ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

The Elucidation of Malaria Transmission and its Prevalence in Highland Urban Area, Akaki Town, Addis Ababa, Ethiopia.

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A Thesis submitted to the School of Graduate Studies in partial fulfillment of the requirement for the degree of Master of Science in Biology (Parasitology)

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DEDICATION

This work is dedicated to my late mother

A/e Ayantu Nagari.

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ABSTRACT

To elucidate malaria transmission and determine its prevalence in a highland-fringe urban area, Akaki, parasitological and entomological investigations were conducted between October 1999 and October 2000. Review of malaria cases was using records of the Addis Ababa and Akaki health institutions for the years between 1993 and 2000. Parasitological survey was conducted, during a peak malaria transmission season, October through December 1999. A total of 712 persons (264 males and 448 females) were examined for three consecutive months (Oct.-Dec. 1999). Using different mosquito sampling methods a monthly collection of larvae and adult mosquitoes was conducted for 1 year from October 1999 to October 2000.

The review of 6 Zonal Health Department records in Addis Ababa indicated that malaria is one of the major causes of outpatient consultation. A significant increase in malaria prevalence was noted after 1996 reaching a peak in 1998. The records do not show the geographical origin of the cases but most of them are believed to be internally imported. This however, can not rule out the possibility of its importation from the peripheral Towns like Akaki, with active malaria transmission considered. The occurrence of malaria outbreak during 1997/98 with its peak in October through November in Akaki and their sharing *Plasmodium vivax* as the dominant species both in Addis Ababa and Akaki suggest the likely hood.

A total of 2136 blood films were examined, 78 (3.7 %) persons were malaria positive of which 54 (69%) were due to *Plasmodium vivax* and only 24 (31%) due to *P. falciparum*. Parasitological surveys done in this study in Akaki Town shows 30 (4.2%) were malaria positive with predominance of *P. falciparum* (70%); in the second survey, 48(6.7%) were positive with a predominance of *P. vivax* (93.7%); no case was detected in the last survey. Although prevalence increased with age, the detection of cases in children below the age of 5 years suggested autochthonous malaria transmission in Akaki area.

Two *Anopheles* species were encountered in the larval collection. *Anopheles christyi* (91.7%), *An. gambiae* s. l., (presumably *An. arabiensis*, 6.7%) and *An. cinereus* (1.6%). In the adult collection, four species of were recorded: *An. arabiensis*, *An. christyi*, *An. pharoensis* and *An. coustani*. *Anopheles arabiensis* and *An. christyi* were the dominant man-biting species in the area. They were both more exophagic and active in the early evening unlike *An. pharoensis* that showed an endophagic tendency.

The dissection of 49 *An. christyi,* 43 *An. arabiensis, 2 An. pharoensis* and a single specimen of *An. coustani* turned negative for sporozoites. *Anopheles arabiensis* might be the major vector in the area. However, further and detailed investigations are required to ascertain the relative importance of *An. arabiensis* and the other man-biting species (particularly *An. christyi)* in the transmission of malaria in Akaki and surrounding areas to design appropriate control strategy. The findings are discussed.

1. INTRODUCTION

Malaria remains the most important parasitic disease of humans in the world. At present it is known to be endemic in over 100 countries and territories worldwide. World Health Organization estimates that in 1998 up to 500 million clinical malaria cases occurred with nearly 3 million people dying of the disease (WHO, 2000a). Almost 90% of these deaths occurred in Africa, South of the Sahara.

The disease can be stable or unstable in its form. In the former, community developed immunity to the disease in which epidemic is absent. Nevertheless, in the latter the communal immunity lacks and recurrent epidemics are very common.

Ethiopia because of its heterogeneous physio-geographic features and climatic variability suffers mostly of the latter form. The country has experienced severe epidemics in highland-fringe areas that caused innumerable deaths. Similar situations are believed to occur in urban highland that suffered from malaria. In view of the absence of information regarding highland malaria in urban Ethiopian, this study was conducted in Akaki Town southeast of Addis Ababa.

2. LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND

From the time immemorial malaria has plagued mankind. The disease also remained to be one of the prevalent infectious diseases of public health importance, especially in Africa, south of the Sahara than in anywhere else in the world.

The pathogens causing malaria are, parasites belonging to, family Plasmodiidae within the order Coccidiida, sub-order Haemosporidiidea, and genus *Plasmodium* which comprises various parasites found in the blood of reptiles, birds and mammals. Human malaria is caused by four species of *Plasmodium*, viz. *P. falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*, which are transmitted by the bite of several species of the *Anopheles* mosquito.

Clinical manifestations of malaria and some complications of the disease were discovered by Hippocrateus, an earliest Greek physician. He was able to associate the appearance of the disease to the seasons of the year and the places where the patients lived. The knowledge on malaria transmission by *Anopheles* mosquito, however, took long time to be verified. The development of malaria parasites in the human body and in the body of the mosquito were demonstrated by Laveran in 1880, and Ross in 1897, respectively (cited in Bruce-Chwatt's, 1993). This was a turning point in the advancement of malaria epidemiology. It laid a corner stone to begin a systematic malaria control (WHO, 1998).

2.2 GLOBAL MALARIA SITUATION

Malaria is severe infectious disease. It ranks second to tuberculosis. It is currently on the rise in many areas of the tropics (WHO, 1996 cited in Gubler, 2000). The World

Health Organization (2000a) estimates that 300 to 500 million clinical cases of malaria occur annually, resulting in up to 2.7 million deaths. It is endemic in more than 100 countries or territories inhabited by about 41% of the world population (WHO, 1996 cited in Gubler, 2000). Today malaria is one of the two top killer diseases in sub-Saharan Africa. Approximately 80% of malaria cases and 90% to 95% of malaria related deaths in the world are estimated to occur in Africa (AAAS, 1991). In recent years, the continent has experienced a dramatic resurgence of this disease and almost the entire population of more than 550 million is now at risk, with up to 500 million clinical cases of malaria recorded every year (Samba, 2000). It causes more than one million deaths each year, most of them among children under five years of age. In fact, one out of every 20 children born in the region die of malaria-related illnesses before the age of five. About 74% of the people of the region live in malaria endemic areas where there are periodic outbreaks of epidemics of the disease (Samba, 2000).

The risk of getting malaria attack and its severity has recently increased with the improved transportation facility of modern world that escalated population mobility from non-malarious areas to malarious and the vice-versa. For instance, during the 1970s and 1980s the resurgence of an imported malaria in some of the developed countries, such as the U. S. A., Europe and the U. K. was reported (Bruce-Chwatt's, 1993).

Moreover, the occurrence and widespread of resistant malaria parasites to anti-malarial drugs and the vectors to insecticides has resulted in flare-ups of malaria and complication of its control. Chloroquine-resistant falciparum malaria first occurred in South American and in Indo-Chinan sub-continent from 1959 to 1960. Since then it has conquered most of the endemic areas (Wernsdorfer, 1994). Increment in the number of *Anopheles* species resistant to insecticides is equally on the increasing momentum. For instance, in 1946, only two species of *Anopheles* were resistant to DDT, but from two subsequent reports by 1991 and 1992 a total of 55 resistant *Anopheles* species have been recorded. Of these 21 were very important vectors of malaria. Nearly all members of *An. gambiae* complex, that are the potent vectors of malaria in tropical Africa, have shown various degrees of resistance to DDT as well as to other organo-chlorine insecticides (Bruce-Chwatt's, 1993).

The disease is not only a health problem but also an important impediment to economic development in most developing countries. It imposes very significant economic costs on some of the poorest nations. According to health economists, in 1997 alone, the African region lost more than $2 billion because of malaria and malaria-related diseases (Samba, 2000). The economic cost as determined from direct costs of care and control and indirect costs due to losses in productivity and lost future earnings from death of malaria in South Africa is conservatively estimated to be 20 million USD in 1997/98 (Tren, 2000). In selected Southern African countries it could cost as much as 1,000 million USD or 4% of GDP in 1998. The incidence of malaria in these areas has severe economic impacts and as in the past, continues to hamper economic development. Researchers have estimated that families with malaria clear only 40% as much land for crops and they yield 30% below normal and a single bout malaria estimated to cost the equivalent of more than ten working days in Africa (Liese, 1998).

Therefore, malaria remained to be WHO's top priority and a new initiative, i. e., Roll Back Malaria (RBM) begun in 1998 to reduce the global burden of disease associated with malaria (WHO, 1999; WHO, 2000a). RBM represents a global partnership that will address malaria as a priority health issue at country and local levels within the wider context of sustainable health sector development.

2.3 EPIDEMIOLOGY OF MALARIA

2.3.1 DISTRIBUTION

Indigenous malaria has been documented as far north as 64°N latitude and as for South as 32°S latitude. It has occurred in the Dead Sea area at 400m below sea level and at Londiani (Kenya) at 2600 meters above sea level or at 2800m. a. s. l. in Cochabamba (Bolivia) (Bruce-Chawatt's, 1993). Within these limits of latitude and altitude there are large areas free of malaria, which is essentially a focal disease, since the transmission of malaria depends greatly on local environmental and other conditions. Malaria has a major place among the endemic tropical diseases occurring in epidemic form. The repeated epidemics of different extent in modern times, were reviewed elsewhere (Najera *et al*, 1998; Bruce-Chwatt's, 1993).

2.3.2 THE PARASITES

Of all the four human plasmodia, *Plasmodium falciparum*, *P. vivax*, *P. ovale*, and *P. malariae*; *P. vivax* has the widest geographical range; it is prevalent in many temperate zones, but also in the subtropics and tropics. *Plasmodium falciparum* is the commonest species throughout the tropics and subtropics as well as in some areas with a temperate climate. *Plasmodium malariae* is patchily present over the same range as *P. falciparum* but much less common. *Plasmodium ovale* is found mainly in tropical Africa, but also occasionally in the West Pacific.

Plasmodium vivax and *P. ovale* are reported to remain in the liver and enter dormant stage, as long as 20 years (Martin and Lefebvre, 1995). But, *P. falciparum* and *P. malariae* do not persist in the liver, however in untreated or inadequately treated infections, erythrocytic parasites may persist from a month (*P. falciparum*) to years (*P. malariae*) and produce recrudescence clinical disease.

2.3.3 THE VECTORS

Out of the total 380, different *Anopheles* species between 50 to 60 have been reported to transmit the human malaria (Martin and Lefebvre, 1995). The most intensive risk of infection was documented in both East and West Africa, with an infective mosquito bite ranging between 200-300 annually (Molyneaux and Gramacia, 1980; Beier, *et al.*, 1998). Anopheline vectors transmitting human malaria are divided into main and secondary vectors based on their role of transmissions. In tropical Africa region the main vectors are the *An. gambiae* complex and the composite *An. funestus* having a wide distribution and *An. nili* and *An. moucheti* with a distribution limited to more restricted localities (Janssens and Wery, 1987). The secondary vectors include *An. pharoensis*, *An. ziemanni*, *An. rufipes* and others.

Anopheles gambiae complex, which has the six sibling species (*An. gambiae* s. s., *An. arabiensis*, *An. quadriannulatus, An. merus, An. melas,* and *An. bwambae*) is uniquely effective and efficient vector of human malaria in the region, and often considered the most important in the world. The distribution map of *An. gambiae* complex in Africa is recently reviewed. In large areas of Africa, *An. gambiae* s. s. and *An. arabiensis* occur in sympatry. The distribution of *An. arabiensis* is concentrated in the lower rainfall zones, which represent the drier Savannah areas. In collection sites where annual rainfall was <1000mm *An. arabiensis* was recorded more often than *An. gambiae* s. s., whereas the reverse was true where rainfall was >1000mm (Coetzee *et al.*, 2000).

Anopheles arabiensis is predominant in dry areas and the savanna belt, but it is also present in some degraded forest areas of central and West Africa. It is more abundant in the drier inland areas of East Africa and during the dry season. *Anopheles arabiensis* is dominant in the Sudan savanna and further north to the Egyptian border (Zahar, 1974; Janssens and Wery, 1978). It also exhibits some degree of zoophily and exophily, at least in the southern humid areas, and hence is a less efficient vector than *An. gambiae* s. s., but for the same reasons residual spraying will also be less efficient.

Anopheles quadriannulatus is markedly expohilic, except endophilic tendency reported in stables and dwellings in Ethiopia (White *et al.*, 1980). In general, this species is zoophagic and has negligible malaria vectorial capacity under natural conditions, although experimental infections with *P. falciparum* demonstrated its susceptibility (Takken *et al*, 1999). The sixth member of *An. gambiae* complex is *An. bwambae*, with a very localized and minor malaria vector in Uganda. It breeds in geothermal waters (Bruce-Chwatt's, 1993). *Anopheles melas* lives along the West (Atlantic) coast of Africa, but spreads up to 100km inland. *Anopheles merus* is the East Coast or Indian Ocean counterpart, and also penetrates inland as far as 220km (Janssens and Wery, 1987). Both species also have a local importance in malaria transmission.

Anopheles funestus which is not a member of *An. gambiae* s. l. is also capable of producing very high inoculation rates in a wide range of geographic, seasonal, and ecological conditions in Africa (Coluzzi, 1984). It has a somewhat more restricted distribution than *An. gambiae* s. l. and is probably a composite species (Janssens and Wery, 1987). In Ethiopia four members of the *An. funestus* groups, which comprises seven species that are not morphologically distinctive in the larval or adult stages, occur. While all four can be specifically identified in the larval stage, it is very difficult to differentiate them in the adult stage. They are *An. funestus*, *An. confusus*, *An. leesoni*, and *An. rivulorum* (Mekuria, 1983). It is present neither in arid zones nor in dense forest, but is found in a degraded forest and savanna, and on mountain slopes. Although being anthropophilic and endophilic, this potentially good vector usually has a low sporozoite index. *Anopheles pharoensis* is also widely distributed in Africa, and can maintain active transmission of malaria even in the absence of the main malaria vectors (Janssens and Wery, 1987).

Anopheles pharoensis has a very wide distribution and occupies a broad variety of ecological zones except primary forest in Africa. It is a vector and can maintain active transmission of malaria in areas where the main vectors are absent. According to a study conducted in Aswan Governerate, Egypt, has indicated that *An. pharoensis* shows the highest potential for serving as malaria vector (Kenawy *et al.*, 1987). It constitutes 2.5% and 4.9% of indoor and outdoor collections, and a human blood index of 0.63 for indoor and 0.50 for outdoor collected specimens.

Anopheles nili and *An. moucheti* are both associated with running rivers, their larval stages finding a suitable environment along the riverbanks. *Anopheles nili* lives in the west and central African equatorial area, mainly in forest but occasionally in Sahel Savanna, and is more abundant during the rainy season. It needs fast running water, and there are anthropophilic and zoophilic forms. *Anopheles moucheti* occurs in the Central African equatorial forest and the neighboring area, in more slowly running water with dense vegetation on River banks (Bruce-Chwatt's, 1993).

2.4 HIGHLAND MALARIA

Highland malaria is an epidemic or unstable malaria that is occurring above 1600m a. s. l. (Rees, 1994). In African Region, areas of unstable malaria are usually in the semi-arid zones, areas of high altitude, particularly in East and Southern Africa and some islands like, Mauritius, Reunion and Cape Verde. The main characteristic of this epidemiological prototype is the monthly and yearly fluctuation in the incidence of the disease. This fluctuation can also be observed from place to place with high variations in localities of the same zone. Seasonal transmission can lead to high prevalence rates and high epidemic potentials due to none or a little collective immunity. For instance, the high altitude epidemics ('highland malaria') in Kenya occur in areas with altitude that range from 1,700 to 2,500m a. s. l., these are found in the highlands east and west of the Great Rift Valley (Some, 1994).

The upper height limit for malaria transmission in the African highlands is highly variable. For instance, in Burundi, Ethiopia, Kenya, Morocco and Rwanda that the boundary was thought to occur around 2000m a. s. l., while it is slightly lower in Zaire and Zimbabwe at around 1700–1800m a. s. l and 1200m a. s. l., respectively, (Lindsay and Martens, 1998).

It is believed that altitude is one of the oldest defenses against malaria. For several centuries, hills and mountains have therefore been recognized as a natural shelter against diseases of the lowlands as well as heat. European settlers and other expatriates have recognized the comfort attained at higher altitudes in various parts of the tropics (Lindsay and Martens, 1998). Indeed, as altitude increases temperature declines so does the risk of infection, and there is a typical threshold below which transmission ceases.

Previous studies show that in the pioneering highland settlements the activities of the growing human and animal populations created many new opportunities for *An. gambiae* s. l. to breed. This species typically breeds in small sunlit puddles, such as those formed by feet, hoofs, and wheels (Gillies and De Meillon, 1968), all of which flourished around the expanding communities. Making bricks for new homes and collecting material for road construction produced numerous borrow pits filled rapidly with water, creating yet more breeding sites to mosquito. Most of these pits were close to human habitation, increasing the ease with which female mosquitoes could locate a human blood meal and transmit parasite. Furthermore, *An. gambiae* s. l. probably colonized the highlands through a process of passive dispersal, being transported there by car, truck, train, or ox wagon (Lindsay and Martens, 1998). Evidently, vehicles travelling to the hills were sprayed with insecticide to prevent importation of anophelines into malaria-free areas. This can be best exemplified by the changed pattern of malaria endemicity and transmission at Amani in the eastern Usambara Mountains, north-eastern Tanzania, in which various factors including climatological changes and increased agricultural activities are attributable to the changes (Matola *et al.*, 1987).

The rapid change the world is underlying as human-environment relations evolve, global interdependency increases, and previously stable equilibrium is disrupted (Meyer, 2000) causing malaria to rise. Mainly the warm up of the globe in the last century is believed to be a contributor for malaria spread (Lindsay and Birley, 1996; McMichael *et al.*, 1996; Martin and Lefebvre, 1995). A potential consequence of human-induced climate change, and its positive effect on the distribution and incidence of malaria was assessed by modeling techniques of Martens *et al.* (1995). Subsequently, they were able to forecast a global mean temperature increment of several degrees in the next century (in the year 2100), and subsequently that could increase the epidemic potential of the mosquito population in tropical regions in two folds and more than 100 folds in temperate climate. Such an increase is most pronounced at the borders of malaria endemic areas and higher altitudes within malarial places (Martens *et al.*, 1995) causing epidemic malaria owing to lack of or a little communal immunity.

In general, any change in temperature, rainfall, relative humidity or in the structure and habits of populations can lead to an important change in the incidence and prevalence of the disease. Since the inhabitants of these areas have limited immunity to *Plasmodium* species owing to infrequent exposure, epidemics or outbreaks are very common. The recent epidemics of malaria in highland areas of Madagascar, Kenya, Burundi, and Uganda at different altitudes of 1200m, 1780m, 1450m and 1800m, respectively, (Lindblade *et al.*, 1999) is worth mentioning. In the past Gernham (1945) also recorded seasonal outbreaks of malaria in parts of Kenya at about 1900m.

One further factor to consider is that the altitudinal limit of transmission in an area may be due to a lack of breeding sites, rather than unfavorable climatic conditions, as appeared to be the case in the highlands of Kigezi, Uganda (Zulueta, 1964).

Temperature variations have even greater effect on both vector density and the infectivity of the species of the *Plasmodium* underlying its development in the female anophelines. It affects the survival of the parasite only during its life cycle in the *Anopheles* vector. All species have the shortest development cycle around 27-31°C to a maximum of 15–21 days for *P. malariae* (Dutta & Dutt, 1987), the lower the temperature, the longer the cycle (Bruce-Chwatt's, 1993). The maximum duration roughly doubles around 19-20°C for *P. falciparum*, and 15-16° C for the rest three species.

