insufficient attention from researchers and funding organisation. Most of such studies have focused on malaria but very few studies have been carried out regarding the NTDs, particularly schistosomiasis (UNECA, 2005).

Due to lack of attention, little is currently known about the pattern of the spread of schistosomiasis and the potential links with climate change. In the Ga Districts for example, though have been tagged by the WHO as endemic area and is confirmed by the baseline data from the National Schistosomiasis Control Programme receives very little attention. As a result the transmission-promoting factors, the pattern of spread and the population at risk as well as the water contact patterns remain unknown let alone the potential links with climate change and other environmental factors. As a result, prevention and control interventions are likely to fail due to the knowledge deficit about the transmission dynamics.

1.3 Rationale of the study

Only a few studies have been carried out concerning the pattern of spread of schistosomiasis due to climate change; and the results have been inconclusive (US Meteorological Office 2009). Although earlier climate change disease impact models predicted that the area conducive to schistosomiasis transmission would expand, later models projected a decrease. Mangal et al, (2008), for instance mentions that the impact of temperature on disease prevalence and abundance is not straightforward.

There has not as yet been any convincing evidence that the seasonal shifts in schistosomiasis prevalence are due to the climate change. Thus the nature and extent of climate change on the transmission of schistosomiasis remain poorly understood. Research on the effect of climate change on schistosomiasis transmission is limited due to the quality of data for an extended period of time schistosomiasis epidemiology required. As a result, wide knowledge gaps remain resulting in extensive need for additional research to improve our understanding of how climatic factors, both directly and indirectly can influence schistosomiasis transmission. Filling these knowledge gaps will help better define the potential health impacts of climate change and identify specific public health adaptations to increase population resilience. Besides, one of the research areas that the IPCC recommends is the effect of short-term climate variability on disease incidence (IPCC, 2001), which is within the domain of this study.

Finally, the relevance of this study to population studies cannot be overemphasized as it will enable us to understand the course and dynamics of schistosomiasis morbidity like the population at risk and other demographic risk factors. Besides, the study also assesses the knowledge, perceptions and coping strategies of schistosomiasis, which is very crucial for effective public health response.

1.4 Objectives of the study

The general objective of the study is to investigate the influence of climate variability on the schistosomiasis prevalence in the Ga Districts of Ghana. The specific objectives are:

1. To describe the knowledge and perceptions of climate change and schistosomiasis infection in the study communities.

2. To find out the coping strategies as well as schistosomiasis control and prevention interventions of people in the study communities.
3. To examine the effects of the climate variables on schistosomiasis prevalence.
4. To make policy recommendations aimed at increasing resilience of the populace to schistosomiasis infection.

1.5 Hypotheses

- There is a negative association between the average maximum temperature and the schistosomiasis prevalence.
- Moderate total annual rainfall is likely to produce higher schistosomiasis prevalence than high rainfall
- The relationship between schistosomiasis prevalence and the number of rainy days is directly proportional.
- The annual average minimum temperature is positively correlated with schistosomiasis prevalence.

1.6 Definition of Concepts

Weather is the current atmospheric condition in a given place and is characterised by variables like temperature, rainfall and relative humidity

Climate refers to the average weather and its variability over a certain geographical area and time span, typically over a period of over thirty years (Hansen, Sato and Ruedy, 2011).

Climate variability: is the variation around the average climate, including seasonal variations and large-scale regional cycles in atmospheric and ocean circulations.

Climate change: ‘‘a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods” (UNFCCC, 1994).

Prevalence is a measure of disease that allows us to determine a person's likelihood of having a disease. Therefore, the number of prevalent cases is the total number of cases of disease existing in a population.

Time lag – “the time elapsing between application of a stimulus and the resulting reaction” (Medical Dictionary)

1.7 Limitations of the study

- Schistosomiasis epidemiological data could only be acquired from 1985 to 2008 at the regional level as total annual reported cases and a combination of the Ga Districts from 2000 to 2006. This did not allow for in-depth monthly and community-specific analysis.
- Mindful of the fact that other factors could contribute to schistosomiasis transmission, it would have been better to control for other socio-demographic factors to know the combined effect of these risk factors. However, since the data was not tied to any of these characteristics only the effect of the climate variables was examined quantitatively.
- Due to data paucity, the latest schistosomiasis epidemiological data used was up to 2008, which is a bit aged. However a more recent data could not be obtained.
- The water temperature should have been used in this study. However due to the constraints in measuring the water temperature and because the thermal conditions of shallow water usually reflect the ambient air temperature (Martens et al., 1995). The air temperature was used as an approximation for the water temperature.

1.8 Organisation of the of Study

CHAPTER ONE: is on the introduction of the study and consists of the background to the study, statement of problem, rationale of study, study objectives, definition of terms, limitations of the study and organisation of the study.

CHAPTER TWO: consists of literature review, theoretical and conceptual framework

CHAPTER THREE: The study area and the methodology of the study are described in chapter three.

CHAPTER FOUR: The knowledge and perceptions of climate change and schistosomiasis infection in the study communities are described in chapter four.

CHAPTER FIVE: is focused on the description trend and variability of rainfall, rainy days, maximum and minimum temperature and that of schistosomiasis prevalence. It also includes the relationship between the climate variables and schistosomiasis prevalence.

CHAPTER SIX: The coping strategies as well as schistosomiasis control and prevention interventions of people in the study communities are presented in chapter six.

CHAPTER SEVEN: Contains the summary, conclusion and recommendations of the study.

CHAPTER TWO

Literature Review, Theoretical and Conceptual Framework

Introduction

This chapter is focused on three key areas including the literature review, the theoretical and conceptual frameworks. Literature on climate variability/ change and health outcomes nexus, specifically schistosomiasis prevalence are reviewed. The studies on the factors that predispose people to the risk of schistosomiasis infection are also reviewed. Also, whiles theoretical framework explains theoretical underpinnings of the study, the conceptual framework shows the inter-linkages between the variables. The chapter ends with a summary and the gaps identified in the literature.

2.1 Literature review

The key themes in this section include the extent of climate variability/ change and the effect on human health, climate variability/ change and schistosomiasis transmission, seasonality and schistosomiasis prevalence, other environmental factors and schistosomiasis transmission and finally the socio-economic factors and schistosomiasis risk.

2.1.1 Climate variability/change and human health

There has been evidence that the global climate is changing and it is affecting basic requirements for health - clean air and water, sufficient dietary requirements and climate-related disasters (Hales et al., 2003; Ezzati et al., 2004; Stensgaard et al., 2011). In the last century, the global temperature has risen by about 0.75^{o}C and over the last 25 years, the rate of global warming has increased at over 0.18^{o}C per decade (McMichael et al., 2006; UK Met Office, 2008 Cited in: WHO, 2012). The IPCC's TAR projected that, as we continue to change atmospheric composition, global average surface temperature will rise by 1.4 to 5.8ºC in this century, along with changes in precipitation and other climatic variables (IPCC, 2001).

The implications of the change in climate is made evident in the rising sea levels, changing rainfall patterns, increases in the intensity and frequency of extreme weather events, among others which are experienced globally including Ghana (Haines et al., 2005; Adejuwon, 2006, IPCC 2007; WHO, 2009).

The environmental consequences of climate change, both those already observed and those that are anticipated will affect human health both directly and indirectly (UNECA, 2005; Interagency Working Group on Climate Change and Health, 2012). This has had significant influence on food production, human health, human livelihood in general and other interference of the ecosystem (Christensen et al. 2007). The situation of Ghana is not so different, as it is having its share of the effects of climate variability and change in diverse ways, notable is the effect on health and agriculture due to drought and unreliable rainfall patterns (EPA, 2009). For instance Fosu-Mensah, Manschadi and Vlek, (2011) reported that temperature in the sub-humid region of Ghana is likely to have 1-6^{o}C increase by 2050. Also, Christensen et al. (2007) and Hulme et al. (2001) reported that inter-annual variability in rainfall is expected to increase in many parts of the country, with an increase in the intensity of high rainfall events but an overall decrease in the number of rain days. With this change, it is projected that while the rainfall amount at the start of the rainy season in April decreases by 30–50%, that in July, the month between the major and minor rainy seasons would experience an increase by a similar amount.

Although climate change may bring some benefits, such as reduction in cold-related deaths and increased food production due to the availability of land at places previously covered by ice, the overall health effects are likely to be negative (Ghana Health Report, 2006; WHO, 2012). However, the actual types of health outcomes due to longer-term climate change, against the shorter-term natural variation are not clear and so making the detection of health effects due to climate change is difficult (IPCC, 2001). It is reported that each year, about 800 000 people die from causes related to urban air pollution, 2.2 million from diarrhoea resulting from water contamination and poor hygienic conditions, 3.5 million from malnutrition and approximately 60 000 in climate-related disasters (Ezzati et al., 2004).

Climate change is projected to result in higher levels of some air pollutants, increased outbreaks and transmission of diseases through unclean water and through contaminated food, exacerbating malnutrition by threatening agricultural production in some of the poorest countries (Hales et al., 2003; IPCC, 2007). Climate change may also bring new challenges to the control of infectious diseases. Already, most of the infectious diseases like cholera, diarrhoeal diseases and other vector borne diseases like malaria, dengue and schistosomiasis which are killing people in the tropics are climate-sensitive (Haines et al., 2005; WHO et al., 2009). The WHO has also reported that the variable rainfall patterns are likely to affect fresh water sources and this lack of safe water can compromise hygiene and increase the risk of diarrhoeal disease, which kills 2.2 million people every year (WHO, 2012). With regards to vector-borne diseases in general, temperature changes can affect both vector distribution and the infective potential of pathogens (Hunter 2003; Malone 2005). The ways in which temperature affects transmission include; changes in the survival rate of both vectors and parasites, changes in the growth rate of disease vectors, changes in incubation period of parasites and changes in seasonality of both vector activity and parasite transmission (Gubler et al., 2001; IPCC, 2001; Carter Centre, 2010).

Anthropogenic environmental changes are mostly mentioned as primary drivers of disease emergence in human and other wildlife populations (Daszak et al., 2000; Jones et al., 2008). Also, the disturbance of aquatic habitats by waste disposal causing contamination and changes in the habitat of disease vectors, coupled with the change in climatic factors are contributing to a geographic shift in the incidence of most water-borne diseases (Daszak et al., 2000; Gajadhar and Allen, 2004; Johnson et al., 2007). The incidence of several infectious diseases may be altered by the difference in responses of hosts and parasites to rising temperatures and changing rainfall patterns which may result in an increase or decrease in disease prevalence (NCCARF, 2009; Paull and Johnson, 2011; Stensgaard et al., 2011).

The WHO has also projected that global warming will cause an expansion of the areas that are conducive to infectious disease transmission (WHO, 2009). Initial research on climate-sensitive infectious diseases predicted potential increases in disease prevalence due to climate change; however recent studies report geographic shifts in disease distributions, and not mere increases in the disease abundance (Hales et al., 2003; Zhou et al., 2008; Randolph, 2009; Ostfeld, 2009). Thus, higher temperatures are intensifying the risks of transmission of vector-borne diseases, such as malaria among the hitherto non-endemic high-altitude populations that lack immunity against such diseases (WHO et al., 2009). In China for instance, climate change is projected to expand significantly the area where the snail-borne disease schistosomiasis occurs (Zhou XN et al., 2008; WHO, 2012). Climate models indicated that the average temperature in January will increase by 0.9°C by 2030 and by 1.6°C by 2050, suggesting that area of schistosomiasis transmission will cover an additional 8.1% of China's surface area, and thus exacerbate the intensity of transmission in areas where the disease is currently endemic.

The IPCC in its third assessment report mentioned that climate variability/change is strongly affecting the transmission of water-borne diseases as well as other diseases transmitted through insects, snails or other cold blooded animals. It is also projected that changes in climate are likely to lengthen the transmission seasons of vector-borne diseases that have significant public health impact, alter their geographic scope of others and still cause the re-emergence of new ones (WHO, 2012). For instance, the identification of 35 new disease-causing agents between 1972 and 1999 and the re-emergence of other ones have been attributed to climate change (WHO, 2003; Wagner, 2008)**.** The IPCC has also reported that many of the diseases that are highly sensitive to climate also have a significant global impact. Examples include malaria, dengue, leishmaniasis and schistosomiasis, which are classified as NTDs. For instance drought make people resort to schistosomiasis infested ponds for irrigation and water for domestic use and thus putting them at higher risks (WHO, 2009; Carter Centre 2010).

2.1.2 Climate variability/change and schistosomiasis transmission

Schistosomiasis (bilharzia) is one of the main occupational diseases acquired by man through activities associated with freshwater such as washing, bathing, fishing and recreation (WHO 2010; Carter Centre 2010; Schistosomiasis Factsheet, 2011). It has also been recognized as a disease of significant socio-economic and public health importance, second only to malaria (Lengeler et al., 2002 cited in Tay, Amekudzi and Tagoe, 2011; WHO 1993). It is caused by the blood fluke Schistosoma haematobium (the species that causes blood in urine) and Schistosoma mansoni (the species that causes blood in the stool) (Carter Centre, 2010; Tay, Amankwa and Gbedema, 2011; Disease Control Priorities Project (DCPP), 2003). The disease is transmitted to humans when the cercaria penetrates the skin of people who wade, swim or make any form of contact with contaminated water. The microscopic worms migrate through the body until they develop into sexually mature adults, and lay eggs in about 25 to 30 days of infection (Xue et al., 2011). Some of the eggs are passed out of the body in the tool (S. mansoni, S. japonicum) or urine (S. haematobium) to continue the parasite life cycle.

Under serene environmental and climatic conditions in fresh water, the eggs hatch into larvae called miracidia and later penetrate the appropriate snail host, develop and release hundreds of microscopic worms called cercariae. Given the appropriate water volume and flow, these cercariae move about briskly for several days after they are released from the snail. During this time, when they come into contact with unprotected human skin, they get attached and discard their tails, and penetrate the skin to continue the cycle (Zakhary, 1997; Medical Ecology, 2004). The rest of the eggs which are about half of the total are trapped in body tissues, causing an immune reaction and progressive damage to organs (Ryan, 1994; Xue et al., 2011).

Rainfall and temperature are the climatic factors that have been identified to cause significant turbulence to the normal rhythms of snail population dynamics (Hunter, 2003; Schistosomiasis factsheet, 2010; Carter Centre, 2010, Xue et al., 2011; Arshad et al., 2011; Tay, Amekudzi and Tagoe, 2011). Extremely high temperatures make snail reproduction reduced or interrupted (Barbosa and Barbosa, 1994; Malone, 2005). Thus when the volumes of water in water bodies are low as a result of very low rainfall, they become predisposed to being heated to temperatures above 50^{o}C. In irrigation systems, the frequency and timing of water delivery into the channels also has an effect on snail populations. (Dazo et al., 1966). A number of studies have established various relationships between these weather variables - predominantly temperature and rainfall and the prevalence of schistosomiasis (Hunter, 2003; Paull and Johnson, 2011; Tay, Amekudzi and Tagoe, 2011).

The influence of climate change on the development of intermediate host snail species has been extensively studied. Laboratory studies have indicated that all the three genera of snail hosts can tolerate a wide temperature range (Barbosa, 1989; Odongo-Aginya, 2008). Whereas at low temperatures, snails are dormant have low fecundity but good survival, egg production and snail mortality increase proportionally with increasing temperature (Hairston, 1973; Gillett, 1974; Schiff *et al.*, 1979). As temperature increases above the optimal range, the period within which the schistosomiasis parasite (cercaria) stays active in the water becomes less. This in turn decreases the infection rate of the parasites, resulting in lower prevalence (IPCC, 2001; WHO, 2012).

The effects of temperature on prevalence and development of schistosomes have been studied in the laboratory by a number of authors (Anderson et al., 1979; Zhou et al., 2010), where they found that the rate of development increased with temperature as a linear relationship. The suitable temperature range for larval development in the laboratory was between 15°C to 35°C.

Similarly, McNally, (2001) also reported a minimum temperature requirement of 15.3°C and an optimum of 22°C for S. haematobium. On the other hand, an inverse relationship between rate of development and temperature above the optimum temperature was observed by Mangal et al., (2005). Malone (2005) also reports that the optimum temperature for the development of S.

mansoni is 20–27^{o}C and that the cercariae remain infective for 5–8 hours once they are released under optimum temperature conditions, and this duration becomes shorter under adverse temperature conditions. The maximum temperature (Tmax) reflects the hottest daytime temperatures, while the minimum temperature (Tmin) reflects the coolest nighttime temperatures (IPCC, 2001).

In a study by Rubaihayo et al., (2008) in Uganda, contrary to previous reports which indicated no transmission of schistosomiasis at altitude higher than 1,400m above sea level, it was reported that schistosomiasis transmission was taking place at an altitude range of 1487–1682 m above sea level in western Uganda. It was speculated in that study that the change in the geograghic range could be as a result of climatic factors and recommended further research to establish whether the observed altitudinal threshold change is as a result of climate change or other factors. Githeko et al. (2000) also found that Schistosomiasis cases have recently begun appearing in high-altitude (greater than 2000 m above sea level) regions, which were historically not endemic. In a different study in irrigated agricultural region in Ethiopia using Satellite temperature and precipitation, Xue et al., (2011) found that temperature and precipitation play a role in the transmission of schistosomiasis. They found a weak but significant positive correlation between monthly maximum temperature and the number of schistosomiasis patients. In the same study they also established a significant negative correlation between monthly precipitation volume and the reported cases. These associations were observed at lags of 1 and 2 months for the temperature and rainfall respectively.

Thus, changing temperatures and rainfall patterns have consistently been reported to influence the reproductive cycles and behaviours of disease vectors, leading to a more suitable environment for the spread of disease and the potential for the emergence of new ones (United Nations Economic Commission for Africa (UNECA), 2005). For instance, the host snail of genus Ribeiroia have their eggs developing four times faster at 26^{o}C than at 17^{o}C and did not develop at 12^{o}C (Raffel et al., 2008). Higher temperatures increased snail growth, egg production but extreme temperatures results in mortality (Paull and Johnson, 2011). Woolhouse et al., (1990) describes the fecundity rate as being dependent on temperature by modeling a bell curve relationship with the optimum temperature peak at 20.6°C. The host snails for example do not usually lay eggs at temperatures below 18^{o}C (Olivier and Barbosa, 1955).

Other studies have also found that the egg laying behavior of the snails increases proportionally with temperatures up to 30^{0}C (Medical Ecology, 2004; Malone, 2005). Similarly, some researchers have also placed the ideal temperature range form 22-25 and the ideal humidity in the range 55-70% (Arshad et al., 2011). The disparity in the temperature range is due to the different snail genus and species involved in the disease transmission and also the geographical location of the study sites. However, it is generally accepted that rainfall and temperature are very important variables for the spread of the disease (Arshad et al., 2011; Hunter, 2003; Olivier and Barbosa, 1955; Dazo et al., 1966). Above 35^{o}C, snail and egg mortality is reported to rise dramatically (Barbosa and Barbosa, 1994). Malone, (2005) also added that the temperature of water bodies governs the development rate of the parasites within snails and the infectivity of cercariae. Thus, this temperature-dependent increase in the growth of infected snails coupled with the cessation of parasite development at lower temperatures suggests that increasing temperatures will change the host–parasite dynamics. This means that future climate change could alter parasite abundance and distribution (Paull and Johnson, 2011).

There is a myriad of pathways by which rainfall can impact the transmission of schistosomiasis. These include; increase in surface water which can provide breeding sites for snails (Hunter, 2003), low rainfall can also increase breeding sites by slowing river flow (Odongo-Aginya et al., 2008), vectors which are dependent on vegetation may receive expansion in population because increase rain encourages vegetation growth (Martens et al., 1995; Medical Ecology 2004; Gerald et al, 2010). In addition, flooding may eliminate habitat for both vectors and hosts by dispersing them (Gubler et al., 2001). Xue et al., (2011) make it clear that intense rainfall often results in increased runoff which end up in ponds and irrigation canals, and thus creating high flow velocities and turbulent shear that may kill the schistosomes. For instance, flooding in the Yangtze River has been reported to produce approximately, a threefold decrease in acute cases of schistosomiasis per annum compared with years of normal water levels (Xiao-Hua et al. 2008). Droughts on the other hand may increase the frequency of water contacts due to the need to get water from infested ponds (Watts, 2006; Ugbomoiko et al., 2010; Aboagye and Edoh, 2011), Schistosoma species have been found to vary considerably in their preferences for amount of rainfall, length of the rainy and dry seasons, and interval between rainy and dry seasons.

It has been reported by a number of researchers that, the factor that has the greatest effect on freshwater snail population dynamics in the tropics is rainfall (Barbosa and Barbosa, 1994; Medical Ecology, 2004; Odongo-Aginya et al., 2008). Flooding resulting from excess rainfall can cause turbulence in snail habitats, as annual floods have been found to drown adult snails. Extensive floods have a significantly negative effect on snail populations (Patz et al., 2000; Medical Ecology, 2010). At regions with constant flooding, some snail species live about one year but where less frequent or no flooding, the species can live at least twice as long, and often longer (Barbosa and Barbosa, 1994; Medical Ecology, 2010). Water level and velosity also influence the snail populations, with high water currents, the snails are relocated downstream to a place of lower current (Medical Ecology, 2004).

In another study by Xue et al., (2011), it is reported that rainfall and temperature are important drivers of malaria and schistosomiasis transmission. They established that rainfall is largely responsible for creating the conditions that allow sufficient surface water accumulating in ponds and providing abundant snail breeding sites (Carter Centre, 2009; European Centre for Disease Control (ECDC), 2010). Long period of time without rain causes some of the natural snail habitats dry out for a considerable part of the year, leading to the death of a significant number of the snails, despite their ability to withstand drought (Stensgaard et al., 2011). However, due to the extremely high reproductive capacity of these snails their habitats are quickly repopulated in a matter of six weeks after the rains (Barbosa and Barbosa, 1994). Thus the rains are favourable for the multiplication of the snail populations, but the excess of it which causes floods tends to disperse the snails and hence reduce their population (Olivier and Barbosa, 1955). However, the exact process and rainfall amount where there is a shift from increasing snail reproduction as against decreasing cercariae activity or dispersal of snails is not clear in the literature (Xue et al., 2011). Studies on the population dynamics of some snail species have shown the instability of snails' populations is associated with the variations in seasonal, climatic, and ecological factors (Barbosa, 1989).

