Jimma University
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Anopheline mosquito species composition, density, longevity and malaria prevalence around Gilgel-Gibe area, Southwest Ethiopia

By: Alemayehu Dagne

Thesis Submitted to Department of Biology, College of Natural Sciences, Jimma University; In Partial Fulfillment of Master of Science Degree in Biology (Ecological and Systematic Zoology)

December, 2014

Jimma, Ethiopia

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CONTENTS **page**

LIST OF TABLES

LIST OF FIGURES

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ACRONYMS AND ABBREVIATIONS

ACT: Artemisinin-based Combination Therapy

An: Anopheles

CDC: Center for Disease Prevention and Control

DDT: Dichlorodiphenyltrichloroethane

IRS: Indoor Residual Spraying

ITNs: Insecticide Treated Nets

Km: Kilo meter

LLINs: Long- Lasting Insecticidal Nets

MOH: Ministry Of Health

PBS: Phosphate Buffer Saline

PCD: Passive Case Detection

PSC: Pyrethinium Spray Catch

RBM: Roll Back Malaria

RDT: Rapid Diagnosistic Test

WHO: World Health Organization

ABSTRACT

***Background**: Ethiopia has recently constructed dams to produce electricity, irrigate farmlands and control flood to reduce poverty and sustain economic growth, this may result in elevated malaria transmission. In this paper, we investigate the effects of a mega hydropower dam on Anopheles mosquito species composition, density, longevity and malaria prevalence.*

***Method**: Longitudinal entomological study was conducted from June –December 2013 in two kebeles (four villages) in Tiro Afeta district, jimma zone Southwest Ethiopia. The two kebeles are; Koticha Gibe, which is located near Gilgel Gibe hydroelectric dam and Decha Nadi, located away from the dam. Anopheline mosquitoes were collected using CDC light trap catches and pyrethrum spray catches. In addition retrospective parasitological study was conducted from June-December 2013. Data were analyzed using SPSS version 16.0 statistical package. Descriptive statistics and student t-test were used during analysis and p-value less than 0.05 was considered statically significant.*

***Results**: Overall, 1521 Adult anopheline mosquitoes belonging to two species were collected. An. gambiae s.l. was the predominant species accounting for 72.9% followed by An. coustani s,l (27.1%). Over all mean* monthly *An. gambiae s.l. density collected by LTCs and PSCs was 5.6 per trap/night and 3.51 per house, respectively. Of these 8.5 per trap/night and 5.6 per house/day of them was collected from kebele located near to the dam (Koticha Gibe) by LTCs and PSCs, respectively and the rest 2.71and 1.95 was collected by the same methods from kebele far from the dam (Decha Nadi). There was significant difference in mean monthly An. gambiae s.l. density between the two kebeles* (*$P < 0.05$).There was significant ($P < 0.05$) difference between mean indoor and outdoor An. gambiae s.l. density. However, there was no significant ($P > 0.05$) difference between mean indoor and outdoor density of An. coustani s.l between the two kebeles.* duration of indoor resting after blood feeding *decreased from 1.61to 1.28 and1.35 to 1.23 in Koticha Gibe and Decha Nadi kebele, respectively during Post IRS operations and LLITNs distributions .Over all probability of daily survival of An. gambiae s.l. decreased from 0.70 to 0.56 during Post IRS operations and LLITNs distributions. The prevalence of malaria in the study setting was 10.71%. There was no significance difference in malaria prevalence between two kebeles ($x^2 = 9.386$, $P = 0.052$).*

***Conclusion**: A Clear impact of dam on Anopheline mosquito density has been seen. In other word, the dam is more favorable than the area far from it.*

CHAPTER ONE

1. BACKGROUND

Malaria is an infectious vector borne disease caused a protozoan parasite of the genus *Plasmodium*. It is one of the leading causes of illness and death in the world (Lagerberg, 2008; Martens and Hall, 2002). In 2013, there are 97 countries and territories with ongoing malaria transmission, and 7 countries in the prevention of reintroduction phase, making a total of 104 countries and territories in which malaria is presently considered endemic. Globally, an estimated 3.4 billion people are at risk of malaria. WHO estimates that 207 million cases of malaria occurred globally in 2012 and 627 000 deaths. Most cases (80%) and deaths (90%) occurred in Africa and most deaths (77%) were in children under 5 years of age (WHO, 2013).

According to the WHO, 2012, more than 68% of the Ethiopian population was at risk of malaria. Malaria transmission is temporally and spatially dynamic (Abeku *et al*., 2003), with unstable and seasonal transmission, and linked to environmental variables such as altitude and rainfall (Hay *et al*., 2008). Peak malaria transmission occurs at the end of the rainy season, generally lasting from mid-September to mid-November (Ghebreyesus *et al*., 2006).

The most common malaria parasites in Ethiopia are *P. falciparum* and *P. vivax*, accounting for around 56% and 44% of infections respectively and *An. arabiensis*, a member of the *An. gambiae* complex, is the primary malaria vector in Ethiopia (WHO, 2013). Despite the major attempts over the past century to control malaria, vector resistance to insecticides, (Yewalaw *et al.,* 2009) and malaria parasite resistance to drugs (Ketema *et al*., 2009; Tarleton, 2001; Kwiatkowski, 1999) have stood in the way of malaria control. It is obvious that the construction of water storage reservoirs is critical for eradicating hunger, improving access to clean water (Millennium Development Goals 1 and 7, respectively), and generating electricity—usually results in elevated malaria transmission in surrounding human communities and contributes to a disease burden that claims 1.5 and 2.5 million lives each year (Lautze,2007).Therefore, the proximity of human habitation to the breeding sites directly influences vector-human contact and transmission. In other word, the stability of breeding sites is influenced by water supply, soil and vegetation. Generally, irrigation schemes, dams and other man-made changes affecting land use can have a radical; alter for stable patterns of malaria transmission (Keiser *et al*., 2005).

According to Ledec and Quintero, (2003) to reduce poverty and enhance sustain economic growth; Ethiopia has recently constructed a large number of dams to produce electricity, irrigate farmlands and control flood. However, these development projects could have impact on ecology of vectors and malaria transmission dynamics. This study was designed to assess the impact of the dam and metrological variables on anopheline mosquito species composition, abundance, longevity, density and malaria prevalence pattern. The current study was conducted in Gilgel-gibe hydro-electric dam I which is located in Jimma zone southwest Ethiopia and shares boarder with Tiro Afeta to the North, Kersa to the East, Ommo Nada to the South and Sokoru to the West. Particularly the study was conducted in Koticha Gibe (1km) and Dacha Nadi kebeles (5km) which are located near and far from the dam respectively.

1.2. Statement of the problem

Man-made ecological transformations have occurred at an unprecedented magnitude over the past 50 years. Prominent among them are water resource development projects: an estimated 40,000 large dams and 800,000 small dams have been built and some 272 million hectares of land is currently under irrigation worldwide. The development, management and operation of water resources have a history of modifying the frequency and transmission dynamics of malaria (WHO, 2005).

Change in the environment of the mosquito habitat, such as those taking place in Ethiopia, whether natural or man-made, transform mosquito ecology. Every Anopheles species occupies a specific ecological niche that is genetically determined. Change in temperature, humidity, altitude, population of humans and deforestation are just a few ecological factors that play essential roles in changing the dynamics of malaria transmission (Shililu, 2003).From these ecological change occurring in Ethiopia one is construction of dams. For instance, study conducted in gilgel-gibe hydro-electric dam I South west Ethiopia, showed that prevalence of *Plasmodium* near the reservoir was statistically higher as compared to the in more distant communities (p-value = 0.013). The main reason for the higher prevalence of malaria among children living close to the reservoir may be due to the man-made ecological transformations, which may influence the presence of mosquito-breeding site and might have an impact on the behavior, parity rate and longevity of malaria vectors (Yewhalaw *et al*, 2009). Anopheles mosquito assessment is the base to determine when, what, and if control should be implemented hence assessment of presence of vectors species, abundance, density, longevity, are important parameters to develop effective vector control strategy. Ethiopia is known by having disperse water resources using this opportunities' for eradicating hanger, to get access to cleaning water, to generate electricity and for irrigation One of the most lethal consequences of dams is increased malaria prevalence (IWMI, 2010).

Though the country possesses a substantial amount of water resources little has been developed for drinking water supply, hydropower, agriculture and other purposes. There is a gap in knowledge existed in mitigating the challenges of vector borne diseases such as malaria when using opportunities of water resources. There for this study try to find anopheline mosquito species composition, abundance, and longevity and malaria prevalence in Gilgel-Gibe hydropower dam I proximity and distance kebeles.

To the best of our knowledge, no entomological and passive malaria prevalence survey had been conducted/documented before in the two kebeles. Therefore, this study was aimed at determining the impact of dam and metrological variables on anopheline mosquitoe species composition, abundance, longevity, and malaria prevalence in selected kebeles located near and far from Gilgel-Gibe hydropower dam I, Tiro Afeta district, Jimma Zone, southwestern Ethiopia.

1.3. Objective

1.3.2. General objective

- To determine anopheline mosquito species composition, abundance, longevity and malaria prevalence proximity to and distance from the Gilgel-gibe Hydro-electric dam I together with seasonal variables in Tiro Afeta district, Southwest Ethiopia.

1.3.3. Specific objectives

- To determine anopheline mosquito species composition, density, in selected villages' located near and far from Gilgel-Gibe I dam.
- To determine mean indoor and outdoor Anopheles mosquitoes density in selected villages' located near and far from Gilgel-Gibe I dam.