In addition, temperature also modifies the vectorial capacity of the *Anopheles*. The female mosquito has to live long enough for the malaria parasite to complete its development if transmission is to occur. Usually, vectors prevailing in areas of unstable malaria, i. e., in highland and desert fringe areas are short-lived but their longevity could increase according to climatic changes. At higher altitudes, low temperature slows down or inhibits sporogonic development (WHO, 1991a). Optimal values of temperature, ranging between 22 and 30°C, lengthen the life span of the mosquitoes and increase the frequency of blood meals taken by the females, up to one meal every 48 hours (Dutta & Dutt, 1987). Therefore, temperature in excess of this range increases mosquito mortality, and there is a threshold temperature above which rapid death is inevitable. There is also a minimum temperature (assessed to be 9°C) below which the mosquito cannot become active. Besides this, higher temperatures also shorten the aquatic life cycle of the mosquitoes from 20 to 7 days (Kondrashin, 1992 cited in Martin and Lefebvre, 1995), and reduce the time between successive ovipositions (Lindsay and Birley, 1996).

Consequently, increase in temperature results in rise of malaria cases. There are evidences that show a relationship between a progressive rise in annual temperatures with increasing malaria, for instance, in the Usambara Mountains in the United Republic of Tanzania (Matola *et al.*, 1987). In addition, a study in Rwanda indicated that recent increase in temperature and rainfall were associated with a steep rise in malaria (Loevinsohn, 1994). This rise being more pronounced among people with little immunity living at higher altitudes compared with those at lower altitudes where immunity to malaria was greater. Surprisingly, this study confirmed that the difference in altitude between the high and low villages was only 0.6°C between the two sites (Linacre, 1992 cited in Lindsay and Martens, 1998). Such a small difference might suggest that in this case factors other than temperature were favoring transmission.

Recently, outbreaks of malaria were implicated to a global warming. The year 1998 was the warmest year of the century (WMO, 1999). Malaria may also have been moving to higher altitudes in the Eastern Africa highlands in association with local warming. There are evidences showing that higher malaria epidemics covering highland areas of African countries such as Ethiopia (unpublished report of MOH, 1999), Kenya (Brown *et al*, 1998), and Uganda (Lindblade *et al.*, 1999) in the same year.

Integrated mathematical models have been developed to forecast future changes in malaria risk in relation to climate change scenarios from global climate models. Indeed, climate-related increases in malaria incidence are most likely to occur primarily in regions next to endemic areas, where disease transmission is currently limited by temperature (Martens *et al.*, 1995; Lindsay and Birley, 1996; Lindsay and Martens, 1998). The African highlands are fragile ecosystem under great pressure from rising populations, deforestation, and increased farming. Therefore, endemic malaria is becoming a growing problem in the African highlands.

Rainfall is also another prevailing climatic factor that limits malaria distribution in highland areas. In the African highlands it varies greatly from year to year that provides new opportunistic breeding places in concert with temperature and relative humidity. Consequently, repeated epidemics were recorded in highland areas due to climatic changes that favors the development of parasite in the mosquito vector that were once precluded due to low temperature (Martens *et al.*, 1995). Rainfall above normal in Eastern and Southern Africa has been linked with malaria epidemics (Connor *et al.*, 1999). For example, the catastrophic malaria epidemic in Ethiopia in 1958 was associated with unusually high rainfall over an extended period as well as with elevated temperatures and relative humidity (Fountaine *et al.*, 1961). In Sudan periods of abnormally high rainfall and their effects on discharge levels along the Nile have long been linked to reports of periodic malaria epidemics (Najera *et al.*, 1998). In addition, the 1940 outbreak in Nairobi, Kenya resulted from heavy rains, which followed two years of low rainfall (Roberts, 1949 cited in Lindblade *et al*, 1999). Similarly, Lindblade *et al.* (1999) indicated that heavier than normal rainfall associated with El Nino initiated malaria epidemic in the southwestern highlands of Kabale District of Uganda. The epidemic began in February 1998 and peaked in March with a malaria incidence almost three times greater than the mean of previous five years. In East African, El Nino, the warming phase of the Southern Oscillation, typically produces heavier than normal rainfall and higher temperatures from December to March (Ropelewski and Harpert, 1987). Through retrospective analyses, El Nino events have recently been associated with malaria epidemics in the Indian subcontinent and Latin America (Bouma *et al.*, 1997; Lindblade *et al.*, 1999). On the other hand, Lindblade *et al.*(1999) cited the work of Ropelewski and Halpert (1987) in which they have discussed the role of El Nino-Southern Oscillation (ENSO) in causing the variation in annual rainfall in Africa, subsequently causing malaria epidemics. ENSO is a meteorological phenomenon that occurs every 2–10 years and tends to exaggerate the extremes of climate in specific regions of the world (WMO, 1999). Studies conducted by Bouma *et al.* (1997) have also clearly shown associations between El Nino (and its opposite La Nina) and malaria epidemics in Asia and Latin America, provided that the events follow periods of drought.

Similarly, the same phenomenon was observed in Punjab and Central-South Sri Lanka (Najera *et al.*, 1998).

Nevertheless, rainfall can also destroy existing breeding places; heavy rains can change breeding pools into streams; impede the development of mosquito eggs or larvae, or simply flush the eggs or larvae out of the pools. Conversely, exceptional drought conditions can turn streams into pools. The appearance of such opportunistic breeding sites sometimes precede epidemics (Bruce-Chwatt's, 1993).

The interaction between rainfall, evaporation, runoff, and temperature modulates the ambient air humidity, which in turn affects the survival and activity of *Anopheles* mosquitoes. The ideal climate for malaria transmission is a relative humidity of at least 60 per cent and a mean temperature range between 20-30°C (Bruce-Chwatt's, 1993). Thomson *et al.* (1996) revealed its effect on mosquito longevity in epidemic forecasting in Africa by citing early studies and indirect estimations using vegetation index.

Within the limits set by climate, other factors are also responsible for the distribution of disease and its level of transmission. Among the main factors are the local biogeography, the vector behavior and distribution, and the distribution and activities of humans. Human-induced (anthropogenic) climate change may directly affect the behavior and geographical distribution of the malaria mosquitoes and the life cycle of the parasite, and thus change the incidence of the disease (Martens *et al.*, 1995). Therefore, agricultural development projects have seriously affected transmission through deforestation, desalinization and irrigation that has altered the environment drastically. Furthermore, development projects and agriculture have created ecological changes increasing mosquito contact with humans, many of whom lack prior immunity. For instance, a resurgence of malaria transmission has been observed to be associated with the introduction of a large-scale agricultural projects in an area in which malaria had been controlled (Packard, 1986). Large-scale irrigation schemes for cultivating crops can also sharply increase malaria transmission. The building of dams in the Usain Gishu highlands, for example, in Burundi and Rwanda, particularly rice fields (in Madagascar) created a profusion of breeding sites for malaria vectors (Lindsay and Martens, 1998). Ghebreyesus *et al.* (1999) also identified proximity to a micro-dam is one of the risk factors for increased malaria incidence in highlands of Tigray, northern Ethiopia.

A study also indicated that human mobility into certain areas increases the risk of infection for adults provided that mobility coincides with peak rainfall and vector densities (Sevilla–Casas, 1993). In addition, population migration of the non–immune to agro-industrial areas of Balcad, south Somalia, which is malaria endemic has resulted in increased malaria incidence with high frequency of severe cases (Warsame, 1991). As the human highland populations grew, there was an inevitable increase in human-vector contact and a consequent increase in malaria transmission. Thus, it become harder to find productive land as the Usambara Mountains in United Republic of Tanzania, people living in the highlands, often staying overnight in their lowland fields where transmission is high, and returning to their highland homes harboring an infection. Indeed, studies carried out in Rwanda (Gascon *et al.*, 1988; and Burundi van der Stuyft, *et al.*, 1993 cited in Lindsay and Martens, 1998) confirmed that adult males were at greatest risk from malaria because they traveled most often to endemic areas. On the other hand, epidemics in the highlands may have been precipitated by immune populations harboring gametocytes from earlier outbreaks or by travelers from endemic areas (Rees, 1994).

Moreover, deterioration of basic health services and vector control activities aggravate intensity of malaria transmission. Many of the highland areas in Africa have experienced a decline in basic health services as a result of war, civil conflicts, and declining resources as well as aggravated by growing resistance to antimalarials, most commonly to chloroquine (Lindsay and Martens, 1998). This is studied among a tea estate population of Kenyan highlands. The coincident arrival of chloroquine resistance is a key factor in the current pattern and burden of malaria among this highland population. In the 1950s vector control programs in Madagascar led to the eradication of *An. funestus* in the central highland Plateau and almost total eradication of malaria (WHO, 1991a; Lepers *et al.*, 1988 cited in Lepers *et al.*, 1991). Later on, as a result of the collapse of the spraying program a progressive increase in malaria took place (Fontenille *et al.*, 1990). Indoor spraying campaigns with DDT were effective at reducing both morbidity and mortality in Ethiopia (Fontaine *et al.*, 1961). But over the last two decades there has been an increase in cases partly because of a breakdown in the health service as a result of civil war and forced movement or resettlement of people. Similarly, Towns in the highlands of Zambia, where malaria was once rare now experience a substantial number of cases as a result of the cessation of vector control activities (Fisher, 1985).

Concerning its distribution, about 18% of the people in Africa live in areas prone to epidemic, where malaria transmission is unstable and seasonal (WHO, 1993). It includes down the East African highland chains, from Ethiopia in the north to South Africa in the south, including highlands of Ethiopia (Lindsay and Martens, 1998). In Kenya (Khaemba *et al.*, 1994; Some, 1994), Rwanda (Loevinsohn, 1994), United Republic of Tanzania (Matola *et al.*, 1987), Zimbabwe (Freeman and Bradley, 1996), and Madagascar (Lepers *et al.*, 1991) have indicated the occurrence of highland malaria at higher altitudes.

Obviously Ethiopia is one of the Eastern African countries experiencing highland malaria known with frequent epidemics. About 50% of all the land above 2000m altitude in Africa is comprised in Ethiopia (Yalden, 1983). Consequently, the country experienced frequent epidemics of a cyclical pattern occurring every 5-8 years (Abose *et al.*, 1998b), that overlaps with famine and drought prevailing in the country (Tesfaye *et al.*, 1998b). It is more compounded with high population pressure in the highland areas as a result of stronghold of malaria in the lowlands from the past (Pankhurst, 1990).

Moreover, the change of eco-epidemiological characteristics of an area due to unplanned urbanization results in appearance of an efficient malaria vector in Africa, *An. gambiae* s. l., and attraction of people for its economic importance. This trend has been observed in major cities, which in recent years have lost their malaria–free status, as well as in areas of higher altitudes (AAAs, 1991), for instance, in Madagascar and Kenya, among others. Malaria is becoming an important public health problem in many cities of Africa, for example, in Dar-es-Salaam (Stephens *et al.*, 1995), and Kinshasa (Coene, 1993). Urban residents, being less exposed, tend to be less immune than their rural counterparts.

2.5 EPIDEMIOLOGY OF MALARIA IN ETHIOPIA

2.5.1 DISTRIBUTION

Geographically Ethiopia is located between arid south Asia and humid central Africa. It is particularly situated in the tropical zone, physiogeographically constituting a mass of central highlands girdled by low-lying, hot and generally arid regions (Wolde-Mariam, 1972). Thus, the physiogeographic diversity of the country is pertinent to a wide variation for climatic conditions, i. e., tropical climate prevailing in deep valley and the lowlands and the temperate climate in highlands. Therefore, the country experiences three locally known climatic zones, i. e., cold, temperate and warm climatic zones with elevations >2500m, 1500m to 2500m, and <1500m, respectively, (Tulu, 1993).

In spite of limited documentation, malaria is believed to be a disease of antiquity in Ethiopia. The bibliographies of malaria in Ethiopia until late 1980 were compiled by Kitaw *et al.* (1989). In addition, Chand (1965) documented the problem impacted by the disease on health and socio-economic situation of the country before decades. Moreover, Tulu (1993) suggested that the overcrowded population settlement to highland areas of the country for centuries be partly considered to be due to malaria endemicity in the fertile lowlands. European travelers early in the 19th century attested the presence of malaria in the lowlands of the country, i. e., Lake Tana, Awash Valley, Lake Ziway, and Gambella (Pankhurst, 1990).

Altitude and topographical and climatic factors determine the distribution of malaria in Ethiopia. Thus, the malaria situation in the country is characteristically unstable in higher altitudes (WHO, 1991a), particularly above 1800m (Gebre-Mariam, 1984). In these areas the disease is occurring immediately after the light rainy season of March and April as well as after the long rains of June through September. In contrast, in lowland areas with convenient breeding sites, transmission is usually perennial with a slight seasonal variation in magnitude. This is common in areas such as Gambella, Metekel, Metema, and Setit-Humera districts (Tulu, 1993).

Normally, the upper limit for malaria transmission was considered as 2000m. a. s. l., but periodic epidemics were recorded above this level (Covell, 1957; Fontaine *et al.*, 1961, Chand, 1965; Gebre-Mariam, 1984). Based on this observations Malaria Control Program (1983 cited in Gebre-Mariam, 1984) estimated that about 75% of the landmass either malarious or potentially malarious and about 64% of the population are at a risk of infection.

As far as unstable malaria is predominantly occurring in the country, periodic malaria epidemic is inevitable. Consequently, moderate to severe malaria epidemics was known to occur in the country (Fontaine *et al.*, 1961; Gebre-Mariam, 1988). Moreover, the epidemic in nature of malaria in Ethiopia can be substantiated by its repeated events with similar feature but of lesser intensity in 1965, 1973 and 1981-82 (Gebre-Mariam, 1988). Recently, frequent malaria epidemics of cyclical patterns of variable magnitude were recorded. For example, the epidemics of the years 1988, 1991, 1995 and 1997/98 in different parts of the country were cited elsewhere (unpublished report of MOH, 1999).

In addition to annual changes in climate, the ecological upheavals in the late 1980s and early 1990s has an immense role in changing the epidemiology of malaria in the country. For instance the Pawie settlement scheme and development activities in the area of the township of Arba Minch is worth mentioning. The introduction of more than half a million non-immune highlanders, into the malaria-endemic lowlands has elevated malaria prevalence of the country from the year 1984 to 1989 (Nega and Haile-Meskel, 1991).

2.5.2 THE VECTORS

The mosquito fauna of Ethiopia have studies from the time of the Italian occupation, in late 1930s followed by British investigators after 2nd World War between the mid-1940s to 1950s. The works of Giaquinto-Mira (1950), Verrone (1962a, b), O'Connor (1967), and Gillies and De Meillon (1968) were the cornerstones for the knowledge of Anopheline identification and distribution in the country. A total of 42

Anopheles species have so far been recorded. It has already been mentioned that two members of the *An. gambiae* complex, *An. arabiensis* and *An. quadriannulatus* are so far known to occur in Ethiopia (White *et al.*, 1980). A recent study has shown that the latter species in Ethiopia is probably a new species provisionally designated as *An. quadriannulatus* species B; *An. quadriannulatus* species A occurs in south Africa (Hunt *et al.* 1998), thus making a total of 7 sibling species of the *An. gambiae* complex. Although the Anopheline fauna of Ethiopia is highly diversified, the most important vector of malaria is *An. arabiensis* (White *et al.*, 1980; Abose *et al.*, 1998a; Abose *et al.*, 1998b). *Anopheles arabiensis* breeds in small, temporary, sunlit water collections created during the rains.

Anopheles funestus was regarded as the most important secondary vector of malaria after *An. gambiae* s. l. (*An. arabiensis*) (Mekuria, 1983). But results of country wide collections during the period 1984-88 have shown that *An. pharoenis* is the next abundant (6 fold) but is considered to play a secondary role in Ethiopia (Tulu, 1993).

Both *An. funestus* and *An. pharoensis* prefer large, permanent, and shaded water bodies with emergent vegetation, irrigation canals and lakeshores. *Anopheles nili* is the least common species, and it is more localized, to southwestern, western and northwestern parts of the country. Krafsur (1970) identified this species as the important vector of malaria in Gambella.

The resistance of malaria vectors to DDT in many countries is becoming impediment to malaria control activities in many countries (Roberts and Andre, 1994). For instance, the expanding problem of resistance of the *An. gambiae* complex to organo-chlorine insecticides, especially DDT in many countries of the African Region was indicated in WHO document (WHO, 1980 cited in Bruce-Chawatt's, 1993). In the African Region the three main vectors, *An. arabiensis, An. gambiae s. s and An. funestus* have developed widespread resistance to dieldrin and HCH, while the *An. gambiae* complex has developed more focal resistance to DDT (WHO, 1992). DDT resistance of *An. arabiensis* of different magnitude was reported in the country (Abose *et al.*, 1998b; Ameneshewa and Service, 1996, Meshesha Balkaw, Pers. Comm.). High and epidemiologically significant DDT resistance of major vector, *An. arabiensis,* has been documented in the Gambella and the Arba Minch areas.

This review has indicated the existence of heterogeneous level of resistance of *An. arabiensis* to DDT (5 to 33%), i.e., considered as moderately low (Ameneshewa and Service, 1996; Abose *et al.*, 1998b).

2.5.2.1 SPOROZOITE RATE

Generally, various workers based on salivary gland dissections and ELISA have detected low sporozoite rates. Rishikesh (1966) noted a sporozoite rate of 0.2% for *An. gambiae* s. l. (presumably *An. arabiensis*) 9 out of the 4513 mosquitoes dissected in Ziway area. Another test in Kobo-Chercher region of Wello province reported 3 salivary gland infections from 100 *An. gambiae* dissected. During April and May 1956 in the same area, 50 *An. gambiae* were found to be negative for both sporozoites and oocysts. The WHO Pre-eradication Project Team in the lake region of Shoa and Sidamo Provinces south of Addis Ababa performed dissections of 7740 specimens during 1964 and 1965. In this, a sporozoite rate of 0.2%, 9 positives out of 4594, was detected for *An. gambiae* (cited in O'Connor 1967). In Gambella area an average sporozoite rate of 1.87%, 156 positives out of 8348 was recorded for *Anopheles gambiae* (Krafsur, 1971). In this study a relatively high sporozoite rates recorded among *Anopheles gambiae* in October (4.97%, 19 positives out of 1346), and in November (5.43%, 34 positives out of 1297). Nigatu *et al.*, (1992) detected 0.76%, 2 positives out of 262, for *P. falciparum* of *An. gambiae* s. l. using ELISA method in Gambella area during 1989 to 1990. Similar sporozoite rates of 0.76% (*P. falciparum*), 2 positives out of 264, for *An. gambiae* s. l. was detected using ELISA method in this area (Nigatu *et al.*, 1994).

Moreover, Ameneshewa (1995) reported an infection rate of 1.52% out of total 3626 dissected *An. arabiensis* specimens from Middle Awash (Gergedi) using the ELISA method. However the dissection of 638 specimens of the same species revealed a lower infection rate of 0.63%.

Recent sporozoite detection of *An. arabiensis* in Ziway area, Eddo Kontola, gave negative results in both salivary gland dissection and ELISA method (Abose *et al.*, 1998b). A total of 334 *An. arabiensis* were tested for the presence of *P. falciparum* and *P. vivax* sporozoite antigens in the head-thorax region by the ELISA method. Similarly, a total of 274 *An. arabiensis* were dissected and their salivary glands examined. But all of them were resulted to negative.