This diversity of pathways results in rainfall not having the same effect across communities and regions. Thus some studies have found a negative association between rainfall and schistosomiasis incidence (Xue et al., 2011; Tay, Amekudzi and Tagoe, 2011) whiles other reports the opposite (Samie et al., 2010). Thus there could be other local and community-specific mediating environmental, social, behavioral and physiological factors affecting the climate change and schistosomiasis prevalence nexus.

2.1.3 Seasonality of schistosomiasis prevalence

Concerning seasonality of the disease prevalence, Tay, Amankwa and Gbedema (2011) found the highest prevalence occurring in January (15.4 %) and the minimum in March (3.4 %). However, in their study prevalence were inconsistent between April and December, and were in the range of 5.86 % and 10.19 %. They also found a general three-year pattern of S. haematobium peaks of infection during the period under review with infection occurring throughout the year. Adewunmi et al., (1990) also reported that transmission of S. mansoni was demonstrated throughout the year in a man-made dam, whereas transmission of S. haematobium in a stream only occurred in the dry season. This is in consonance with the findings of Chandiwana et al., (1987) who reported that transmission of S. mansoni was erratic and unpredictable and has no clear seasonal transmission pattern. On the contrary, S. haematobium showed a seasonal pattern, with increased intensity in the hot and dry months (September to November) and noticeably reduced during the cold and dry months, thus the June-August season in his findings. Also, moderate and variable, but occasionally intensive observations were made during the December-February and the March-May seasons. This is no different from the report of Etim et al. (1998) that the snail vector populations fluctuate strongly, decreasing at the peak of the rainy season. Thus decreasing snail population would mean decreasing infection rate. In corroboration to the higher prevalence in the dry season, Tay, Amekudzi and Tagoe (2011) and Bavia et al., (1999) also reported higher prevalence in the November- April season.

Obviously, there are disparities in the seasonality of schistosomiasis prevalence across study communities. This suggests that there may be other local factors relating to the habitat, population and behaviour as indicated in Meade and Earickson, (2000) potentially accounting for the regional and community differences in the seasonality of schistosomiasis incidence.

2.1.4 Other environmental factors and schistosomiasis prevalence

The literature identifies a number of environmental factors potentially creating the enabling environment for the breeding of the snail as well as the pupal and larval parasites and hence leading to schistosomiasis transmission and infection. Meade and Earickson, (2000) classifies these factors under the social, natural and built habitats. The topography of an area has been identified to play a significant role in determining the concentration of snail populations, especially for marshlands that lie above low water level of lakes and rivers (Patz et al., 2000, Medical Ecology, 2010). Seasonal standing ponds are characteristic of these elevated areas. Odongo-Aginya, (2008) and Stensgaard et al., (2011) identify that flat land with dry-season ponds and streams, with thick grass covering the ground form optimal snail habitats.

Other places found to provide the environment apposite for snails include shallow shores with little or no fluctuation in water levels and drainage canals with high levels of agricultural runoff (medical ecology, 2011; Zakhary, 1997). Dams, ponds and irrigation canals also to a large extent influence the disease abundance (Zakhary, 1997; WHO, 2008; Nkegbe, 2010). In the Volta River basin in Ghana for instance, before the damming in 1964, prevalence of urinary schistosomiasis was below 5% among communities living along the River. However, after damming, by 1971 many communities living along the lakeshore had prevalence as high as 80 - 90% (Zakhary, 1997). In 1989 infection rates of 76.2% for S. mansoni and 6.3% for S. haematobium were recorded (Ghana National Health Profile, 2004). However, the construction of a dams and the formation of reservoir on a river could have both positive and negative impact on schistosomiasis transmission and control (Steinmann et al., 2006; Stensgaard, 2011). With regards to the positive impact, the creation of the large dams could reduce the frequency and the intensity of floods in the river and hence a decrease in the dispersal of snails and the chances of infection for humans. The floods could also interfere with the development of snails (Zheng et al., 2002). The negative impacts seem to be enormous because aside the fact that the flushed beaches may become snail habitats, the uprising of the water body level may cause expansion in the snail habitats at some places as well. Also the beach may provide the grounds suitable for the growing of reed-grass for an extended period of time and thus benefiting the reproduction of the snails (Zheng et al., 2002; WHO, 2008, Medical Ecology, 2011).

Urbanization, deforestation and agricultural practices can have an effect on the distribution of most snail species (Ripert, 2003; Bruun and Aagaard-Hansen, 2008). This is because poor sewage systems and lack of latrines and potable water which is characteristic of urban slums create local transmission sites (Saker et al., 2004). Also, large slums and squatter areas around towns and cities are characterized by overcrowding and very poor hygienic conditions and thus providing a conducive atmosphere for the disease transmission (Bruun and Aagaard-Hansen, 2008). With regards to deforestation, Martens et al., (1995) mention that generally drought and desertification resulting from deforestation decreases vector breeding as most disease vectors depend on aquatic environments and drought conditions severely curtail the vector longevity. With regards to agricultural practices, Martens et al., (1995) mention that in areas where there is effective use of pesticides there is resistance among the vectors to the pesticides and has major consequences on disease transmission. In addition, the rains tend to wash these pesticides from the crops and farmlands into the river bodies and thus having dire consequences on the survival of disease vectors.

2.1.5 Socio-economic and demographic factors and schistosomiasis prevalence

The literature points out to some household characteristics as possible explanatory variables to the prevalence and intensity of schistosomiasis. With regards to occupation, fishermen household heads gave the highest prevalence (Takougang et al 2004; Ugbomoik et al., 2010). Household income level was also reported to be associated with schistosomiasis prevalence where household with the lowest income had very high prevalence compared with those with higher income (Ugbomoik et al., 2010; Kapito-Tembo et al., 2009). Also, marital status, sanitation status of the household, level of education of family head, number of children aged 10–15 years in the household, relationship with household head have all been found to be independently associated with higher prevalence of urinary schistosomiasis (Watts, 2005; Ugbomoik et al., 2010; Kapito-Tembo et al., 2009; Aboagye and Edoh, 2011; Stensgaard et al., 2011).

Furthermore, three schistosomiasis risk groups have been identified in the literature - those engaging in certain occupations like fishing and agricultural activities associated with irrigation, women who are exposed during domestic activities, and finally Children of school age (Watts, 2005; Nkegbe, 2010; WHO, 2010). Though the disease is mostly associated with rural communities (Takougang et al., 2004; Carter Centre, 2010; WHO, 2009), Tay et al., (2011) had an interesting finding where the overall prevalence of the infection at Kumasi South Hospital-surrounded by urban-poor communities was about nine times higher (40.2%) than that of Aninwa Medical Centre (4.5%) in a peri-urban settlement. This could be due to the influx of patients outside the community. But in consonance with other studies and what one would expert, while Kumasi South Hospital recorded erratic episodes of the infection in some of the years with total absence in others; the infection was low and persistent in the Animwa Medical Centre throughout the study period. Location of settlement is another factor influencing the rate of infection. Zakhari (1997) found a high infection rate among residents of the Volta Region due to the construction of the Akosombo Dam. Also there is high infection rate in communities closer to contaminated rivers than communities with no rivers (Kapito-Tembo et al., 2009; Ugbomoiko et al., 2010).

Sex has been found to play a major role in the prevalence of the disease. Many researchers have reported a consistently higher infection rate in males than their female counterparts. (Tay et al., 2011, Nsowah-Nuamah et al, 2001; Chimbari and Chirundu, 2003). For instance from the findings of Nsowah-Nuamah et al., (2001), the infection rate among the males was as high as 55.9% as against the 3.7% in the females. Contrary to these findings, Nkegbe, (2010) found a rather higher prevalence among the females (64%) than the males (21.8%). This was attributed to the numerous water contact activities of females as a result of inevitable domestic chores that the females undertake which compel them to enter the river to fetch water. However Mafiana et al., (2003) in a study in Nigeria found no significant difference in the infection rate between males and females. These observations are expected considering the fact that some socio-cultural practices such as farming, fishing and recreational activities tend to expose males to infected water bodies than the female counterparts. Besides, these contradictions could be due to the different circumstances prevailing in the study communities. For instance in communities where the females are responsible for fetching water and washing clothes in the river, female infection rate is likely to be higher compared to places where swimming as a recreational activity is dominant or where fishing from streams or irrigational farming using water from ponds prevail.

Age is another important demographic variable reported to be associated with schistosomiasis prevalence. Several studies have shown that the highest prevalence lies in the age range 5-25 (Xue et al., 2011; Aboagye and Edoh, 2011; Tay, Amekudzi and Tagoe, 2011; Nkegbe, 2010; Danso-Appiah, 2010). Aboagye and Edoh, (2011) for instance, found that as high as 78% of those infected were between the ages 5 and 15. Similarly, Xue et al., (2011) reported a prevalence of 87.3% and 84.1% respectively among children in the age groups 8-11 and 12-14. This is something to be concerned about because these are people in the formative ages of their lives and this infection could be very detrimental to their growth and development.

Population density is another factor that has been associated with schistosomiasis prevalence. Bavia et al., (1999) found population density as one of the most important explanatory variables to schistosomiasis prevalence. Similarly, Watts, (2005) also explains why globalization and urbanisation coupled with population movements is having influence on the incidence of schistosomiasis. She argues that rural people bring the diseases with them to the rapidly expanding population centres. Then the unsafe sanitation and water supplies, plus unchanged behaviour act to facilitate the establishment of disease transmission in urban slums. The main mechanism is that movement leads to fresh exposure to the infectious agents – either because the migrating population moves into new areas and gets in touch with infective environments or because they carry the infection and bring it to hitherto unexposed destination (Gushulak and MacPherson 2004; Mac-Pherson et al. 2007; Aagaard-Hansen, Nombela and Alvar, 2010).

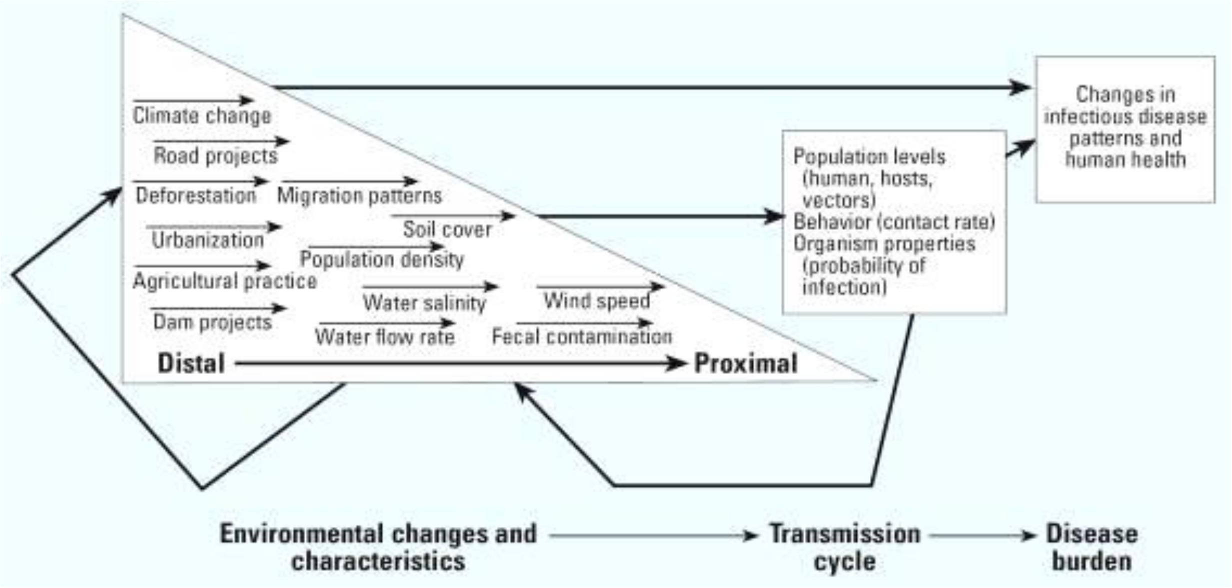
2.1.6 Summary of literature review and gaps identified

The main identified climate factors that affect schistosomiasis prevalence are minimum and maximum temperature and total rainfall amount. Other socio-demographic and environmental factors that influence the risk of schistosomiasis have been discussed. The socio-demographic characteristics include sex, occupation, income level and age. Also, the environmental factors identified include dam projects, population movement, closeness to water bodies and agricultural practices. The association between the climate variables and schistosomiasis incidence has been contradictory in the literature. For instance, whiles some studies report a positive association between rainfall and schistosomiasis prevalence, others report a negative association, and the same applies to temperature. However no single study has sought to find out what could be accounting for this. Also the rainfall variable has always been measured by the total rainfall amount and not the number of rainy days which gives the measure of distribution of the rainfall. The number of rainy days to a large extent determines whether or not the rainfall amount might results in floods. This is very critical in determining the impact on climate variability/change on disease prevalence.

2.2 Theoretical framework

This section focuses on the theoretical underpinnings of schistosomiasis prevalence. The Environmental Determinants of Infectious Disease (EnvID) framework is discussed and adapted for the purpose of this study.

Figure 2.1: The Environmental determinants of infectious disease framework



Source: Eisenberg et al., (2007)

The EnvID framework integrates three interrelated levels of the environment and disease transmission nexus, with the first level being the environmental changes and characteristics that drive ecological and social factors ultimately impacting disease prevalence (Figure 2.1). The second level is the disease transmission dynamics, mediating environmental changes and the disease burden. This level includes factors related to the behaviour and population of both humans and disease vectors. This study focuses on the behaviour and population characteristics of humans and not the disease vectors (Meade and Earickson, 2000). The final part is the disease burden, which is the outcome of the interplay between environmental change and the transmission cycle of a pathogen (Eisenberg et al., 2007). In this study, the disease burden is the schistosomiasis prevalence. This interplay of environmental characteristics and disease transmission cycles eventually lead to a shift in the prevalence, distribution, or severity of an infectious disease. The direct linkages of some distal environmental changes like climate change on disease transmission as shown in the framework are also applied in his study. This study also focuses on how environmental changes like dam projects, agricultural practices, faecal contamination, migration patterns, urbanisation, water level and flow rates and the changes in climate variables such as rainfall patterns and temperature influence schistosomiasis prevalence (Zakhary, 2007; WHO, 2009).

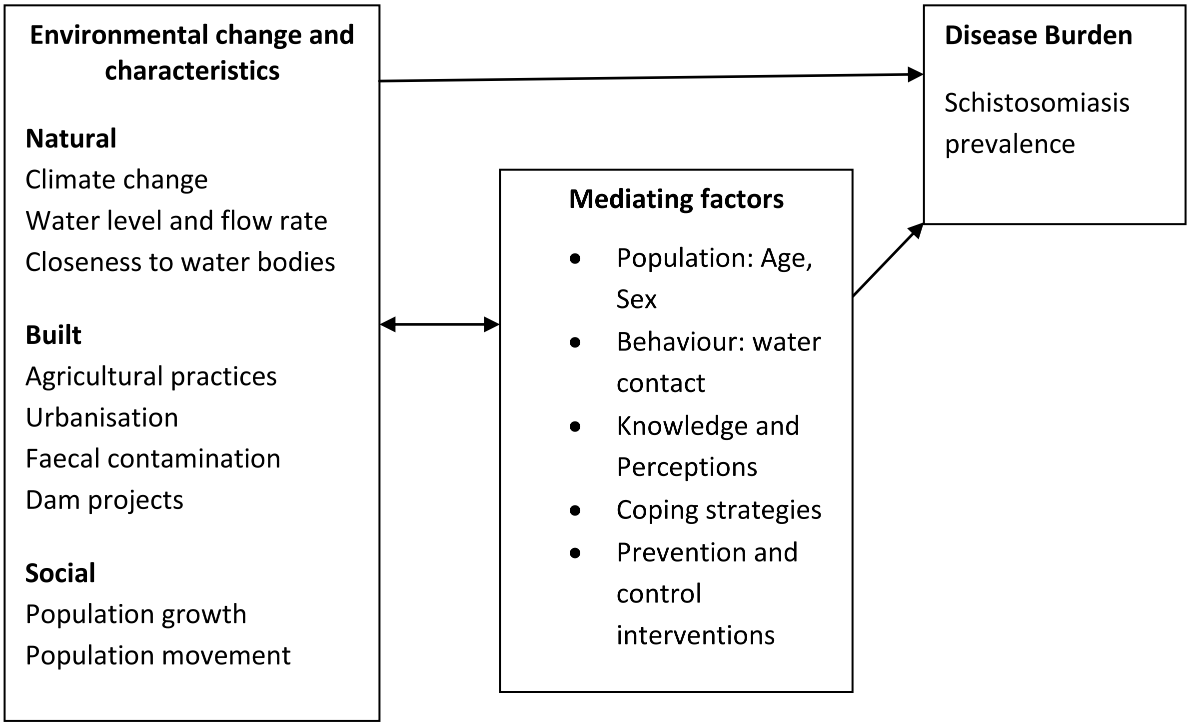
With regards to the transmission dynamics, Eisenberg et al., (2007) identified three players – humans, the vector and the snail host. In this study, the emphasis is not on the vector and host, but rather human characteristics like age and sex. This is because age and sex play a role in defining the risk of schistosomiasis infection (Chimbari and Chirundu, 2003; Nkegbe, 2010). Also with the behaviour, the EnvID framework focuses on the contact rate of parasites. However this study adds the aspects of prevention, treatment and control interventions as well as knowledge and perceptions of the disease (Meade and Earickson, 2000).

2.3 Conceptual Framework

The conceptual framework for this study involves the direct linkages between four climate variables and schistosomiasis prevalence used in the macro (regional level) study. The four climatic variables involved in this study are total rainfall measured in millimetres, number of rainy days (any day with 1mm or more rainfall amount), minimum temperature and maximum temperature measured in degrees Celsius. The literature identifies a multiplicity of pathways that rainfall affects schistosomiasis prevalence, either positive or negative. Rainfall creates seasonal ponds which acts as breeding sites for the snail host and at the same time the excess of it could disperse snails and kill the cercariae and thus affecting the risk of schistosomiasis infection (Martens et al., 1995; Paull and Johnson, 2011, Medical ecology, 2010). Temperature provides the serene atmosphere for the breeding of snails and the growth and development of the cercariae. However, extreme temperatures tend to cause the mortality of cercariae and inhibit the reproduction of snails.

The study employs a two level framework – the macro and micro levels in the analysis of the climate change and schistosomiasis prevalence nexus. The framework used in the community level study is as shown in Figure 2.2.

Figure 2.2: Climate Variability/Change and schistosomiasis prevalence: A conceptual framework



Source: Adapted from Eisenberg et al., (2007) and Meade and Earickson (2000)

Macro level

The macro level is focused on the quantitative associations between the climate variables and schistosomiasis prevalence at the regional level. It adopts the approach for examining the relationship between climate variables and infectious diseases discussed by Mangal, Paterson and Fenton (2008). In this approach, the variations in climate are examined and the short-term effects on disease transmission are monitored. The climate variables examined here are total annual rainfall, number of rainy days, minimum temperature and maximum temperature which form the independent variables.

Micro (Community) level

The framework for the community level study is as shown in Figure 2.2. It shows how climate change together with other environmental and demographic factors influences disease transmission and for that matter the schistosomiasis disease burden.

Dependent variable

At the regional (macro) level, the number of reported cases at the health facilities in the Greater Accra Region was used as a proxy for schistosomiasis prevalence with the assumption that cases reported from other regions is negligible. However, in the determination of the schistosomiasis disease burden at the community (micro) level which was done qualitatively, respondents were asked to rank the disease of greatest concern in the community. Then they were asked to rate the schistosomiasis burden in relation to the other diseases. Finally, they were asked to rate the severity of the disease now and then in different retrospective time scales like five, ten and twenty years ago depending on the age category in the discussion.

Explanatory variables:

The explanatory variables for the community level include climate change, dam projects, population movements, faecal contamination, urbanisation, agricultural practices and water level and flow rates (Figure 2.2). Also, the water contact behavior, knowledge and perceptions of climate change and schistosomiasis as well as the coping strategies which serve as mediating factors between the environmental factors and schistosomiasis prevalence were inquired. In the determination of climate change, the participants of the FGD were asked of the rainfall and temperature patterns and trends. They asked of how the patterns and intensity now compared with that in different time scales in the past as above. The pathways along which climate change influence the prevalence of schistosomiasis has been discussed extensively above.

With regards to urbanisation and population movement, Watts, (2005) also argues why globalization and urbanisation coupled with population movements is having influence on the incidence of schistosomiasis. As rural people move to urban centres they tend to bring the diseases with them to the rapidly expanding population centres. Then the unsafe sanitation and water supplies, plus unchanged behaviour act to facilitate the establishment of disease transmission in urban slums (Mac-Pherson et al. 2007; Aagaard-Hansen, Nombela and Alvar, 2010). In the study, the respondents were asked how often people move in to settle and others move out of the communities. In the determination of urbanisation, basic amenities like schools, clinic and electricity supply were used in addition to the population size. They were asked if the urbanisation process is having any influence on the schistosomiasis infection.

Concerning the dam construction, the participants of the FGDs were asked if there are any ongoing or completed dam projects in the community and whether or not they thought it is affecting the incidence of schistosomiasis. Dams, ponds and irrigation canals provide suitable breeding sites for snail host as well as offering a place for recreational activities for children in rural communities especially and hence in schistosomiasis transmission (Zakhary, 1997; WHO, 2008; Nkegbe, 2010).

Farming and fishing have been identified as occupations with higher risks of schistosomiasis infection (Watts, 2010; Ugbomoiko et al., 2010). The intensity of infection and the frequency of contact with water have been shown to be inversely related to the distance from infested water body (Yeboah, 1981; Kloos *et al.* 1997; Clennon et al., 2002; Aboagye and Edoh, 2011). The distance of the community to a water body was measured in relative terms as to whether there is a water body located within thirty minutes of walking distance or more as used by (Ugbomoiko et al., 2010).

The transmission of schistosomiasis is dependent on the disposal of human excreta in water bodies; this is because the eggs of the schistosomes are passes from the urine or stool to continue the life cycle in a water body given the availability of an appropriate snail host (Carter centre, 2010). This would continue the life cycle of the schistosomes and hence increase the risk of contracting the disease (Figure 2.2). In the determination of the level of faecal contamination in the water bodies, the participants were asked if the rivers in the community experience any faecal contamination from the public.