- To determine mean indoor, duration of resting indoor after blood feeding, parity and longevity of anopheline mosquito before and after intervention in the study area.
- To determine the association between metrological variables and anopheline mosquito density and malaria prevalence in the study area.
- To determine prevalence of malaria in selected villages' located near and far from the Gilgel-Gibe I dam.

1.4. Significance of the study

The result of the study helps to have insight on the species composition, density, dynamics, longevity, of anopheline mosquitoes and malaria prevalence in the study area. In addition, the study is important to understand the effectiveness of malaria vector control intervention in the locality and effects of dam on species composition, density, dynamics and longevity of anopheline mosquitoes and malaria prevalence in the study area.

CHAPTER TWO

2. REVIEW LITERATURE

2.1. Global malaria situation and its burden

Malaria is the world's most wide spread infection (WHO, 2013). According to WHO (2013) report there are 97 countries and territories with ongoing malaria transmission, and 7countries in the prevention of reintroduction phase, making a total of 104 countries and territories in which malaria is presently considered endemic.

2.1.1 Burden of malaria

The estimate of malaria burden vary; every year. It has been estimated that 90% of deaths in 2012 were in the African Region, followed by the South-East Asia (7%) and Eastern Mediterranean Regions. About 482 000 malaria deaths (uncertainty interval, 408 000–565 000) were estimated to occur in children under 5 years of age, or 77% of the global total (3%) (WHO, 2013).

Of the 35 countries that accounted globally for ~98% of malaria deaths, 30 were located in sub-Saharan Africa, with four countries (Nigeria, Democratic Republic of Congo, Uganda and Ethiopia) alone accounting for ~50% of deaths on the continent (WHO, 2013).

The goal set by the world health Assembly and Roll back Malaria (RBM) partnership reduce the number of malaria cases and deaths recorded in 2000 by 50% or more by the end of 2010 and by 75% or more by 2015 have not been achieved yet. Instead over the past 35 years , the incidence of malaria has increased 2-3 fold and this continues to upsurge has comes from several factors like the weakening of public health systems in some poor countries ,continuing poverty and political instability, drug resistance parasite ,insecticide-resistance mosquitoes ,global climate change, population movement in to malarious regions, changing agricultural practices including the building of dams and irrigations schemes, deforestations (WHO,2011).

2.1.2 Epidemiology and burden of malaria in Africa

Malaria infection and poverty are geographically specific, and restricted to the tropical and sub-tropical zone of the globe. Therefore the devastating effects of malaria infections have been linked to a malicious cycle of poverty and ill-health, particularly in area of low economic growth (Sachs and Malaney, 2002). The intensity of malaria transmission fluctuate largely along with variations on geophysical characteristics, climatic, environmental conditions, malaria mosquito vectors and parasite species and the socio-economic status, behavior and distribution of human population(CDC,2012).

In general, the wide range of the amount and/ or the severity of malaria infection can be categorized in two broad situations: unstable and stable malaria. Unstable malaria is characterized by its unpredictable occurrence over a given period of time. The exposure to malaria infection is inconsistent, and consequently, an effective and long-lasting level of collective immunity is not acquired. All age groups are vulnerable to infection. Areas of unstable malaria prone to epidemic out breaks (Sachs and Malaney, 2002).

In stable malaria situation, conditions are favorable for long and persistent periods of transmission, with little variations related to seasonal and climatic changes. The amount of malaria is enormous, reflecting the presence of highly effective vectors (Boland *et al*., 1999).

Regarding the burden of malaria in Africa it is estimated that malaria costs Africa US$ 12billion per year in direct cost and reduced GDP growth by 1.3% annually. The burden was carried mostly by poor, rural families that have less access to current prevention and treatments service. Despite the devastation caused by malaria, increased international attention and funding for prevention and treatments is saving lives (WHO, 2013).

2.1.3 Epidemiology and burden of malaria in Ethiopia

The epidemiology of malaria may vary considerably within relatively small geographic areas (Breman *et al.,* 2006). The transmission patterns and intensity vary greatly due to the large variations in altitude, rainfall, humidity and population movement (Negash *et al.,* 2005). Unstable malaria occurs in moist parts of the country especially in the lowland-highland fringes where climatic conditions are suitable for malaria transmission (WHO, 2009). Transmission usually occurs at altitudes below 2000m *asl.* Areas below 2,000m *asl* are malarious (potentially malarious) (Paulander *et al.*, 2009).There are two malaria transmission seasons in the country: one is the major malaria transmission season that occurs between September and December following the rain from June to September and the second, relatively low, occurs between April and May due to the February and March rains (MOH, 2003; MOH, 2000). Some localities may also experience perennial malaria as the environmental and climatic situations permit the continual breeding of vectors in permanent breeding sites (Gebre-Mariam *et al*, 1998; Mouchet *et al*., 1998).

Despite the low malaria parasite prevalence compared to many African countries, malaria remains the leading communicable disease seen at health facilities in Ethiopia. Historically, malaria has forced people to inhabit the less agriculturally productive highlands. Given that the country's economy is based on agriculture and peak malaria transmission coincides with the planting and harvesting season, this has placed a heavy economic burden on the country (PMI, 2014).

2.2 Life cycle of malaria parasites

There are five identified species of the parasite causing human parasites, namely *P. falciparum, P.* vivax*, P. malariae, P. ovale* and *P. knowlesi*. It is transmitted by the female anopheles mosquitoes'. It is the diseases that can be treated in just 48 hours, yet it cause fatal complications if the diagnosis and treatment are delayed. It is re-emerging as the number one killer and it is the number one priority tropical disease of the WHO (WHO, 2011; Daneshvar *et al*., 2009).
The natural ecology of malaria involves malaria parasites infecting successively two types of hosts: humans and female Anopheles mosquitoes. In humans, the parasites grow and multiply first in the liver cells and then in the red cells of the blood. In the blood, successive broods of parasites grow inside the red cells and destroy them, releasing daughter parasites ("merozoites") that continue the cycle by invading other red cells.

The blood stage parasites are those that cause the symptoms of malaria. When certain forms of blood stage parasites ("gametocytes") are picked up by a female *Anopheles* mosquito during a blood meal, they start another, different cycle of growth and multiplication in the mosquito. After 10-18 days, the parasites are found (as "sporozoites") in the mosquito's salivary glands.

When the *Anopheles* mosquito takes a blood meal on another human, the sporozoites are injected with the mosquito's saliva and start another human infection when they parasitize the liver cells.

2.2.1 Distribution of plasmodia

Of the five Plasmodia species that infect human beings *P. falciparum* and *P. vivax* cause the significant majority of malaria infections. *P. falciparum*, which causes most of the severe cases and deaths, is generally found in tropical regions, such as sub-Saharan Africa and Southeast Asia, as well as in the Western Pacific and in countries sharing the Amazon rainforest(WHO,2011). *P. vivax* is transmitted in 95 countries in tropical, sub-tropical and temperate regions (Guera *et al.*, 2010), except where there is a natural absence of *anopheles* mosquitoes (east of Vanuatu in the South Pacific) or among populations lacking the Duffy receptor on red cells (in much of Africa). It is only *P. vivax* malaria that occurs in the temperate latitudes — up to the Korean peninsula and across the southern temperate latitudes of Asia to the Mediterranean Sea (Baird, 2008).

P. malariae is wide spread throughout sub-Saharan Africa, much of Southeast Asia, into Indonesia, and on many of the islands of the western Pacific. It is also reported in areas of the Amazon Basin of South America (Collins *et al.*, 2007). *P. ovale* is found in Africa and sporadically in Southeast Asia and the Western Pacific. *P. malariae* and *P. ovale* contribute to only a small number of malaria infections, but the incidence of *P. malariae* is probably underestimated (WHO, 2011).

P. knowlesi a primate malaria species that is being increasingly reported from remote areas of Southeast Asia from countries such as Malaysia, Thailand, Viet Nam, Myanmar and Philippines (Danshevar *et al.*,2009;Peter,2009;Pulaporntip *et al.*,2009; Cox-singh and singh ,2008; Balbir *et al.*,2004).

2.3. Malaria vectors

Africa has over 140 recorded *Anopheles* species, of which at least eight are considered to be effective vectors of malaria (Gillies *et al.*, 1987; Gillies and De Meillon 1968). Not all anopheline mosquitoes are vector of malaria (Muriu *et al.,* 2008). Some members of *An.*

gambiae, An. funestus, An. nili, are the main vector of malaria in Africa (Beier *et al*., 1999). *An. gambiae complex* consists of eight sibling species. There are***:*** *An. gambiae sensu stricto, An. coluzi, An. arabiensis, An. merus****,*** *An. melas****,*** *An. quadriannulatus****,*** *An. amharic's****,*** *An. bwambae* and *An. comorensis* which is under question to be considered under *An.gambiae sibling* species not where its single specimen recorded from Indian ocean islands of the Comoros in the Mozambican channel(Coetzee *et al*.,2013). *An. merus* and *An. melas* are associated with salt-water with a localized distribution along the eastern and western coasts of Africa, respectively, while *An. bwambae* has only been found breeding in mineral springs in the Semliki forest in Uganda. *An. quadriannulatus****,*** found in south-east Africa (Coluzzi, 1984) and *An. amharicus*, which has been described in Ethiopia (Hunt *et al*., 1998), are not considered vectors of human malaria as they are generally zoophilic (Coluzzi, 1984).