O'Connor (1967) reviewed that dissections of salivary glands of 2694 *An pharoensis* no infection in lake region of Shoa and Sidamo during 1964 and 1965 by WHO Pre-eradication Project. Nigatu *et al.* (1992) detected 0.46%, 2 positives out of 436, for *P. vivax* of *An. pharoensis* using ELISA method in Gambella area during 1989 to 1990. After few years another study using the same method for this species revealed an infection rate of 0.47% (*P. vivax*), 2 positives out of 428, (Nigatu *et al.*, 1994). Abose *et al.* (1998b) tested 272 *An. pharoensis* for the presence of *P. falciparum* and *P. vivax* sporozoite antigens in the head-thorax region by the ELISA method, and 624 *An. pharoensis* on dissection of their salivary glands in Zway area. None of these were found to be positive.

Anopheles funestus is generally considered to be the secondary vector. O'Connor (1967) cited the reports of USAID team, 1955-1965, in which they have dissected 70 *An. funestus* and found 1 positive to sporozoite (1.4%) in March 1959 at Gambella. But the dissection results of 357 *An. funestus* in Lake Region of Shoa and Sidamo gave negative result.

Anopheles nili detected for a sporozoite rate in Gambella area during 1967-68 by dissecting 619 specimens and 8 positives (1.3%) were found (Krafsur, 1971).

The reasons for such low rates considered as due to relatively low malaria endemicity prevailing in Ethiopia compared to highly endemic regions of tropical Africa, and the possibility that vectorially non-vector species are included in the dissections.

2.5.2.2 RESTING AND FEEDING HABIT

It was shown in west Africa that resting and feeding behavior, which has a bearing on the response of *An. gambiae* s. l. to control, is related to inversion polymorphism in both *An. gambiae* s. s and *An. arabiensis* (Coluzzi *et al.*, 1977; Coluzzi, 1984).

The partially exophilic behavior of *An. arabiensis* in the African continent has been reviewed by White (1974). Insecticides house spraying appears to affect the resting behavior of mosquitoes. For example, in Sudan exophily in *An. arabiensis* was increased by the irritant effect caused by DDT spraying (Zahar, 1985). High proportion of exophily (37.5%) was observed in *An. arabiensis*, in Gergedi (Middle Awash) and a tendency to avoid DDT-sprayed surfaces (Ameneshewa and Service, 1996). Rishikesh (1966) and Krafsur (1971) in the Rift Valley and Gambella, respectively, have reported the exophily exhibited by this species.

From country wide studies conducted by malaria control sectors during the 1984-1988, *An. funestus* was considered as the third most common vector of malaria in Ethiopia comprising 3.2% (19,352). It primarily feeds outdoors (76.2%) and also rests outdoors (63.5%) (Tulu, 1993). *Anopheles pharoensis*, which has a wide distribution and regarded as a secondary vector in Ethiopia, feeds predominantly outdoors (65.1%) but rests indoors (88.5) (O' Connor, 1967; Krafsur, 1971). *Anopheles nili* observed in Gambella is detected to feed on man indoors but rests outdoors postprandially (Krafsur, 1970; 1971).

2.5.3 THE PARASITES

Of the four *Plasmodium* species known to cause human malaria in Ethiopia, *P. falciparum* and *P. vivax* respectively constitute 60% and around 40%. *Plasmodium malariae* comprises less than 1% and is mainly reported from the Arba Minch area but more recently it is also reported from Nazareth, Central Ethiopia (monthly report of Malaria Control Unit, East Shoa, 1999). *Plasmodium ovale* is identified from a few patients who live or lived in Humera, Gambella, Gamu-Gofa or Tepi (Gebre-Mariam, 1984). The presence of *P. ovale* at this parts of Ethiopia was believed to lie in the *P. ovale* belt of Africa (cited in Gebre-Mariam, 1988).

Plasmodium falciparum causes the most frequent and fatal cases of malaria in Ethiopia; a case fatality rate of about 10% in hospitalized adults and up to 33% in children less than 12 years old. It is the leading cause, (70%), of malaria illnesses and death, especially in its epidemic form. *Plasmodium vivax* is also widely distributed in Ethiopia and often precedes the transmission of *P. falciparum*. *Plasmodium vivax* is more common during the dry season, and whether this is due to active transmission or relapses has not been clearly determined. Nilotic Ethiopians have been found to be more resistant to *P. vivax* than Semitic and Cushitic speaking populations (Armstrong, 1978 cited in Gebre-Mariam, 1988) possibly due to the absence of Duffy antigen in Nilotic speakers.

Resettlement activities and agricultural expansion programs undertaken in lowland areas from the end of 1970s to mid-1980s have played a crucial role in changing the pattern of malaria transmission in the country. For example, Nigatu *et al.* (1992) indicated the predominance of *P. falciparum* and *P. vivax* in Gambella in relation to the previous work of Armstrong (1978), in which the distribution of *P. falciparum*, *P. malariae*, *P. ovale* and *P. vivax* were 69%, 16.6%, 1% and 0.6% among the native Anuaks. This study suggested that the rehabilitation and resettlement programs and agricultural activities undertaken in the area might have brought changes to the socio-economic situation and environmental factors. Tulu (1993) also explained the occurrence of explosive epidemics due to disruption of the long-established equilibrium in the man-vector-parasite relationship. That is, introductions of non-immune highlanders to previously known malarious areas of moderate to highly endemic during 1984-85 by the settlement program.

2.5.4 MALARIA CONTROL PROGRAM

Ethiopia initiated to launch National Malaria Eradication Service in 1967 (Gish, 1992). Malaria Eradication Service (MES) was the first scientifically supported international campaign pledged against malaria in the 1950s under WHO, UNICEF/USAID sponsorship (Chand, 1965). The long time economic interest in the fertile lowland areas and the devastating malaria epidemic of 1958 (Gebre-Mariam, 1984), as well as persuasion with successes of eradication campaigns in other parts of the world are some of the reasons that initiated the country to launch eradication service (Gish, 1992). Moreover, the epidemiological observations of Italian malariologists in the late 1930s, Giaquinto-Mira (1950), and Covell (1957) laid a background to launch this program. The strategy of MES was to break the chain of transmission by spraying pesticides (DDT) that kills the mosquito vectors. It was conducted in areas of elevations below 2000 meters with the DDT spray in human dwellings and chemotherapy to malaria cases and their families throughout the country. Unfortunately the effort to achieve malaria eradication in the country was not successful partly due to some technical and financial constraints in countries and institutions that were supporting the eradication effort (MOH, 2000).

Following the resolution of 22nd World Health Assembly in 1969, the Malaria Eradication Program was replaced with Malaria Control Program in 1971(Gish, 1992). The Control Strategy was operating in Vertical Program to prevent and control malaria until integrated with general health services in 1993 with the concept of Primary Health Care. The main approach of Control Program is delivering early diagnosis and prompt treatment, and selective and effective vector control as well as epidemic prevention and control. DDT spray remained to be the major tool in malaria control during and post eradication and up to the present. Although, some degree of DDT resistance has been detected in Gambella by Nigatu *et al.* (1994), in the Awash Valley by Ameneshewa and Service (1996), and in Ziway areas by Abose *et al.* (1998b) the resistance level is not considered sufficiently high to abandon DDT. However in some areas where resistance to DDT is considered epidemiologically significant Malathion spray is used as an alternative.

Other vector control measures such as source reduction, chemical larviciding and very recently insecticide treated nets (ITNs) are also used in selected areas. Use of ITNs was introduced as one of the important malaria control measures in 1997/98 to some Regions on cost recovery basis (MOH, 2000).

2.5.5 MALARIA IN URBAN AREAS

Tulu (1993) indicated the presence of 33 urban centers with a total population of about 1 million in malaria endemic areas. The presence of huge populations in confined areas and migration from highly endemic areas are believed to be the favorable factors for the transmission in these areas.

The occurrence of locally contracted malaria cases at Addis Ababa that lies at an altitude of 2500m, was recorded during early 1940s (Martin, 1943; Ovazza and Neri, 1955) and mid-1950s (Giaquinto-Mira, 1950). Ovazza and Neri (1955) also document the breeding of An. gambiae during the cessation of the rainy season, from mid-September to early November, in the bed of the Kabana River.

In addition, Ovazza and Neri (1955) confirmed the occurrence of numerous malaria cases in Akaki, and the villages around the artificial lakes and the vicinity. They have also identified female *An. gambiae* near the Railway Station in the lower part of the City near Filwuha at 2470m. It was suggested then that this vector species may extend its upward range and reach suitable breeding places in the warm springs of the Filwuha quarter of Addis Ababa from Akaki Valley as a potential site to support the vector species, *An. gambiae* (Giaquinto-Mira, 1950). In spite of repeated epidemics no information has been generated on the occurrence of *An. gambiae* s. l. in Addis Ababa. With this background and occurrence of malaria epidemic in Akaki Town and its surroundings in 1997/98 a study was required to explain the epidemiology of highland malaria in urban situation of Akaki.

3. OBJECTIVES OF THE STUDY

Based on data obtained from different health services and the epidemic report of 1997/98 in Akaki Town and surrounding areas, a study was conducted to document the presence, magnitude and transmission of the disease. The study comprised parasitological and entomological surveys with the following objectives.

3.1 GENERAL OBJECTIVES

The general objective of this study was to elucidate the prevalence of malaria and its transmission in Akaki Town and surrounding area.

3.2 SPECIFIC OBJECTIVES

a) To review and document the malaria situation in Addis Ababa City Administration and surrounding areas

b) To determine the prevalence of malaria in Akaki Town

c) To determine the *Anopheles* species, their breeding sites, resting habits, feeding preferences, biting behavior

d) To determine the sporozoite rate and the anopheline species responsible for malaria transmission in Akaki Town.

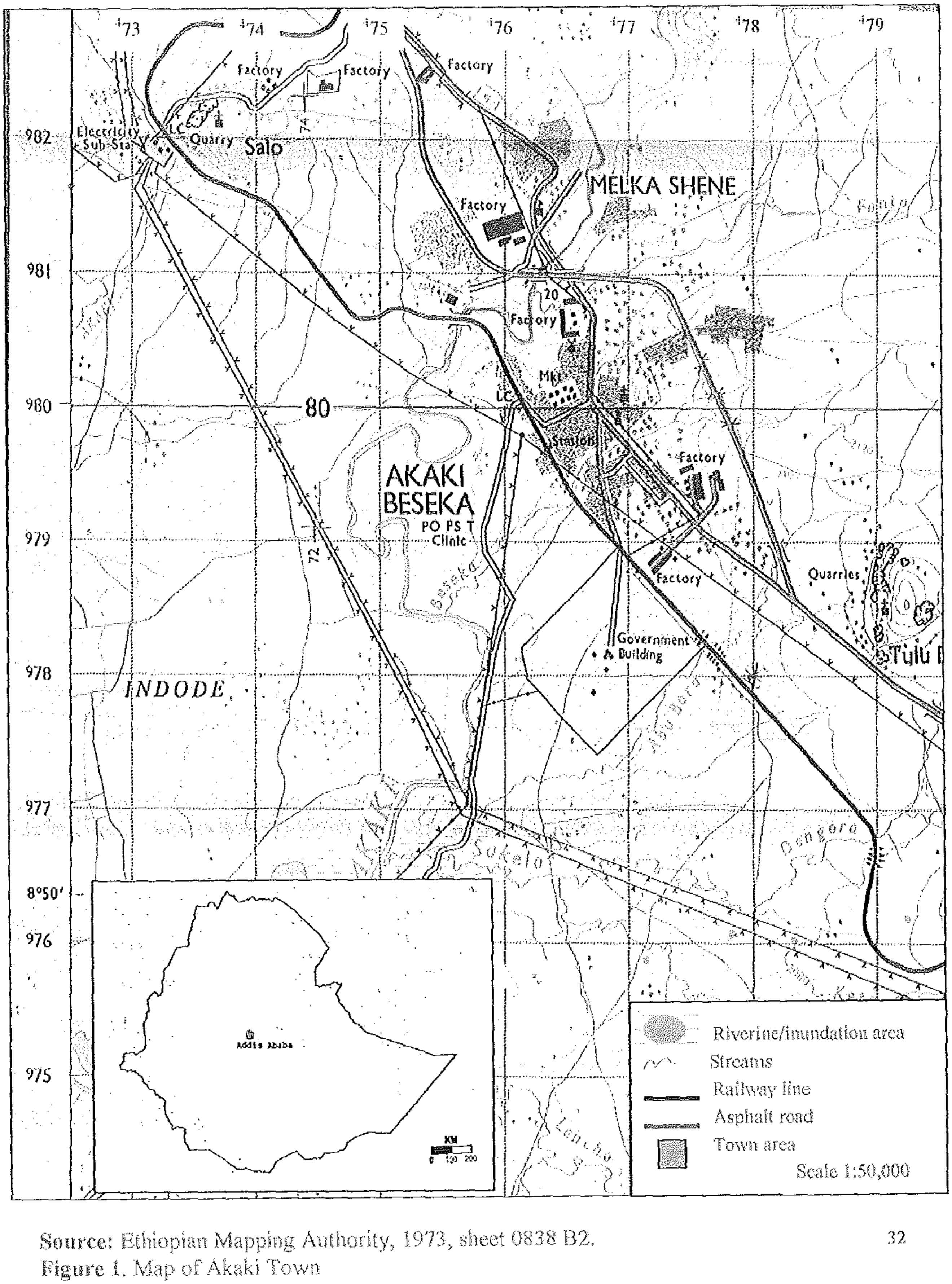
4. MATERIALS AND METHODS

4.1 STUDY AREA

Akaki Town (also known as Akaki Beseka) is a low-lying old residential and industrial town situated at about 23km southeast of Addis Ababa (Fig.1) along the Addis Ababa-Debre Zeit highway road. It lies at an altitude of 2110m and between latitudes 8°50' to 8°53'N and longitudes 38°45' to 38°48'E. The history of its establishment goes back to the establishment of Addis Ababa-Djibouti railway making its first destination in the then Beseka village in 1907. The railway line bisects the Town with a substation located at the center.

In northern and eastern part, it is bounded by hills that empty their-flooding to the Town in the wet season. The frequently overflowing Akaki River, inundate the Town. Other flooding rivers occasionally displaces families. Pools of mosquito breeding sites are created during the cessation of the rainy seasons and effluent ones during the rainy season. In the last few years the Town extended to the rural areas with peri-urban type in its setup. This part of the Town is bounded by cultivation that provides numerous breeding sites during wet season. Akaki River and streams of Fanta and Beseka are the potential water bodies supporting mosquito survival during the wet and dry seasons.

Akaki has a humid temperate climate. The mean relative humidity varies from 51% to 81%. The warmest months are between March and June with maximum average temperature of 25.4°C and 26.7°C in February and March, and the coldest months are November, December and January with minimum average temperatures of 5.4, 5.6 and 5.5°C, respectively. In 1998, the total annual rainfall was recorded to be 1070.9mm, the highest of all in the last ten years for the area.



Source: Ethiopian Mapping Authority, 1973, sheet 0838 B2.
Figure 1. Map of Akaki Town

The Town has a municipality, a bank, a digital telephone line, piped drinking water, electricity, two factories, a health center, four private clinics, three drug venders, two senior secondary and three elementary schools and few other development projects. Most of the dwellings are constructed of mud-wall without ceiling and with corrugated iron roofing, and are occupied on an average by 6-7 people. Proper waste disposal facilities are unevenly distributed, even absent in most of the localities.

The canals alongside the railway and flowing down to the low-lying western direction of the Town and the sewage from a metal factory and a mission school are potential mosquito-breeding habitat.

The population of Akaki Town is estimated to be 37,404, comprising 2% of the total population of Addis Ababa (Statistical Report of Population and Housing Census, 1994). The people get medical care at the Akaki Health Center (AHC) as the primary care center, as well as at private clinics and drug venders. No systematic malaria control program has been known to be undertaken in Akaki in recent years, though, extensive vector control, such as, DDT spray of 7000 houses, and larviciding of breeding sites with Abate chemical was reported as an anti-epidemic measure in 1997/98 (Akaki Health Center unpublished data, 1998). Debre-Zeit Malaria Control Laboratory is the nearest service provider for the people obviously free of charge. Young and middle aged individuals are mostly hired in daily works in the vicinity, road construction and other development projects. Few people are engaged in contraband trade along the railway to Dire-Dawa. During planting and harvesting seasons, non-immune people from different parts of the country temporarily stay in the town to be hired in the rural areas as daily laborers.

AHC unpublished report (1998) has indicated the occurrence of malaria epidemic in the Town that involved about 3,203 clinical cases. The malaria epidemic of Ethiopia in 1958 has also reported in the rural vicinity of Akaki Town (Fountaine *et al.*, 1961).

4.2 STUDY POPULATION

The survey was conducted in a geographically restricted section of the Town rather than a random sample of specified size from the 37,404 population of Akaki and the surrounding areas. Morbidity report of Akaki Health Center shows that there had been a variation in temporal and spatial distribution of malaria from the beginning to the end of the 1997/98 malaria epidemic in the Town. Therefore, selection of Kebeles was limited to the focal characteristics of malaria as confirmed by studies conducted elsewhere (Greenwood, 1989; Yohannes and Petros, 1996; Vercruysse *et al.*, 1983; Mouchet *et al.*, 1993; Sharma, 1995). Thus, sections of the Town were selected on the basis of: (a) pre-survey data from health center compiled during the1998 malaria epidemic (Akaki Health Center, unpublished data, 1998) and (b) the local knowledge of the people.

The study area included residential areas with overcrowded houses, slums, easy access for entry and exit of mosquito and vegetation in the compound and/or surrounding to serve as resting and the vast pools of temporary breeding sites lying besides the canals of the railway water bodies in the surrounding. These are dispersed widely around the Town, but dry out during the dry season. An irrigation scheme, adjacent to Akaki River, utilized to grow grass with the help of motor pumps during the dry season and there are streams crossing passing adjacent to the Town suspected to support mosquito breeding and survival during the dry season were all considered.

4.3 SAMPLE SIZE DETERMINATION

Sample size for prevalence study (P) of malaria was estimated on bases of the result of unpublished report (Akaki Health Center, unpublished report 1998), and consideration of an estimation of those cases that are out of the scope of the local health center service. Taking these and an acceptable error of 0.04 the sample size was calculated using the formula for estimating single proportion with a level of significance $\alpha = 0.05$ (Polit and Rins, 1991).

4.4 SAMPLING TECHNIQUE

4.4.1 RESTRICTION OF THE STUDY SITES

Peripherally located (01 and 03) of the six urban Kebeles with relatively high potential for malaria incidence were selected.

4.4.2 SELECTION OF STUDY SITES AND KAPs STUDY

The lists of the households of the 2 selected Kebeles were used as a sampling frame, with an assumption of similar exposure of clusters of houses and random malaria infection among inhabitants. Since the study units are the individuals from the selected households, two step sampling was performed to fulfill the sample size required. First, 50% of the households of each of the 2 Kebeles were taken, next the actual requirement from each Kebele and sections of both Kebeles were determined by using proportional stratified sampling (Polit and Rins, 1991). A total of 116 households were selected systematically based on the calculated proportions for both Kebeles to sample 576 individuals. This was based on reports of population census of 1994, by the Addis Ababa

City Administration that included Akaki (Statistical report of population and housing census, 1995). From 116 households 712 individuals were sampled.