Also, in the determination of the water level and flow rate, the respondents were asked if they have observed any seasonality in the water level and whether or not they think it affects schistosomiasis incidence. In addition to that, the water levels were observed at different times in the year to ascertain the level and the associated activities carried out in the rivers. The floods resulting in high water levels and flow rates could also interfere with the development of snails and at the same time shear resulting from the high water turbulence tend to kill the cercariae (Zheng et al., 2002).

Mediating factors

The factors that mediate the environmental characteristics and the schistosomiasis disease burden are what Meade and Earickson (2000) calls behaviour. These include contact rate to the source of infection, disease prevention and control interventions as well as knowledge and perceptions. The participants of the focus group discussions were segmented by age and sex to incorporate the diversity of these categories into the study.

The knowledge of the mode of transmission and the symptoms, the coping strategies and the perceptions about schistosomiasis was inquired qualitatively through focus group discussions. At the household level, these parameters to a very large extent can influence the prevalence of schistosomiasis (Aboagye and Edoh, 2011).

Knowledge about the mode of transmission is key in the disease incidence. In Ackumey et al., (2007), the majority of the inhabitants of the Afram Plains attributed the disease to contact with infected water but in Takougang et al., (2004), a study in Cameroun, the majority thought it was acquired by exposure to the sun, others even associated it with puberty and crossing the urine of an infected person. Kamga, (2003) studied the relationship between knowledge of mode of infection and schistosomiasis prevalence and found that the prevalence measured in percentage of infected subjects was inversely proportional to the awareness of mode of transmission. Thus ignorance of the cause of urinary schistosomiasis is strongly related to its prevalence. This means that people who have knowledge of the disease are more aware of the consequences and may engage in positive practices as far as the disease control and prevention is concerned than those who have not.

All these have implications on the incidence of the disease, because perceived severity of the disease is the most important determinant of seeking health care or visiting a health facility in Ghana for instance (Danso-Appiah et al., 2010). Also Kamga, (2003) in a study in Cameroun found a strong negative correlation between the perception and the prevalence of urinary schistosomiasis when he measured perceptions quantitatively.

With regards to the coping strategies, there is generally low reporting of the disease in the health facilities (Carter Centre, 2011; Ackumey et al., 2007; Danso-Appiah et al., 2010). Thus people resort to other modes of treatment such as herbal medicines or even medical inaction rather than seeking medical care. This may result in under reporting of the disease and thus affecting the public health concern associated with it.

CHAPTER THREE

Methodology and Description of the Study Area

3.0 Introduction

This chapter is focused on the methodology employed in this study as well as the description of the study area. The methodology describes the data sources, data collection techniques and data analysis as well as the measures and the statistical analysis and tools employed. The description of the study area on the other hand includes the population size and distribution, topography and drainage, economic activities, and in addition, the vegetation and climate are discussed.

3.1 Methodology

This section is focused on the study design, sources of data, methods of data collection and methods of analysis.

3.1.1 Study Design

The study employed a mixed method using both qualitative and quantitative methods. While the quantitative was used to check the association between the climate variables and schistosomiasis prevalence, the qualitative explored the community knowledge and perceptions about schistosomiasis, the water contact behaviour, the environmental factors and characteristics that potentially predispose people to the risk of infection as well as the control and prevention interventions.

3.1.2 Data sources

The study uses data from both primary and secondary sources. The New LocClim Model developed by the Food and Agricultural Organisation (FAO) was used to describe the climatic characteristics of the study area. New LocClim is a freeware tool to estimate local climatic conditions for any location on earth. It gave the descriptions of the total rainfall, runoff, evaporation rate, the growing seasons and other climatic characteristics. The geographical coordinate of the study area was fed into the model to provide the local climate descriptions.

Secondary data sources:

The secondary data constitute monthly rainfall and temperature data from the Meteorological Services Department (GMet) for the Airport synoptic station in Accra and also two other stations in Tema and Ada, all in the Greater Accra Region (GAR) from 1970 to 2010 and disease epidemiological data from the Centre for Health Information Management (CHIM) of the Ministry of Health. CHIM collates the health data on all diseases from all the health facilities- both private and public from all the ten regions countrywide. GMet on the other hand is responsible for providing efficient and reliable meteorological information by collecting, processing and dissemination of meteorological information to the public. It has 169 working climatological and 22 synoptic stations across the country where temperature, rainfall and relative humidity data are collected every hour. The schistosomiasis prevalence data was available for the GAR from 1985 to 2008 and for the Ga Districts from 2000 to 2006. Due to the limited disease epidemiological data obtained at district level, the regional data was used for the macro level analysis.

Primary data sources:

At the micro or community level, focus group discussions (FGDs) and participant observations were made. The value of focus group discussions in behavioral studies of schistosomiasis has been described by investigators in other endemic areas as valid (El-Katsha and Watts, 1994). It was also deemed appropriate because the community view was required in the study. Similarly, observational studies have been reported as more valid than interviews of reported water contacts (Kvalsvig and Schutte, 1986; WHO, 2008). The knowledge, perceptions and coping strategies of the people in the community were also elicited. In addition the study sought to find out the communities' understanding of climate change. The researcher also assumed the role of a passive participant to observe the water contact behavior and activities in the communities.

Preliminary visits were made to obtain the informed consent from the household heads, hospital officials, school teachers and community leaders, after a detailed explanation of the study. Two communities in the study area –Oboom and Kojo Ashong were purposively selected.

3.1.3 Study population

From the baseline information from the Centre of Neglected Tropical Diseases, two communities -Oboom and Kojo Ashong were selected as the study comunities. These communities were selected due to the high schistosomiasis prevalence and also their location along the major rivers in the study area. Age and gender differentials were observed by grouping the participants into adult male, adult female and the youth in each of the two communities.

3.1.4 Data collection

The data collection was done by the researcher, two research assistants and two community facilitators after a thorough training. Each FGD lasted between 45 minutes and an hour.

A total of 7 focus group discussions were held with about 78 participants segmented by age, sex and community of residence. There were approximately 10 participants in each group. The groups were adult male, adult female, male youth and female youth. All persons aged 30 and above were classified as adults while the youth were between 15 and 29. At Oboom, adolescents aged between 15 and 18 were selected from a local school. Also in-depth interviews were conducted with the medical officer in charge of the Oboom health facility and a community leader.

The discussions revolved around knowledge of climate change and its effect on health, the disease burden of the communities, knowledge of mode of transmission of schistosomiasis, the vulnerable groups, and effect of climate change on schistosomiasis prevalence, other environmental changes and their possible effects on schistosomiasis. Also the perceptions, prevention and attitudes related to schistosomiasis as well as any past interventions by the government or any organisation were discussed. With regards to the measurement of the schistosomiasis disease burden, the respondents were asked to rank the disease of greatest concern in the community. Then they were asked to rate the schistosomiasis burden in relation to the other diseases. Finally, they were asked to rate the severity of the disease now and then in different time scales like five, ten and twenty years ago depending of the age category in the discussion.

The focus group discussions were conducted in Ga, the local vernacular language, and were recorded after seeking the consent of the participants. However, with the pupils, a blend of English and Ga was used. One discussion was done at a time, during which the thoroughly trained field assistant moderated the discussion while the researcher took notes. This dual method of recording responses and taking notes has been discussed by Gazzinelli et al., (1998) as increasing data content validity and reliability and thus allowing comparison between audio recordings and handwritten notes. Community facilitators were employed to organise the participants according to the segmentation. The audio recordings were subsequently transcribed in English verbatim.

With the observation, the water contact activities were observed at the major river in each community- River Densu at Kojo Ashong and Popon at Oboom. The observations were made between 9 am and 4 pm for two days in each river. The frequency for the various contact activities were recorded as well as the duration for each activity. These were necessary for the computation of the relative exposure index, a measure of the activity that exposes the community most to the risk of infection.

3.1.5 Data analysis

The macro level analysis was done first to ascertain the association between the climatic variables and schistosomiasis prevalence. Then the community level analysis explored those environmental factors that possible predispose people to the risk of infection. The analysis of the qualitative data was undertaken in five steps –familiarisation, identification of thematic frameworks, indexing, charting, mapping and interpretation as discussed by Rabiee, (2004). In the familiarisation stage, the transcripts were read thoroughly and the tapes were listened several times. The next stage involved the identification of thematic frameworks where ten themes which includes: knowledge of climate change, effects of climate change on health, knowledge and perceptions of schistosomiasis, climate change-schistosomiasis relationships and coping strategies for people living with schistosomiasis and interventions were identified. During the indexing stage, the transcripts were analyzed in detail that is line by line. The “in vivo” codes –

codes from interviews using the respondents' own words and phrases were identified (Strauss and Corbin, 1990). Then after, the issues were grouped as themes according to the objectives of the study, which is what Rabiee (2004) called charting. In that process, a coding frame was developed after which the codes for each of the above themes were independently identified from the transcripts. In order to make the charting easier, each line of the transcript was numbered then two copies were printed. Whiles the codes on one of the transcripts were cut out, the other remained intact. The cut pieces were arranged under the listed themes and categories – age, sex and community, a process referred to as mapping by Krueger and Casey (2000). The codes that were not relevant to the objectives of the study were left out.

Then the data was ready for interpretation. In the course of the interpretation, attention was paid to the words, context, internal consistency, the frequency and extensiveness of comments, specificity of comments and the intensity of comments as recommended by Rabiee, (2004).

3.1.6 Methods of analysis

Line graphs, percentages and frequencies were used to show the trend of the climate variables – minimum temperature, maximum temperature, total annual rainfall, number of rainy days and also the schistosomiasis prevalence. Correlation analysis was done to measure the relationship between total rainfall, number of rainy days, minimum temperature and maximum temperature and schistosomiasis prevalence. Variability indices were represented as the coefficient of variability, which were computed as the standard deviation of annual rainfall divided by the average annual rainfall (Adejuwon, 2006). The resulting fractions were converted to percentages. In addition to the computation of the indices of variability, linear graphs based on actual records showing the actual changes in rainfall over the years are also shown. The meteorological data used in the macro level analysis of climate variability was for the period 1970-2010. However, because the regional schistosomiasis data was available yearly for the period 1985-2008, the analysis for association between climate variability/change and schistosomiasis prevalence spanned the period 1985-2008. Also, monthly schistosomiasis reported cases available from 2000-2006 was used for assessing the seasonality of the incidence of schistosomiasis.

In order to examine the rainfall amount that results in increase in schistosomiasis prevalence as against the amount the results in a reduction, the total rainfall 100mm above and below the median was coded as moderate rainfall. Then the rainfall amounts below that range and that above the range were coded as low and high rainfall respectively. Similarly, the annual schistosomiasis prevalence below and above the median value were coded as low and high prevalence respectively (Xue et al., 2011). Then a cross-tabulation of the two variables was done to ascertain the rainfall amount the yields high schistosomiasis prevalence as against the amount the yields low prevalence. The strength of the associations was checked at 95% confidence level.

Again, in order to examine the month by month differentials in schistosomiasis prevalence, line graphs were plotted with monthly schistosomiasis data which was available from 2000 to 2006. This was to examine the months with consistently higher peaks representing higher prevalence and the months that record the lowest incidence. In addition, being mindful of the fact that a reported schistosomiasis case in a particular month may not be due to the climatic event for the same month but probably due to that of a month or two earlier, there was the need to set time lags. Because the incubation period of schistosomiasis is a minimum of six weeks, time lags of one month, two months and three months were set and in each case the correlation between schistosomiasis and the weather variables was tested.

Furthermore, the Granger causality test was used to test which of the climate variables was useful in predicting schistosomiasis prevalence. In theory, a time series *X* is said to Granger-cause *Y* if it can be shown, usually through a series of t-tests and F-tests on lagged values of *X*, that those *X* values provide statistically significant information about future values of *Y*.

If *y* and *x* are stationary time series variables, then in order to test the null hypothesis that *x* does not Granger-cause *y*, then the lagged are expressed in the auto-regression as:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + \text{residual}_t.$$

Also, the lagged values of *x* are included as:

$$y_t = a_0 + a_1 y_{t-1} + a_2 y_{t-2} + \cdots + a_m y_{t-m} + b_1 x_{t-1} + \cdots + b_q x_{t-q} + \text{residual}_t.$$

Where, where y=predicted value, α_o= constant, α_m= co-efficient, *x*=predictor, b= lagged coefficient.

p is the shortest lag length

q is the longest lag length for which *x* is significant.

The null hypothesis that *x* does not Granger-cause *y* is accepted if no lagged values of *x* are retained in the regression (Granger, 1969). In the model, while y was the schistosomiasis time series, *x* took values of minimum temperature, maximum temperature, total rainfall and number of rainy days. Then schistosomiasis prevalence was lagged at one and two years.

With regard to the qualitative data, an estimate of the relative index of exposure to contaminated water was computed as the product of number of contacts, mean duration of contacts (in minutes) and mean activity coefficient. The index is regarded as the best estimate for exposure (Hagan, 1992; Ofoezie, Christensen and Madsen, 1998). The coefficients of the activities relevant to this study were: fetching water- 0·18; bathing, 0·20; washing clothes, 0·15;

swimming, 0·90; using boats, 0·10; washing fishnets, 0·35; sorting fish, 0·35; and washing limbs, 0·10. These coefficients were first deduced by Chandiwana (1987) and Wilkins *et al*. (1987) and have been used by Ofoezie, Christensen and Madsen, (1998) in the analysis of water contact behaviour.

3.1.7 Tools used

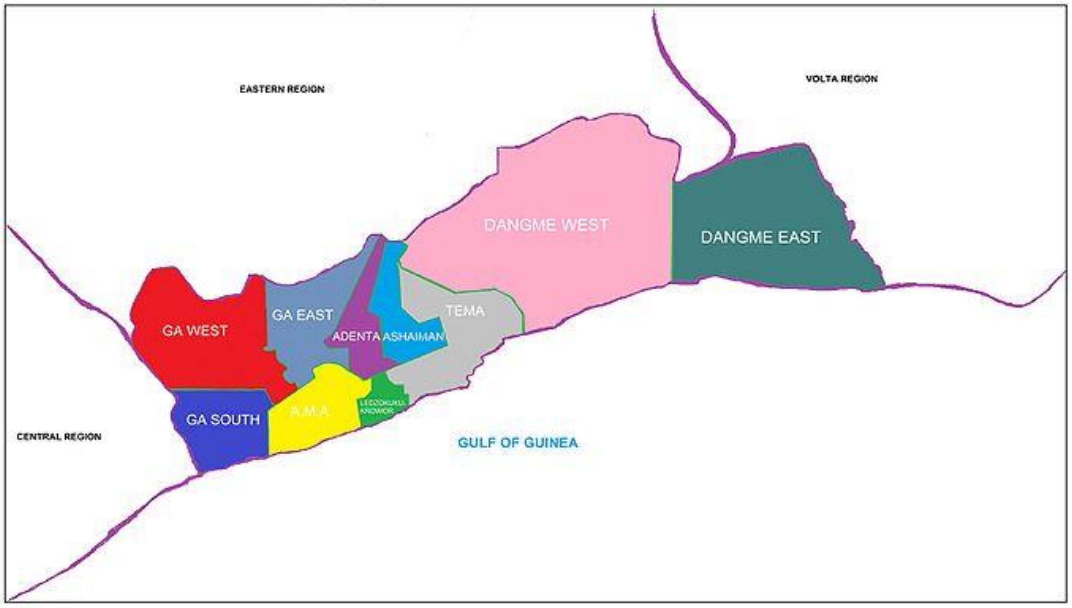
The macro level data was analysed using Statistical package for Social Sciences (SPSS), Microsoft excel, R and RClimdex. The RClimdex was used to extract and clean the climate variables. Also whiles SPSS was used for the correlation analysis and the chi square tests, Microsoft Excel was used for the graphs and charts.

3.2 Study area

Ghana has been identified as a schistosomiasis endemic country by the International Association for Medical Assistance to Travelers (IAMAT) and the World Schistosomiasis Risk Chart, (2012). The Ga District consisting of the Ga West, Ga South and Ga East Districts was selected as the study area because it has one of the highest prevalence in Ghana according to the WHO epidemiological chart (WHO, 2009) and the baseline data from the Centre for Neglected Tropical Diseases NTD Control Programme, (2007). Oboom in the now Ga south District and Kojo Ashong in the now Ga West District, both farming communities were the two communities selected due to the high schistosomiasis prevalence. The Greater Accra Region where these communities are located was used to find the linkages between the climate variables and schistosomiasis prevalence due to the lack of such data at the community level. This was a methodological constraint as the measurement was done at different time scales.

Until 2004, the two districts was known as the Ga Municipality and was bordered on the north by the Akuapim South District in the Eastern Region, to the south by the Gulf of Guinea, on the east the Tema and Accra Metropolis and to the west by the Awutu Efutu Senya District of the Central Region (Figure 3.1). In 2004, the Ga Municipality was divided into two with Amasaman the former municipal capital remaining the capital for the newly created Ga West Municipal and Abokobi being the capital for Ga East. Then in 2008, Ga south was created with its capital being Gbawe. So from 2000, there have been a number of socio-political demarcations of the erstwhile Ga Municipality (*Ghana Districts*, 2012). So the secondary data collected on schistosomiasis prevalence covers all these newly created districts.

Figure 3.1: A map of Greater Accra Region showing the locations of the Ga Districts



Source: *Ghana Districts,* 2012

The Ga West and South Districts are noted for high buruli ulcer, schistosomiasis and other water-borne diseases, affecting productivity (*Ghana Districts,* 2012). One of the developmental challenges in the area is the lack of access to potable water. The large number of the rural population rely heavily on open ponds and streams as sources of water for their domestic use. These unhygienic water sources are shared with animals and often polluted by human activities and thus making water borne diseases rife in the communities. In 2009 for example, there were 28, 019 malaria cases, 1,349 typhoid fever, 4,964 diarrhea, 603 cases of schistosomiasis and 164 buruli ulcer cases in the Ga West District (*Ghana Health Service,* 2010). The presence of many stagnant fresh water ponds left over from sand mining is thought to predispose the district to schistosomiasis and other water-borne diseases. In addition, the location of the area also provides enabling environment for climate sensitive diseases. The geographical coordinates for Amasaman, the Ga West District Capital is 5°42′N 0°18′W (*Ghanadistricts*.com, 2012).

3.2.1 Population size and distribution

Latest census figures from Ghana Statistical Service (2010) indicate that there are 485643 persons within the Ga south district, out of which a little less than half (48.9 percent) are males and the rest (51.1 percent), are females. Similarly, of the 262742 people in the Ga West District, the male and female populations are almost at par (49.0 percent and 51.0 percent respectively). This male to female population ratio for the Ga West District is the same for Ga East which has a total population of 259668 (Ghana Statistical Service (GSS), 2012). Another thing worth noting is that whiles the under 15 population for Ga south is 175421 (51.5 percent), that for Ga West is 86648 (25.4 percent) and Ga East is 78408 (23.0 percent), (GSS, 2012). This population distribution could have implications on the prevalence of schistosomiasis because children form the greatest schistosomiasis risk group due to the recreational water contact activities (Watts, 2006; Sudtida et al., 2006; Kapito-Tembo et al., 2006; Aboagye and Edoh, 2011).

With relative stability in fertility rates and the appreciable reduction in death rates nationwide, the general expectation was that the district would not record much increase in the population. However, that is not the case as all the districts are rapidly urbanizing due to the influx of migrant workers to Accra, the capital city who tend to settle in these areas. Also, due to the stagnation in agriculture productivity and the inadequate number of secondary activities and the district's proximity to Accra, there is a pull of a significant number of the natives from the district. This is a cause of worry as population growth and movements influence schistosomiasis transmission, as people move to and fro with the disease and infesting other non-endemic areas (Aagaard-Hansen, Nombela and Alvar, 2010).

3.2.2 Economic activities

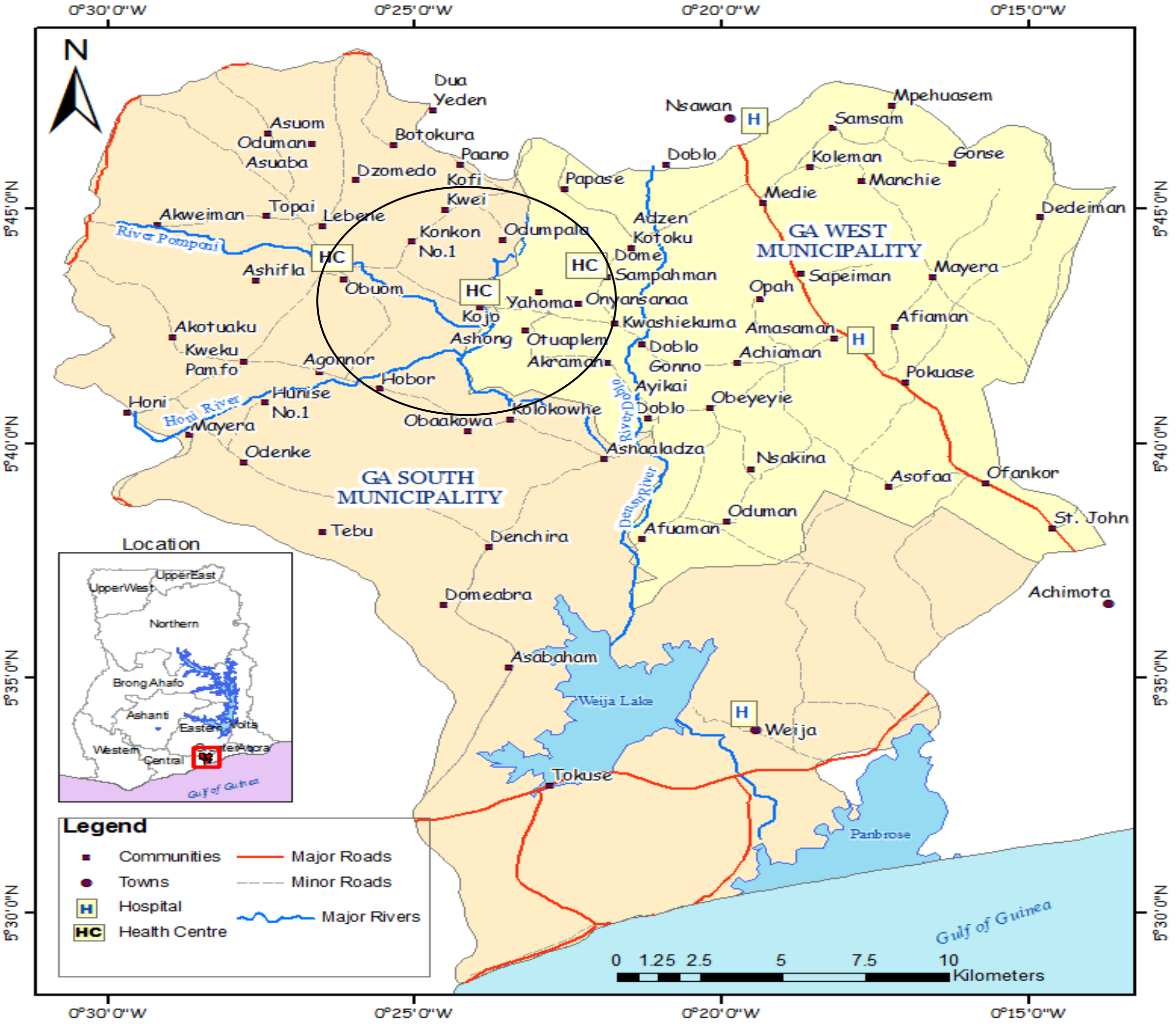
The inhabitants of the rural communities including Oboom and Kojo Ashong are predominantly farmers who grow mainly vegetables like okra, tomatoes, cassava and the raising of livestock. Agriculture supports about 55 percent of the economically active population in the District directly or indirectly through farming, livestock development, fisheries, and distribution of farm produce and provision of services to the sector (GSS, 2009). About 95% of the farmers are small holders with 5% being large-scale holders. Approximately 70% of those in the rural areas depend on agriculture and agricultural related activities for their livelihood (GSS, 2000). Commercial farmers grow mainly export crops such as pineapple and pawpaw (Ghana Districts, 2012). The agricultural activities predispose people to risk of schistosomiasis infection as they irrigate their crops with contaminated water during the dry season. In addition to that, they grow the crops on the marshy lands during the dry season and thus exposing them to infection.