Anopheles funestus which belongs to the *Funestus* group of which there are two African subgroups (*Funestus* subgroup includes *An. aruni****,*** *An. confusus****,*** *An. funestus****,*** *An. parensis****,*** *An. vaneedeni****;*** Rivulorum subgroup includes *An. brucei, An. fuscivenosus, An. rivulorum****,*** and *An. rivulorum*-like species (Gillies, 1987). Other species, such as *An. paludis****,*** *An. mascarensis* and *An. hancocki* play only a limited, secondary and localized role where they are found (Fontenille and Simard, 2004).Several of these vector species are found to occur in sympatry in much of Africa and their importance in malaria transmission varies depending on behaviour (e.g. biting activity, feeding and resting preferences), seasonal prevalence and vectorial capacity (Fontenille and Simard 2004; Coluzzi, 1984).

In Ethiopia, about forty-three anopheles mosquito species have been recorded in the country. Some of these are *An. arabiensis, An. funestus, An. nili, An.pharoensis, etc,* (MOH, 2002). Malaria transmission in Ethiopia depends substantially on *An. arabiensis* Patton (principal malaria vector in the country), a member of the *An. gambaie* Giles complex, in the intermediate highlands of Ethiopia. *An. funestus* Giles is the second most important malaria vector in Ethiopia. *An. nili* Theobald is an important local malaria vector in the low land region of south-west Ethiopia (MOH, 2007; Woyessa *et al*., 2002).

2.3.1. Malaria vector biology and ecology

All mosquitoes require water to complete their life cycle. Development is of the complete type, and consists of four stages: egg, larva, pupa, and the adult. 200-1,000 eggs can be laid; the quantity is influenced by the amount of blood taken in. Once egg lying is complete, the female retires to an area where it may once again take another blood meal (Leopoda, 2008). The female takes in blood as a rich source of protein in order to produce her clutch of eggs. She often takes her first blood meal the night after emerges from the pupal stage and not immediately infective after taking a blood meal and needs at least two feedings to complete one transmission cycle. This parameter is strongly dependent on actual air average temperature (WHO, 1975;WHO,2012).

Blood feeding usually occurs between dusk and dawn, although some species feed during daylight hours in densely shaded woodland areas. (Anon, 2012; CDC, 2012; Price, 2007; Mendes, 2001).

The range and relative abundance of major malaria vectors is strongly influenced by climatological factors, particularly annual precipitation (Lindsay and Martens, 1998). Spatial and temporal fluctuations in their densities are seasonal and coincide with rainfall patterns (Cohuet *et al*., 2004; Rogers *et al*., 2002). For example, *An. gambiae* and *An. funestus* are more dominant in wet and humid areas, whilst *An. arabiensis* is better adapted to drier conditions and predominate in arid savannas (Coetzee *et al*., 2000; Lindsay and Martens, 1998; White, 1974). In areas where *An. arabiensis* and *An. gambiae* co-exist, there are huge heterogeneities in densities, with the former predominating during the dry season and the later becoming more abundant in the rainy season (Kulkarni *et al*., 2006; Takken *et al*., 1998; Smith *et al*., 1993;Gillies *et al*. 1968). The female Anopheles is not immediately infective after taking a blood meal and the parasite requires a period of time with in the mosquito for its developments to an infective stage.

The development of the parasite *(plasmodium*) within the mosquitoes (sporogenic cycle) is dependent on temperature. That is, it takes about 6-10 days at temperature of 28^0C, but stops at temperature below 16^0C.The daily survival of the vector mosquito is dependent on temperature as well. For range of temperature between 16^0C-36^0C, daily survival is about 90%; while with a temperature above 36^0C survival shown to drop rapidly. Humidity and rainfall have been shown to regulate malaria vector survival. Relative humidity below 60% was related to a decrease in vector life span, hence, which means ultimately low rate of malaria transmission. In contrast, at a humidity level above 60%, the infection rate increases substantially, this can be explained by improved vector survival (Ye *et al*., 2007; Martens *et al*., 1995).

2.3.2. Malaria vector behavior

The principal malaria vectors are quite discriminating in their biting and resting behaviours, which has implications for vector control. *An. gambiae* s.l. and *An. funestus* are highly endophagic and endophilic (Gillies and Coetzee, 1987; Gillies and De Meillon, 1968) nocturnal feeders with maximum biting taking place between midnight and 4:00 am, but continuing until just after sunrise (Dossou-Yovo *et al*., 1999; Lindsay *et al*., 1989; Gillies and De Meillon, 1968). *An. arabiensis* behaviour is more varied than that of *An. gambiae.* It can feed and rest both indoors and outdoors due to its zoophilic behaviour (Kulkarni *et al*., 2006; Shililu *et al.,* 2004). Generally the period for blood-feeding is genetically-fixed (Gimnig *et al*., 2003; Sampath *et al*., 1998; Magesa *et al*., 1991). In Ethiopia peak biting by *An. arabiensis* was early in the night (20:00 to 22:00 hours), mainly before people went to bed (Yohannes *et al*., 2005; Abose *et al*., 1998).

The breeding sites of infected mosquitoes vary greatly with regards to species. Some prefer clear water, inhabiting the edges of streams, while others thrive in irrigation ditches and reservoirs. Some species require extensive vegetative cover, preferring swamps and other permanent bodies of water laden with dissolved organic matter. Mosquito breeding sites are found anywhere fresh water collects. In fact, there is a direct correlation between the availability of water and the frequency in which mosquitoes feed on humans. Permanent natural bodies of water, such as swamps, serve as unique breeding grounds. In the tropics, as mentioned, mosquito breeding sites have emerged due to construction of dams and canals. Many of these sites develop into zones of transmission due to the concomitant increase of human populations moving to these areas. (Afrane *et al*., 2005).

2.4. Malaria and dams

Construction of dams and irrigation schemes has long been associated with the creation of breeding habitats for malaria vector mosquitoes (Keiser *et al*., 2005). Throughout much of Ethiopia, unstable malaria transmission and very low entomological inoculation rates (i.e., less than one infective bite per person per night during the main transmission season) mean immunity is relatively low and thus all age groups in the population are likely to suffer from the disease (MOH, 2008). Lower levels of natural immunity resulting from lack of year-round sustained malaria transmission in zones of unstable transmission often result in severe malaria epidemics when environmental conditions shift to favor malaria transmission (Kiszewski and Teklehaimanot, 2004). In such areas, impounded water holds great potential to increase malaria transmission so long as daily temperatures are warm enough (i.e., typically higher than 20 ^{o}C) to support the development of the aquatic stages (i.e., egg, larva, pupa) of mosquitoes. Although rarely quantifiably documented in Africa, a few studies have shown a link between the presence of impounded water and elevated malaria transmission in nearby communities (King,1996; Roggeri,1985;Oomen,1981) and increased anopheline densities but without exerting any significant influence on malaria transmission(Dia *et al*.,2008).

Studies in northern Ethiopia have demonstrated that malaria incidence among children living in communities close to irrigation micro-dams was seven times higher than amongst those living further away (Ghebreyesus *et al*., 1999). Entomological surveys in the same area confirmed that increased malaria incidence associated with dams resulted from a rise in mosquito abundance, particularly *An. arabiensis* (Yohannes *et al*., 2005). A study in southwestern Ethiopia also showed a higher prevalence of malaria in villages closer to the Gilgel-Gibe Reservoir than in control villages (Yewhalaw *et al*., 2013 and 2009).

2.5. Malaria parasite and vector control

Long lasting insecticidal nets (LLINs), indoor residual spraying (IRS) and environmental management are the most widely used tools for malaria vector control (WHO, 2007). Similarly in Ethiopia LLINs and IRS are the two key vector control interventions while early diagnosis and treatments of cases using Artemisia and rapid diagnosis therapy (RDTs), early detection, prevention and control of epidemics are also used in Ethiopia (PMI,2014;WHO, 2007).

Since the discovery of the role of anopheles mosquitoes in malaria transmission over one hundred year ago, malaria control experts have recognized the value of changing mosquito larva habitats to reduce or eliminate malaria transmission. Habitat elimination and modification efforts have included general programs to reduce the density of important vectors as well as more targeted projects of “species sanitation” directed at the principal malaria vectors (PMI,2014;WHO, 2007).

A better understanding of the biology and ecology of principal vectors is essential in malaria preventions (Gillies and Coetzee, 1987).For instant endophilic mosquitoes are readily controlled by indoor spraying of residual insecticides. In contrast, endophilic/ exophilic vectors are best controlled through source reduction (destruction of breeding sites) (WHO, 2007).The endophilic anopheles mosquitoes can be markedly reduced through the use of insecticide treated bed nets (PMI, 2014; WHO, 2007).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Study area and period

The study was conducted from June-December 2013(June-August pre-IRS intervention and LLINs distribution and post IRS intervention and LLINs distribution) in Koticha Gibe and Decha Nedhi Kebeles (the smallest administrative unit) in Tiro Afeta district which is located 260 km south-west of the capital, Addis Ababa in Oromia Regional State, southwestern Ethiopia and about 65 Km Northeast of Jimma Town. Koticha Gibe is located within 1km from the reservoir of Gilgel Gibe Hydroelectric dam while Decha Nedhi is relatively far from the dam (5km) (Figure 3). The study area lies at an altitude of 1,734–1,864 m above sea level. The kebeles has a sub-humid, warm to hot climate, both cultivated and uncultivated land, is characterized by two rainy seasons, June to September-the main rainy season and March to May-the short rainy season and receives Annual minimum and maximum rain fall ranges from 1,300-1,800mm of annual rainfall and has mean minimum and mean maximum annual temperatures of 30^0C and 16^0C respectively. The census from the district administrative office showed that the population of Koticha Gibe and Decha Nedhi was 3493 and 3240, respectively (Tiro Afeta District Communication Office, 2013).