If the indexed house could not be located at the address listed, the occupants refused to participate in the survey for any reason or if it was unoccupied, the house nearest the putative address was selected. After obtaining consent, blood samples were taken from all selected family members of households by finger prick, and thick and thin smears were prepared. This was done monthly from these individuals from October through December. In addition, all the household heads or the next responsible person were also interviewed for additional socio-demographic and knowledge on malaria transmission and practice of control methods by using a questionnaire.

4.5 REVIEW AND DOCUMENTATION OF MALARIA CASES IN ADDIS ABABA CITY ADMINISTRATION

Data on all malaria cases treated at different health service units in outpatient department were collected using a pre-developed format for the Addis Ababa City Administration health bureau. Information was collected from Akaki Health Center for the periods between 1996 to 2000.

4.6 PARASITOLOGICAL SURVEY IN AKAKI TOWN

Blood film collection was performed in peak malaria transmission season of the country (Tulu, 1993; Gebre-Mariam, 1984; 1988; Fontaine *et al*, 1961; Covell, 1957), from October through December 1999 after cessation of the major rainy season. Thin and thick films were prepared and labeled. The slides were carefully dried, packed and transported to the laboratory where it was fixed with methanol stained with a 3% Giemsa Stain (WHO, 1991b).

Thick and thin films were examined by using 100X magnification (oil immersion) for the presence of plasmodia and species identification was performed, respectively, oil immersion.

4.7 MOSQUITO COLLECTION

To determine the bionomics of *Anopheles* mosquito in the study area, larval and adult stages were collected using different entomological techniques (WHO, 1994). Adult collections were conducted from October 1999 to October 2000 while larvae collections were from September 1999 to October 2000.

4.7.1 LARVAL COLLECTION

Anopheline larvae collection was performed from suspected breeding sites such as artificial pond, canals, excavation ditches, stream margins, swamps and rain pools (Fig. 2) using ladles and pipettes. Once the larvae were in the ladle they were transferred to vials by direct pipetting. The collected samples were immediately preserved in 70% ethanol and then processed and mounted on microscope slides using gum chloral for further identification.

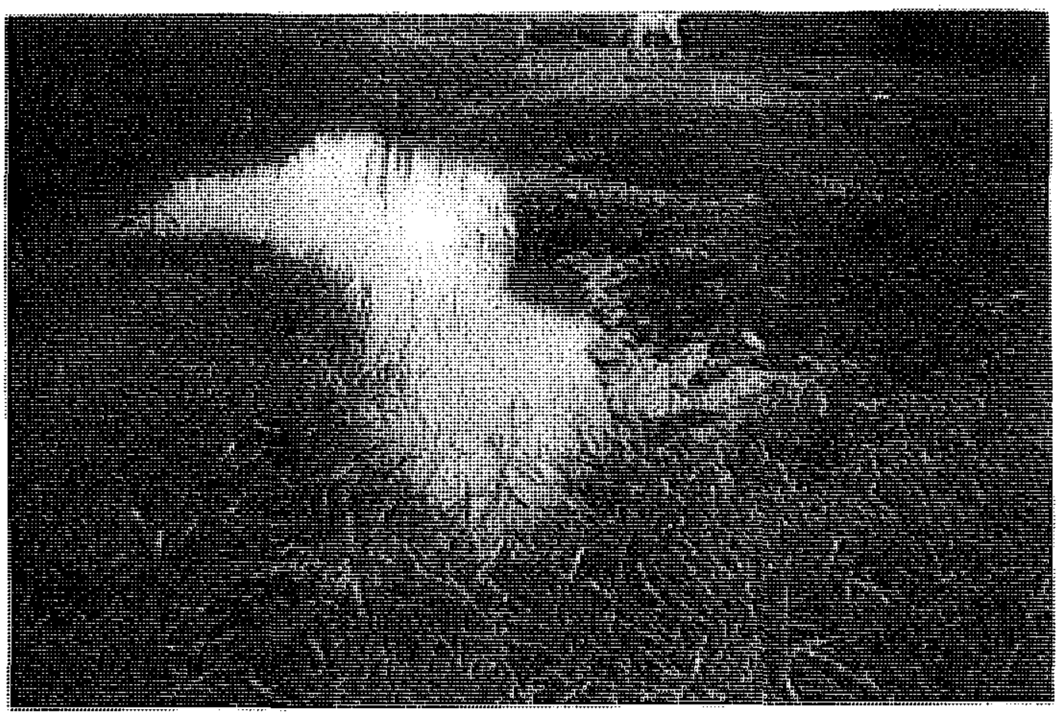


Figure 2. Breeding site of Anophelines

4.7.2 ADULT COLLECTION

Collection of adult anophelines was carried out using night-biting collection, CDC light-trap, indoor resting collections, and outdoor resting collection procedures.

4.7.2.1 NIGHT-BITING COLLECTION

Monthly man-biting collection of adult mosquito was conducted using human-bait method for 4-8 consecutive nights in selected four sites of the town. Indoor and outdoor collections of anophelines were conducted to determine their feeding behavior and density. At each site a pair of baits/collectors sat on low chair with their legs and arms exposed to collect mosquitoes biting on them and from each other with test tubes and torchlight (Fig. 3). All night collections (18:00 to 06:00hr) were made at each site in two shifts which changed over at midnight. The same baits were used throughout the study period. The collections were sorted out into culicines and anophelines in the field. Only, anopheline were brought to the laboratory for species identification and dissections of fresh specimen. Moreover, bites per man per night were computed for the common anophelines collected by dividing total number of mosquitoes captured by the number of man-nights each month.

Relative humidity readings were recorded for each specific hour using psychrometer at the beginning of each hour.

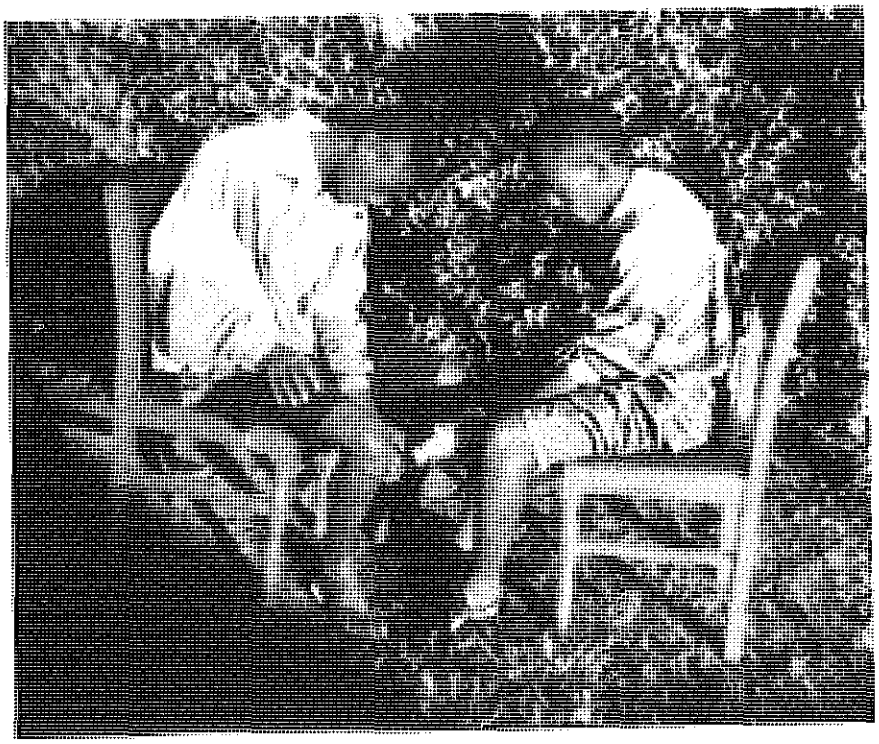


Figure 3. Human-baits catching mosquitoes

4.7.2.2 CDC LIGHT-TRAP

Two dry cell battery-operated CDC light-traps were hung in the vicinity of night biting collection sites (Fig. 4) from 18:00 in the evening to 06:00 in the morning. The collections were sorted out into anopheline and culicine mosquito for identification and dissections.

4.7.2.3 INDOOR RESTING COLLECTIONS

Indoor resting mosquitoes were searched from 06:30 to 08:30 on consent of the inhabitants. Mouthpiece aspirator and torchlight, and space-spray were the two techniques implemented to determine the resting mosquito. Aspirator collections were done from 15 houses per month for about 20 minutes in each house. One person (self) did the collection.

To perform space spray in selected houses a white cloth and aerosol were used. A white cloth was used to cover its entire floor of the house. All openings that could allow mosquito escaping, doors and windows were closed. The houses were then sprayed with aerosol for about 5-10 minutes. After waiting for about 10 minutes after spraying, the sheet was brought outside the room to inspect and collect the fallen mosquitoes. The mosquitoes were picked using forceps and were put in pillbox for later identification.

Figure 4. Dry cell battery-operated CDC light-trap collection

4.7.2.4 OUTDOOR RESTING COLLECTIONS

A drop net collection was performed to collect outdoor resting mosquitoes. For this purpose, conical net of 3x4m^2 prepared from transparent (mesh-like) nylon netting was carefully dropped on vegetation suspected of mosquitoes. Then the site was disturbed to agitate the mosquitoes to the narrow end of the net after which the net was carefully raised and the mosquitoes were collected using aspirator (Fig.5).

4.7.2.5 IDENTIFICATION OF ANOPHELINES

By using the key by Anopheline adults and larvae were identified using the keys by Veronne (1962a, b) and Gillies and Coetzee (1987).

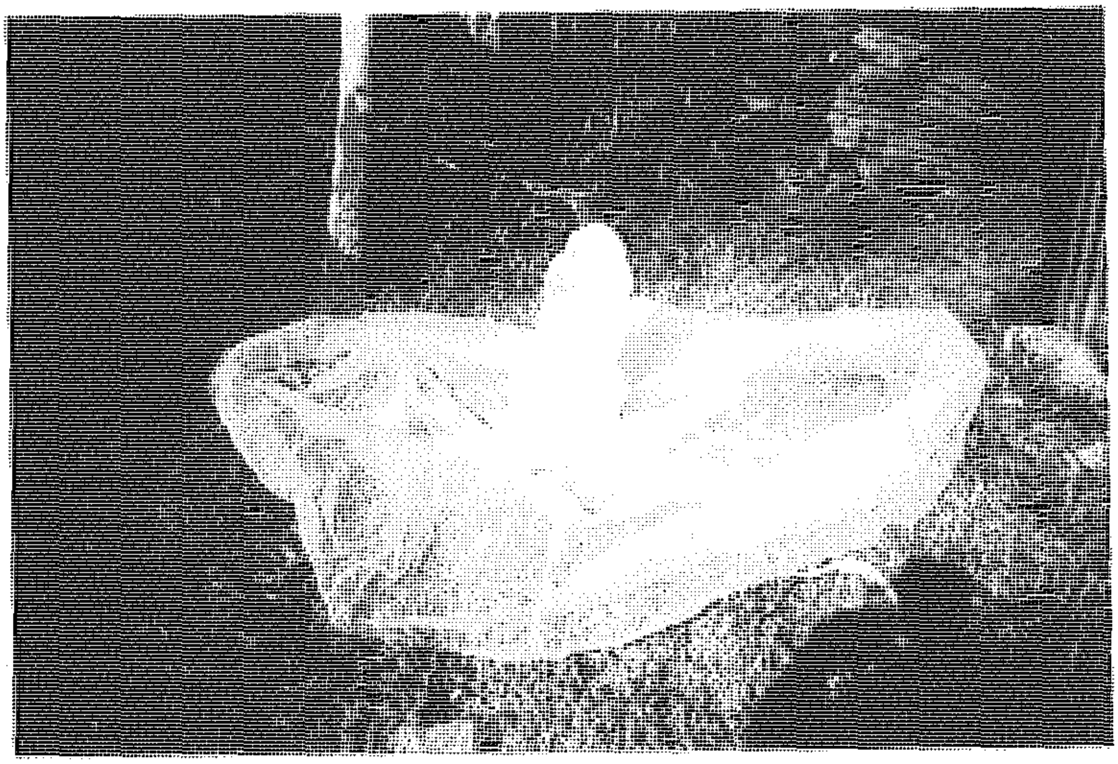


Figure 5. Outdoor mosquito collection using dropnet

4.7.2.6. DISSECTION FOR SPOROZOITE AND PARITY RATE

The dissection of female anopheline mosquitoes were conducted to determine their sporozoite and parity rates (WHO, 1994). To perform dissection, mosquitoes were anaesthetized and the species identified. Then, their legs and wings were removed, and placed on its sides on a slide with a drop of saline solution (0.65%) with the head pointing to the right. To remove the glands, with the left hand the thorax was held firmly with a dissecting needle and the right hand on the neck of the mosquito. Finally, the glands come out of the thorax attached to the head when the head was pulled gently away from the thorax. Immediately, the glands were covered with a cover slip and examined under a high power X40 to observe sporozoites released from salivary glands on pressing. On the other hand, only unfed or freshly fed mosquitoes are suitable for detecting parity. These female mosquitoes were killed, trimmed and placed on a slide. A drop of distilled water was added. Then, the abdomen was cut on each side of the body between the sixth and seventh segment. While one needle holding on the thorax, the tip of the abdomen pulled away from the rest of the body with another needle held in the right hand. Thus, ovaries come out of the abdomen and were separated from the rest of the specimen. Then, the ovaries transferred to a drop of distilled water on another slide and allowed drying. To differentiate between nulliparous and parous ovaries the dried ovaries were examined under a compound microscope using the X10 objective and confirmed using the X40 objective. Females in which the ovaries have coiled tracheal skeins are nulliparous, while those with stretched out tracheoles are parous.

4.8 METEOROLOGICAL DATA

To substantiate the malaria transmission prevailing in the area and previous epidemic that has occurred in 1998. Monthly temperature, rainfall and relative humidity data of the study area for the periods between January 1997 to March 2000 were obtained from the National Meteorological Service Agency.

4.9 DATA ANALYSIS

Data collected on parasitological observations were managed and analyzed using a statistical computer program EPINFO version 6.03. The associations of different variables were assessed using chi-square tests. In addition, other statistical methods were performed to determine the prevalence of malaria and its spatial and temporal distribution.

4.10 ETHICAL CONSIDERATION

After briefing on the objective and application of the study to Zone 6 Health Department and the local administrators, the inhabitants were contacted to secure their verbal consent in the same way.

Blood smear was obtained with finger prick using disposable sterile blood lancet and cotton immersed in 75% alcohol (WHO, 1991b). Treatment of malaria to Confirmed cases of malaria was given with chloroquine in collaboration with Akaki Health Center according to the national guideline for treatment of uncomplicated malaria in the country (unpublished document MOH, 1999). After interviewing, the persons were given basic health education on malaria transmission and control methods. The human-baits involved in this activity have been on Chemoprophylaxis with the same drug during the study.

5. RESULTS

5.1 MALARIA CASES IN ADDIS ABABA CITY ADMINSTRATION FROM 1993 TO 1999

Review of malaria cases seen at the outpatient departments of health institutions in Addis Ababa from 1993 to 1999 is presented in Table 1. There appears to be a trend of increment of malaria cases from 1996 on wards until it decreased relatively in 1999. Adults aged 15 years and above were more affected compared to other age groups. Moreover, infants and children aged between 1 and 4 years were also treated for malaria.

Table 1. Age distribution of all forms of malaria cases treated based on clinical and laboratory diagnosis at different health facilities in Addis Ababa City Administration between 1993 and 1999.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1993	1	2	44	72	119
1994	0	2	17	78	97
1995	1	1	31	147	180
1996	7	112	418	4858	5395
1997	38	243	821	6330	7432
1998	58	220	1116	8266	9660
1999	79	155	1338	4451	6023
Total	184	735	3785	24202	28906

Source: Planning and programming department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Tables 2, 3 and 4 show distribution *P. vivax*, *P. falciparum* and *P. malariae* in different age categories, respectively, in order of importance of each species. *Plasmodium vivax* is the predominant species in all age groups. It was about 5 times greater than *P. falciparum* in infants. Microscopically confirmed malaria cases were absent in children less than 5 years between 1993 and 1995. However, few cases of *P. vivax* and *P.*

falciparum were diagnosed in age groups above 5 years. From 1996 onwards *P. vivax* has shown a continuous rise until it reached maximum in 1998. This was observed in all age groups except in age groups of 1 to 4 in 1998. Similarly, *P. falciparum* has also shown an abrupt increment after 1996 with the maximum in 1996 and 1998. A twice increment of *P. vivax* was observed compared to *P. falciparum* in all age groups, except in infants with five times more in the former species in this period. Regarding *P. malariae*, only four cases were recorded in age groups 15 years and above from 1993 to 1995. From 1996 onwards most of the *P. malariae* cases (88%) were diagnosed in age groups 15 years and above and the rest few cases were below 15 years with highest cases in age groups 5 to 14 years in 1998. This species was diagnosed in infants only in 1998 and 1999.

Table 2. Age distribution of *P. vivax* cases at different health facilities in Addis Ababa City Administration between 1993 and 1999.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1993	0	0	1	1	2
1994	0	0	1	1	2
1995	0	0	0	1	1
1996	3	64	219	1972	2258
1997	31	155	433	3707	4326
1998	35	136	497	4305	4973
1999	59	112	743	2052	2966
Total	128	467	1894	12039	14528

Source: Planning and programming department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Table 3. Age distribution of *P. falciparum* cases at different health facilities in Addis Ababa City Administration between 1993 and 1999.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1993	0	0	0	1	1
1994	0	0	2	0	2
1995	0	0	0	2	2
1996	3	34	147	2278	2462
1997	7	65	248	1512	1832
1998	15	60	233	2103	2411
1999	1	31	121	706	859
Total	26	190	751	6602	7569

Source: Planning and programming department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Table 4. Age distribution of *P. malariae* cases at different health facilities in Addis Ababa City Administration between 1993 and 1999.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1993	0	0	0	4	4
1994	0	0	0	0	0
1995	0	0	0	0	0
1996	0	2	3	184	189
1997	0	6	5	458	469
1998	5	12	93	410	520
1999	14	4	0	26	44
Total	19	24	101	1082	1226

Source: Planning and programming department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Table 5 shows clinically treated malaria cases between 1993 and 1999. These are malaria cases treated clinically even if the laboratory result is negative to malaria parasite. Unlike microscopically confirmed cases in children aged less than 5 years, few cases of clinical malaria were treated in the same age group from 1993 to 1995 including infants except in 1994. A general trend of increment of clinical malaria was observed throughout the review years showing a great variation in all age groups including children below five years. Overall, the geographical origin of the patients could not be identified since no data was available in the document of the health institutions.

Distribution of malaria cases in the six administrative Zones of Addis Ababa from 1997 to 1999 is depicted in Table 6. The distribution of health centers in each administrative Zone is presented in Table 7. Highest malaria cases were recorded in Zone 6 to be followed by Zones 1 and 3. A trend of dropping of malaria prevalence was seen in all the Zones from 1997 to 1998. On the other hand, it rose again in 1999 compared to 1998 except in Zone 6. In Zone 5 malaria cases in 1999 are higher than that of 1998. In general, the lowest number of cases was recorded in Zone 2 and the highest in Zone 6 in between 1997 and 1999.

Table 5. Age distribution of other unspecified malaria cases or clinically treated for malaria at different health facilities in Addis Ababa City Administration between 1993 and 1999.