3.2.3 Topography and drainage

There are three major rivers namely; the Densu, Nsaki and Ponpon Rivers that drain all the districts (Figure 3.2). The largest of the three is the Densu which drains down from the Eastern Region through Kojo Ashong in the Ga West District, Oboom in the Ga South and other communities to Weija after which it enters the sea. The River Densu is the main source of water supply to over half the entire population of the Accra Metropolis. Other water bodies, mostly tributaries of the Densu which pass through Oboom and Kojo Ashong are the Adaiso, Doblo, Ntafafa and the Ponpon Rivers. This plentiful water bodies makes swimming the major recreational activity for the children especially and also the youth. In addition, a number of activities are carried out in the rivers and ponds – washing, bathing, fishing, among others. These activities put the entire population at risk of schistosomiasis infection. Since some of the communities are separated by rivers, children have to wade these rivers bare footed to and from school. Some adults also have to do the same to and from the farm and market. Thus the water contact activities goes beyond recreational but also economic.

Concerning the topography, there are slopes mostly formed over the clay soils and the alluvial areas surrounding the coastal lagoons are generally flat and thus making the areas prone to seasonal standing ponds which form a serene breeding place for the snail host (Ghana Districts, 2012). The lands at the coast of the river are mainly covered with mangrove swamps and blackish water lagoons so malaria is also common (Renzaho et al., 2007). The inhabitants of the rural communities are predominantly farmers. Because of the water bodies, fishing activities are also widespread. This increases the risk of infection as proximity to water bodies could lead to high schistosomiasis prevalence (Kapito-Tembo et al., 2009; Ugbomoiko et al., 2010).

Figure 3.2: Map of the Ga Districts showing the study communities



Source: Google Earth, 2012

3.2.3 Climate and vegetation

The Ga Districts lies wholly in the coastal savanna agro-ecological zone. The Rainfall pattern is bi-modal. The average annual rainfall is about 730mm, which falls mainly during the two rainy seasons. The major rainy season is between May and July and the minor one between August and October (Ghana Districts, 2012). The annual average temperature ranges between 23.1°C and 33.4°C. The period between February and April is the hottest. Humidity is generally high during the year. The soil in the area is rich in sandstone and limestone that are good source of material for the construction industry, thus making sand mining a predominant activity in the area (Ghana Districts, 2012). This leaves crevices and pits which are filled with water after rains and could serve as habitats for snails and other disease vectors.

Current climate information from the FAO New LocClim Model

The New LocClim Model is a freeware tool for estimating the local climate and was developed by the FAO and is used to estimate local climatic conditions for any location on earth. The local climate is estimated based on two classifications- the Budyko and the Koeppen climate descriptions.

Koeppen climate descriptions

A reliable way of measuring biological/vegetative activity is the estimation of the Net Primary Production (NPP). There is a strong correlation between vegetation dynamics and climatic conditions The Koeppen climate system is based on the concept that native vegetation is the best expression of climate. Thus, climate zone boundaries have been selected with vegetation distribution in mind. It combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation. The Ga Districts have an “As” Koeppen classification, thus a savannah with dry summer in an equatorial climate (Table 3.1). Also with a temperature sensitivity of 0 g(DM)/m2/year/mm and a precipitation sensitivity of 1.1 g(DM)/m2/year/mm, the Net Primary Production (NPP) can be described as precipitation sensitive. This means that the vegetation growth in the district is controlled primarily by precipitation. Thus the precipitation pattern may control most disease like schistosomiasis, malaria and diarrhoea since it drives vegetation growth and the breeding of disease vectors. Another thing that is worth noting is that the NPP (Temperature) of 2583 g(DM)/m2/year means that temperature also plays an integral in the net primary production.

Table 3.1: Koeppen Climate Characteristics of the Study Area

Koeppen climate characteristics	Descriptions
Koeppen climate class (As)	A= Equatorial Climate S= savannah with dry summer
Climatic net primary production	1313 g(DM)/m2/year
NPP(Temperature)	2583 g(DM)/m2/year
NPP(Precipitation)	1313 g(DM)/m2/year
Precipitation sensitivity	1.1 g(DM)/m2/year/mm
Temperature sensitivity	0 g(DM)/m2/year/mm
NPP is precipitation limited	

Source: New LocClim Model, 2013

The Budyko climate for the study areas is described as steppe; grassland interspersed with a few trees which is also characteristic of the general climate- savannah with dry summer (Table 3.2).

With a Budyko evaporation of 768mm/ year (at a rate of 88.6 percent), and runoff 99mm/ year (at a rate of 11.4 percent) it indicates water deficit (541mm/ year) in the area as 11.4 percent of the rainfall results in runoff and the rest evaporated into the atmosphere at an alarming rate of 88.6 percent. The model indicates a sub-humid environment with an aridity index of 0.62 signifying marked dryness in the area (a moisture index of -38 percent) and this could have severe implications on the water contact activities like irrigation. The rains through the runoff process deposit organic matter into water bodies resulting in the growth of aquatic vegetation which provide food and shelter for snails and other disease vectors. At the same time human activities that require water contacts such as watering crops, swimming, fishing and other things begin with the rains. This interaction of processes may increase schistosomiasis transmission and rate of infection.

Table 3.2: Budyko Local Climate Information for the Study Area

Budyko climate characteristics	**Descriptions**
Budyko Climate class	Steppe
Radiation index of Dryness:	1.948
Budyko Evaporation	768 mm/year
Budyko Runoff	99 mm/year
Budyko Evaporation rate	88.6 %
Budyko Runoff rate	11.4 %
Aridity	dry sub-humid
Aridity index	0.62
Moisture Index	-38%
Precipitation Deficit	541 mm/year
NPP(Temperature)	2583 g(DM)/m2/year
NPP(Precipitation)	1313 g(DM)/m2/year

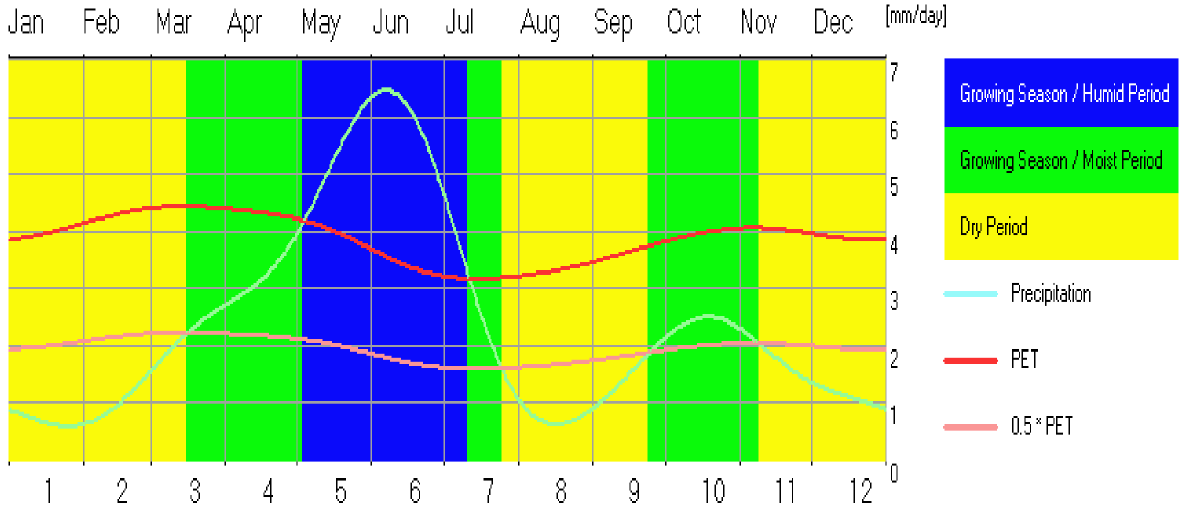
Source: New LocClim Model, 2013

The hydrological cycle is an important driver of human and natural systems and to a greater extent determines the onset, duration and cessation of most tropical disease vectors and their impact on health and well-being.

Vegetative characteristics

The model indicated two main growing seasons in the area, the major season starting from the mid of March and ending mid-July. The minor growing season starts towards the end of September and ends early November. The major growing season consists of the humid period and the moist period, with the humid period overlapping the moist season. The dry period begins in early December and ends in mid-March as shown in Figure 3.3. In addition, there is another dry period beginning in mid-July and ending in mid-September. This could have implications on farming activities and seasonality in disease transmission.

Figure 3.3: Vegetative Characteristics of the Study area



Source: New LocClim Model, 2013

CHAPTER FOUR

Knowledge and perceptions of climate change and schistosomiasis prevalence

4.0 Introduction

This chapter focuses on the community knowledge and perceptions of schistosomiasis, climate change and the relationship that exist between the two. It also looks at the environmental changes and characteristics in the communities and how they are perceived to relate with the transmission and hence prevalence of schistosomiasis. The objective was to understand the extent to which the community knowledge and perceptions translate into their behaviour towards these environmental factors and also coping strategies, that is, prevention and control of schistosomiasis at the community level. This is because the knowledge of the mode of transmission of the disease could influence the attitude and consequently the behaviour of the community folks, which could also determine their susceptibility to the disease. Besides, the perceptions that communities have of urinary schistosomiasis could make challenging the implementation of a control programmes.

4.1 Knowledge and perceptions of climate change

The focus of this session is the analysis of indigenous knowledge and perceptions of climatic changes in the communities. These were compared with the empirical climate trends and events from the meteorological data for Accra (Christensen et al. 2007; Tschakert et al., 2010; Codjoe and Owusu, 2011).

Though the communities did not have any local term for climate change, they explained it in their own words as “*koryor mi etsake*” which literally means “the weather has changed” and gave vivid examples and instances why they think climate change is occurring in their communities. The male adults, especially those at Oboom seemed to have experiential knowledge of the changing or varying climate because they gave a historical account of the change in the rainfall patterns and intensity as well as temperature increases. For instance, one community leader had this comment to make:

> *"Formerly we had two or three heavy rains in March to prepare us for the planting season, but for the past four or five years, it has not been like that. You see, we are in March but it is still dry"* (Community leader, Oboom).

Furthermore, with regards to the rainfall pattern, almost all the groups (5 of the 7 groups) as indicated in the coding frequency in Appendix 4, mentioned that the onset of the rain has changed. This observation was explained in statements like:

> *"the onset of the rains has changed, the rains used to start in late February or early March but today for example is 28th (March), but we don't see any sign that it will rain any time soon".* (Male Youth, Kojo Ashong).

These changes in the rainfall pattern were attributed to the changes in the pattern of the harmattan. Community members mentioned that the harmattan which used to start in November now start as late as January and extend into March and thus changing the rainfall pattern.

With regards to the rainfall intensity, all the groups including the key informants (Appendix E) mentioned that the heaviest rainfall has always been in the June/July period and hastily commented on the recent decline of the rainfall amount in that period.

One thing that remained common in all the two communities and across all the groups was the fact that March with the local name "*Otsoklikli"* is the hottest month, and that the intensity of the temperature has increased significantly. When asked to rate the severity of the hotness now vis-a-vis that in different retrospective time scales of 5, 10, 20 and 30 years depending on the age group. Though there were some disparities in the ratings, the average temperature intensity in the past was rated as 2 on a scale of 1 to 5, and the present as 4 and the future as 5. Similarly, the amount of rainfall was rated 4 in the past, 3 now and 2 for the future.

Concerning climate variability a participant made this statement:

"The rainfall pattern has changed, the months have changed, and the harmattan season has changed. This year for example the harmattan did not come. The time you expect the sun to shine, it does not shine but when you don't expect it, that is when it shines. When it happens like that it destroys our crops" (Male adult, Kojo Ashong)

As a matter of fact, this indigenous knowledge, perceptions, observations and experiences concur with the empirical data from the meteorological service for the area. Thus these indigenous reports can be drawn on in the prevention and control of schistosomiasis and even areas like food security.

4.2 Knowledge and perceptions of schistosomiasis

The common name for schistosomiasis in the communities was bilharzia and also among the elderly especially, it was also called *"la shamor"* in the local dialect which literally means urinating blood. This implies that there was the knowledge that having blood in the urine is a symptom of the disease. Among all the groups, contrary to studies in some communities that blood in the urine was seen as a sign of maturity or as male hood (Takougang et al, 2004; Kloos et al.,2006), the community identified it as a symptom to bilharzia. Though it was generally known that the mode of transmission was swimming in the river, probably because there had been community education and treatment by an NGO, the exact mechanism for the transmission was missing. In this regard, they wouldn't mind walking across the river to the farm or school and even washing in the river as was observed. However, it was stated in a vast majority of the discussions that there are some germs in the river that caused the infection, and that one gets infected when the germs penetrate the skin when swimming. This explanation is similar to the biomedical model, only that the respondents did not associate the disease to the snails. One of the youths explained….

> *"When the officials from World Vision came here, they collected samples of the water in the rivers and our urine as well. Then they performed some tests and reported that there are some germs in the water that causes the bilharzia when you swim in the river and they gave us some medicine"* (male youth, Kojo Ashong)

The risk of infection was only associated with swimming in the river and schistosomiasis was believed to be curable. Also, a bad perception of risk of infection was demonstrated especially among the youth. They explained that some people swim in the river and they are infected and yet others swim and are not infected, and argued that the infection is not only due to the swimming but also your luck. This perception was predominant among the youth in both communities.

Howbeit, contrary to the reports from some studies that the blood in the urine was associated with witchcraft and curses from the gods, schistosomiasis in the study communities was viewed as a natural phenomenon. The respondents perceived swimming as the only way by which one could contract schistosomiasis. As a result, no spiritual interventions were sought. A section of the youth at Oboom stated humorously that:

> *"Nobody seeks cure for bilharzia from the fetish priest in this community. There is even no fetish priest in this community; the former priest is now a convert in our church"* (Youth, Oboom).

The Oboom medical officer however revealed that prior to the education in the community about the disease, it was associated with curses from the river god. He explained that it was a general belief that the river god inflicts blood in the urine of those who abuse the river and their families. Thus the community education by the health centres and the NGO had been very useful in shaping the perceptions of the community about schistosomiasis.

Concerning the schistosomiasis disease burden in the community, it was reported that the prevalence now is low compared to that in the time past. On a scale of one to five, the average rating of the severity now was 2 whiles that in 10 years ago was about 4. Among all the groups in both communities, the prevalence of the disease was said to have reduced drastically. A community leader reported that in the past, it was very common to see people urinate with stains of blood but it's not so common now and people are shy to talk about theirs. This could be because the disease was seen as a normal occurrence in those days so people did not mind letting others know about their situations. However, the hospital records indicated an increase in the reported cases, which could be attributed to the knowledge the community have about the disease. So though the level of infection might have reduced, people report it more because they now know that it is a disease, the Oboom medical officer stated.

4.2.1 Schistosomiasis vulnerable groups

Water contact is intimately linked with the different social roles and practices of men, women, boys and girls in particular communities (Watts, 2005; WHO, 2008). Though the community members believed that all the population are susceptible to the disease, the discussion identified children, fishermen, women and farmers who by virtue of their occupation or chores or recreational activities were perceived to be at higher risk of infection than the other members of the communities. These groups and the activities that put them at risk are outlined in Table 4.1.

Table 4.1: Schistosomiasis vulnerable groups and water contact activities

Vulnerable groups	Activities
Children	• Swimming and wading in the rivers • Crossing the rivers with unprotected skin to and from school • Fetching water for household use • Bathing in the river, especially the boys
Fishermen	• Fishing in the rivers, especially when the level of the water is low
Women	• Washing clothing in the river • Fetching water for household use
Farmers	• Irrigating and watering crops with the contaminated water, especially in the dry season • Using the water to spray insecticides and other chemicals on crops

Source: field work, 2013

This observation is in consonance with the findings of Watts, (2005) and WHO, (2008: 53-56), where it was reported that most water contacts activities are defined by gender, age and occupation. This explains the gender and age differentials in schistosomiasis prevalence.

4.3 Climate variability/ change and schistosomiasis transmission relationship

Though climate variability/ change was perceived to have adverse consequences on the health of people in the communities, schistosomiasis was not perceived to be in that category of diseases. Almost all the groups asserted that intense heat causes increases malaria incidence. The male adults at Kojo Ashong explained that increases in temperatures do not only enhance the breeding of mosquitoes but also make people expose themselves to the mosquitoes by sleeping outside due to the extreme heat in the rooms. It was also mentioned that drought and extreme heat results in malnutrition due to the destruction of the crops on the farm. The effect of other climate indicators and health outcome is delineated in Table 4.2.

Table 4.2: climate indicators and associated health challenges

Climate indicator	Health outcome
Rainfall	Malaria, diarrhoea, foot rot, cholera
Drought	Malnutrition, catarrh, cough
Temperature	Malaria, skin rashes, head aches

Source: Field work, 2013

Concerning schistosomiasis, changes and variability in the climatic conditions was not readily associated with its prevalence like the other diseases above in any of the groups. However upon probing further, a number of interesting issues regarding the climate change and schistosomiasis incidence nexus were unraveled.

In the first place it was identified that heat stimulates the drive to swim in the river. Respondents stated that when the weather is hot and one is sweating profusely, then the remedy in the community is to resort to the river. This was particular for Kojo Ashong as one of the FGD participants made this assertion…..

"In March (Otwoklikli), the weather is very hot so when you come from the farm and you are sweating so much, then you have to go and cool yourself in the Densu River"

(Adult male, Kojo Ashong)

This could result in a positive correlation between temperature and schistosomiasis prevalence. There exist a complex relationship between the climate variables and schistosomiasis prevalence due to the diverse pathways –both physiological and behavioural by which climate influences the rate of schistosomiasis infection (Martens et al., 1995; Watts, 2005; WHO, 2008) Cold on the other hand was said to make swimming unattractive to people, just like during the wet months.

Furthermore, excessive rainfall resulting in floods was linked to the sweeping of debris and other faecal contaminants into water bodies. This could enhance the growth of aquatic vegetation and create the serene environment for the breeding of the intermediate snail host. At the same time moderate rainfall was associated with the resumption of all water contact activities – swimming, washing, bathing and others. Thus it was explained by one of the participants that:

> *"if it does not rain for a long time, the water becomes green and one cannot use it for anything, you cannot even use it for washing and so people don't use it"* (Male youth, Kojo Ashong).

This observation was made at the Densu River at Kojo Ashong on our last visit, as the lower part of the river had turned green due to the algal bloom and was therefore not attractive for any purpose. Thus, this could result in a positive association between total rainfall and schistosomiasis incidence (Martens et al., 1995; Xue et al., 2011).

Drought was also cited as causing some of the rivers to dry and thus reducing the frequency of water contacts and consequently, minimizing the risk of infection. On the other hand, it was mentioned that droughts makes farmers farm close to the rivers and so have to fetch water from ponds to water their crops. Furthermore it was stated that long periods without rain makes the rivers stagnant and form patches and thus providing high risk of infection according to the medical officer in charge of the Oboom health centre. He mentioned that there has not been any observed seasonality in the reporting of the disease. Regarding the water forming patches, he mentioned that it could have double effect because though it increases the risk of infection due to the concentration of the cercaria, the water is also susceptible to extreme heating from the sun and thus killing the cercariae and the snail host. This means that in rivers with shades from trees, the droughts would rather enhance the risk of infection whiles rivers and ponds that are open to the sun would rather have a positive effect on the risk of infection.

CHAPTER FIVE

Association between Climate Variability/ Change and Schistosomiasis Prevalence

5.0 Introduction

This chapter examines the trends in pattern and variability of climate variables prevailing in the Greater Accra Region (GAR) and for that matter the Ga District. Also the associations between the climate variables and schistosomiasis prevalence are examined. Furthermore, the seasonality of schistosomiasis prevalence is delineated and quantified, in addition to how the climate variables correlate with schistosomiasis prevalence at different time lags. Also, the sex and age differentials in the prevalence of schistosomiasis are examined in this chapter. Finally, the Granger causality model was used to test which climate variable explains the variation in schistosomiasis prevalence.