According to the clinical records from the Health Center, malaria is common in both kebeles. Hence, malaria prevention and control interventions are being implemented. These include annual indoor residual spraying (IRS), distribution of ITNs/LLINs and prompt treatment of malaria cases using ACT(Coartem) as a first line treatment based on rapid diagnostic Tests (RDTs) (District Malaria and Other Infectious Diseases control unit, 2013).

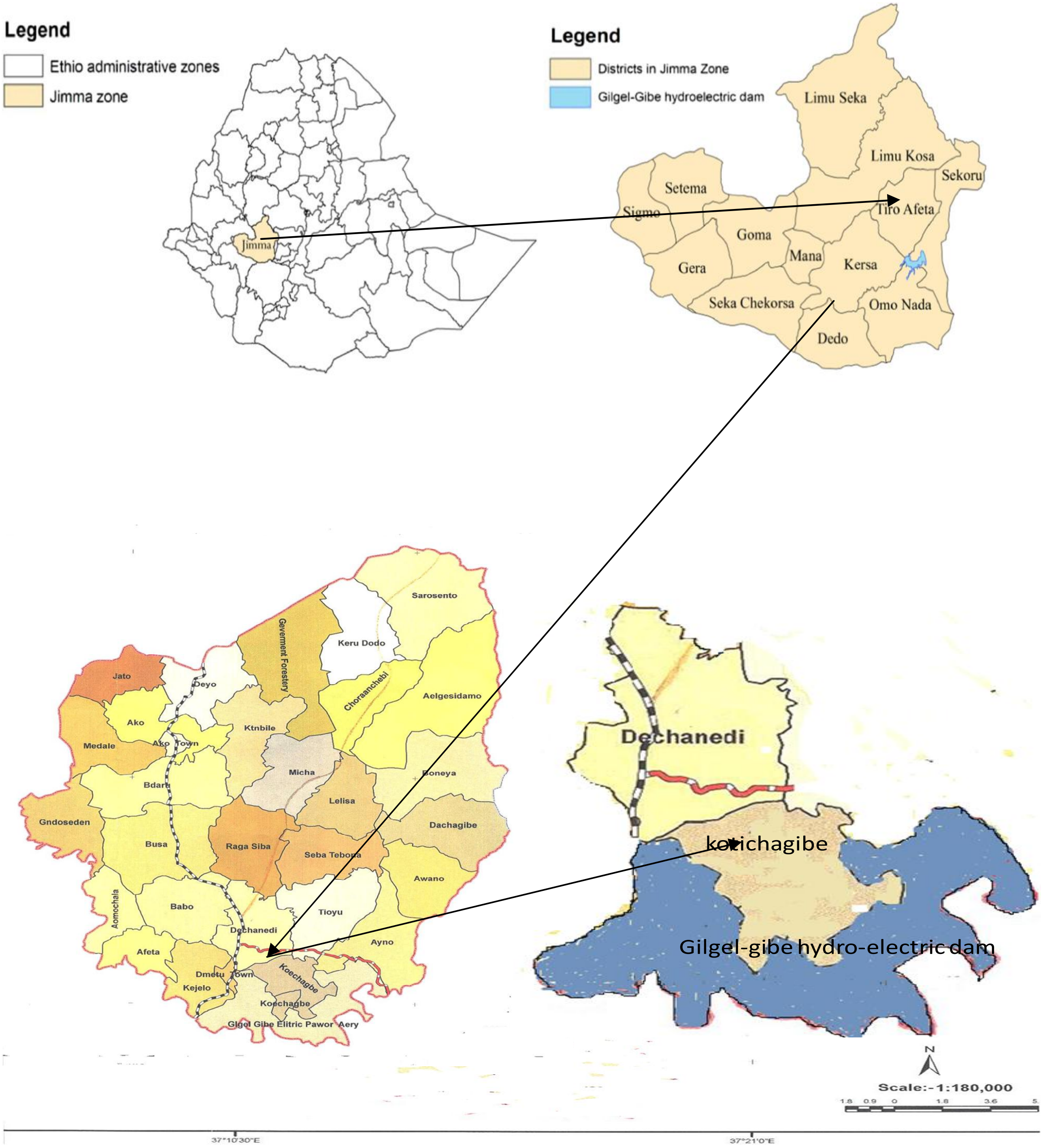


Figure 1: Map of the study area. (Tiro Afeta District Communication Office, 2013; Yewhalaw *et al*., 2013).

3.2. Study design

Longitudinal entomological study and retrospective parasitological study was conducted.

3.3. Mosquito sampling and identification

Adult mosquitoes were collected from the two kebeles (four villages) using pyrethrum spray catches (PSCs) and Center for disease control and prevention (CDC) light trap catches (LTCs). Two villages were selected from each kebeles for mosquito sampling. From the two kebeles a total of 16 houses for CDC LTCs (eight from Koticha Gibe and Eight from Decha Nadi) and twenty houses for PSCs (ten from Koticha Gibe and ten form Decha Nadi Kebele) were randomly selected and mosquito collection was conducted monthly on each of the selected houses. LTCs were placed indoor near the bed at 1.5 meters above the ground whereas outdoor mosquito collection was set in the radius of 8 m surrounding the house selected for outdoor collection from 12:00PM in the evening to 12:00AM in the morning.

For PSCs each selected house was sprayed between 6:00-7:00AM hours following the standard procedure (WHO, 1975). After removal of all food items from each selected house, white cloth sheets were spread to cover the entire floor surface. Windows and doors were closed and other openings were covered to prevent the exit of mosquitoes. A commercially available insecticide (Byogon) containing pyrethroids (Tetramethrin 0.3%,Permethrin 0.25%,Perfurme 0.25%,Kerosine and propellant 99.2% ;manufactured by Changzhou Zhongtian Aerosol product co.ltd) was used. The room was kept closed for 15 minutes after the spray to ensure maximum knock-down of mosquitoes. All mosquitoes were collected from sheets with a hand-held battery-powered with forceps. Specimens were killed with chloroform and placed in paper cup. The collected mosquito specimens were morphologically identified at Asendabo Field Vector Biology Laboratory of Jimma University; following standard key (Gillies and Coetzee, 1987; Verrone, 1962). Gravid and half gravid mosquito were labeled according to site, species, date and sampling techniques and preserved individually in eppendorf tubes over silica gel.

3.4. Parity determination

The freshly killed mosquito with chloroform was placed on a microscope slide with a drop of Phosphate Buffered Saline (PBS) solution. On the sixth or seventh abdominal segment, the contents were pulled out gently. The ovaries were then were left to dry. The ovaries were then observed under the stereo dissecting microscope to determine parity based on ovarial tracheoles skeins. (Detinova, 1962). The parity rate (PR) reflects the proportion of parous from the total number of ovaries dissected (Warrell and Gilles, 2002).

3.5. Parasite prevalence survey

A record and chart review of malaria cases were conducted in Dimtu Health Center, Koticha Gibe and Decha Nedi health post of Tiro Afeta district from June to December 2013.

3.6. Meteorological data

Relative humidity (%), monthly rainfall (mm), maximum and minimum temperature (°C) of the study area were obtained from the south-western branch regional office of the Ethiopian Meteorological Agency from June-December 2013.

3.7. Data analysis

Data were entered and analyzed using SPSS version 16.0 statistical package. The abundances and percentage composition of anopheline mosquitoes were computed. Student t-test was used for mean density comparison of anopheline mosquitoes between kebele located near dam and far from the dam. Chi-square was used for comparison of malaria prevalence between Kebeles located near and away from the dam. An association between mean Anopheles mosquitoes density, monthly malaria prevalence and meteorological variables was assessed and further checked by Pearson's correlation at zero, one, two months and three months lag periods. P-value less than 0.05 were considered statistically significant during the analysis. Indoor Density (D) = (number of females ÷ number of houses) ÷ number of nights. P = duration of indoor resting after blood feeding. This parameter is obtained from the analysis of the abdominal condition of resting females. P = 1 + (number of half-gravid and gravid females ÷ number of freshly fed females).

The probability of surviving one day (denoted as *p*) can be estimated as: $p =^{gc}\sqrt{}$ Proportion parous and three day interval were assumed for *An.gambiae* s.l. gonotrophic cycle (gc). Life expectancy was estimated using the formula $L=1/-\text{Log}_e^{p}$

l= life expectancy p= probability of daily survival

3.8. Ethical consideration

Ethical approval for the study was obtained from Jimma University, College of Natural Science. Written informed consent was also sought from head of the selected house hold.

CHAPTER FOUR

4.RESULTS

4.1. Entomological survey

4.1.2. Composition and abundance of anopheline mosquitoes

A total of 1521 adult anopheline mosquitoes belonging two species were collected during longitudinal entomological survey. *An. gambiae* s.l. was the predominant species in the study setting which accounted for 72.9%, followed by *An. coustani* s.l. (27.1%). The majority (70.41%) of anopheline mosquitoes was collected from Koticha Gibe (Table 1).

Table 1: Species composition and abundance of anopheline mosquitoes in Tiro Afeta District, jimma zone Southwest Ethiopia.