	Age groups				
Year	<1	1 to 4	5 to 14	15+	Total
1993	1	2	43	66	112
1994	0	2	14	77	93
1995	1	1	31	144	177
1996	1	12	49	424	486
1997	0	17	135	653	805
1998	3	12	293	1448	1756
1999	5	8	474	1667	2154
Total	11	54	1039	4479	5583

Source: Planning and programming department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Table 6. Distribution of all forms of malaria cases treated at different health facilities in Addis Ababa City Administration between 1997 and 1999 based on clinical and laboratory diagnosis.

Zones							
Year	1	2	3	4	5	6	Total
1997	1008	92	604	234	94	1573	3605
1998	461	28	34	112	45	1129	1809
1999	786	75	94	164	142	488	1749
Total	2255	195	732	510	281	3190	7163

Source: Disease prevention and control department, Addis Ababa City Administration Health Bureau, Addis Ababa.

Table 7. Distribution of Health Centers in different Zones of Addis Ababa City Administration.

Zones(Woreda)	Health Centers
1. (3, 4, 5, 6)	Tekle-Haimanot, Beletshchew, Addis Ketema
2. (20, 21, 22, 23)	Lideta, Woreda 23, Kirkos
3. (17, 18, 19, 28 or Kotebe	Woreda 17, 18, 19, Kotebe
4. (1, 9, 11, 12, 13, 15, 16)	Gulelle, Shiro Meda, Entoto No. 1, Woreda 13, Kazanchis, Yeka
5. (2, 7, 8, 10, 14, 25)	Arada, Woreda 25
6. (26, 27)	Akaki, Kaliti

Source: Addis Ababa Health Bureau

5.2 MALARIA CASES TREATED AT AKAKI HEALTH CENTER

Table 8 shows distribution of all new cases and malaria cases treated at Akaki Health Center. New cases are the number of illnesses of all types including malaria cases over a period of time. A continuous rise of malaria cases was observed reaching its maximum in 1998 followed by a decline in 1999 and 2000. In 1997 a rise of malaria cases by almost 3 times that of 1996. Similarly, cases in 1998 were 5 times that of 1996. Both in 1999 and 2000 a reduction of cases of malaria nearly by half compared to that of 1998 and remained constant.

Table 8. Annual distribution of all new and malaria cases treated at Akaki Health Center between 1996 and 2000.

Year	All New Cases	Malaria Cases (%)
1996	10, 435	536 (5.1)
1997	16, 639	1, 456 (8.8)
1998	20, 158	2, 728 (13.5)
1999	11, 852	716 (6.0)
2000	14, 325	912 (6.4)
Total	73409	6348 (8.6)

Source: Zone 6 Health Department, Kality, Addis Ababa.

Age distribution of all forms of malaria cases in Akaki Town, i. e., laboratory diagnosed and clinically treated cases, is presented in Table 9. Most of the cases (75.9%) were in age groups 15 years, some of them (22.7%) in younger children aged 5 to 14 years. The rest few cases were in infants (0.2%) and children aged between 1 to 4 years (1.12%).

Table 9. Age distribution of all forms of malaria cases treated in Akaki Health Center based on clinical and laboratory diagnosis between 1996 and 2000.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1996*	0	0	117	419	536
1997	4	8	354	1090	1456
1998	2	5	604	2117	2728
1999	3	12	156	454	625
2000+	2	46	161	565	774
Total	11	71	1392	4645	6119

1996* = January, February and March data and 2000+= December data not obtained

Source: Zone 6 Health Department, Kaliti, Addis Ababa.

Distributions of microscopically confirmed malaria cases by species in different age groups are shown in Tables 10, 11 and 12. *Plasmodium vivax* is the commonest species followed by *P. falciparum* and *P. malariae*. However, only few cases of these species were diagnosed in infants compared to the clinically treated cases for malaria.

Table 10. Age distribution of *P. vivax* cases treated at Akaki Health Center between 1996 and 2000.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1996	0	0	52	151	203
1997	0	1	119	306	426
1998	0	4	245	823	1072
1999	1	2	52	192	247
2000	0	31	53	153	237
Total	1	38	521	1625	2185

Source: Zone 6 Health Department, Kaliti, Addis Ababa.

Table 11. Age distribution of *P. falciparum* cases treated at Akaki Health Center between 1996 and 2000.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1996	0	0	17	81	98
1997	0	3	33	76	112
1998	0	0	28	104	132
1999	0	3	20	46	69
2000	2	8	17	63	90
Total	2	14	115	370	501

Source: Zone 6 Health Department, Kaliti, Addis Ababa.

Table 12. Age distribution of *P. malariae* cases treated in Akaki Health Center between 1996 and 2000.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1996	0	0	0	2	2
1997	1	1	41	122	165
1998	0	0	45	148	193
1999	0	0	0	0	0
2000	0	0	0	0	0
Total	1	1	86	272	360

Source: Zone 6 Health Department, Kaliti, Addis Ababa.

The distribution of clinically treated malaria cases in different age categories is depicted in Table 13. It was also noted here that cases were seen in all age groups including infants; highest number of cases being in the age groups 15 and above. Here again, highest number of clinical cases occurred during the epidemic years of 1997 and 1998.

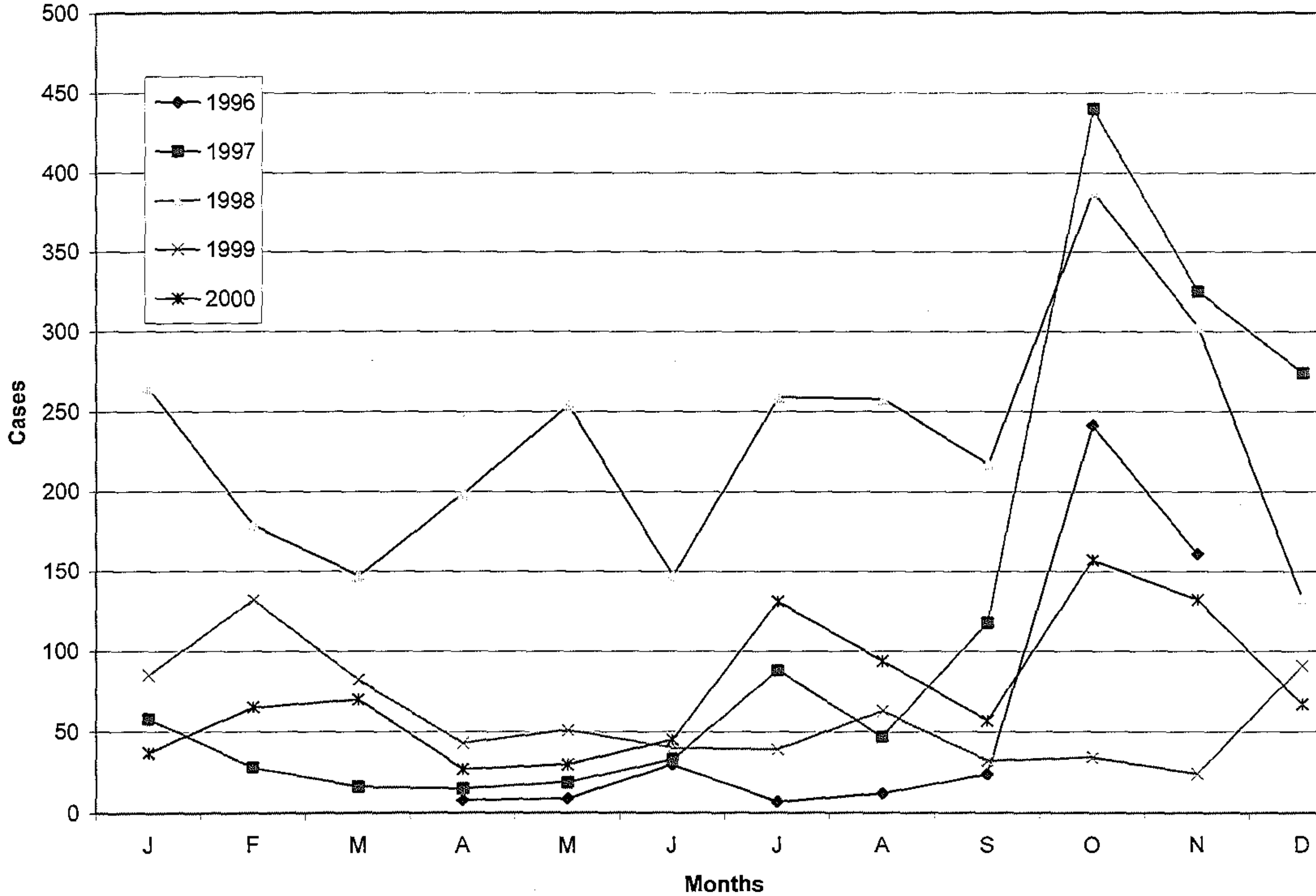
Table 13. Age distribution of clinically treated malaria cases at Akaki Health Center between 1996 and 2000.

	Age group				
Year	<1	1 to 4	5 to 14	15+	Total
1996	0	0	48	185	233
1997	3	3	161	586	753
1998	2	1	286	1042	1331
1999	2	7	84	216	309
2000	0	7	91	349	447
Total	7	18	670	2378	3073

Source: Zone 6 Health Department, Kaliti, Addis Ababa.

Figure 6 shows the seasonal pattern of malaria cases from April 1996 to December 2000. Malaria transmission peaks in October in all the years and the highest cases were obtained in 1997 followed by that of 1998. This was an epidemic period for this area and also other parts of the country, for instance, West Shoa, Central Ethiopia.

Fig. 6. Monthly distribution of malaria cases treated at Akaki Health Center from 1996 to 200



5.3. THE STUDY POPULATION AND MALARIA PREVALENCE IN AKAKI TOWN

The proportion of the households and individuals sampled from each Kebele and 'Ketena' is presented in Table 14. A total of 712 individuals were enrolled in the study from 116 sampled households from the two Kebeles.

Table 14. The description of the study population in Akaki Town from October to December 1999.

Kebelle/	Total	Sampled	Sampled population		
Ketena	households	households (%)	Male	Female	Total
01/1	250	11(4.4)	16	31	47
01/2	431	20 (4.6)	33	63	96
01/3	390	18(4.6)	23	42	65
01/4	375	17(4.5)	58	74	132
03/1	490	22(4.4)	58	108	166
03/3	590	28(4.7)	76	130	206
Total	**2526**	**116(4.5)**	**264**	**448**	**712**

The study population was composed of mainly people above 15years old (58.71%), of which 2.5% were old age groups (>65 years older), the age group varying from 3 months to 100 years (Table 15). Of the total study population, 264 (37%) were females and 448 (63%) males with a ratio of 1:1.7.

5.3.1.MALARIA PREVALENCE IN AKAKI TOWN

With a quarterly prevalence survey conducted for three months (October-December, 1999) malaria prevalence in Akaki Town was determined. Out of the total 2136 blood films examined in three surveys 78 (3.7%) were found infected. Fifty-four of the 78 (69.2%) and 24 (30.8%) of them were due to *P. vivax* and *P. falciparum*, respectively.

Table 15. The age and sex distribution of study population in Akaki Town from October to December 1999.

	Sex		
Age groups	M	F	Total
0-11 months	2	1	3
1-4 Years	30	40	70
5-9	55	51	106
10-14	56	59	115
15-19	36	66	102
20-24	14	51	65
25-29	8	34	42
30-34	4	27	31
35-39	10	30	40
40-44	14	24	38
45-49	9	25	34
50-54	8	16	24
55-59	6	7	13
60-64	4	7	11
65-100	8	10	18
Total	264	448	712

The distribution of malaria infection in both Kebeles is indicated in Table16. Differences in malaria prevalence were observed among different 'Ketenas' of each Kebelle. It was absent in three 'Ketenas' located centrally and detected in the other three located at the periphery of the Town. Moreover, a slight variation in malaria prevalence among the peripheral portions of the Town was observed.

On the other hand, the prevalence of malaria infection in relation to the survey period is shown in Table 17. In the first two surveys, October and November 1999, malaria infection was observed, while, in the last survey, December 1999 no cases were detected. Of the total 78 individuals, 32 (41%) and 46(59%) of them were males and females, respectively.

Table 16. Cumulative malaria prevalence by Kebelle and section in relationship to geographical location in Akaki Town from October to December 1999.

			Number	
Kebelle/ Ketena	Geographical Location	Total Examined	Positive (%)	Negative (%)
01/1	Central	47	0(0.0)	47(100.0)
01/2	Central	96	0(0.0)	96(100.0)
01/3	Central	65	0(0.0)	65(100.0)
01/4	Peripheral	132	38(28.8)	94(71.2)
03/1	Peripheral	166	20(12.0)	146(88.0)
03/3	Peripheral	206	20(9.7)	186(90.3)
	Total	712	78(11.0)	634(89.0)

Table 17. Prevalence of parasite species in relation to the survey period in all age groups in Akaki Town from October to December 1999.

			Infection by sex		Infection by species (%)	
Months	Total Examined	Total Positive (%)	male(%)	female(%)	*P. falciparum*	*P. vivax*
Oct. 1999	712	30 (4.2)	12(40.0)	18(60.0)	21(70.0)	9 (30.0)
Nov. 1999	712	48 (6.7)	20(41.7)	28(58.3)	3 (6.3)	45 (93.7)
Dec. 1999	712	0 (0.0)	0 (0.0)	0 (0.0)	0(0.0)	0(0.0)
Total	2136	78 (3.7)	32(41.0)	46(59.0)	24 (30.8)	54 (69.2)

In the first survey conducted in October 1999, 30 (4.2%) of the 712 individuals examined had malaria (Table 18). Most of the positive cases observed were among the age groups 15 years and above and *P. falciparum* was the commonest species (70%) during this survey. On the other hand, during the second survey, which was conducted in November 1999, 6.74%(48) of the individuals examined was positive for malaria infection (Table 19). *Plasmodium vivax* was the commonest (93.7%) species, while the rest few cases were *P. falciparum* (6.3%) during this survey. Most of the cases were individuals aged 15 years and above. In general, malaria infection was observed in all age groups, except infants, in both surveys. However, the difference in malaria prevalence is not statistically significant among different age groups (P>0.05, DF=3). Similar study in Nazareth indicated that inter-age variations in parasite rates were statistically significant (Yohannes and Petros, 1996). However, it did not show a distinct peak and decline with an increase in age.

The frequency of infection during the second survey was 1.6 times as high as that of the first survey. In the first survey *P. falciparum* was the most prevalent species, while this was reversed in the second survey. In fact, *P. vivax* was absent in children aged less than five years in the first survey, and *P. falciparum* was absent in the same age group in the second survey. The latter species was observed at very low frequency (6.3%) in the second survey.

On the other hand, all the malaria parasite positives were asymptomatic and no travel history to malaria endemic areas within the last fifteen days.

Table 18. Prevalence of *Plasmodium* species among the study population in Akaki Town in October, 1999.

Age groups	No. Exam.	Total positive (%)	*P. falciparum* (%)	*P. vivax* (%)
<1	3	0(0.0)	0(0.0)	0(0.0)
1-4	70	2(2.86)	2(100.0)	0(0.0)
5-14	221	8(3.62)	5(62.5)	3(37.5)
15+	418	20(4.78)	14(70.0)	6(30.0)
Total	712	30(4.21)	21(70.0)	9(30.0)

Table 19. Prevalence of *Plasmodium* species among the study population in Akaki Town in November, 1999.

Age groups	No. Exam.	Total positive (%)	*P. falciparum* (%)	*P. vivax* (%)
<1	3	0(0.0)	0(0.0)	0(0.00
1-4	70	3(4.28)	0(0.0)	3(100.0)
5-14	221	16(7.23)	2(12.5)	14(87.5)
15+	418	29(4.10)	1(3.5)	28(96.5)
Total	712	48(6.74)	3(6.3)	45(93.7)

5.3.2 KAP SURVEY

Of a total 116 households 101(87.1%) interviewees were Orthodox Christians, 11(9.5%) Muslims and the rest 4(3.4%) were Protestant Christians. Among those interviewees, Oromo ethnic groups were the predominant 59(50.9%), followed by Amhara 41(35.3%), the rest 11(9.5%) were Guraghe, 2(1.7%) Hadiya, 2(1.7%) Kambata and 1(0.9%) Tigre. The educational status of the interviewees, 40(34.5%) were illiterate and the rest 76(65.5%) were literate. Of the total literate 20(17.2%) said they could read and write only, 36(31.0%) completed elementary school, 16(13.8%) junior and high school and the rest 4(3.5%) studied at higher institutions.

Their occupation consisted of government employee, 47(40.5%); retired, 26(22.4%); merchants, 10(8.6%) and farmers, 4(3.5%). While the rest one-fourth of the interviewees were unemployed 18 (15.5%) and daily laborers 11 (9.5%). Table 20 shows the monthly income of the study population in Birr. Since the monthly income of unemployed and daily laborers could not be determined it was categorized as unspecified.

When asked how malaria is transmitted from one person to another, 86 (74.2%) of them said through mosquito bite, while 20 (17.2%) said it is not transmitted from person to person. The rest 10 (8.6%) said drinking unhygienic (polluted) water and living and feeding with malaria patient transmits malaria.

Table 20. Distribution of the study households by monthly income in Akaki Town, 1999.

Monthly income groups	Frequency (%)
Below 200	46(39.7)
201-400	25(21.6)
401-600	9(7.8)
601-700	1(0.8)
701-900	0(0.0)
Above 901	1(0.8)
Unspecified	34(29.3)
Total	116(100.0)

When heads of households were asked where they go to get treatment for malaria, 77 (66.4%) said to government clinics and health centers, 18(15.5%) replied they go to the nearest malaria control laboratory. The rest replied 14 (12.1%) to private clinics, 4 (3.4%) use traditional healing practices and the rest 3 (2.6%) replied to any health service facility conditionally. The suggested measures to prevent and control malaria by the households of the study population are shown in Table 21. More than half of them responded that environmental management as a method to prevent and control malaria.

Households studied were interviewed about the history of malaria epidemics in the area and three-fifth of the respondents remembered the occurrence of malaria epidemics in 1997/98. They remarked the occurrence of many deaths localized to peripheral parts of the Town, mainly south of the railway, locally known as 'Megala Sefer'. Zone 6 Health Department reported this epidemic. In addition, three male informants of 82, 78 and 68 years old remembered the 1958 malaria epidemic that affected villages surrounding Akaki Town and most parts of the country (Fountaine *et al.*, 1961).

Table 21. Suggested control measures of the households of the study population in Akaki Town, 1999.

Types of control measures	Frequency (%)
Environmental management	59(50.9)
Combination of all (treatment of cases, DDT spray and environmental management)	13(11.2)
Eating garlic and drinking squash of *Vernonia* leaf	13(11.2)
Treatment of cases	9(7.7)
Spray of DDT	8(6.9)
Both environmental management and treatment of cases	11(9.5)
Do not Know	3(2.6)
Total	116(100.0)

5.4 ENTOMOLOGICAL INVESTIGATION

5.4.1. LARVAL MOSQUITO COLLECTION

A total of 1223 anopheline larvae were collected from different types of breeding sites. The majority (42.1%) were collected from stream margins which only served as breeding sites during the dry season, while the remaining sites served as breeding sites during the rainy season (Table 22). Of the collected, 1156 larvae, three species were identified namely: *An. arabiensis*, *An. christyi* and *An. cinereus*. About 67 of the larvae could not be identified because of bad preparation and mechanical damage. *Anopheles christyi* is the most abundant (91.7%), the rest were scarce; *An. arabiensis* and *An. cinereus* made up 6.7% and 1.6% of the larvae identifiable collection, respectively, (Table23).