5.1 Trends in the total annual rainfall in GAR (1970-2010)

The rainfall trend for GAR from 1970 to 2010 is shown in Figure 5.1. There is inter-annual rainfall fluctuation with a variability coefficient of 25.7 percent. The least rainfall amount (333.1 mm) was recorded in 1983 and the highest (1264.7mm) was recorded in 1977. This is expected as the entire country experienced severe drought in 1983 (Christensen et al., 2007, Codjoe and Owusu, 2011). In general there is a slightly increasing trend in the volume of rainfall as shown by the fitted line. In addition, within the same period, whiles the December-February period recorded the highest inter-monthly rainfall variability, the June-July period recorded the lowest (Appendix B). With regards to inter-decadal changes, there were marginal variations in the decadal rainfall pattern, with each decade varying slightly from the other but the bimodal rainfall pattern maintained (Appendix A).

This inter-annual variability could have implications on the water levels and flow rates and consequently on the schistosomiasis transmission rate (Barbosa and Barbosa, 1994). For instance, it is likely that in 1977 (which recorded the highest total rainfall) most snail populations were adversely affected because flooding resulting from excess rainfall can be problematic for their development, as floods have been found to drown snails and disperse others. Thus extensive floods have a markedly negative impact on snail populations. At regions with constant flooding, some snail species live about one year but where less frequent or no flooding occurs, the species can live at least twice as long, and mostly longer (Barbosa and Barbosa, 1994; Xue et al., 2011).

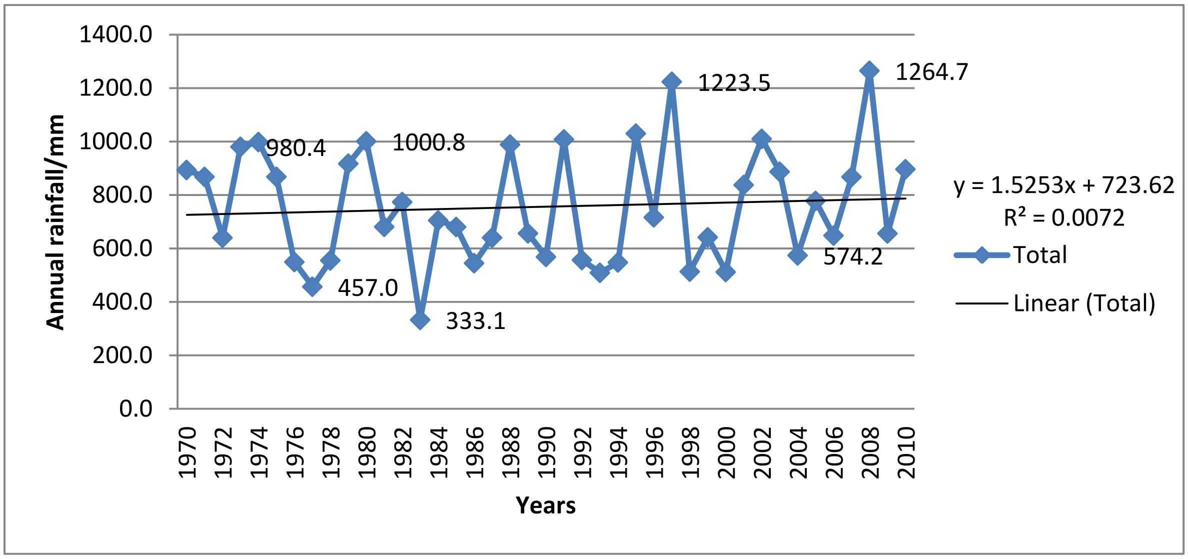
On the other hand, years like 1983 that record scanty rainfall could have adverse effect on snail as well, as most snail habitats may end up drying up (Paull and Johnson, 2011). Thus the rains are favourable for the breeding of snails, but the excess of it which causes floods tends to disperse the snails and hence reduce their population. However, the exact rainfall amount where there is a shift from increasing snail reproduction as against decreasing cercariae activity or dispersal of snails is not clear (Xue et al., 2011). The rainfall amount also affects the water contact behaviour through a myriad of ways (Watts, 2006). For example, in explaining the water contact behaviour of the children in the community regarding the water level, one participant stated that:

> *"When the water level is too high, they don't go to swim in the river because they are afraid that the river will carry them way but when the level comes down, then they go swimming".* (Oboom youth)

This means that some moderate water level is required even for recreational activities in the water. The situation is not so different for economic activities that depend on the rivers. The fishing season is also dependent on the water level, which is closely related to the total rainfall as explained by a participant at Kojo Ashong community:

> *"Yes, we fish in the Densu River, and we have the seasons for that. When the water comes down, that is when we get the fish"* (Adult male, Kojo Ashong).

Figure 5.1: Trend in the Total Annual Rainfall in Greater Accra Region, 1970- 2010

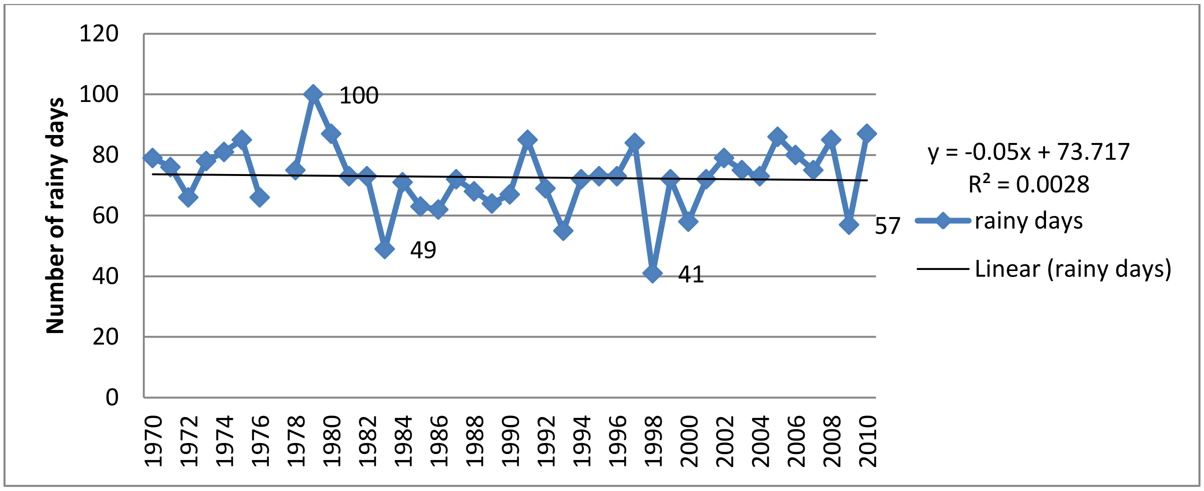


Source: Computed from GMet data

5.2: Trends in the number of rainy days in Greater Accra Region (1970-2010)

With regards to the number of rainy days, Figure 5.2 indicates a high degree of inter-annual variability. The highest number of rainy days (116 days) was recorded in 1979 and the lowest (76 days) in 1983. Other years which recorded low rainy days are 1977 (91 days) and 1998 (92 days). The low number of rainy days in 1983 has a corresponding lower rainfall amount giving the indication of a severe drought that year. Howbeit, on the whole, rainy days shows a slightly increasing trend as shown by the gradient of the fitted line in Figure 4.2. The number of rainy days gives a sense of the distribution of the rainfall which could have implications on the frequency of water contacts Thus, droughts may increase the frequency of water contacts due to the need to get water from infested ponds for irrigation and household use (Watts, 2006; Ugbomoiko et al., 2010; Aboagye and Edoh, 2011). Long period of time without rain resulting from fewer rainy days cause some natural snail habitats dry out for a considerable part of the year, leading to the mortality of a significant number of the snail populations. Thus it is likely that in both 1979 and 1983 with marked rainfall deficits, the schistosomiasis infection rate was low. Aside the year 1977 which recorded as high as 100 rainy days, most of the other years recorded a somewhat moderate rain days which is very conducive for snail breeding, cercaria development and movement as well as water contact activities like swimming and hence schistosomiasis infection from both the survival of the snail and cercaria and for water contact activities like swimming and fishing (Paull and Johnson, 2011).

Figure 5.2: Trend in the number of rainy days in Greater Accra Region, 1970-2010



Source: Computed from GMet data

5.3 Inter –Annual Rainfall Variability

The inter-annual rainfall variability was estimated using the coefficient of variability. The overall rainfall variability between 1970 and 2010 for the study area was computed as 25.7 percent which means that the volumme of rainfall for each year is about 0.26 times different from the other years. This means that there is moderate rainfall variability acording to the classification of Charles et al., (2005). This is in consonance with the proposition by Schaik and Reitsma (1992) that the inter-annual rainfall variability in sub-humid regions with between 4.5 to 7 rainy months does not exceed 30 percent. This means that as far as the impact of rainfall on the prevalence of schistosomiasis is concerned, there would be disparities in the prevalence from one year to the other. This is because research has shown that schistosoma species vary considerably in their preferences for amount of rainfall, length of the rainy and dry seasons, and interval between rainy and dry seasons (European Centre for Disease Control (ECDC), 2010).

Figure 5.3 shows the seasonal variations of water levels of the Ponpon River at Oboom, one of the study communities in the Ga District and its implications on the survival of the snail hosts. It can be seen that in November, the end of the minor rainy season, the water level is usually very high and not conducive for swimming and the breeding of the snails and cercaria as indicated in the section labeled “A”. In the section labeled “B”, the water level is often conducive for swimming and the breeding and movement of snails, resulting in a higher risk of infection. However in section “C”, the beginning of March the water level is so low that the snails could be noticed in the water. This could expose them to the direct rays from the sun and thus hamper their reproduction and at the same time kill the cercaria (Paull and Johnson, 2011). By the beginning of April, before the onset of the rains, the water was almost dried and is accompanied with mass snail mortality as shown in section “D” of Figure 5.3.

Figure 5.3: Seasonality of water level and snail survival

High Water level of the Ponpon River (Oboom)

Moderate water level Popon River (Oboom)

Pictured on 09/11/2012

pictured on 12/01/2013

Very low water level showing the snail host

Almost dried Popon River showing a dying snail

Pictured on 05/03/2013

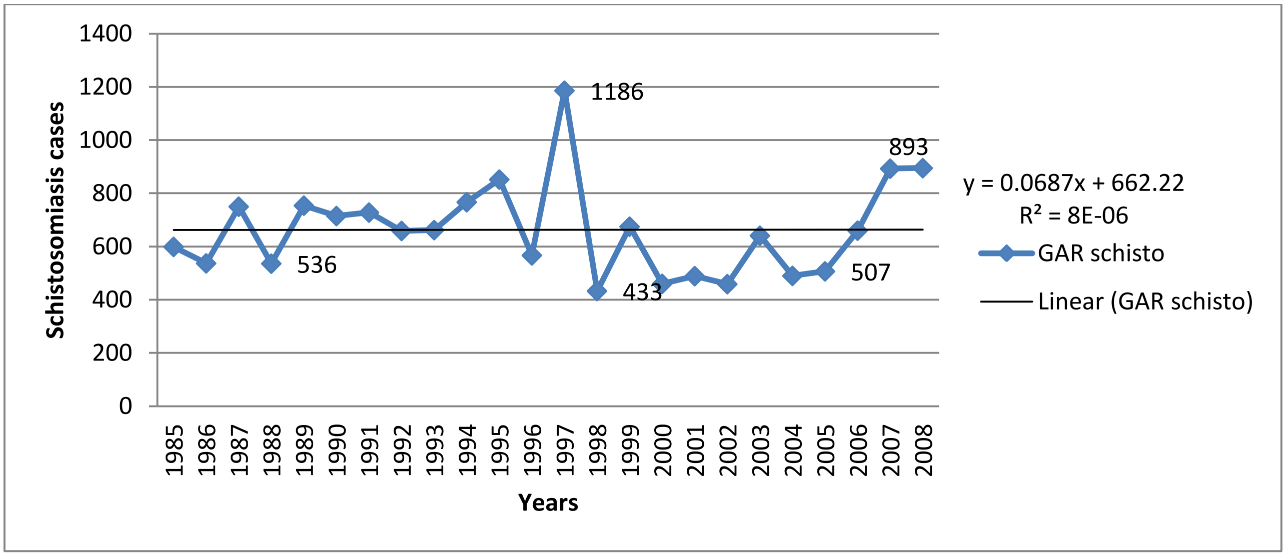
Pictured on 10/04/2013

Source: field work, 2012/2013

5.4 Trend in Schistosomiasis prevalence in Greater Accra Region (1985 - 2008)

The prevalence of schistosomiasis shows inter-annual fluctuations from 1985 to 2008. The highest reported cases (1186) occurred in 1997 whiles the lowest (433) occurred in 1998 (Figure 5.4). Though verbal reports in the communities indicated a decline in the infection, the empirical data shows an increase. This could be due to the increase schistosomiasis reporting rate or the high knowledge is the infection. Thus because there has been some form of community education, the people now recognize the symptoms as an infection so report it more.

Figure 5.4: Greater Accra Regional Schistosomiasis Prevalence (1985-2008)

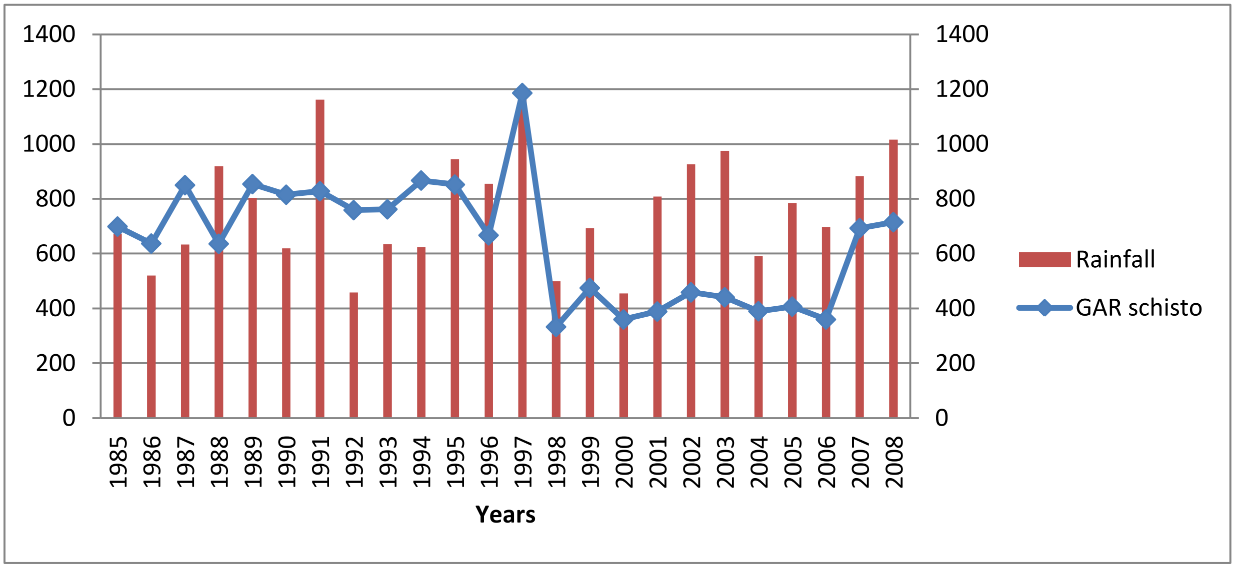


Source: Computed from CHIM data

5.5 Rainfall variability and schistosomiasis prevalence (Greater Accra Region, 1985 – 2008)

Figure 5.5 shows the mean annual rainfall trend vis-a vis schistosomiasis prevalence for the GAR. It is evident that the schistosomiasis incidence rises with the mean rainfall values. This implies that rainfall could be a major predictor of the incidence of the disease in the region. Though the increases are not proportional in magnitude, the general trends are directly proportional. Besides, the correlation analysis indicated a moderately positive association between the two variables ($r=0.404$, $p<0.05$). This could be explained by the fact that while rains create seasonal ponds as snail habitats and thus resulting in higher infection rates, scarcity of rain causes some natural snail habitats dry out, leading to the mortality of a significant number of the snail populations and thus decreasing the risk of schistosomiasis infection (Barbosa and Barbosa, 1994; Paull and Johnson, 2011; Stensgaard et al., 2011).

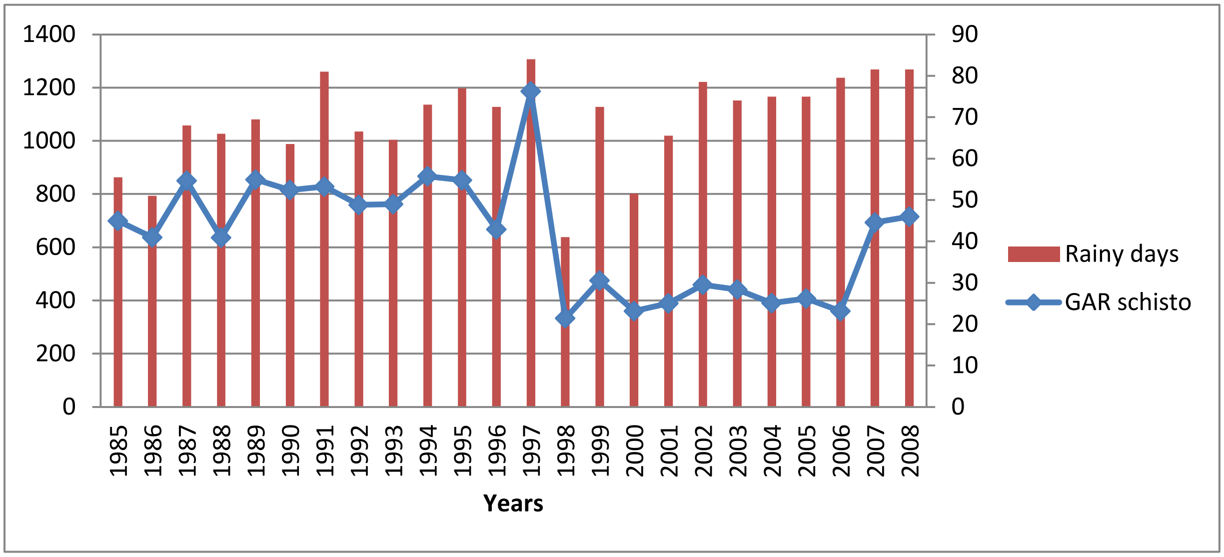
Figure 5.5: Total annual rainfall and of schistosomiasis prevalence (1985 – 2008)



Source: Computed from GMet and CHIM data for Greater Accra Region

Similarly, schistosomiasis prevalence rises and falls with the number of rainy days, which buttresses the point that rainfall could indeed be a predictor of schistosomiasis in the region. The schistosomiasis graph peaks with those of the rainy days specifically in 1987, 1989, 1995, 1995, 1998, 2007, among others (Figure 5.6). This implies that as the number of rainy days increase, more ponds are created where children and even adults would make contact with contaminated water and hence increase their risk of contracting the disease. This concurs with the findings of Xue et al., (2011). Also, probably the increases in the rainy days triggers a number of water contact activities like farming and fishing and consequently increasing the risk of infection (Watts, 2006).

Figure 5.6: Rainy days and schistosomiasis prevalence (1985 – 2008)



Source: Computed from GMet and CHIM data for Greater Accra Region

Table 5.1 shows the correlation between total rainfall, rain days and schistosomiasis prevalence that there is a weak positive correlation between both total rainfall and rainy days and schistosomiasis prevalence. While the rainy days correlation is not significant, that for rainfall is significant at 90% confidence level.

Table 5.1: Correlation between rainfall, rainy days and schistosomiasis prevalence

	Pearson Correlation	Sig. (2-tailed)
Rainfall	0.404	0.086
Rainy days	0.263	0.277
	N	21

Source: Computed from CHIM and GMet data for Greater Accra Region

In order to check the effect of rainfall extremes on schistosomiasis prevalence, the total rainfall was coded into low, moderate and high. It can be observed from Table 5.2 that about three quarters (75 percent) of the years with low rainfall recorded low schistosomiasis prevalence, a higher proportion (56.3 percent) of the years with moderate rainfall also recorded high prevalence. Also, about three-quarters (75.0 percent) of the years with high rainfall also recorded high schistosomiasis prevalence. However, statistically there is no significant difference between the rainfall amount recorded and schistosomiasis (X^2=2.098, df=3, p>0.05). This means that the hypothesis that "moderate total annual rainfall is likely to produce higher schistosomiasis prevalence than high rainfall" is not accepted. This could be attributed to the fact the Greater Accra Region and for that matter the Ga District receives one of the lowest total rainfall in Ghana (EPA, 2009). This means that the highest rainfall in the Greater Accra Region is not high enough to cause harm to neither the snails nor the cercaria, but probably promotes the water contact activities rather and facilitate the schistosomiasis transmission dynamics as discussed in the EnvID framework. This observation is contrary to the suggestion of Barbosa and Barbosa, (1994); Stensgaard et al., (2011).