Kebeles	**Anopheline species**	**Collection method**				Total
		LTC (Indoor)	LTC (Outdoor)	LTC (Total)	PSC	
Dacha Nadi	*An .coustani* s.l.	54 (38.8)	63 (45.3)	117	22 (15.8)	139 (100.0)
	An. gambiae s.l.	116(37.3)	36 (11.6)	152	159(51.1)	311(100.0)
Koticha Gibe	*An. coustani* s.l.	93(34.1)	118(43.2)	211	62(22.7)	273(100.0)
	An. gambiae s.l.	305(38.2)	152(19.0)	457	341(42.7)	798(100.0)
Overall	*An. coustani* s.l.	147 (35.7)	181 (43.9)	328	84 (20.4)	412 (100.0)
	An. gambiae s.l.	421 (38.0)	188 (17.0)	609	500 (45.0)	1109 (100.0)
	Total	568 (37.3)	369 (24.3)	937	584 (38.4)	1521(100.0)

Key: LTC = Light trap catches, PSC= Pyrethrum spray catches, Number in parenthesis indicate percentage.

4.1.2. Anopheline mosquito density

Mean monthly *An. gambiae* s.l. density was 8.5 and 2.70 per trap/night and 5.07and1.95 per/house/day in Koticha Gibe kebele and Decha Nedi kebele, respectively (Figure 4). In both kebeles statistically significant difference in mean *An. gambiae* s.l. per trap /night and per /trap /house was observed, (p = 0.04) and (p = 0.04) respectively.

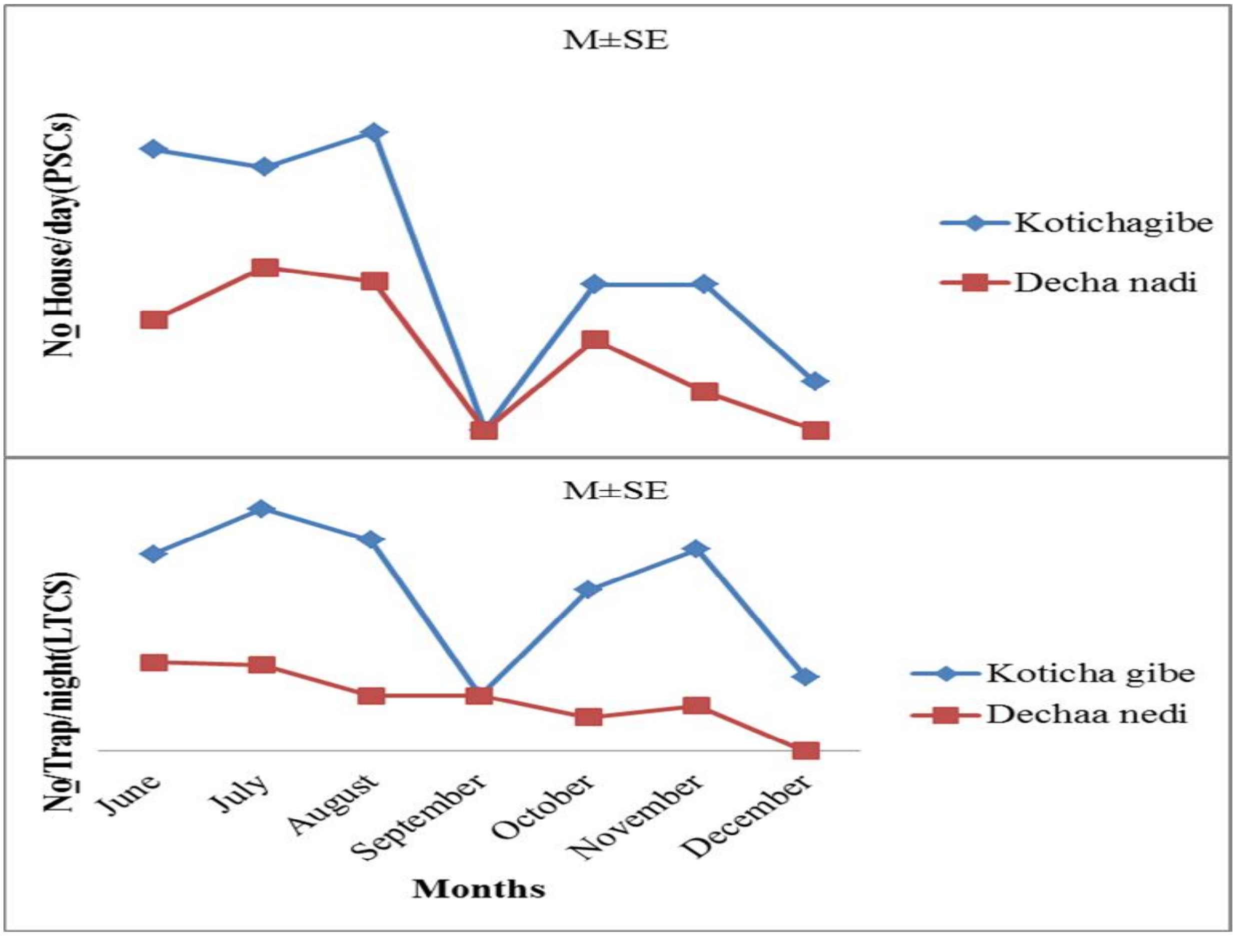


Figure 2: Mean *An. gambiae* s.l. density in villages near dam (Koticha Gibe) and away from dam (Decha Nedi), Tiro Afeta district, Jimma zone Southwest Ethiopia (June-December 2013).

Table 2 presents Indoor and Outdoor *An. gambiae* s.l. and *An. coustan* s.l. *density* In Dacha gibe and Koticha gibe Kebeles. The result shows that in both kebeles, indoor outdoor *An. gambiae* s.l. density shows significant difference ($P < 0.05$). On the other hand, *An. coustani* s.l. indoor outdoor density didn't show significant difference ($P > 0.05$).

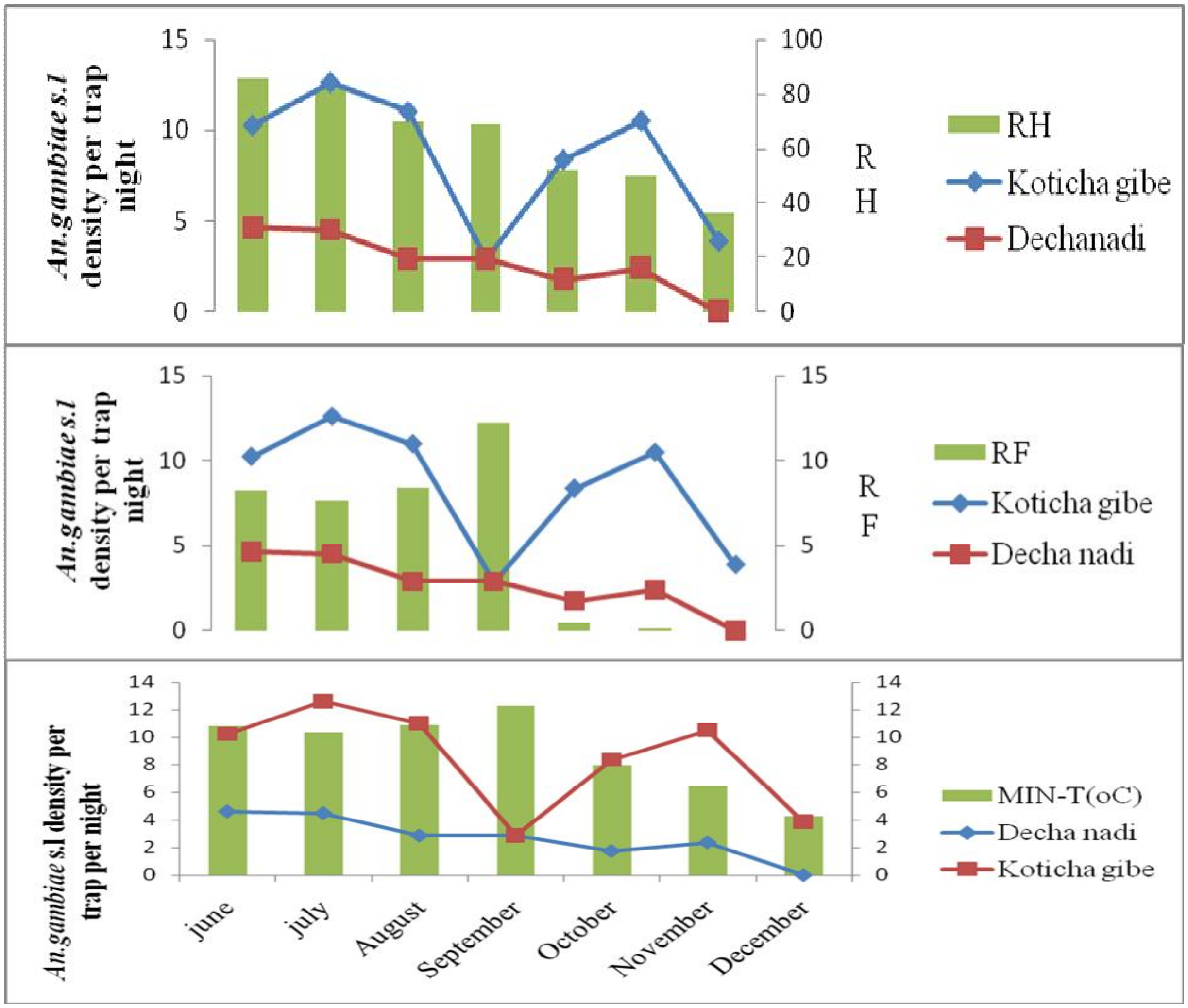
Moreover there was no significant difference ($p > 0.81$) in mean indoor density of *An. coustani* s.l. before (June-August 2013) and after (September-December 2013) after IRS operation and LLINs distributions while there was significant ($p < 0.038$) difference in mean indoor density of *An. gambiae* s.l. in both kebeles.