Table 22. Anopheline larvae sampled in Akaki Town from September 1999 to October 2000.

	Number of anopheline larvae sampled monthly												
Breeding sites	Sep	Oct	Nov	1999 Dec	2000 Jan	Feb	Mar	Jun	Jul	Aug	Sep	Oct	Total (%)
Artificial pond	22	10	0	0	0	0	0	28	0	0	0	0	60 (4.90
Canals	0	4	32	0	0	0	0	0	13	42	0	0	91 (7..5)
Excavation ditches	0	0	0	0	0	0	0	90	0	0	46	0	136 (11.1)
Stream margins	0	122	102	150	113	24	4	0	0	0	0	0	515 (42.1)
Swamps	72	107	0	0	0	0	0	0	0	0	0	0	179 (14.6)
Rain pools	46	34	0	0	0	0	0	20	36	46	60	0	242 (19.8)
Total	**140**	**277**	**134**	**150**	**113**	**24**	**4**	**138**	**49**	**88**	**106**	**0**	**1223 (100.0)**

Table 23. Species of *Anopheles* larvae collected from various breeding sites in Akaki Town from September 1999 to October 2000.

Breeding sites	*An. arabiensis*	*An. christyi*	*An. cinereus*	Total
Artificial pond	0	27	0	27
Canals	14	70	0	84
Excavation ditch	36	111	0	147
Stream margin	0	492	0	492
Swamp	0	161	0	161
Rain pool	27	199	19	245
Total (%)	77 (6.7)	1060 (91.7)	19 (1.6)	1156

During the dry season small pockets of rain pools and associated collections of water disappeared. Hence breeding sites along the stream were sampled. Monthly distribution of larvae of *An. arabiensis*, *An. christyi* and *An. cinereus* is presented in Tables 24, 25 and 26, respectively. A stream margin was found to be a typical breeding site to *An. christyi*, and short lived breeding sites such as canals, excavation ditches, as well as rain pools were restricted to *An. gambiae* s. l.

Anopheles arabiensis appeared during the rainy season and several occurred from excavated ditch and rain pools. *Anopheles christyi* seem to breed throughout the year in stream margins, but also in excavated ditch, rain pools and canals during the rainy season. *Anopheles cinereus*, which only appeared during the rainy season, was found breeding in rain pools and in small numbers compared to the other anopheline species.

Table 24. Monthly distribution of *An. arabiensis* larvae different breeding sites in Akaki Town, September 1999 to October 2000.

Breeding Sites	Sep	Oct	Nov	1999 Dec	2000 Jan	Feb	Mar	Jun	Jul	Aug	Sep	Oct	Total
Artificial pond	0	0	0	0	0	0	0	0	0	0	0	0	0
Canal	0	0	0	0	0	0	0	0	5	9	0	0	14
Excavation ditch	0	0	0	0	0	0	0	34	0	0	2	0	36
Stream margin	0	0	0	0	0	0	0	0	0	0	0	0	0
Swamps	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain pool	0	0	0	0	0	0	0	8	3	10	6	0	27
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**42**	**8**	**19**	**8**	**0**	77

Table 25. Monthly distribution of *An. christyi* larvae in different breeding sites in Akaki Town, September 1999 October 2000.

Breeding Sites	Sep	Oct	Nov	1999 Dec	2000 Jan	Feb	Mar	Jun	Jul	Aug	Sep	Oct	Total
Artificial pond	17	10	0	0	0	0	0	0	0	0	0	0	27
Canals	0	4	32	0	0	0	0	0	4	30	0	0	70
Excavation ditch	0	0	0	0	0	0	0	88	0	0	23	0	111
Stream margin	0	120	98	142	104	24	4	0	0	0	0	0	492
Swamp	65	96	0	0	0	0	0	0	0	0	0	0	161
Rain pool	44	34	0	0	0	0	0	6	24	27	64	0	199
Total	**126**	**264**	**130**	**142**	**104**	**24**	**4**	**94**	**28**	**57**	**87**	**0**	**1060**

Table 26. Monthly distribution of *Anopheles cinereus* larvae in Akaki Town, Sept. 1999-Oct. 2000

Breeding Sites	Sep	Oct	Nov	1999 Dec	2000 Jan	Feb	Mar	Jun	Jul	Aug	Sep	Oct	Total
Artificial pond	0	0	0	0	0	0	0	0	0	0	0	0	0
Canal	0	0	0	0	0	0	0	0	0	0	0	0	0
Excavation ditch	0	0	0	0	0	0	0	0	0	0	0	0	0
Stream margin	0	0	0	0	0	0	0	0	0	0	0	0	0
Swamp	0	0	0	0	0	0	0	0	0	0	0	0	0
Rain pool	0	0	0	0	0	0	0	6	7	0	6	0	19
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**7**	**0**	**6**	**0**	**19**

Anopheles cinereus was obtained during June, July and September 2000, in the second survey. Thus, it is almost similar to *An. arabiensis* in its duration of distribution. Unlike both *An. arabiensis* and *An. christyi* it was present only in rain pool during this entomological survey period. In addition, this species was the least abundant relatively compared to these species. On the other hand, similar to *An. arabiensis* it was not obtained in the dry months of both study years.

5.4.2. ADULT MOSQUITO COLLECTION

During the study period, a total of 110 adult *Anopheles* species were collected by various methods and identified. The species and number of *Anopheles* and culicine mosquitoes collected by different methods is shown in Table 27. Of these *Anopheles* species, *An. arabiensis* and *An. christyi* were the most abundant comprising 50% and 44.5%, respectively. The other two species, *An. pharoensis* and *An. coustani*, were scarce. About three-fifth of the total *Anopheles* mosquitoes were caught with human-bait catches. A total of 3193 culicines were also caught with more than 90% of them were caught biting/landing on human-baits.

5.4.2.1 NIGHT BITING CATCHES

The result of night biting catches with the human-baits indoors and outdoors is shown in Table 28. The commonest species caught in night biting catches, were *An. arabiensis* and *An. christyi. Anopheles pharoensis* was also caught in small numbers throughout the survey in some months and *An. coustani* only one specimen in July 2000.

Table 27. Adult *Anopheles* mosquitoes collected by different methods in Akaki Town between October 1999 and October 2000.

Anopheles spp.	Human-bait	Space spray	CDC	Aspirator	Drop net	Total (%)
An. gambiae s. l. (=*An. arabiensis*)	36	12	7	0	0	55(50.0)
An. pharoensis	5	0	0	0	0	5(4.5)
An. coustani	1	0	0	0	0	1(1.0)
An. christyi	23	7	19	0	0	49(44.5)
Total *An.* Sp.(%)	65(59.1)	19(17.3)	26(23.6)	0(0)	0(0)	110(100.0)
Total culicine (%)	3193(91.3)	164(4.7)	95(2.7)	16(0.5)	30(0.8)	3498(100.0)

Table 28. Biting rates of *Anopheles* species caught on human-baits indoors and outdoors in Akaki Town between October 1999 and October 2000.

Months/ Years	No. man-nights*	*An. arabiensis* In	*An. arabiensis* Out	*An. pharoensis* In	*An. pharoensis* Out	*An. coustani* In	*An. coustani* Out	*An. christyi* In	*An. christyi* Out
Oct. 1999	10	0	0	1 (0.1)	1 (0.1)	0	0	0	0
Nov. 1999	10	0	0	1 (0.1)	0	0	0	0	1 (0.1)
Dec. 1999	8	0	0	0	0	0	0	0	0
Jan. 2000	8	0	0	0	0	0	0	0	0
Feb. 2000	8	0	0	0	0	0	0	0	0
Mar. 2000	8	0	0	0	0	0	0	0	0
Jun. 2000	8	0	3 (0.38)	1 (0.13)	0	0	0	0	0
Jul. 2000	16	2 (0.13)	4 (0.25)	0	0	0	1 (0.13)	0 (0)	2 (0.13)
Aug. 2000	16	2 (0.13)	5 (0.31)	0	0	0	0	1 (0.10)	9 (0.56)
Sep. 2000	16	1 (0.10)	16 (1.0)	0	0	0	0	3 (0.38)	3 (0.38)
Oct. 2000	16	0	3 (0.38)	1 (0.10)	0	0	0	0 (0)	4 (0.25)
Total (%)	124	5 (0.36)	31 (2.32)	4 (0.43)	1 (0.3)	0	1 (0.10)	4 (0.48)	19 (1.42)

( )= mosquitoes/man/night

*= No. man-nights varied to increase the chance of collecting much more anopheline mosquitoes during wet season.

The monthly anopheline biting rates per man per night of *An. arabiensis*, *An. pharoensis* and *An. christyi* collected using human bait catches are shown in Figures 7, 8 and 9, respectively. The outdoor density rose during August to a peak in September (1bite/man/night) and thereafter dropped by October for *An. arabiensis*. But, this was not found true for indoor catches that remained similar in July through September. Similarly, *An. christyi* seems to have shown an immediate rise in August that slowly declined in October in outdoor collections.

Fig. 7. Monthly densities of
An. arabiensis in night biting catches
in Akaki Town, Oct. 1999 to Oct. 2000.

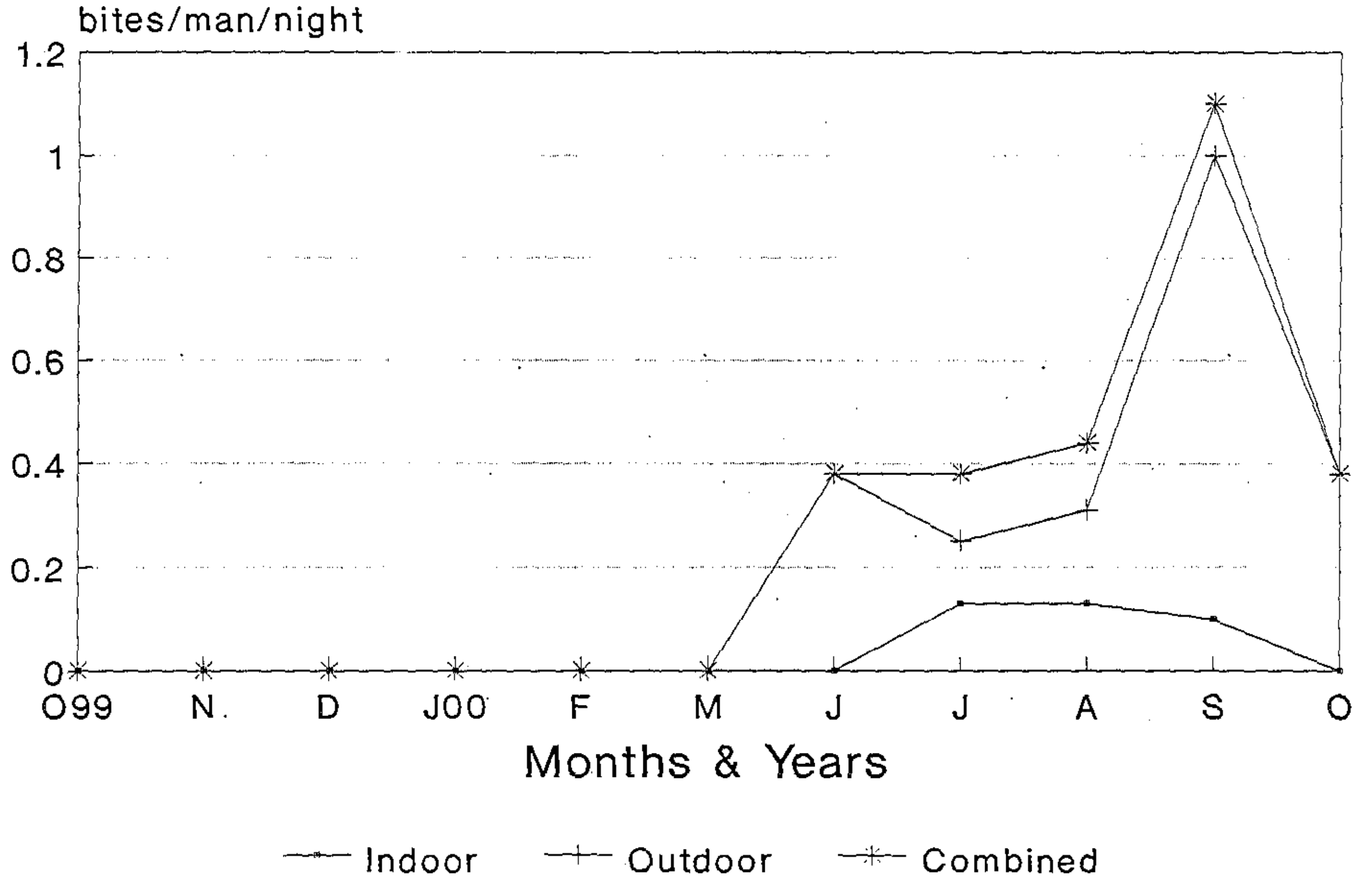


Fig. 8 Monthly densities of
An. pharoensis in human bait catches,
Akaki Town, Oct. 1999 to Oct. 2000.

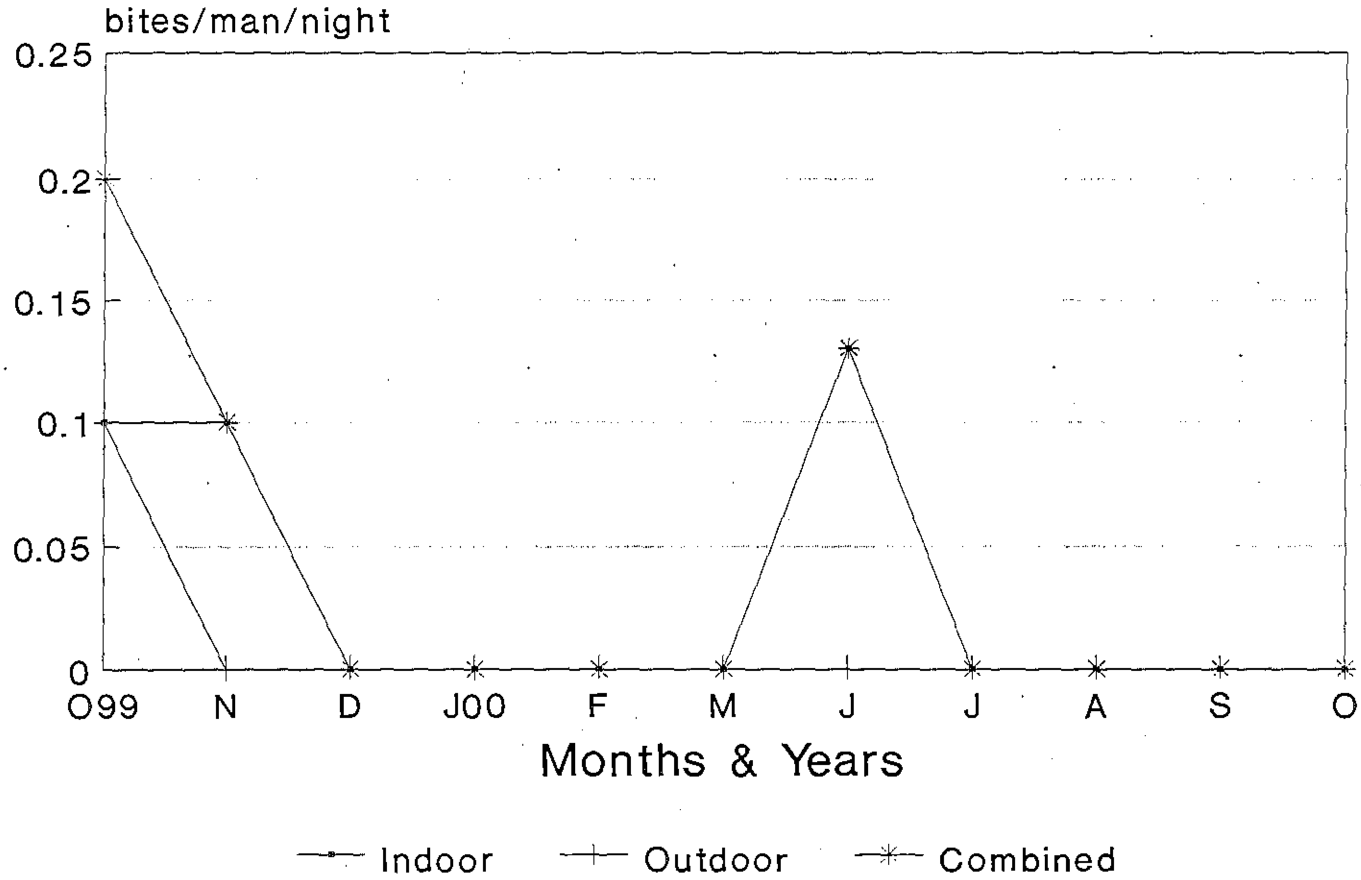
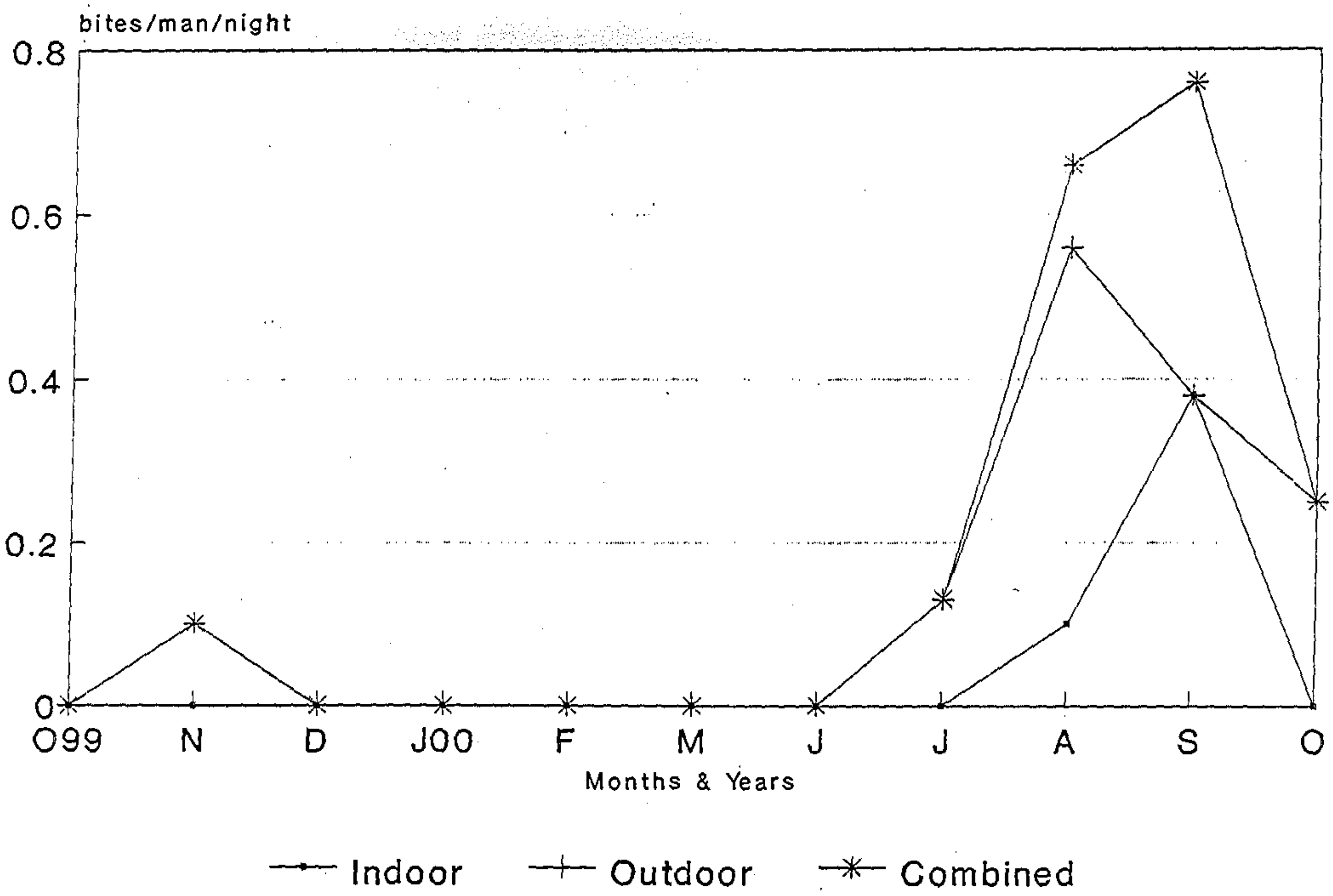


Fig. 9. Monthly densities of *An christyi* in night biting catches in Akaki town, Oct. 1999 to Oct. 2000.