Table: 5.2: Association between total rainfall and schistosomiasis prevalence

	Low prevalence (%)	High prevalence (%)	N
Low rainfall	75.0	25.0	7
Moderate rainfall	43.8	56.3	11
High rainfall	25.0	75.0	6
Total	45.8	54.2	24

$\chi 2$=2.098 df=3 sig. =0.35

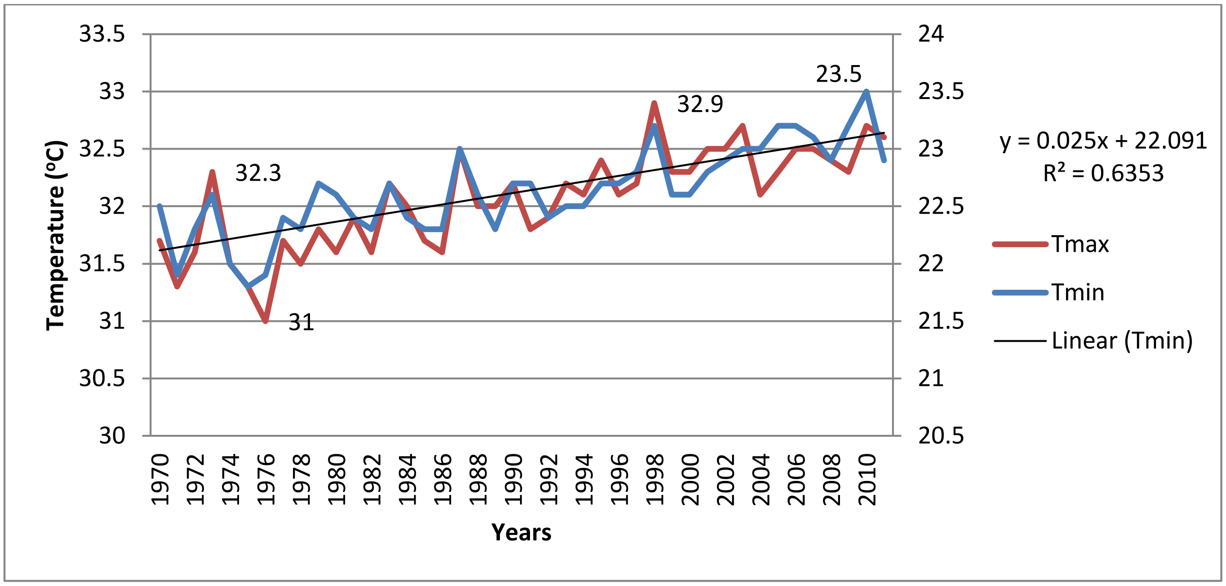
Source: Computed from GMet and CHIM data for GAR

5.6 Temperature trends and variability

The Mean annual maximum temperature for the period 1970 to 2010 varies between 31.0°C in 1976 and 32.9°C in 1998 as shown in Figure 5.7. In general, though there is inter-annual variation, the mean maximum temperatures increases at an annual rate of 2.5%. This is in accordance with the report of the IPCC WG2. It is reported that the global climate continue to warm and by the end of this century, the global mean temperature will have increased by 1.4 – 5.8 (IPCC, 2007). This can have dire consequences on human health but could rather result in a reduction in schistosomiasis prevalence. Similarly, the minimum temperature varies between 21.8 in 1975 and 23.5 in 2010 (Figure 5.7). The suitable temperature range for larval development has been found in laboratory studies to be between 15°C to 27°C (Martens et al., 1995). Also, the rate of schistosoma larvae development, as influenced by temperature was shown to have a linear relationship starting with the minimum temperature 15.3°C to an optimum temperature 22°C for S. haematobium (McNally, 2001). And an inverse relationship between rate of development and temperature above the optimum temperature has been reported (Mangal et al., 2008). Other studies have also placed the ideal temperature range at 22^{o}C-25^{o}C.

This means that the minimum temperature for the GAR lies within the optimal range for the breeding of schistosomes as well as for snail survival and so could increase the schistosomiasis incidence. The maximum temperature on the other hand extends beyond the optimal range and so could result in disturbing the habitats and development of schistosomes and hence a reduction in the prevalence of schistosomiasis. Thus Mangal et al., (2005)'s model indicated that the impact of temperature on disease prevalence and abundance is not straightforward; the mean infection burden increased up to 30^{o}C, but then crashed at 35^{o}C, which was attributed to the increased mortalities of the snail intermediate host. It was also explained that the dynamics of the disease changed from stable, endemic infection to unstable, epidemic cycles at 35^{o}C. This means that temperature is a key determinant of the dynamics of schistosomiasis prevalence.

Figure 5.7: Annual minimum and maximum temperature trend for GAR (1970-2010)

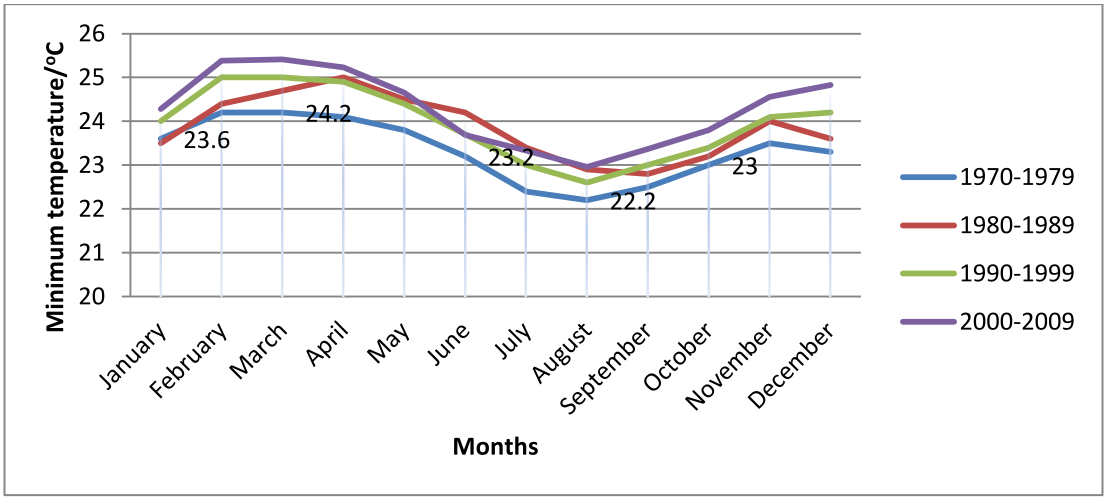


Source: Computed from GMet data

On the average, mean minimum temperatures are about 9.4°C lower than the mean maximum temperatures, varying between 27°C in August and 33°C in March. The highest minimum temperatures are observed in March, which is the same month in which the highest maximum temperatures are observed as shown in Figures 5.8 and 5.9. Thus this gives the indication that March is generally hot whiles August is generally cold.

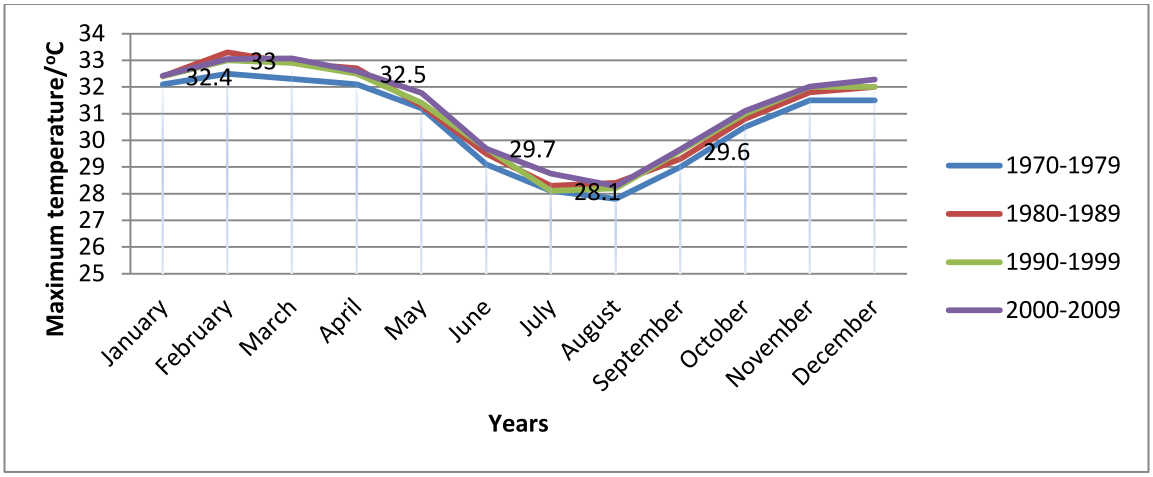
The decadal temperature changes indicate that decade after decade, the temperatures keep increasing. Thus, for the period under consideration (1970-2010), the 1970s recorded the lowest temperatures followed by the 1980s, then the 1990s and so on. This pattern is common to both the minimum and maximum temperatures (Figures 5.8 and 5.9). Also, consistently the highest temperatures have been between February and March and the lowest in August but the intensity increased decade after decade.

Figure 5.8: Monthly variability in minimum temperature trends for GAR (1970 -2010)



Source: Computed from GMet data

Figure 5.9: Monthly variability in maximum temperature trends for GAR (1970-2010)



Source : Computed from GMet data

This monthly temperature variability could be responsible for the seasonality of schistosomiasis prevalence as it also explains the water contact behaviour. For instance a respondent at Kojo Ashong had this to say:

> *"In March (Otwoklikli), the weather is very hot so when you come from the farm and you are sweating so much, then you have to go and cool yourself in the Densu River"*
> (Adult male, Kojo Ashong community)

Similarly, a youth participant made this comment concerning the water contact behaviour of the children in the community:

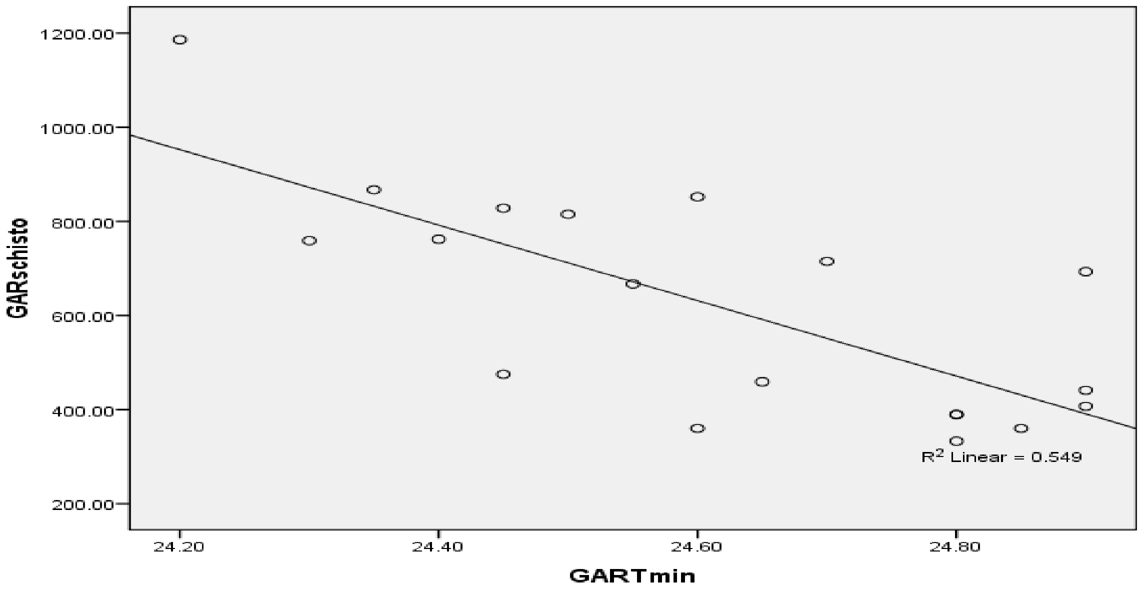
> *"We are not like the children, because they go to the river at all times but we go there only when the weather is very hot"*. (Male youth, Oboom)

This means that higher schistosomiasis infection is likely to occur in the months with consistently high temperatures.

5.7 Temperature variability and schistosomiasis prevalence

Temperature is also a predictor of schistosomiasis infection in that it could affect the abundance of the disease through both the physiological and the behavioral pathways. Figure 5.10 shows an inverse relationship between the minimum temperature (Tmin) and schistosomiasis in the GAR. Also the correlation analysis shows a statistically significant negative association between the two variables ($r=-0.761$, $p<0.05$) as shown in Table 5.3. This association is in consonance with findings by Tay, Amekudzi and Tagoe, (2011) but contradicts that of Xue et al. (2011) in a study carried out in Ethiopia. Thus this observation could be explained by the fact that increases in the Tmin result in mass death of the cercariae due to the reduced oxygen content in the water and also makes snail reproduction reduced or interrupted hence decreasing the risk of infection (Barbosa and Barbosa, 1994; Medical Ecology, 2005; Arshad et al., (2011). The same applies to the maximum temperature, which also had a significantly negative correlation with schistosomiasis prevalence ($r=-0.620$, $p<0.05$) (Table 5.3).

Figure 5.10: Correlation between minimum temperature and schistosomiasis for GAR



Source: Computed from CHIM and GMet data for Greater Accra Region

Table 5.3: Correlation between temperature and schistosomiasis prevalence

	Pearson Correlation	Sig. (2-tailed)
Tmax	-0.620	0.022
Tmin	-0.761	0.002
	N	21

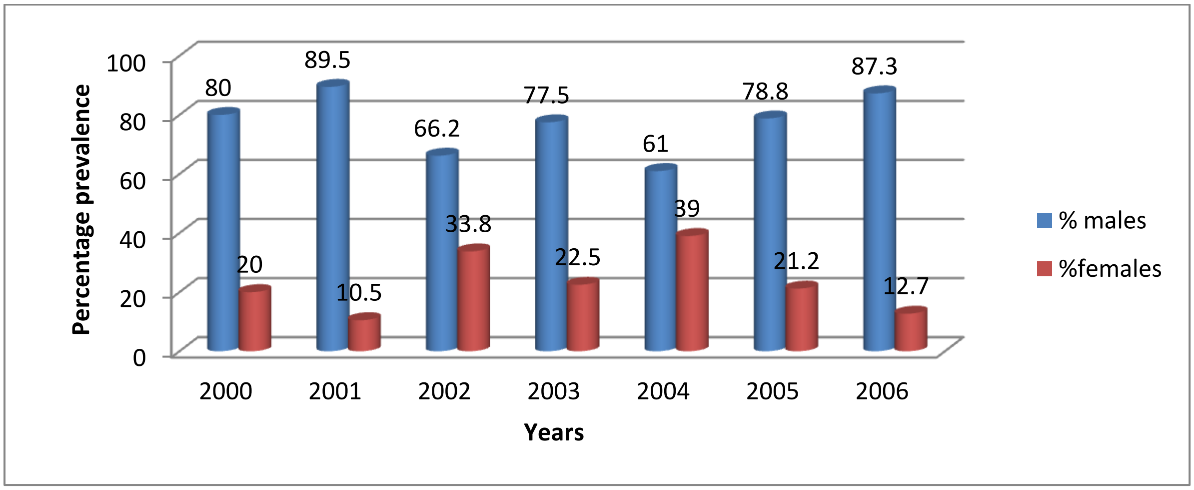
Source: Computed from CHIM and GMet data for Greater Accra Region

5.8 Gender differentials in schistosomiasis prevalence

Figure 5.11 shows consistently higher schistosomiasis prevalence among the males than the females with 2001 showing the most pronounced difference where the prevalence in the males was 89.5 percent as against the 10.5 percent for their female counterparts. The lowest difference in prevalence was recorded in 2004, with males recording more than half (61.0 percent) and the females recording 39 percent. This high prevalence among the males could be attributed to occupational and recreational activities. With the districts comprising of predominantly farming communities, the men are more likely to come into contact with the contaminated water for the purposes of watering and irrigation more often than the females. Also the men are more likely to go fishing than females. Though the females may go to the river to collect water, the frequency may not be as much as the other activities will expose the males. Concerning recreational activities, obviously males are more likely to swim or bath in the water body than females most especially the adolescents who form the bulk of the infected.

This finding contradicts that of Nkegbe in 2010, where there was higher prevalence among the female pupils (64%) than their male counterparts (21.8%), but corroborates the reports of anumber of researchers like Nsowah-Nuamah et al, (2001), Chimbari and Chirundu, (2003), Aboagye and Edoh, (2011) and many others. The higher schistosomiasis prevalence among the females than the males in Nkegbe's study was attributed to the numerous water contact activities of females as a result of unavoidable domestic chores which compel them to enter the river to fetch water thereby exposing them to the infection.

Figure 5.11: Sex differentials in schistosomiasis prevalence, (Ga Districts, 2000 - 2006)

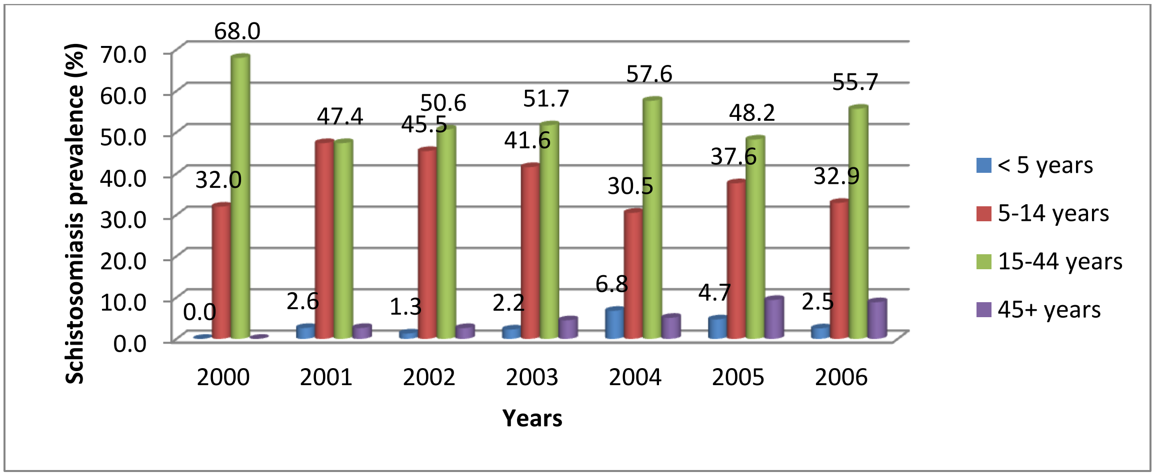


Source: computed from CHIM data

5.9 Differences in schistosomiasis prevalence by age

From 2000 to 2006, though the ages could not be grouped into the conventional form because it was secondary data, consistently schistosomiasis prevalence was higher among people in the age group 15-44 and then 5-14 (Figure 5.12). Watts et al. 2006 attributes this to the recreational and occupational activities engaged in by the people in these age groups which tend to put them at higher risk. In 2000 for instance more than half (68 percent) of the people who were diagnosed of schistosomiasis were aged 15-44 and the remaining 32 percent were all within the 5-14 age group. These have serious implications on socio-economic development. With regards to the age group 5-14, these are children of school going age and looking at serious consequences of schistosomiasis on cognitive performance (Carter centre, 2010), it implies that the academic performance of these children will be affected. Again, those aged 15-44 are people in their productive and reproductive years. Considering the fact that untreated schistosomiasis causes infertility and that urogenital schistosomiasis causes bleeding after sexual intercourse and thus increasing the risk of HIV transmission (WHO, 2009), this is a serious cause for concern because of the propensity for leading to other disease conditions. Children below five years reported the lowest cases with prevalence ranging from 0 to 6.8 percent. This is because they make the least contact with contaminated water. The other age group, 45+ also has prevalence ranging from 0 to 9.4 percent. This could also be due to the lower frequency of contact with the contaminated water because of their age.

Figure 5.12: Age differentials in schistosomiasis prevalence (Ga District, 2000-2006)

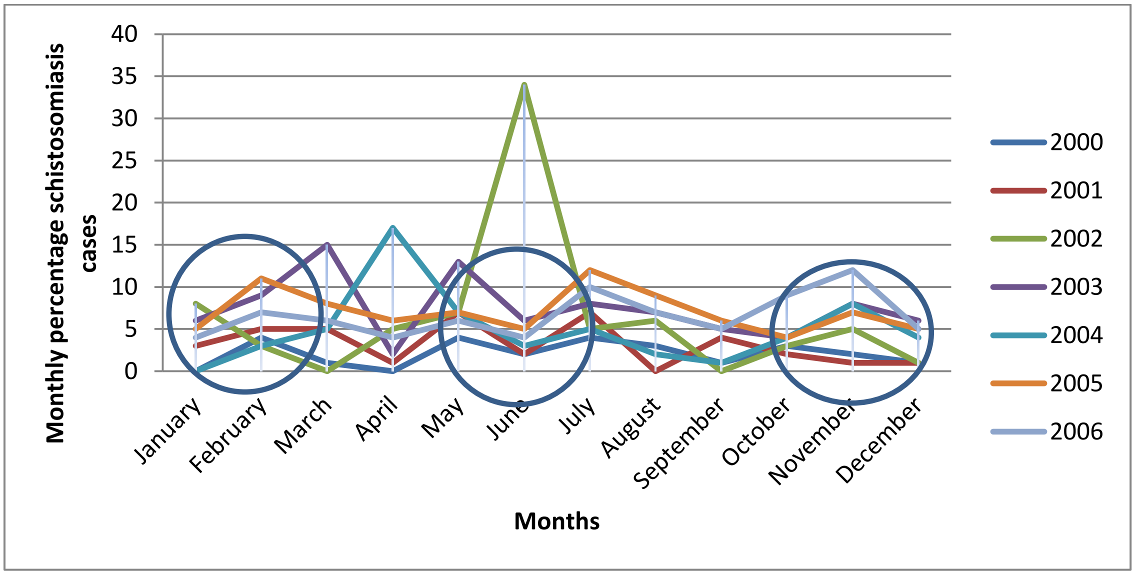


Source: computed from CHIM data

5.10 Seasonality of schistosomiasis prevalence

The monthly distribution of the reported cases gives an idea of the seasonality of the disease. Figure 5.13 shows the monthly percentage of reported schistosomiasis cases, there are some observed discernible patterns. Generally the January-February season shows higher percentages just like the months of May and November. On the other hand April, June and September show a clear decline, except the 2002 observation for June. Also there are significantly higher peaks for most of the years in May and July. However, months like August and October show no discernible patterns. These patterns in schistosomiasis prevalence could be attributed to the water contact behaviour that usually occurs in certain months. For instance in the FGD, one participant stated that in March the weather is usually hot so people often go to “cool down” in the river. in addition to that, in the participant observation, it was observed that most people went into the river to wash the dust from their feet which was as a result of the road construction and the dryness. All these go a long way in increasing the risk of infection and thus could account for the seasonality.

Figure 5.13: Pattern of monthly schistosomiasis reported cases (Ga District, 2000 - 2006)



Source: Computed from CHIM data

The nature of the seasonality of schistosomiasis prevalence is presented in Table 5.4. All the reported cases below the median were coded as low and the median and above as high as done in Xue at al., (2011). The months were classified in quarters with the first three months coded as the first quarter and so on. The results indicates that more than half of the months in the first quarter (57.1 percent) recorded high incidence, the same applies to the second and the forth. However, the third quarter had a higher proportion (58.4 percent) of the months recording low incidence rather. Finally, a higher proportion (61.9 percent) of the months in the final quarter recorded high prevalence. However, the disease might have been contracted in other months or seasons and the months in which they were reported due to the effects of the lag time.