Table 2: Mean Indoor and outdoor Anopheline mosquitoes density per trap night in Tiro Afeta District, Jimma zone Southwest Ethiopia (June-December 2013).

Kebele	Speceis	Density	M±SE	p-value
Decha Nadi	*An. gambiae* s.l.	In	2.21±0.48	0.04*
		Out	0.50±0.44	
	An. coustani s.l.	In	0.96±0.38	0.49
		Out	0.98±0.26	
Koticha Gibe	*An. gambiae* s.l.	In	5.45±1.03	0.03*
		Out	2.70±0.46	
	An. coustani s.l.	In	1.66±0.29	0.79
		Out	2.11±0.29	

*Significant at $p < 0.05$

The mean monthly *An. gambiae* s.l. density per trap night and its association with metrological variables in the two kebeles is shown in figure 5. In both kebeles the mean monthly densities were highly correlated with *An. gambiae* s.l. density with two month lag of minimum temperature ($r = 0.74$, $p = 0.058$) and ($r = 0.92$, $p = 0.004$). And correlated with relative humidity RH($r = 0.034$, $p =0.94$ and($r =0.0026$, $p = 0.95$) and RF ($r = 0.39$, $p = 0.37$ and $r = 0.24$, $p = 0.61$) in koticha Gibe kebele and Decha Nadi respectively



Key:-RH=Relative Humidity, RF=Rain fall, Min-T=Minimum Temprature. RH in % RF in mm Min-T in ^{O}C.

Figure 3: Correlation of mean *An. gambiae* s.l. density with metrological variables in Tiro Afeta district, Jimma zone, Southwest Ethiopia (June-December 2013).

4.1.3. Duration of resting indoor after blood feeding

Over all 500 *An. gambiae* s.l were collected from the two kebeles nearby and far from the dam by PSCs for seven consecutive months (June-December 2013). Of these, 365 *An. gambiae* s.l. collected during pre IRS operations and LLINs distributions (June - August 2013), 241were fed mosquito specimens while 124 half gravid gravid to gravid. After IRS operation and LLINs distribution (September - December 2013) of the total 135 *An. gambiae* s.l. collected, 124 of them were fed and the rest 28 were half gravid gravid to gravid (Table 3). In Koticha Gibe duration of resting indoor after blood feeding decreases from 1.61to 1.28 during Pre and post IRS operation and LLINs distributions respectively. Also in Decha Nadi kebele duration of resting indoor after blood feeding decreases from 1.35 to 1.23 during Pre and post IRS operation and LLINs distributions respectively.

Table 3: Fed to gravid ratio and degree of exophily of *An. gambiae* s.l. pre and post IRS operations and LLINs distributions in Tiro Afeta district, Jimma zone Southwest Ethiopia.

Intervention (IRS & LLINs)	**Kebeles**	**F**	**HGG**	**F:G**	**P**
Pre	Decha nadi	90	32	2.80:1	1.35
	Koticha gibe	151	92	1.64:1	1.61
Post	Decha nadi	30	7	4.29:1	1.23
	Koticha gibe	77	21	3.66:1	1.28
Total		348	152	2.29:1	1.44

Key: F= fed, HGG=half-gravid to gravid, P = duration of indoor resting after blood feeding, IRS= Indoor Residual Spraying, LLITNs= long- lasting insecticidal nets.

4.1.4. Parity rate and longevity of *An. gambiae* s.l.

The parous rate of *An. gambiae* s.l. was higher (0.35) pre intervention than post intervention (0.21) (Table 4).Moreover, *An. gambiae* s.l. showed longer survival rate before control intervention as compared to post control intervention.

Table 4: Parity rate, daily survival and longevity of *An. gambiae* s.l. before and after control intervention in Tiro Afeta District, Southwest Ethiopia (June-December 2013).

Intervention (IRS & LLINs)	Number dissected	Nulliparous	Parous	Parity rate (%)	P(days)	LE(days)
Pre	98	20	34	55.1	0.75	2.80
Post	68	35	12	0.21	0.56	1.72

Key: P=Probability of Daily Survival, LE= Life Expectancy.

4.2.Malaria prevalence

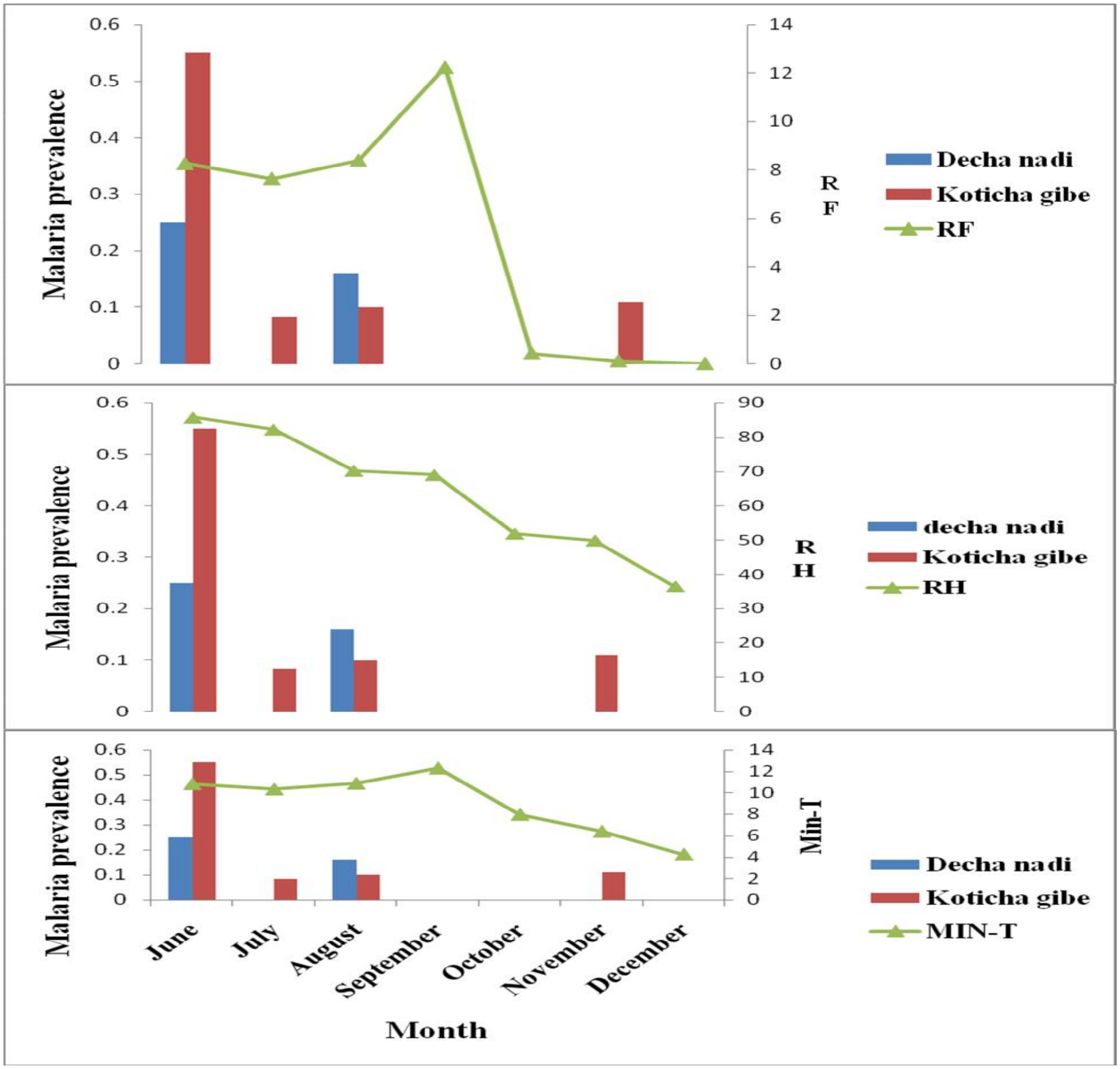
During the study period, 112 febrile patients visited the three health facilities from the two kebeles. Overall, 15 (10.71%) positive cases has been recorded. *P. falciparum* accounted for 73.3% of the positive cases and the remaining 26.7% cases was due to *P. vivax.* More than half (53.3%) of the positives cases were recorded from Koticha Gibe kebele. There was no significance difference in malaria prevalence between the two kebeles (x^2 = 9.386, P = 0.052). (Table 5).

Table 5: Malaria prevalence in Tiro Afeta district ,Jimma zone southwest Ethiopia.

Kebeles	Number of cases	Species		Total	X^2	P-value
		Pf	Pv			
Dacha Nadi	43(87.8)	5(8.2)	2(4.1)	50(100.0)	9.386	0.05
Koticha Gibe	54(87.1)	6(9.7)	2(3.2)	62(100.0)		
Total	97(86.6)	11(9.8)	4(3.6)	112(100.0)		

Key: Pf: *Plasmodium falcifurum*, Pv: *Plasmodium vivax,* Number in parenthesis indicate percentage.