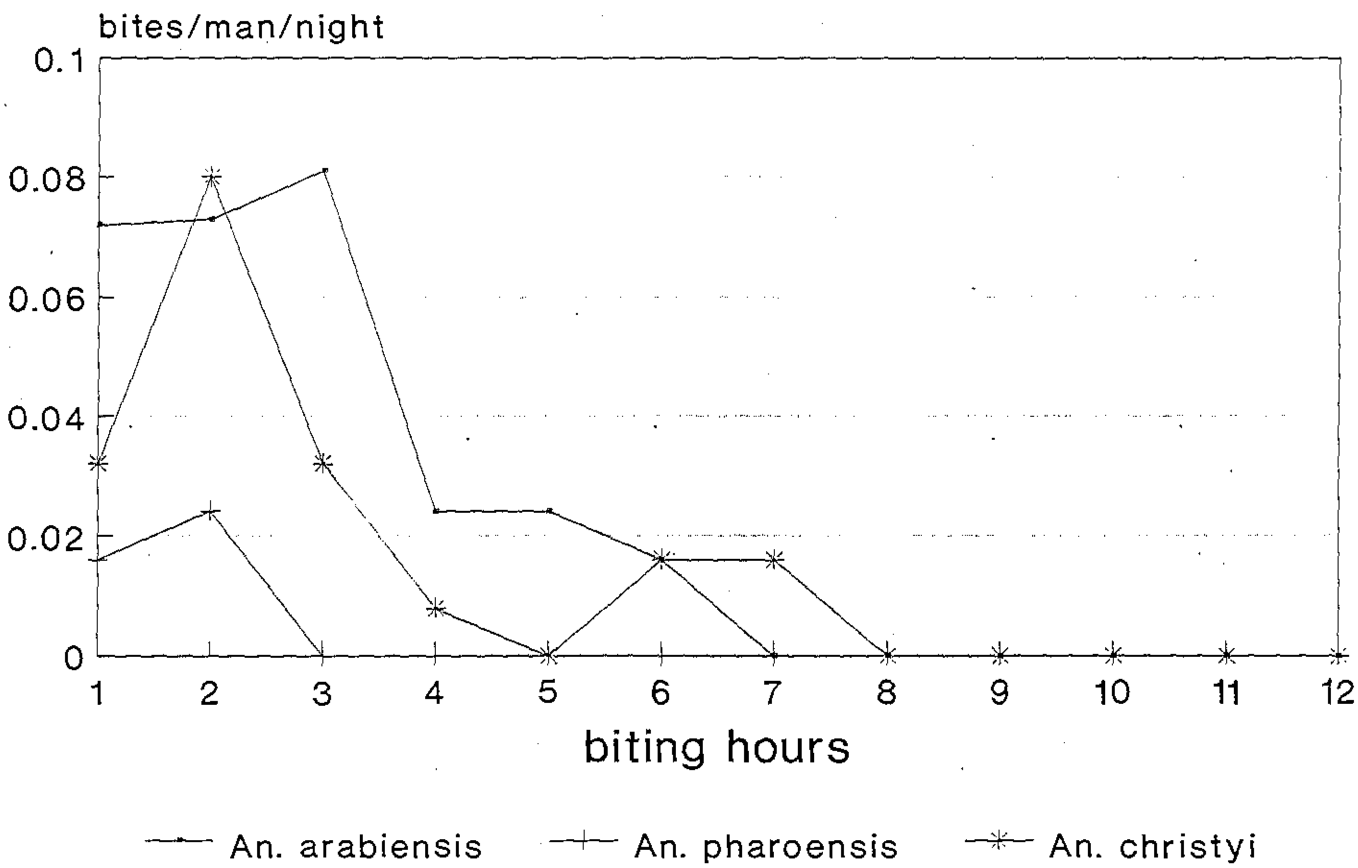
High prevalence of *An. arabiensis* and *An. christyi* in the area appears to be associated with heavy rainfall, which produces many small water collections favoring intensive breeding of these species. The average biting cycles of *Anopheles* species is presented in Table 29. Both *An. arabiensis* and *An. christyi* were predominantly caught biting/landing on human-bait outdoor. Anophelines biting activities were observed to be vigorous before mid-night. For instance, *An. arabiensis* was observed to bite actively before the mid-night and completely disappeared after 24:00 hrs.

It is evident that biting cycle of *An. arabiensis* slowly increase until it reaches the peak activity between 20:00 and 21:00 hrs, then dropped to very low numbers biting until 23:00 to 24:00hrs. The hourly biting activities of *Anopheles* mosquitoes captured on human bait were recorded to determine the biting pattern of the species involved (Fig. 10). The peak biting time of *An. pharoensis* was not determined due to limited collections. More indoor than outdoor biting by this species was observed between 19:00 and 20:00 hrs. *Anopheles christyi* were observed to actively bite and peaks at early evening between 18:00 and 21:00hrs, followed by a sharp decline between 21:00 and 22:00hrs. Followed by a disappearance between 22:00 and 23:00hrs it occurred with a slight rise from 24:00 to 01:00hrs. *Anopheles christyi* as a whole, except between 18:00 and 19:00hrs were observed biting outside throughout. *Anopheles coustani* was observed to bite outdoors between 21:00 and 22:00hrs. More outdoor than indoor biting by *An. christyi* was observed at all hrs. Biting activity by *An. pharoensis* occurred in dispersed fashion among different periods of the study.

Table 29. Biting cycles of *Anopheles* species caught biting/landing on human-baits indoors and outdoors in Akaki Town between October 1999 and October 2000.

Time	*An. arabiensis*		*An. pharoensis*		*An. coustani*		*An. christyi*	
	In	Out	In	Out	In	Out	In	Out
18-19	2 (0.016)	7 (0.056)	1 (0.008)	1 (0.008)	0	0	1 (0.008)	3 (0.024)
19-20	1 (0.008)	8 (0.065)	3 (0.024)	0	0	0	3 (0.024)	7 (0.056)
20-21	0	10 (0.081)	0	0	0	0	0	4 (0.032)
21-22	0	3 (0.024)	0	0	0	1 (0.008)	0	1 (0.008)
22-23	1 (0.008)	2 (0.016)	0	0	0	0	0	0
23-24	1 (0.008)	1 (0.008)	0	0	0	0	0	2 (0.016)
24-01	0	0	0	0	0	0	0	2 (0.016)
01-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
02-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
03-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
05-06	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5 (0.4)	31 (0.25)	4 (0.32)	1 (0.008)	0	1 (0.008)	4 0.32	19 (0.152)

Fig. 10. Biting cycles of the commonest anophelines in human-bait catches both indoor and outdoor combined, Akaki Town, Oct. 1999 to Oct. 2000.



1=18-19 2=19-20 3=20-21 4=21-22
5=22-23 6=23-24 7=24-01 8=01-02
9=02-03 10=03-04 11=04-05 12=05-06

5.4.2.2 INDOOR SPACE SPRAY CATCHES AND CDC LIGHT-TRAP

The results of indoor space spray catches for selected houses in Akaki Town is shown in Table 30. A total of 19 *Anopheles* mosquitoes were caught of which 12(63.2) and 7(36.8%) of them were *An. arabiensis* and *An. christyi*, respectively. The monthly abundance of *An. arabiensis* was the highest (0.4 bites/man/night) during July. However, in all the rest of the months the density of this species was apparently equal. *Anopheles christyi* was only collected in one month September 2000. The most abundant species in this catch was *An. arabiensis* (63.2%).

Figure 11 shows the monthly distribution of mosquito bites/house/night throughout the survey. *Anopheles arabiensis* appeared in June through October, with highest density in July. But *An. christyi* was caught only once in September. For both species heavy rains preceded their appearance and increase in densities. Even though *An. arabiensis* is abundant species in both night biting and space spray catches this species was found to bite commonly outdoors. The result of CDC light-trap catches is presented in Table 31. *Anopheles christyi* is the commonest species caught only in August and September. *Anopheles arabiensis* was caught only once in September.

Table 30. Monthly densities of different *Anopheles* species collected using space spray methods in Akaki Town between October 1999 and October 2000.

Months/ Years	No. Houses searched	*An. arabiensis*		*An. pharoensis*		*An. coustani*		*An. christyi*		Total	
		a	b	a	b	a	b	a	b	a	b
Oct. 1999	4	0	0	0	0	0	0	0	0	0	0
Nov. 1999	4	0	0	0	0	0	0	0	0	0	0
Dec. 1999	4	0	0	0	0	0	0	0	0	0	0
Jan. 2000	4	0	0	0	0	0	0	0	0	0	0
Feb. 2000	4	0	0	0	0	0	0	0	0	0	0
Mar. 2000	4	0	0	0	0	0	0	0	0	0	0
Jun. 2000	10	1	0.1	0	0	0	0	0	0	1	0.1
Jul. 2000	10	4	0.4	0	0	0	0	0	0	4	0.4
Aug. 2000	16	2	0.13	0	0	0	0	0	0	2	0.13
Sep. 2000	18	3	0.17	0	0	0	0	7	0.39	3	0.56
Oct. 2000	18	2	0.11	0	0	0	0	0	0	2	0.11
Total (%)	96	12	0.91	0	0	0	0	7	0.39	19	1.3

a= Total mosquitoes collected, b =Mosquitoes/hut/night

Fig. 11. Monthly densities of An. arabiensis and An. christyi caught by space spray method in Akaki Town befween Oct. 1999 and Oct. 2000

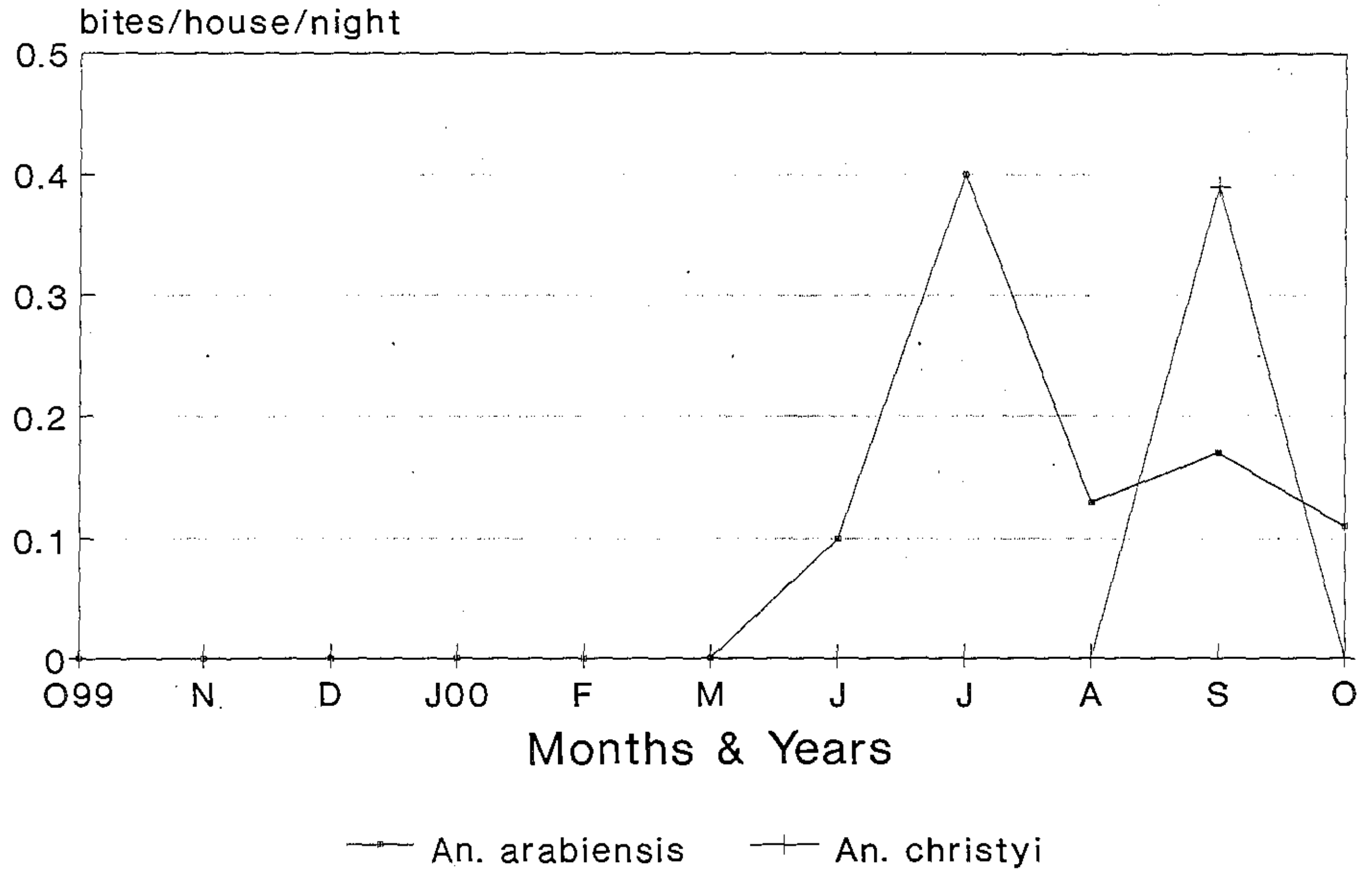


Table 31. Monthly densities of different *Anopheles* species collected using CDC light-traps in Akaki Town between October 1999 and October 2000.

Months/ Years	No. light-traps	*An. arabiensis* a	*An. arabiensis* b	*An. pharoensis* a	*An. pharoensis* b	*An. coustani* a	*An. coustani* b	*An. christyi* a	*An. christyi* b	Total a	Total b
Oct. 1999	2	0	0	0	0	0	0	0	0	0	0
Nov. 1999	2	0	0	0	0	0	0	0	0	0	0
Dec. 1999	2	0	0	0	0	0	0	0	0	0	0
Jan. 2000	2	0	0	0	0	0	0	0	0	0	0
Feb. 2000	2	0	0	0	0	0	0	0	0	0	0
Mar. 2000	2	0	0	0	0	0	0	0	0	0	0
Jun. 2000	2	0	0	0	0	0	0	0	0	0	0
Jul. 2000	2	0	0	0	0	0	0	0	0	0	0
Aug. 2000	2	0	0	0	0	0	0	2	1.0	2	1.0
Sep. 2000	2	5	2.5	0	0	0	0	19	14.5	24	17.0
Oct. 2000	2	0	0	0	0	0	0	0	0	0	0
Total	22	5	2.5	0	0	0	0	21	15.5	26	18.0

a =Total mosquitoes collected, b =Mosquitoes/trap/night)

5.4.2.3 DISSECTION RESULTS

The results of dissection of *Anopheles* species caught by different methods are shown in Table 32. A total of 43 *An. arabiensis* were dissected of which 1(2.3%) were parous. None were found infected with sporozoite. Moreover, of the total 2 and 1 *An. pharoensis* and *An. coustani* dissected, respectively, none were parous and infected with sporozoite. But of a total 49 *An. christyi* dissected 6(12.2%) were parous and none were infected with sporozoite.

Table 32. Dissection results of *Anopheles* species in Akaki Town between October 1999 and October 2000.

Species	Human-bait	CDC	Space spray	Total
An. arabiensis				
No. dissected	33	5	5	43
No. parous (%)	1(3.0)	0(0)	0(0)	1(2.3)
No. infected (%)	0(0)	0(0)	0(0)	0(0)
An. pharoensis				
No. dissected	2	0	0	2
No. parous (%)	0(0)	0(0)	0(0)	0(0)
No. infected (%)	0(0)	0(0)	0(0)	0(0)
An. coustani				
No. dissected	1	0	0	1
No. parous (%)	0(0)	0(0)	0(0)	0(0)
No. infected (%)	0(0)	0(0)	0(0)	0(0)
An. christyi				
No. dissected	23	21	5	49
No. parous (%)	1(4.4)	5(23.8)	0(0)	6(12.2)
No. infected (%)	0(0)	0(0)	0(0)	0(0)
Total				
No. dissected	59	26	10	95
No. parous (%)	2(3.4)	5(19.2)	0(0)	7(7.4)
No. infected (%)	0(0)	0(0)	0(0)	0(0)

5.5.3. METEOROLOGICAL FACTORS

Table 33 shows the monthly total rainfall, average relative humidity, and maximum, minimum and mean temperature readings in Akaki Town. Heavy rainfall was recorded in July and August, which is true in most part of the country. The mean temperature ranges from 14 to 18.2°C recorded in November and May, respectively. The relative humidity was also above 51% throughout the survey. On the other hand, a prolonged rainfall in normally dry or with minimum rainfall in October and November recorded in 1997.

The difference from the mean of maximum and minimum temperature relative to mean of 1995 to 2000 is presented in Fig. 12. Difference from the mean of both minimum and maximum annual mean temperature in 1997 and 1998 of Akaki Town rose by 0.6°C and 0.5°C, respectively.

Appendix 4 shows a climatic change of the last three decades expressed as a change from the mean (anomalies) of Akaki Town. In the past more than three decades a significant annual mean temperature rise was seen after late 1980 in this Town. Otherwise a trend of reduction in rainfall was observed especially after early 1990s. Similarly, an average relative humidity increased from early 1980s with high variability among years.

Table 33. Maximum, minimum, average mean temperature, average mean relative humidity and total monthly rainfall of Akaki Town from June 1
to December 2000.