Table 5.4: Seasonality of schistosomiasis prevalence

	Low prevalence (%)	High prevalence (%)	N
First quarter	42.9	57.1	21
Second quarter	42.9	57.1	21
Third quarter	58.4	41.6	21
Fourth quarter	38.1	61.9	21
Total	45.2	54.8	84

$\chi 2=17.30$ df=3 sig. =0.136

Source: Computed from CHIM data

Table 5.5 gives the dynamics of the monthly variation of the effects of climate variability/ change on schistosomiasis infection making room for the time lags between the time of infection and the time of reporting. At zero lag, that is with the assumption that the disease was reported the same month the climatic event was observed, there was a significant positive association between rainfall and schistosomiasis incidence. With the assumption that the disease was reported a month after the observation of the climatic event, which is with a one month lag, it can be observed that there is a significant positive association between the number of rainy days in a month and schistosomiasis incidence. Again, with a two months lag, there was a significant positive association between minimum temperature and reported cases of schistosomiasis. Finally, there was a significantly positive association between the temperature (both minimum and maximum) and reported cases schistosomiasis at three months lag.

Table 5.5: Correlation of the climatic variables and reported cases of schistosomiasis

Independent variable	Pearson Correlation	Significance
	No lag	
Min Temperature	0.063	0.570
Max Temperature	0.255	0.122
Rainfall volume	0.357**	0.001
Rainy days	0.199	0.069
	1-month lag	
Min Temperature	0.203	0.066
Max Temperature	0.129	0.244
Rainfall volume	0.184	0.095
Rainy days	0.224**	0.045
	2-months lag	
Min Temperature	0.248**	0.025
Max Temperature	0.205	0.064
Rainfall volume	0.241	0.131
Rainy days	0.382	0.098
	3-months lag	
Min Temperature	0.280**	0.011
Max Temperature	0.243**	0.029
Rainfall volume	-0.169	0.132
Rainy days	-0.163	0.145

Source: Computed from the GMet and CHIM data

5.11 Test of predictability of the schistosomiasis prevalence by climate change

In order to check whether the climate variables predict schistosomiasis prevalence, the Granjer causality test was used. In the first (restricted) model, about 23.6 percent of the variation in the schistosomiasis prevalence was explained by the previous year's prevalence at 95 percent confidence level. (Table 5.6) In the second (unrestricted) model, with the introduction of the maximum temperature variable, 38.7 percent of the variation in the schistosomiasis prevalence was explained by the model at a time lag of one year. This implies that by adding the maximum temperature variable the fit of the model was improved. There was an inverse relationship between maximum temperature and schistosomiasis prevalence, which means that excessive temperature results in a decrease in the risk of schistosomiasis infection and hence the prevalence. The other variables like minimum temperature, total rainfall and number of rainy days though correlated significantly with schistosomiasis prevalence, did not significantly predict schistosomiasis prevalence in the model.

This negative relationship could be due to mass mortality of the cercariae and the intermediate snail host due to the heating up of the water bodies. Rainfall could also have a bearing on this association because the maximum annual temperatures are recorded between February and March (Figures 5.8 and 5.9) which precedes the onset of the rains. Thus the seasonal ponds and small water bodies might remain dry at that time and hence reduced water contacts and less risk of infection. The water bodies which might not dry up may also have very low water levels and thus making them prone to the excessive heating from the extreme temperature. Thus Malone, (2005) reported that the temperature of water bodies governs the development rate of the parasites within snails and the infectivity of cercariae. In addition, Barbosa and Barbosa, (1994) and Manga et al., (2008) established that above 30^{o}C snail and egg mortality rises dramatically. The temperature in the study area exceeds 30^{o}C in a considerable part of the year specifically, during the January-April and the November-December periods (Figure 5.9). This could explain the association between maximum temperature and schistosomiasis prevalence.

With regards to the one year lag time, people may not report the symptoms immediately due to the subtle nature of the morbidity (WHO, 2008). Besides, the incubation period of schistosomiasis is at least six weeks. This may result in the disease being reported at a considerable period of time after the time of infection. However, two years of lag time would also be too long to explain the prevailing schistosomiasis prevalence.

Table 5.6: Granjer-causality test for the climate variables and schistosomiasis

Variable	**Coef.**	**Std. Err.**	**F-stats**	**Adjusted R^2**	**p-value**
Schisto Lag 1	.232	.2081	4.25	0.236	0.056
Schisto Lag 2	.423	.2082	4.25	0.236	0.279
Tmax Lag 1	-371.003	44.4563	4.31	0.386	0.020
Tmax Lag 2	130.512	50.6187	4.31	0.386	0.398
Tmin Lag 1	-107.551	.2589	2.05	0.166	0.646
Tmin Lag 2	101.054	.2650	2.05	0.166	0.663
Total rain Lag 1	-.171	.2429	2.27	0.348	0.299
Total rain Lag 2	-.174	.2407	2.27	0.348	0.087
Rain days Lag 1	3.226	.3038	2.00	0.161	0.631
Rain days Lag 2	-2.024	.3379	2.00	0.161	0.692

Source: Computed from the GMet and CHIM data

CHAPTER SIX

Coping Strategies to Schistosomiasis Infection

6.0 Introduction

This chapter is focused on the major water contact activities, the environmental characteristics and the corresponding coping strategies of the communities in the phase of climate variability/ change. The water contact activities are outlined and the major ones that predispose the community to the risk of infection are identified by the computation of the relative index of exposure. Then the coping strategies which encapsulate cure seeking as well as the prevention and control interventions as prevailing in the communities are discussed.

6.1 Water contact patterns

Despite the knowledge of the risk associated with the water contacts, especially among the youth and the adults, they chose to visit the rivers as and when they wanted. The observed water contact behaviour was classified as recreational, economic, domestic and personal (Ofoezie, Christensen and Madsen, 1998; Watts, 2005). The economic comprised fishing and watering crops, the recreational involved swimming, washing and fetching water were classifies as domestic and finally those in the personal category included the washing of feet and crossing the river. There was marked gender and age differentials in the contact behaviour; whiles the economic activities was predominantly male adults and a section of the male youth, the domestic was mainly females- both young and old and the recreational was predominantly the children and the youth.

The exposure to the risk of infection as indicated by relative index of exposure has been elucidated in Table 6.1. This was computed as the product of number of contacts, mean duration of contacts in minutes and mean activity coefficient (Hagan, 1992; Ofoezie, Christensen and Madsen, 1998).

Whereas the main water contact activity in Oboom was swimming, that for Kojo Ashong was fetching water. This is because whiles Oboom had a borehole that supplied water to the community, Kojo Ashong has none, hence the reliance on the river for water (Table 6.1).

However, as far as the exposure to the risk of infection is concerned swimming was the major exposure activity to both communities, which is due to the high value of the activity coefficient for swimming and the duration of contact involved in the swimming. The exposure due to the washing of clothes and motor bikes is also worth noting as it was the third exposure activity in both Oboom and Kojo Ashong. This is because transportation by motor bike (okada) is widespread in both communities. Howbeit, the medical officer explained that the risk of infection associated with washing is lower if the people do not stand in the water whiles washing because the chemicals in the soap tend to kill or weaken the cercaria and hence lessen the chances of penetration into the skin. The same applies to bathing with soap and sponge.

Table 6.1: Water contact activities and the relative index of exposure for the two communities

Activities	Average Coefficient	Average duration of contact (minutes)	Frequency of activity		Relative index of exposure	
			Oboom	Kojo Ashong	Oboom	Kojo Ashong
Fetching water	0.18	5	8	22	7.2	19.8
Bathing	0.20	10	11	6	22	12
Fishing/ sorting fish	0.35	120	3	1	126	42
Swimming	0.90	60	19	9	1026	486
Washing limbs	0.10	3	10	4	3	1.2
Washing clothes/motor bikes	0.15	30	11	7	49.5	31.5
Crossing river	0.1	2	0	23	0	4.6

Source: field data, 2012/2013

6.2 Other environmental factors and their association with schistosomiasis

The identified environmental changes and characteristics in the study communities are:

- Faecal contamination
- Proximity to rivers
- Population growth
- Population movement
- Road projects
- Sand mining (land use)

It was mentioned among the adult female group at Kojo Ashong that despite the fact that it is a taboo to pass faecal material in the rivers, the children ignorantly to it at the river banks which end up in the river after the rains. Among the youth, it was also emphasised that sometimes people do not deliberately dispose faecal materials into the rivers but they dispose them close to water bodies and are washed into the rivers when it rains. It was narrated as:

> *"Nobody deliberately defecate into the river, but at times if you are in the farm and you want to ease yourself, if you don't go far from the river, the rains will wash it back into the water, you see?*"(Male youth, Oboom)

Thus age and gender seemed to play integral roles in the water contamination behaviour because a large part of the faecal contamination was associated with children who tend to urinate and defecate in or near water bodies as they play or swim. This is in consonance with the findings of Sow et al., (2004) that more than two thirds of school children rarely or never use latrines. Men were also mentioned as culpable of infective behaviour as women for the sake of privacy scarcely relief themselves near water bodies. Another thing worth noting is that while a limited number of the population are involved in the faecal contamination, the entire community and even those beyond are put at risk of infection. The medical doctor at Oboom also gave a narration of the how faecal contaminants flow along with the river from one town to the other.

> *"The river densu takes its roots all the way in the eastern region and it passes through other towns before reaching here. So the faecal contamination may not necessarily be from this town but from the other towns and villages on the path of the river"* (Medical officer, Oboom).

This means that all the towns along the path of the river are at risk of schistosomiasis infection due to the contamination at an endemic community along the path.

Proximity to water bodies has been reported as a risk factor to schistosomiasis infection (Kapito-Tembo et al., 2009). Various measures have used to describe the proximity to water source. For instance Ugbohiko, (2010) described distance less than thirty minutes' walk as proximal whiles Kapito-Tembo et al., 2009 used distance less than one kilometer as proximal. However, in the study communities, the rivers run through the hearts of the communities. Oboom for instance has four major rivers running through the community so it would take one less than five minutes to reach a river. This tend to increase the frequency of water contact and hence the risk of infection.

Population growth means more households, larger household sizes, more children and more water contact activities and hence higher risk schistosomiasis infection (Ofoezie, Christensen And Madsen, 1998). The two communities have both experienced marked population growth and are gradually urbanizing due to the availability of such social amenities as water, school, health centres and access roads linking the communities to the district capital. Thus the community members at Oboom especially attested to the fact that there has been increase in their numbers in the communities.

> *"yes, the numbers have increased. People are giving birth and some also come from other communities to this place because we have light, school and clinic. Now you can't even rent room in this community, it is becoming very expensive."(Male adult, Oboom)*

This to a large extent had also resulted in population movements to and from the communities. As a result, migrants from areas where the disease is not endemic or areas where schistosomiasis has been controlled will be at a higher risk of infection because their limited natural immunity will make them more susceptible to the infection (WHO, 2008; Aagaard-Hansen, Nombela and Alvar, 2010).

With regards to road construction and land use practices, observation and the account of community members revealed that there were ongoing road projects and severe sand mining in the communities. Some of the road projects had been abandoned for years, the community members reported. These, coupled with the drought had created a dusty environment and so people who walked along the road and came cross the river would pass by to wash their feet and hence putting themselves at risk of schistosomiasis infection. Water collected in the holes and pits created from the sand mining could also create habitats for the intermediate snail host and other disease causing organisms. These land use practices pose indirect consequences to the schistosomiasis incidence through a myriad of pathways (Eisenberg et al., 2007).

6.3 Treatment-seeking practices

Many different perceived causes of diseases may be considered in the process of deciding on a diagnosis that relates to different forms of prevention and treatment (de-Graft Aikins, 2005; WHO, 2008). Because schistosomiasis was perceived to be caused by germs in the river and not spiritual activities or any cultural processes, the major health seeking behaviour was reporting to the health centres. Thus the perception of infection and treatment were predominantly biomedical. That is to say pluralistic health-seeking practices are adopted in cases where there was coexistence of diverse disease explanatory concepts (Danso-Appiah et al., 2004). However since the predominant explanatory concept was biomedical or natural, the main health seeking practice was at the health centres. A few of the women also indicated knowledge of herbs that could treat schistosomiasis…… *"yes, there are some herbs that can treat it"* (Adult female, Kojo Ashong).

A situation was also narrated at Kojo Ashong where the victim had to take alcohol to cure the disease. However the idea of seeking spiritual intervention was mocked and refuted by all the groups in both communities. Participants unanimously reacted like this: …

"*….no!, no!, no!, this is not a church matter"* (Adult male group, Kojo Ashong).

At the hospital the schistosomiasis is treated with a single dose of Praziquantel depending on the weight of the patient, the medical officer explained. Furthermore, in cases where the infected persons experienced little or no pain there was total medical inaction. A section of the youth complained about the money they had to pay at the health centre:

> *"When you go to the clinic, they say that it is not covered by the health insurance so you have to pay, and if you don't have the money…."* (Male youth, Oboom).

This is in agreement with the report of Danso-Appiah, (2004) where male teenagers were expected to pay their own health care bills and hence delayed or ruled out visits to the health centres in cases where the symptoms were regarded as mild. This probably explains the low case reporting in the health centres.

A section of the adults explained that the symptoms disappear naturally over time if left untreated. Others argued that though the blood in the urine disappears, the painful sensation persists. This phenomenon was confirmed by the medical officer who expressed worry on the damaging consequences of untreated schistosomiasis. The medical officer in charge of the Oboom health centre explained that due to the low mortality risk associated with the disease, there was low turnout in reporting the condition. He explained that the regular screening found a large number of people predominantly children with high intensity of infection who fail to report. Thus people tend to seek medical attention only when there is a death threat (WHO, 2008). There was also a report of a gendered difference in seeking healthcare with women scarcely reporting infection. Thus social factors related to infection do not only have implications for exposure patterns but also the perception of illness and involvement in decision-making regarding access to treatment (Michelson, 1993; WHO, 2008). Women may ignore feeling of weakness and symptoms of disease for long in attempt to meet the household members' expectations as mothers (Danso-Appiah et al., 2004). In other cases the disease may be ignored and taken as part of the menstrual processes. Finally because schistosomiasis is generally associated with children, some adults confessed being shy reporting it.

6.4 Schistosomiasis control and prevention interventions

The major operational component in schistosomiasis control is chemotherapy with focus mainly on school-age children and other high risk groups like those whose occupations involve contact with infected water (WHO, 2008). Some preventive interventions which had been implemented in the communities included the provision of borehole at Oboom, provision of toilet facilities in the schools in both communities as well as health education. The outreaches by the non-governmental organisation called world vision international and the health centres in the communities had kept the communities somewhat informed about the cause of the disease. The health centres in the communities did regular screening and treatment in the schools especially, so most of the youth in the communities specifically those in the school reported that they used to have blood in their urines but have ceased after the treatment administered by the health centres. Due to these interventions, there was awareness of the disease in the communities which to a large extent had resulted in reduced schistosomiasis incidence and higher rate of reporting compared to the past years.

However, interventions like environmental management and focal snail control which have been recommended by the WHO were not operational in the communities at all. This is probably because of the misconception that these interventions require high level of technical expertise as well as larger capital in their implementation. Also, the little attention attached to schistosomiasis by the communities due to the mild nature of the symptoms and the low risk of death could account for this lack of self-intiative. Environmental management practices such as removal of vegetation and silt from rivers and the creation of steeper banks allowing for higher water flow velocities could result in the reduction of snail population and hence schistosomiasis infection (Boelee and Laamrani, 2004). The removal of silt makes snail habitats unsuitable for the growth of aquatic vegetation, which in turn affects availability of food and shelter for snails (Olivier and Barbosa, 1955). Also silt removal eliminates resistance to flow and increases water velocity (Paull and Johnson, 2011). Increased water flow velocities obstruct snail movement and development and at the same time reduce the availability of food, thus reducing snail populations. These simple but effective environmental management practices have been applied in Morocco and other places to control schistosomiasis intermediate hosts (Boelee and Laamrani, 2004).

In the communities, the intervention and control had all been spearheaded by external agencies like the NGO and the health centre but the communities had not in their own initiative mounted any control or preventive interventions except for behaviour change for a few. This lack of community initiative could be due to the low risk perception associated with the disease in the communities. Besides, schistosomiasis was not regarded as a public health problem due to the mild nature of the symptoms and the low mortality risk involved. It is therefore imperative to alert the communities of the long term effects of untreated schistosomiasis.

CHAPTER SEVEN

Summary, Conclusion and Recommendations

7.1 Summary

This study was aimed at examining the trends in the climate variables and exploring the associations between climate variability/change and schistosomiasis prevalence in the Ga Districts in the Greater Accra Region of Ghana. It also sought to find out the knowledge and perceptions of climate variability/ change and schistosomiasis. Also the study was aimed at examining the coping strategies and schistosomiasis control and prevention interventions in the study communities.

Both secondary and primary data were used. While the secondary data consisted of daily maximum and minimum temperatures, number of rainy days, total rainfall and schistosomiasis epidemiological data, the primary data was collected through focus group discussions, in-depth interviews and participant observations. Thus the study adopted a mixed methods approach. Whiles the quantitative approach was used to find the association between the climate variables and schistosomiasis prevalence, the qualitative approach was used to examine the community knowledge and perceptions of climate change and schistosomiasis and the linkages between them. In addition, the coping strategies as well as the preventive and control interventions were elicited qualitatively at the community level.

The total annual rainfall showed a slightly increasing trend and there was a decline in the number of rainy days for the 1970- 2010 period. Also, both the maximum and minimum temperatures had an increasing trend as projected by the IPCC. Again, within the same period, there was moderate inter-annual rainfall variability, with a variability coefficient of 0.26. In addition, whiles the December-February period recorded the highest inter-monthly rainfall variability, the June-July period recorded the lowest (Appendix B). With regards to inter-decadal changes, there were marginal variations in the decadal rainfall pattern (Appendix A) but increases in both minimum and maximum decadal temperature trends.

A positive correlation was found between the number of rainy days and schistosomiasis prevalence which supported the hypothesis that “relationship between the number of reported cases of schistosomiasis and the number of rainy days is directly proportional”. Also, there was a positive correlation between the total annual rainfall and schistosomiasis, however contrary to the expectation that excessive rainfall would result in lower prevalence, the prevalence increased with the total rainfall. Thus the hypothesis that “moderate total annual rainfall is likely to produce high prevalence of schistosomiasis than high rainfall” was not supported. This was attributed to the fact the region receives one of the lowest rainfall in the country so the highest rainfall amount is not excessive enough to inhibit schistosomiasis transmission and infection. Maximum and minimum temperature both correlated significantly negatively with schistosomiasis prevalence. This confirms the hypothesis that “there is a negative association between the average maximum temperature and the schistosomiasis prevalence”. Finally, the Granger causality test showed at 95 percent confidence that maximum temperature Granger causes a reduction in schistosomiasis prevalence.

There was marked gender differentials in schistosomiasis prevalence rate, with the males having higher prevalence rate than the females. Finally, because the data was secondary the age groups could not be recoded to the conventional five years group intervals; however the 15-44 age group reported the highest prevalence, followed by the 5-14 age group and the least was among the under five age group. Other environmental factors and characteristics found to play a role in the disease prevalence are closeness to major rivers, faecal contamination, population movements, land use and agricultural practices. Due to the prevention and control interventions in the communities, the severity of the disease was ranked lower now than that in the past by the community members. However, the health centres recorded higher cases now compared to different time scales in the past. This was attributed to the education given by the health centres and other organisations informing the people of the symptoms of a disease and the need to report it. However, the reporting was still found to be low compared with the diseases with higher risk of mortality.

At the community level, though there was no specific name for climate change the male adults in Kojo Ashong in particular gave vivid historical account why they think the climate has changed. It was also established from both communities that the changing climate, specifically the extremities of temperature and rainfall affects the water contact activities and hence the risk of schistosomiasis infection. From the computation of the relative index of exposure, it was found that swimming is the main activity that predisposes people to the risk of infection. Though fetching water was the most frequent water contact activity at Kojo Ashong, the high risk associated with swimming due to the high activity coefficient gave it the highest exposure index.

The water contact behaviour varied by age, sex, occupation and community of residence with the youth and children more involved in swimming, the women in domestic chores and the men in economic activities. Thus gender and age related pattern of schistosomiasis infection was explained by water contact behaviour and activities expressed by the relative index of exposure (Hagan, 1992; Gryseels *et al*., 1994). There was a clear discrepancy between the knowledge of the mode of transmission and the behaviour patterns. Thus though there was some form of knowledge about the disease, it did not translate into the risk perception and hence the water contact and disease prevention practices.

7.2 Conclusions

The total annual rainfall showed a slightly increasing trend and there was a decline in the number of rainy days. Also, both the maximum and minimum temperatures had an increasing trend as projected by the IPCC. Again, from 1970 to 2010, there was moderate inter-annual rainfall variability, with a variability coefficient of 0.26. In addition, within the same period, whiles the December-February period recorded the highest inter-monthly rainfall variability, the June-July period recorded the lowest. With regards to inter-decadal changes, there were marginal variations in the decadal rainfall pattern but increases in both minimum and maximum decadal temperature trends. Maximum and minimum temperature correlated significantly negative with schistosomiasis prevalence. The total rainfall and number of rainy days on the other hand correlated positively with schistosomiasis prevalence. Also, there was no significant difference between the effect of moderate and high rainfall on schistosomiasis prevalence. In addition, the Granger causality test indicated that maximum temperature Granger-causes lower schistosomiasis prevalence at 95 percent confidence level.

In both communities, the knowledge about climate variability/change was similar to the empirical observations. Changes in the rainfall patterns and temperature increases were cited as evidence of climate change. March with the local name "*Otsoklikli*" was identified as the hottest month and the hotness was projected to increase from the current rate of 4 to 5 in the future on a scale of 1-5. Schistosomiasis on the other hand was known as bilharzia and locally known as *"la shamor"* in the study communities and was known to be caused by swimming in the river which is similar to the biomedical explanations. Children, women, farmers and the fishermen were perceived to be the groups vulnerable to the risk of infection.

Finally, cure seeking for schistosomiasis infection was mainly medical. There had been control and preventions interventions like school-based education, screening and treatment by the health centres and other non-governmental organisations in both communities. These interventions were mainly targeted to children of school going age to the neglect of the other vulnerable groups.

7.3 Policy Recommendations

- Provision of potable water

Because total rainfall and rainy days correlated positively with schistosomiasis infection meaning that the infection sprouts with the onset of the rains, there is the need to get lasting adaptation options since the climate projections indicate that the variability and change in climate is not going to end anytime soon. As a result improved access to quality and reliable water supplies as well as improved sanitation and sewage disposal facilities should be provided.