In Koticha Gibe monthly malaria prevalence was positively correlated with zero month lag of relative humidity, rain fall and minimum temperature and statistically there was no significant correlation with RH (r=0.62, P=0.13), Min-T (r=0.30, P=0.51) and RF (r=0.26, P=0.56). Similar trend was observed in Decha Nadi kebele. Malaria prevalence was positively correlated with zero month lag of relative humidity, rain fall and minimum temperature and there was no a significant correlation between malaria prevalence and RH (r=0.6, P=0.15), between malaria prevalence and Min-T (r=0.43, P=0.43) and malaria prevalence and RF (r=0.40, P=0.38) .and there was weak correlation between malaria prevalence and meteorological variables at one month, two month and three month lag time in both kebeles.(Figure 6).



Key:RH;Relative Humidity, RF;Rain fall ,Min-T;Minimum Temprature.

NB: RH in % RF in mm Min-T in ^{O}C

Figure 4: Correlation between malaria prevalence and metrological variables in Tiro Afeta district South west Ethiopia (June-December 2013).

CHAPTER FIVE

5.1. DISCUSSION

Malaria is a serious threat to human life in sub-Saharan Africa, claiming many lives and causing the greatest morbidity as compared to other infectious diseases (Obion *et al*., 2014).Ethiopia is one of the sub-Saharan countries which are suffering from this threat. Malaria control program in Ethiopia has a history of more than 40 years. There were a lot of obstacles which could hamper the successful malaria control program in Africa particularly in Ethiopia. Of these problems, occurrence of malaria parasite resistance to drugs (Ketema *et al*., 2009) insecticide resistance species of major malaria vectors (Asale *et al*., 2014; Yewhalaw *et al*., 2011 and 2010), climate change (Avanade *et al*.,2008; Hay *et al*.,2005) and man-made ecological transformation such as construction of dams for controlling flood, producing electricity and irrigated farm land (Guerra *et al.*, 2008;WHO,2005).The development, management and operation of water resources have a history of modifying the frequency and transmission dynamics of malaria in Ethiopia (Kibret *et al*., 2009; Yewhalaw *et al*., 2009; Lautze *et al*., 2007;Ghebreyesus *et al*., 1999) and malaria vector density most importantly *An. gambiae* (Afrane *et al*., 2006;Tuno *et al*., 2005).

The species compositions of Anopheline mosquitoes in the two kebeles (four villages) showed that *An. gambiae* s.l. and *An. coustani s.l* were found in sympathry. *An. gambiae* s.l. was predominant malaria vectors in the study sites which is similar with other parts of Ethiopia (Coetzee., *et al* 2000). Likewise, this study also found *An.coustani* s.l. where some of its sibling which was believed to be less anthropophilic with no epidemiological importance in malaria transmission (Adugna *et al*., 1998; Tekie, 1989) was abundant next to *An. gambiea* s.l. in the study sites.

Significant differences in mean monthly *An. gambiae* s.l. density between the two kebeles were observed. In our surveys, higher density of *An. gambiae* s.l. were collected from kebele which was found near to the dam than kebele which was found far from the dam during the period of long rainy seasons and after long rainy seasons. Thus, the presence of dam together with seasons may have contributed to the presence of higher adult mosquito density in the kebele near to the dam. This finding corroborate with Yewhalaw *et al*. (2013), higher densities of the major local malaria vector, *An. arabiensis*, which were recorded during the wet season in villages nearer to the dam reservoir.

An. gambiae s.l. showed significant difference in indoor and outdoor density, this suggested that this species are endophagic (i.e., indoor feeding) during the night. While, there was no significant difference in indoor and outdoor density of *An. coustani* s.l. Gillies and Coetzee (1987) and White, (1974) reported that *An. gambiae* and *An. funestus*, primarily feed and rest indoors where they can be efficiently targeted with domestic insecticides. The other study which complemented this observation was that *An. gambiae* s.l. showed endophagic behavior in Gambella region, Ethiopia (Krasfur, 1977). In contrast to this, other studies reported that *An. gambiae* s.l. had predominantly exophagic behavior than endophagic behavior in centeral Ethiopia (Woyesa *et al*., 2004; Ameneshewa and Service, 1995). In this study there was no significant difference in mean indoor and outdoor *An. coustani* s.l. density. Other studies also - indicated that *An. coustani* s.l. is well known exophagic species in Ethiopia (Abose *et al*., 1998) and in Kenya (Mwangangi *et al*., 2013). Moreover there was no significant difference in mean indoor density of *An. coustani* s.l. before (June-August 2013) and after (September-December 2013) after IRS operation and LLINs distributions while there was significant difference in mean indoor density of *An. gambiae* s.l. in both kebeles. This finding was in line with (Woyesa *et al*., 2004; Ameneshewa and Service, 1995).

The finding of the study further showed that the density of *An. gambiae* s.l. was more affected by metrological variables as mean monthly density of *An. gambiae* s.l. was influenced by Rain fall, Relative humidity and Temperatures. Other previous studies had also indicated the effect of metrological variables on mosquito density (Yewhalaw *et al.,* 2013; Minakawa *et al*., 2005; Woyesa *et al*., 2004). Mean monthly *An. gambiae* s.l. density and monthly malaria prevalence was positively correlated with two month lag and zero month lag respectively. This finding suggested that malaria prevalence in June 2013 was transmitted by presence of *An. gambiae* s.l. in previous two months (Yewhalaw *et al*., 2013). Previous studies had indicated the biology of the Anopheles mosquitoes and of the Plasmodium parasite, the effect of metrological variables on malaria transmission is expected to be lagged in time. Other Previous empirical studies suggested that the effect of rainfall on malaria transmission is lagged by approximately 8 weeks (Krefis., 2013; Deresa *et al*., 2003; Tull, 1993).

Lower vector density was observed in the middle of IRS intervention and LLINs distributions (September-2013).The results indicated that IRS interventions and LLINs distributions had an effect on the vector population which decreased vector population, density and longevity. This finding is consistent with (Obion *et al*., 2014; Patrica *et al*., 2014). Anopheles mosquito density began to buildup after IRS and LLINs distributions. This may be due the insecticide resistance (Asale *et al*., 2014; Yewhalaw *et al*., 2011) insecticide decay rate or operational problems.

After IRS intervention and LLINs distributions decrease in duration of resting indoor after blood feeding was observed in both kebeles. This could be explained by behavioural resistance or a strong decrease in the proportion of gravid and half gravid mosquitoes (Annex 2). This finding was consistent with Padonou *et al*. (2012) and Mutuku *et al*. (2011) strong decrease in proportion of gravid and half gravid mosquito was observed after IRS and LLINs operation.

Before IRS operations and LLINs distributions June-August 2013 the observed parity rates were high. This indicates that older populations of mosquitoes tend to accumulate with time (Service, 1976).This could be due to availability of potential breeding sites. This allows for increased feeding frequencies and thus, increased chances of the vectors becoming infected or even re-infected during subsequent feeding (Olayemi and Ande, 2008; WHO, 1975). Decrease in parity rate after interventions was due to wide spread distribution of LLINs and IRS in the locality. The current vector control strategies of indoor residual spraying with insecticides and long lasting insecticide treated nets primarily affect the daily probability of mosquito survivorship and/or reduce vector-host contact (Enayit *et al.*, 2010; Curtis *et al.,* 2003).

Of the five plasmodium species known in the world (WHO, 2011) three of malaria parasites occur in Ethiopia. Similar to other studies conducted in Ethiopia (Karunamoorthi and Bekele .2012; Abeku *et al*., 2003; Gebre-Mariam.1987; Krasfur, 1977) *P. falcifurum* and *p. vivax* were found in study area. Of these two species, *P. falcifurum* was predominant.

The prevalence rate of malaria observed in this study was 10.71%, which is consistent with the prevalence rate of 10.5% from similar studies around Gilgel Gibe area (Yewhalaw *et al.,* 2009).

The study documented that there was no significant difference in malaria prevalence between the two kebeles. This may be due to the current intervention programs that have been taking place in the locality. It was also found that dam areas displayed a lower malaria transmission compared with distant settings when integrated vector management or other control interventions have been applied. In Uttaranchal, India, a study, which compared the parasitological indices in a dam area to forest or plain areas, recorded a prevalence and annual parasite incidence of zero in the dam area. Better economic status, insecticide spraying and more awareness towards health maintenance were described to be the main factors accounting for the lack of malaria transmission at the dam site (Shukla *et al.*, 2001). In addition, in Thailand no increase of malaria incidence was observed near the Nong Wai dam and Ubol Ratana dam, probably because of indoor resildual spraying of all houses with DDT, compared to the Srinagarind dam, where an increase in malaria prevalence was reported and for which we are not aware of any vector control measures (Bunnag *et al.*, 1979; Harinasuta *et al.*, 1970) and koka dam(Kibret *et al.*, 2009;Lautze *et al.*, 2007;), small dams constructed for irrigation(Ghebreyesus., 1999) and Gilgel-Gibe hydro-electric dam(Yewhalaw *et al.*,2009) indicated that dams are associated with an increased malaria risk where malaria control program were not under taken.

Generally it has been reported elsewhere that the decline in malaria prevalence over all in Ethiopia (PMI,2014;Ketema and Bacha, 2013) and particularly in the study area has been attributed to a combination of factors including improved access to effective malaria treatment with artemisinin combination therapy, protection from mosquito bites and affecting the daily probability of mosquito survivorship by increased availability of LLINs and IRS which prevent the completion of parasite development into the infectious sporozoite stage (Mboera *et al.*, 2013; Enayit *et al.*, 2010;Curtis., *et al* 2003) and heavy rain fall in September which wash larva breeding site which is similar with the finding of other similar studies (Himeidan *et al.*, 2007;McMichael and Martens, 1995).