- Expansion in the scope of control and prevention interventions to cover all the population at risk

Most of the interventions especially the screening and treatment had been targeted towards the children in the basic schools. However, all the community members are at risk, so these interventions should be extended to them as well. This is because a few of the older youth and even the male adults reported that the blood in their urine has ceased but they do have pain when urinating which is a symptom of advanced untreated schistosomiasis. As a result, interventions should be expanded to cover all the other population at risk- farmers, fishermen and women.

- Education on the mode of schistosomiasis transmission

Also since there is some form of knowledge of schistosomiasis, school and community-based education aimed at building on the preexisting knowledge and perceptions and has a strong potential for raising the awareness of schistosomiasis is highly recommended. This can be done by the teachers in the schools and also the health centres.

- Involving the community members in prevention and control interventions

Finally, there should be collaboration between the local communities and the institutions implementing the control programmes so that they can harness the knowledge and perceptions of the community and integrate them into the implementation strategies. Thus a participatory approach should be adopted including women particularly because they are often responsible for both family healthcare and guiding children’s sanitation habits (WHO, 2008).

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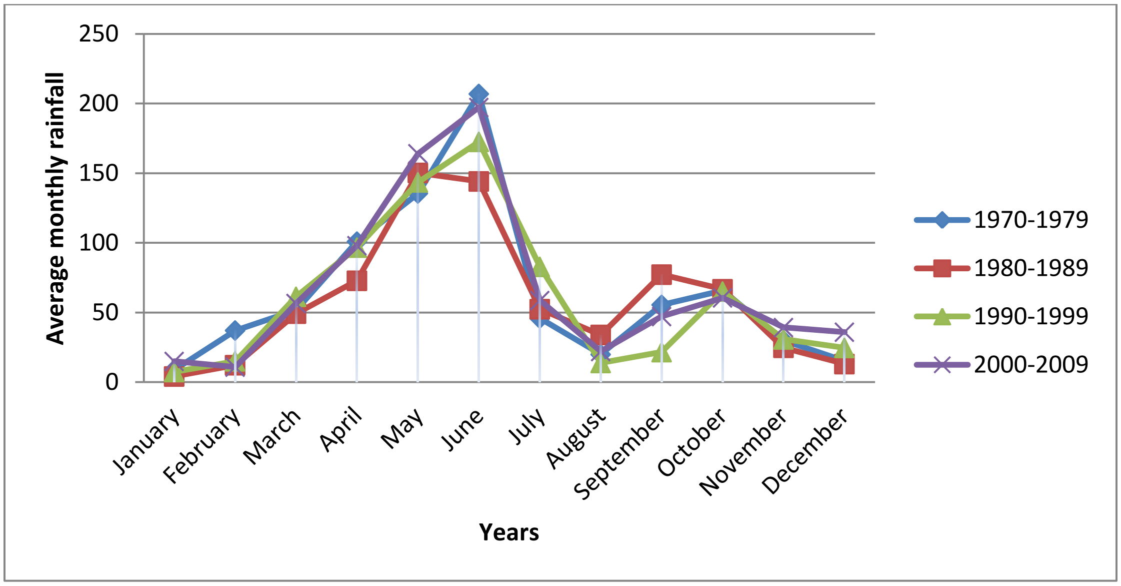
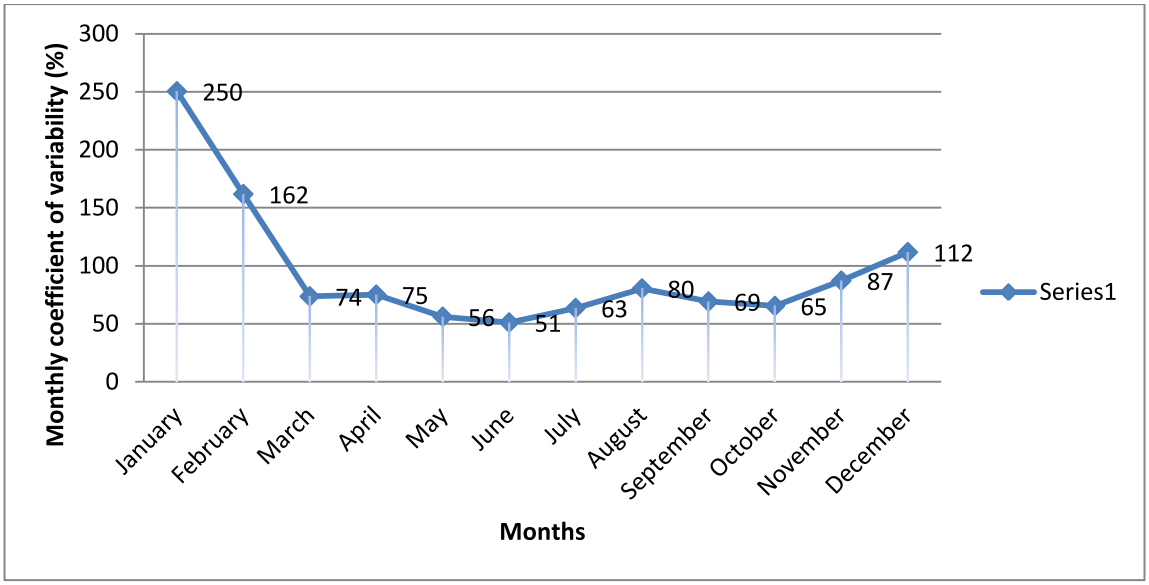
APPENDICES

Appendix A: Inter-decadal rainfall trend (1970-2010)



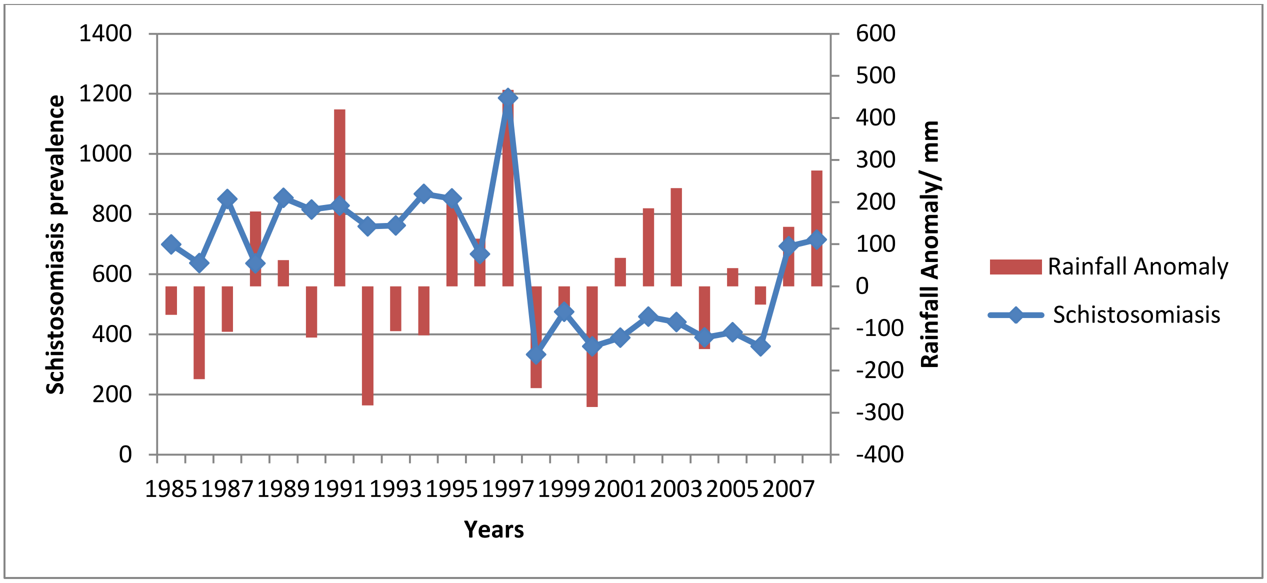
Source: Computed from GMet Data

Appendix B: Monthly rainfall variability 1970-2010



Source: Computed from GMet Data

Appendix C: Rainfall anomaly and schistosomiasis prevalence (1970-2008)



Source: Computed from GMet and CHIM Data

Appendix D: Focus Group Discussion Question Guide

Knowledge of climate change

Introduction …………………….

What do you understand by term climate change?

What do you call climate change in your local dialect?

What is the hottest season (month) in the year?

On a scale of 1-5, how would you rank the severity of the hotness?

What was the hottest month about ten years ago?

How does the hottest month now compare with that ten years ago?

On a scale of 1-5, how would you rank the severity of the hotness about 10, 20 years ago?

What is the coolest season (month) in the year?

How does the coolest month compare with that 10, 20 years ago?

What is the wettest month now?

What was the wettest month 10 years ago, 20 years ago?

When is the onset of the rains now and when does it usually end?

When was the onset of the rain about ten years ago and when did it used to end?

How does the amount of rain now compare with that 10 years ago, 20 years ago?

On a scale of 1-5, how will you rate the difference?

Has the rainfall pattern changed? If yes, explain the change

Effects of climate change on health

Does climate change have any influence on human health?

Are there any positive impacts of climate change on health in this community?

Are there any negative impacts of climate change on health in this community?

Disease burden

What are some of the diseases of great concern in this community?

Which one is of the greatest concern in this community?

On a scale of 1-5, how will you rate the severity?

Ask of schistosomiasis of it is not mentioned?

On a scale of 1-5, how will you rate the severity now? What about 10, 20 years ago?

Knowledge of schistosomiasis

What causes schistosomiasis (blood in the urine)?

Is it curable?

Does it affect adults?

Perceptions of schistosomiasis

Is passing blood in the urine a disease?

Is it wrong to have blood stained urine at any stage of your life?

If no, why?

Do you see people in this community vulnerable to the disease? Why?

Mode of transmission

Are there any activities that predispose people to risk of schistosomiasis?

What are the major occupations in this community?

Do any of them put the people at risk of contracting the disease?

List the occupations that put people at risk

On a scale of 1-5 rank the degree of the risk associated with each

Are there any dam projects in this community?

If yes, do you think they have any influence on the disease transmission?

Climate change-schistosomiasis relationship

Do you think any of these climatic variables has influence on abundance of the disease? (In each case, if yes ask how and if no, ask why)

Rainfall?
Temperature (Heat)?
Drought?

On a scale of 1-5, how will you rate the effect of these climate variables on schistosomiasis incidence?

Seasonality

Have you observed any seasonal abundance of the disease?

If yes, at what times is it more common and at what times is it rare? Was it the same 10, 20 years ago?

Other environmental factors

Are there any environmental factors that influence the abundance of schistosomiasis?

How often do people move in and out of this community? Do you think it affects schistosomiasis infection rate?
Are there any rivers/ ponds in this community?
Do you think the distance from the water body has any bearing on the rate of infection? How?
Do you have any observations concerning the water level and the rate of infection? How?
Do the water bodies experience any faecal or urinal contamination from the public?
Do you think this contamination affects the abundance of the disease? Why?
What do you think influences the contact rate of people to the water body?
Do you think the contact rate has any bearing on the infection rate of the disease? Why?
How does the population size now compare with that 10, 20 years ago?
If there has been a change, do you think it is affecting the infection rate? Why?
Are there any ongoing or completed road projects in the community?
Have these road projects in any way influenced the infection rate of schistosomiasis in this community? Why?
Has this community experienced any mass cutting down of tress?
If yes, is it affecting the infection pattern? How?

Coping strategy

What do people usually do when they have blood in their urine?

Is it worth reporting the condition to the hospital?

Are you aware of any other mode of treatment?

Interventions

Has there been any intervention by the government or any NGO in relation to this disease?

If yes, what exactly?

Summing up

Do you have any additions to this discussion?

Do you have any questions about this research?

Appendix E

KNOWLEDGE AND PERCEPTIONS OF CLIMATE CHANGE AND SCHISTOSOMIASIS: A CODING FRAME

(KAAM-Kojo Ashong Adult Male, KAAF- Kojo Ashong Adult Female, KAY- Kojo Ashong Youth, OAM-Oboom Adult Male, OAF-Oboom Adult Female, OMY-Oboom Male Youth, OFY-Oboom Female Youth, MO-Medical Officer, CL-Community Leader)

Themes /codes	**KAAM**	**KAAF**	**KAY**	**OAM**	**OAF**	**OMY**	**OFY**	**MO**	**CL**	**freq**	**Codes description**	**Sample codes**
Knowledge of climate change												
• rainfall pattern	+	+	+	+	+	+			+	7	Changes in the rainfall pattern	“*Formerly we had two or three heavy rains in March to prepare us for the planting season, but for the past four or five years, it has not been like that. You see, we are in March but it is still dry*” **CL**
• rainfall amount	+	+			+	+				4	Changes in the rainfall amount	*“Previously, it rained a lot but now it is not so”* **OAF**
• heat	+	+	+	+	+	+	+		+	8	Increased temperatures	*“Now the way the sun shines a lot, that is why we say the weather has changed”* **KAAF**
• March (Otsoklikli)	+	+	+	+		+			+	6	Highest temperatures are in March	*It shines a lot. It shines a lot in March getting to the end of March*

												like today's date. **KAY**
• Harmattan	+	+		+	+	+	+		+	7	The harmattan does not come at all or not at the right time	*"… the harmattan season has changed. This year for example the harmattan did not come…"* **OAF**
Effects of climate change on health												
• Bad nutrition	+				+	+				3	Change in rainfall pattern destroys crops and results in bad nutrition	*"…yes, when our crops are destroyed, we only eat kenkey and it affects our health, the children become stunted"* **(KAAM)**
• Fever (Atridii)	+	+	+	+	+	+	+		+	8	High temperatures brings fever	*…and fever…***(KAAM, KAAF, OMY)**
• Malaria	+		+				+		+	4	Rainfall and heat brings malaria	*"…the first one is malaria…"* **OFY**
• Head aches						+				1	High temperatures causes headaches	*"It brings a lot of heat and as a result of the heat it brings a lot of headaches"* **OMY**
• Foot rot	+					+				2	Rainfall causes foot rot	*"When the children walk on rain water, it can cause foot rot"* **KAAM**

• Rashes			+			+				2	Excessive heat brings skin rashes	*"Yes it does,….Skin rashes"* **KAY**
• Catarrh	+					+				2	Drought brings catarrh	*"…..It gives us catarrh"* **OMY**
• No positive effect	+	+		+	+	+	+		+	7	Climate change has no positive effect on health	*"It does no good to us, it has no positive effect on our health"* **OFY**
Knowledge of schistosomiasis												
• organisms in river			+	+	+			+	+	5	Disease organisms in the rivers that causes the schistosomiasis	*"Some NGO's came to conduct certain tests on the river and they said it contained certain organisms but we have no eyes to see them*" **KAY**
• Swimming	+	+	+	+	+	+	+	+	+	9	People contract the disease when they swim in the river	*"…the swimming, the swimming, as for that it's the swimming"* **OAM**
• Urine in blood	+	+	+	+	+	+	+	+	+	9	Having blood in the urine is a symptom of bilharzia	*"..it's a kind of disease that when you want to urinate, you feel pains and you urinate blood"* **KAAM**
• Curable	+	+	+	+	+	+	+	+	+	9	Bilharzia is	"Yes, it is

											curable	curable" **OMY, KAAF**
• Bilharzia	+	+	+	+	+	+	+	+	+	9	The common name is bilharzia	"….*Yes, yes, it is bilharzia*" **KAAM**
• "La shamor"	+	+		+						3	The local name is *"la shamor"*	"…*Yes, it is called la shamor"* **OAM**
• Reduced	+	+	+	+	+	+	+	+	+	9	The prevalence has reduced	*"It has come down. Now it's low. At first the rate was higher but it's now low"* **OMY**
• Any water contact		+						+		2	Any form of water contact can result in bilharzia	*"Any form of contact with the infected water can make the person contract schisto..."* **MO**
Perceptions of schistosomiasis												
• Risk activity is swimming only	+		+	+		+	+			4	The only activity that make people contract the disease is swimming	"….*Yes, yes it's the only swimming* "**OMY** *"eeh, eeh, nothing else. It is the swimming.."* **KAAM**
• Risk of infection depends			+		+	+				3	Whether you will be infected depends on your luck	*"...someone can swim and will not be infected, and another person will swim and will be infected…"* **KAY**

• not normal	+	+	+	+	+	+	+	+	+	9	Blood in urine not normal	*"I had this disease before. It is not normal to urinate blood"*, **OAM**
Vulnerable groups												
• Children	+		+		+	+	+	+	+	7	Children are the most affected	*"For bilharzia, it usually affects the children"* **OFY**
• Women	+	+				+		+		4	Women who wash clothes at the river side	*"The women who wash in the river are also at risk"* **KAAM**
• Fishermen		+				+		+		3	Those who fish in the rivers are at risk	*"They (fishermen) are those who are at risk"* **OMY**
• Farmers	+			+	+			+		4	Farmers are at risk of infection	"…those who make their farms close to the river during the dry season…."**CL**
• Everybody	+		+				+	+	+	5	Everybody is at risk	*"everybody, but the children especially*" **OFY**
Climate change and schistosomiasis												
• No association	+		+		+		+	+		5	There is no linkage between climate change and bilharzia infection	*"No, no, we can't relate bilharzia to the rainfall pattern. It is the swimming in the river"* **KAAM**
• Heat stimulates swimming	+		+				+			3	High temperatures stimulates the drive to swim	*"The weather becomes hot, so it will make people swim a lot"*. **OFY**

• rivers dry	+	+			+					3	Drought causes some rivers and ponds to dry	
• water level and swimming			+			+	+			3	The water level determines when children swim	*"When the water level is too high, they don't go to swim in the river because they are afraid that the river will carry them way but when the level comes down, then they go swimming".* **KAY**
• water level and fishing	+		+							2	Low water level conducive for fishing	*"Yes, we fish in the Densu River, and we have the seasons for that. When the water comes down, that is when we get the fish"* **KAAM**
• water in patches	+						+	+		3	high risk of infection when water is in patches	*"….yes when the water level goes down, the cercaria are concentrated so there is higher risk of infection when you make contact…",* **MO**
• Water becomes			+							1	Long periods	*"if it does not rain*

green											without rain makes water green and unsuitable for use	*for a long time, the water becomes green and one cannot use it for anything, you cannot even use it for washing and so people don't use it"* **KAY**
- Heat kills cercariae								+		1	High temperatures heats up water in rivers and kill the cercaria	*"Yes. Also because the sun can shine directly on them, some will die. Yes some of the snails may die because the water temperature may be too high for their survival"….* **MO**
Water contacts												
- Unwilling	+		+				+	+	+	5	Unwilling to avoid river contacts	*"You see? Not as if they don't know, they are aware that it is the swimming that brings the disease, but they go"* **KAAM** "*they are told but they don't listen.."* **CL**

• Cool yourself	+					+				2	Cool yourself in river when weather is hot	*"In March (Otwoklikli), the weather is very hot so when you come from the farm and you are sweating so much, then you have to go and cool yourself in the Densu River"***KAAM**
• Fetch water	+	+	+		+			+	+	6	Fetch water from the rivers	"…to fetch water for use in.." **KAAF**
• Swim	+	+	+	+	+	+	+	+	+	9	Swim in the rivers	*"I have seen people who swam in water and had the disease"* **OAF**
• Wash clothes		+			+			+	+	4	Wash clothes in the water	*"…and washing clothes at the river side…"* **KAAF**
• Bath	+					+	+	+	+	5	People bath in the water	"*People visit the river a lot. For the children, they like to bath in the river for long before coming out.*", **OMY**
• Fishing	+		+			+				3	Fishing from the river	"*..yes, we fish from it…*", **KAY**
• motor bike		+	+			+	+		+	5	People wash motor bikes	*"yes but they (commercial motor riders) fetch*

												the water and wash on the shore”, **OMY**
Environmental changes and schistosomiasis												
• Faecal contamination		+	+				+	+		4	Faecal contaminants find their ways into the rivers	“*Yes, people do. Because of that we can't drink the water*”, **KAAF**
• Proximity to rivers	+	+	+	+	+	+	+	+	+	9	The proximity of the communities to the rivers makes it easy for the children to swim	*It affects those who are closer to the river, those who most at times go and swim. But if you don't swim, you won't be attacked by the disease”*, **KAAF**
• Population growth		+		+	+				+	4	More people results in more water contacts	“*Yes, the children have become plenty, so and they are always in the river*” **OAF**
• Population movement	+			+				+		3	People carry the disease from one community to the other	“*..these things, someone can have it in one community and go and spread it elsewhere*”, **MO**
• Sand mining	+		+						+	2	Sand mining leaves holes which are filled with	*“When they mine the sand, the pits that are left become small ponds in the*

											water and act as snail habitats	*rainy season….”* **KAY**
• Urbanisation			+		+		+		+	4	Facilities like water and toilet reduces risk of infection	*“no now there is pipe so we don’t drink from the water”* **OMY**
• Water level				+	+		+				Water level influences water contact activities	*“When it rains and there is flooding, the children cannot play in water”* **OAF**
Coping strategies												
• Visit clinic	+	+	+	+	+	+	+	+	+	9	People with schistosomiasis report to the clinic	*“Yes, I went to the clinic and I was given some medicine”,* **OMY**
• Not spiritual	+	+	+		+	+		+	+	7	It is not related to any spiritual cause	*“….no! no! no!, this is not a spiritual issue”,* **KAAM**
• herbs		+			+					2	Knowledge of herbs that cure the disease	*“….yes, some herbs are able to treat it…”,* **KAAF**
• Take alcohol	+									1	Had to take alcohol to cure	*“I was asked to take alcohol and the blood stopped when I took it”* **KAAM**
• Treated	+		+		+	+		+		5	Schistosomiasis is treated in the clinic	*“…It is treated with a single dose of Praziqintel….”* **MO**

Interventions												
- World Vision International	+	+	+							3	Screening and treatment by WVI	*"When the officials from World Vision came here, they collected samples of the water and our urine. Then they performed some tests and told us that there are organisms…",* **KAY**
- Community health centre	+	+		+	+		+	+	+	7	Regular screening and treatment by the community health centre	*"Yes, we go round often. We screen the school children and administer the drugs"* **MO**
- Screening	+	+		+				+	+	5	Community-based screening	*"They came to examine our urine; the children's urine",* **KAAF**
- Education	+	+	+	+		+		+	+	7	School-based education	*"Yes, the people from the clinic came to our school and talked about it,…"* **OMY**