CHAPTER SIX

6. CONCLUSION AND RECOMMENDATION

6.1. Conclusion

- In this study, dam was found to be an important factor in variation in the density of Anopheles mosquitoes. The presence of Gilgel-Gibe Hydro-Electric Dam was the main reason for the creation of potential breeding habitats in kebele near to the dam.
- *An. gambiae* s.l. was predominant malaria vectors in the study sites which is similar with other parts of Ethiopia.
- In both kebeles *An. gambiae* s.l. showed significant difference in indoor and outdoor density. While, there was no significant difference in indoor and outdoor density of *An. coustani* s.l.
- There was no significant difference in mean indoor density of *An. coustani* s.l. before (June-August 2013) and after (September-December 2013) after IRS operation and LLINs distributions while there was significant difference in mean indoor density of *An. gambiae* s.l. in both kebeles.
- After IRS intervention and LLINs distributions decrease in duration of resting indoor after blood feeding, malaria prevalence and longevity was observed in both kebeles.
- Correlation between *An. gambiae* s.l. with two month lag shows that malaria prevalence in June 2013 was transmitted by presence of *An. gambiae* s.l. in previous two months.
- Of the five plasmodium species known in the world *P. falcifurum* and *p. vivax* were found in study area. Of these two species, *P. falcifurum* was predominant.
- No significant difference in malaria prevalence in kebele near and far from the dam.

6.2. Recommendation

- In the study area Anopheles mosquitoes was high in the kebele near to the dam. Therefore, in addition to the current vector control IRS intervention and LLINs distributions environmental management should be taken place.
- The highest composition, abundance and density of major malaria vector were observed in July. So the national IRS intervention of the study area should be in the early of July or late of June.
- Even though malaria control measure such as IRS operation and LLINs distributions are employed, the finding of the study indicated that population of mosquites begun to build up after IRS intervention and *An. gambiae* s.l. showed significant difference in indoor and outdoor density. And also there was no significant difference in indoor and outdoor density of *An. coustani* s.l. There for insecticides resistance species of anopheles mosquito, insecticide decay rate or operational problems will be monitored.
- Most of the study done on impact of damming indicated that dams are associated with an increased malaria risk where malaria control program were not under taken, however the current finding state that dams have no effect on malaria transmission when malaria control program were taken place. Therefore to reach in final conclusion further study will be needed.
- Correlation of *An. gambiae* s.l. with two month lag of metrological variables shows positive correlation. This finding suggested that malaria prevalence in June 2013 was transmitted by presence of *An. gambiae* s.l. in previous two months. Therefore drug resistance species of malaria parasite management strategy plan should be developed and implemented

CHAPTER SEVEN

7. Limitation of the study

Although this is a carefully designed study, there are still several limitations that may affect the quality of this study. Collection of outdoor resting density of Anopheles mosquitoes was not included; the impact of the dam on malaria vector longevity was not computed with kebeles near and far from the dam, because of low number of unfed mosquitoes in kebele far from the dam was collected and those collected mosquitoes were dry.

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ANNEXES

Annex I: Metrological data from Jimma substation for Sokoru and Asendabo District, Jimma zone south west Ethiopia.

Month	**MAX-T**	**MIN-T**	**RH**	**RF**
March	31	16.2	50.73	3.35
April	28.2	15.7	45.86	3.93
May	26.2	15.2	66.3	6.64
June	25.99	10.82	85.7	8.27
July	22.39	10.33	82.23	7.65
August	24.68	10.87	70.2	8.4
September	25.64	12.29	65.98	12.25
October	28.08	7.96	51.85	0.43
November	28.38	6.39	49.85	0.12
December	28.78	4.25	36.39	0

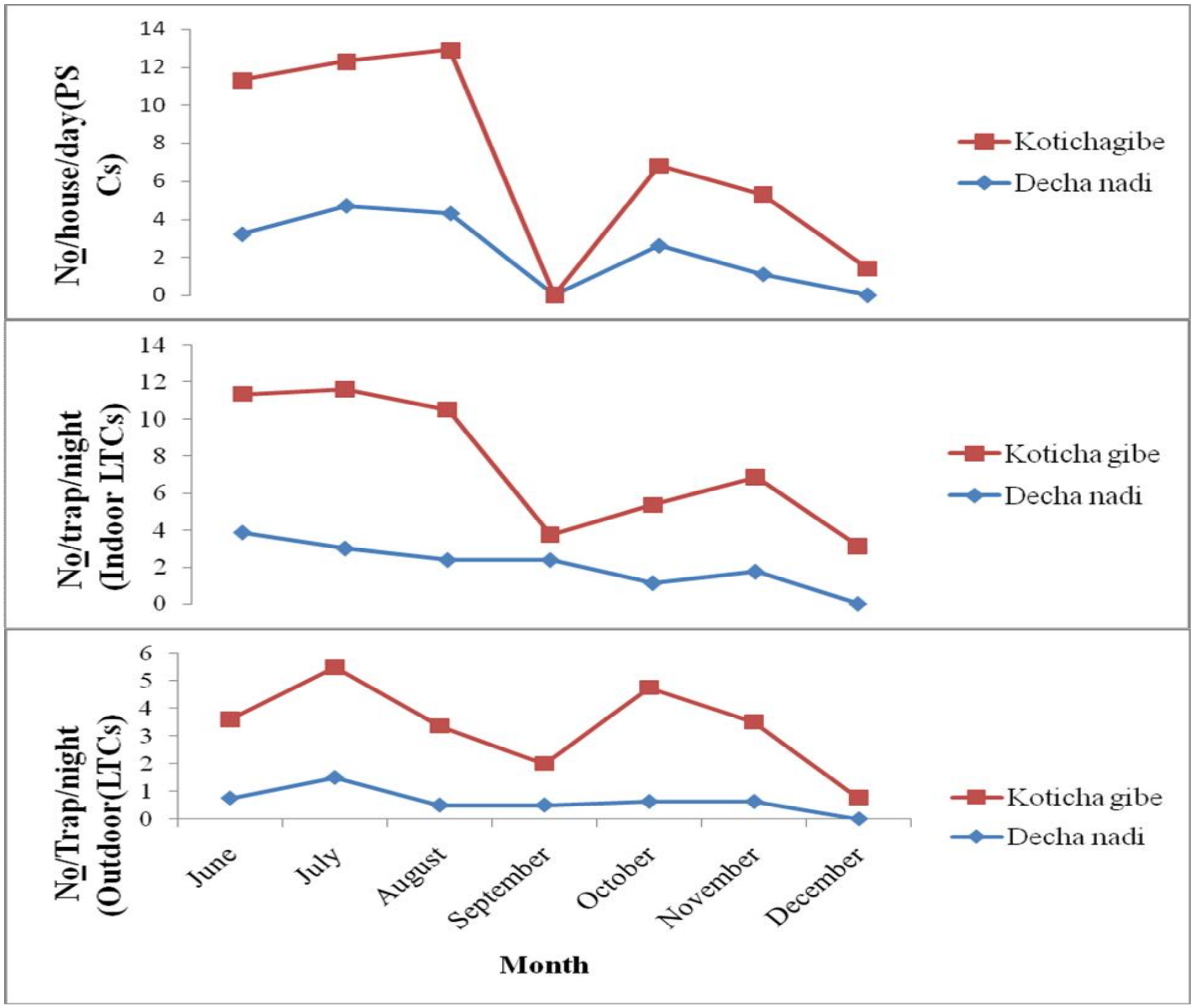
RF=Rain fall, Temp Min= Minimum Temperature Temp Max=Maximum Temperature, RH=Relative Humidity.

Annex II: Abdominal status of anopheline mosquitoes

Blood feeding status	Before IRS and LLINs Interventions	After IRS and LLINs Interventions	Total
F	241	107	348
HG	107	28	135
G	17	0	17
Total	365	135	500

F=Fed, HG=half gravid G=gravid

Annex III: Density of *An. gambiae s.l* in villages near dam (Koticha Gibe) and away from dam (Decha Nedi), Tiro Afeta Southwest Ethiopia (June-December 2013)



Annex IV: Mean monthly *An. gambiae s.l* and *An. coustani s.l* density per trap night and per house per day in in Tiro Afeta district jimma zone southwest Ethiopia (June-December 2013).

Collection methods	Species	Kebeles	ME±SE	Df	F	P	Total ME±SE
CDC	*An. gambiae s.l*	Decha nadi	2.71±0.60	12	4.9	0.046	5.6±1.01
		Koticha gibe	8.5±1.41				
	An.coustani s.l	Decha nadi	0.31±0.09	12	9.74	0.035	0.6±0.16
		Koticha gibe	0.89±0.23				
PSC	*An. gambiae s.l*	Decha nadi	1.95±0.58	12	4.99	0.045	3.51±2.97
		Koticha gibe	5.07±1.26				
	An. coustan s.l	Decha nadi	0.31±0.08	12	9.74	0.009	0.60±0.14
		Koticha gibe	0.88±0.22				

Annex 5: monthly malaria febrile cases and infections in Tiro Afeta district Jimma zone Southwest Ethiopia (June-December 2013).

	Decha nadi			**Koticha gibe**		
Month	**Cases**	**pf**	**pv**	**Cases**	**Pf**	**Pv**
June	16	2	2	9	3	2
July	6	0	0	12	1	0
August	12	2	0	10	1	0
September	4	0	0	4	0	0
October	0	0	0	0	0	0
November	3	0	0	9	1	0
December	1	0	0	10	0	0