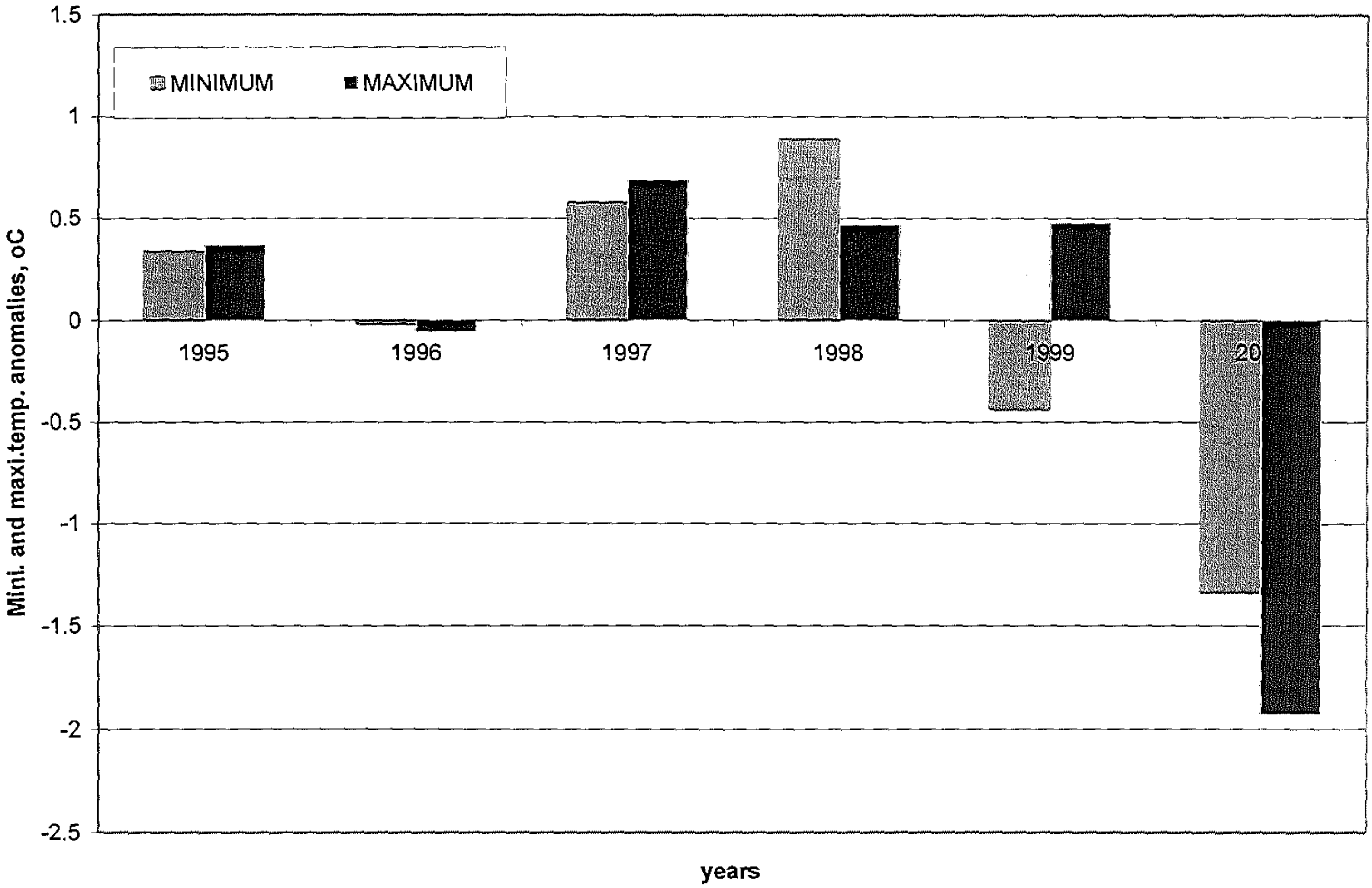
Fact.	Jun	Jul	Aug	Sep	Oct	Nov	1999 Dec	2000 Jan	Feb	Mar	May	Jun	Jul	Aug	Sep	Oct
RF	92.8	282.6	300.7	61.7	65.0	0.0	0.0	0.0	0.0	39.6	131.9	103.8	215.7	192.4	155.2	19.6
Max.	24.6	20.5	20.6	22.1	21.8	22.6	22.7	24.3	25.4	26.7	25.4	23.1	21.5	20.5	21.2	22.5
Min.	10.3	10.5	10.4	9.8	9.2	5.4	5.6	5.5	6.0	8.9	11.0	10.1	11.0	10.8	10.6	8.9
Mean *	17.5	15.5	15.5	16.0	15.5	14.0	14.3	14.9	15.7	17.8	18.2	16.6	16.3	15.7	15.9	15.7
RH^+	64	81	80	72	X	51	X	52	X	X	56	67	74	75	73	62

*= Max. + Min./2, += Readings at 0300+ 0900 + 1500hrs/3

X= RH data not obtained for October, December, February and March and for all factors in April 2000.

Source: National Meteorological Service Agency (NMSA).

Fig. 12. Annual mean minimum and maximum temperature expressed as anomalies relative to 1995 to 2000, Akaki Town (source: NMSA).



6. DISCUSSION

In Ethiopia the upper limit of malaria transmission was known to be 2000m.a.s.l with few exceptions of frequent epidemics above this limit. Many Italian and British malariologists of pre-eradication program have indicated the presence of active malaria transmission below 2000m.a.s.l. Thus, the National Malaria Eradication Campaign of 1967 was undertaken in areas below this elevation (Gebre-Mariam, 1984; Gish, 1992). As far as the elevation of Akaki Town is concerned, it is 2110m. It was one of the areas excluded from this campaign. Nevertheless, the present study confirmed the existence of locally contracted malaria transmission in Akaki Town, i. e., beyond its known upper limit.

In earlier surveys, *P. falciparum* was reported to be the predominant species in many places (Fountaine *et al.*, 1961; Krafsur, 1977; Krafsur and Armstrong, 1978; Gebre-Mariam, 1984). According to their reports, *P. vivax* was also found to be an important species, even though widely distributed at higher altitudes. *Plasmodium malariae* was also commonly reported in Ethiopia, for instance, from south and southwest, and Awash Valley (Armstrong, 1972 cited in Krafsur and Armstrong, 1978; Krafsur and Armstrong, 1982; Annual report of MOH, 2000). But the occurrences of *P. ovale* infections were localized to southwestern lowland areas (Armstrong, 1969 cited in Gebre-Mariam, 1984; Krafsur and Armstrong, 1978). Fountaine *et al.* (1961) reported from country wide survey the prevalence of *P. falciparum* in the country to be as high as 60%, while that of *P. vivax* to be 25% and that of *P. malariae* to be 15%.

From the record reviews of Addis Ababa City Administration malaria is one of the major causes of morbidity congesting health services. In the last half a decade years, a total of more than a quarter of a million malaria cases were treated at different health services in Addis Ababa City Administration, with an average of four thousand cases each year. It is interesting to note that malaria cases were also seen in age groups less than 5 years including infants. However, the majority of the cases were in the age groups above 15 years old. Furthermore, higher numbers of cases were detected in the years 1997 and 1998 coinciding with the epidemic years of malaria.

Obviously, most of the malaria cases are considered to be internally imported and referred cases from malaria endemic regions. Residents and visitors from malaria endemic areas such as Mojjo, Debre-Zeit, Nazareth, Sodere and their surroundings might visit these health services in seeking better services.

A rise in malaria cases from the mid-1990s and reaching its maximum in 1998 was also in agreement with overall pattern of malaria situation in the country. *Plasmodium vivax* was the predominant malaria parasite. This species outnumbers *P. falciparum* by two folds in age groups 15 years and above. *Plasmodium malariae* was the least malaria parasite recorded. *Plasmodium ovale* was not diagnosed in health service units of the area.

On the other hand, the occurrence of active malaria transmission in Addis Ababa could not be disregarded. For instance, a considerable number of infants and children aged 1 to 4 years were diagnosed for malaria both clinically and microscopically. These age groups are less mobile in a stable community. Of the total health centers, Tekle-Haimanot Health Center was previously serving as referral to malaria cases for laboratory diagnosis in Addis Ababa. Thus, people preferred to go to this health center when they suspected malaria and might be the cause for an increment of malaria cases. An early study (Martin, 1943) confirmed the occurrence of indigenous malaria transmission in Addis Ababa around the area locally known as Filwuha (hot spring), 2470m a. s l. at the middle of the City. The author recorded four cases of malaria. One of these patients was a child of 5 years who had never left Addis Ababa, and the other three had not been out of the city for the proceeding 10 years. Three were *P. vivax* infections and one *P. falciparum*. Moreover, adult *An. gambiae* s. l. was frequently found in the railway concession of Addis Ababa during this study. Ovazza and Neri (1955) also mentioned the presence of combination of favorable conditions provided in the Akaki Valley by the presence of the warm springs, the artificial lakes (Abba Samuel) and the sheltered gorges which encourage the survival of *An. gambiae* s. l. Based on this fact they have suggested that this species could in certain circumstances extend its upward range and reach suitable breeding places in the warm springs of the Filwuha area of Addis Ababa. However, further systematic survey of parasitological and entomological parameters are required to confirm the occurrence of active malaria transmission in Addis Ababa City.

Health service reports from outpatient consultation at Akaki Health Center from 1996 to 2000 also show that malaria is one of the major causes of illnesses in Akaki Town and surrounding areas. The highest malaria cases were seen during 1997/98. It was an epidemic year in most parts of the country. For instance, all the Districts of West Shoa, Central Ethiopia, previously malaria free highland areas were affected. It is believed that this was due to abnormal climatic conditions such as a prolonged duration of rain to dry season and rise of both minimum and maximum temperature, which consequently entails malaria transmission in restricted highland areas bordering endemic localities.

On average, about 9% of the total illnesses treated at Akaki Health Center were due to malaria in the last five years. The peak malaria transmission occurs in October following cessation of wet season. On the other hand, the contribution of small rainy season in March and April is limited, except a little increase was observed in 1998. This might be partly due to a prolonged rain to normally dry months in this year.

It is worth mentioning that children <5 years were found diagnosed both clinically and microscopically from 1997 onwards in Akaki Town and that, the laboratory-diagnosed malaria cases at health services include *P. vivax* and *P. falciparum*, the two epidemiologically important species though rarely *P. malariae* as well. *Plasmodium vivax* is the dominant species. It comprised 72% of the total confirmed malaria cases diagnosed between 1996 and 2000. The predominance of *P. vivax* in Akaki Town was observed from reports of Debre Zeit Malaria Control laboratory (Dereje Olana, Pers. Comm., 1999) and Akaki Health Center. On the other hand, detection of *P. malariae* might be ascertained to either mis-diagnosis or internally imported cases owing to population movement especially laborers during harvesting that overlaps with malaria transmission season.

Early studies of Lega *et al.* (1937) documented the predominance of *P. vivax* at heights of 1500m. a. s. l. and on the western slopes as well as eastern parts of the country. Relapse cases of *P. vivax* could also escalate the number of cases. A study conducted in Chennai, India has shown that among the total 100 cases of *P. vivax*, 47% had a relapse, of which 90% gave history of irregular treatment for malaria (Murugesan *et al.*, 2000). Furthermore, Sponsler (2000) reviewed the epidemiological importance of *P. vivax* in urban areas of India. This implies the predominance of this species in urban centers. The highland areas of Ethiopia unlike the lowland areas with tropical climate favor the wide distribution of *P. vivax*. Bruce-Chwatt's (1993) indicated the geographical prevalence of this species in many temperate zones in the world.

However, the pre-control situation has been disturbed by anti-malarial measures, and the distribution and species dominance pattern seems to have obviously changed (Gebre-Mariam, 1984). Therefore, over all predominance of *P. falciparum* is known in the country (MOH, 2000). A review by Kitaw *et al.* (1998) has also shown that *P. falciparum* is the dominant species over all in the country, making up to 60-75% of all cases in most endemic regions, going over 75% during epidemics.

The present parasitological survey conducted in Akaki Town revealed the presence of autochthonous malaria transmission. Of a total 2136 blood films examined during the survey, October to December, 78(3.7%) were found to be malaria infected. From this survey, conducted for three months on the same subjects, totally 78 individuals were found positive for malaria with more proportion (6.7%) in the second survey followed by the first (4.2%) and no malaria detected in the last survey. More interestingly, the prevalence of *Plasmodium* species showed variation between the first two surveys. *Plasmodium falciparum* showed predominance (70%) in the first survey, while *P. vivax* predominated during the second survey (93.7%). This variation might be due to the seasonality of the two important parasites. It is generally known that *P. falciparum* is the dominant species during the peak malaria transmission season in September and October while *P. vivax* tends to dominate during the dry season in Ethiopia (Kitaw *et al.*, 1998). The absence of any case during the third survey in

December (dry season) might be attributed to reduced availability of favorable conditions for the breeding of the vectors and consequently limiting transmission of the parasites.

In the present study, the highest prevalence of malaria was detected in one of the Zones, peripheral area, southern most of the Town. Moreover, variation in prevalence of malaria infection between central and peripheral locations of the Town was observed. The risk of contracting malaria in the inhabitants residing in peripheral areas is higher than the central ones (OR= 38.7, 5.3 to 279.9, RR=0.85,95% CL). The extension of Akaki Town to south and southwestern direction to low-lying plains in the last five to seven years is partly considered to have created favorable environment to mosquito breeding. Artificial breeding sites due to construction activities are also favoring the breeding of *An. arabiensis*, which is widely distributed and responsible to the epidemic. This micro-ecological alteration created suitable condition to prolific vector distribution and case build up effected by climate change.

Moreover, the houses in the newly designed site at the periphery are relatively scattered with open field and allowing more surface water unlike the old (central) parts. In fact, the former site is peri-urban type adjacent to farmland with a typical mosquito breeding sites (artificial and natural), and scattered houses favorable to man-vector contact. But in the latter case, houses are overcrowded and compact that prohibits water collection and intensive human interference for different household purposes.

Yohannes and Petros (1996) also reported variation in malaria prevalence between central and peripheral sites of Nazareth, where the disease predominantly affected the peripheral parts of the Town. This is considered to be as a result of proximity to breeding sites as suggested by Greenwood (1989). Entomological studies demonstrated the importance of this site to malaria transmission. Kazadi *et al.* (2000) reported the variation of malaria transmission between different areas in Kinshasa. Prevalence of 18% to 71% in school children aged 5 to 9 years were documented in this study. Similarly, a review by Mendez (2000) on urban malaria has shown the clustering of malaria at the peri-urban zones and evidenced by positive breeding sites for *Anopheles* species in this area. In addition, Riberio *et al.* (1998) identified a difference in spatial distribution of vectors in an Ethiopian village around Arba Minch.

Comparison of malaria infection among different age groups was not highly significant (χ^2=1.56, 3 DF, P=0.66). The occurrence of malaria infection in infants or children in stable communities confirms continuous local transmission. In fact, exposure to vectors increase with age, if the average exposure is high, its increase with age is probably not very important. With respect to source of infection, the size of the adult population partly compensates for the low infection rate of adult individuals. The standard characterization of the epidemiology of malaria is based on an age-prevalence curve or an age-stratification, showing the proportion of each age group with malaria positive blood smears. Therefore, in areas of high endemicity and hyperendemicity conditions, prevalence of infection peaks at an early age with an increase up to the age of 5 years and show a sudden fall in the age groups of 10-15 years and then slowly declines with age (WHO, 2000b). However, in populations where malaria was either previously absent or persisted at low or moderate endemic level they are characterized by a high incidence at all age groups (Boyd, 1949 cited in WHO, 2000b). A study conducted in Nazareth has shown a parasite rate of statistically significant (χ^2=134.89; $P< 0.0001$) in inter-age variations (Yohannes and Petros, 1996). But it did not show a distinct peak and decline with an increase in age. The fact that the parasite rates did not peak and decline with an increase in age in the population was suggested to be due to a slow development of immunity to malaria in Nazareth. This is owing to easy access to anti-malarial drugs, or a low transmission level brought about by the control measures. The prevalence of malaria in moderate and low endemic areas, such as urban Bueraventura, Colombia, has been classically described as one increasing with age from younger ages in children to finally stabilizing in adults (Aron, 1988 cited in Mendez, 2000). The determinant factors have been associated with behavioral factors such as mobility to the forest. In these situations, it is expected that children and older individuals are less exposed and, subsequently, the incidence of disease is higher in adults aged 20-39 years (Aranha *et al.*, 1996). A similar pattern of transmission was reported in a hypoendemic region in the Philippines where malaria prevalence of 11% in individuals aged 11-19 years was noted (Beliazario *et al.*, 1997). Also, a study conducted in a rural community in the Pacific Coast of Colombia showed a prevalence of infection from 10.4% in those aged 0-9 years to 5.2% in individuals aged >44 years (Gonzalez *et al.*, 1997). A similar study conducted in urban communities of Buenaventura in the Pacific Coast of Colombia indicated that malaria prevalence decreased from 6.5% in children aged 0-9 years to 4.3%, 4.1% and 2.6% in individuals aged 10-19, 20-39 and 40 years and above, respectively. Nevertheless, a significant difference was found only between the first (0-9 years) and last (40 years and above) categories (Mendez *et al.*, 2000). This lower risk in older individuals was suggested to be because of development of immunity against the disease after many years of chronic exposure. In the setting of our study, the most likely scenario is that younger children have acquired low infection compared to other age groups. No gametocyte carriers were observed, i. e., also related to lower infectivity rate and sporozoite circulation in the community. Moreover, intensive epidemic control measures during the previous years, 1997/98, such as mass drug administration, treatment of confirmed cases and vector controls utilized are reckoned to have contributed similarly to low infection rate. In addition, high consumption of anti-malarial drugs in such urban centers is expected to minimize the possibility of obtaining gametocyte from the prevailing infection. But the low density of vector species of malaria in the area owing to different environmental factors could partly play a crucial role in malaria transmission.

The presence of asymptomatic cases in such hypoendemic areas like Akaki is an implication of concomitant immunity developed on repeated infection of malaria.

On the other hand, the choice of treatment has been shown to be affected by a number of factors including access, cost, attitudes towards providers and beliefs about disease (McCombie, 1996). A similar study confirmed that knowledge of disease and of prevention by elimination of breeding sites had a negative impact on malaria. From the KAP survey, most of the inhabitants were found to prefer modern treatment practices than traditional healing. In the current study, out of a total 116 heads of households, 94% replied they prefer to go to different health facilities for malaria treatment. Of those, 15.5% preferred malaria control laboratory found at Debre-Zeit 23Km away from Akaki Town. Similarly, a study in Ziway area (Abose *et al.*, 1998b) has shown that 96.4% of the total households (n=112) preferred to visit a health facility when they need treatment for malaria. Of the 112 interviewees, 72.3% replied that they visit malaria control laboratory, while 21.4% said they would go either to the malaria control laboratory or to another modern treatment clinics showing that the malaria control laboratory is preferred by most of the respondents (93.7%). Yeneneh *et al.* (1993) also reported similar observations.

Regarding the specific causes of malaria disease, about three-fourth of the study households replied that malaria is transmitted by mosquito bite, the rest gave different reasons. The study thus shows that most of the individuals included in the study in Akaki seem to be well aware of the disease and its transmission. In contrast, in Ziway area only one-third of the total interviewees said they get malaria through mosquitoes (Abose *et al.*, 1998b). A study conducted in the same area by Yeneneh *et al.* (1993), reported that the causes of malaria as understood by the women interviewees included: cold, cloudy weather and rain (34.3%); eating maize stalk (21.7%); mosquito bites (17.3%), and dirt and flies (9.7%). Only 4.5% said that malaria was transmitted by the mosquito bites. The discrepancy of knowledge between these two areas on the cause of malaria might be due to variation in accessibility to information between urban and rural areas.

Of the breeding sites investigated for anopheline larvae in the current study, stream margins were the most prolific ones throughout the survey period. It was the only site that supported anopheline larvae during the dry season. In fact, during this season the reduction of the level of the stream resulted in the appearance of floating green algae and its disturbance by cattle and humans. As soon as the level of the stream was reduced, reduction of *Anopheles* larvae and replacement with *Culex* species was observed. Earlier studies in South Africa also found that pools overgrown with algae (*Lemna minor* and *Wollfia arrhiza*) were free from *Anopheles* larvae, whereas adjacent pools not containing these plants harbored larvae, including those of *An. gambiae* (Hopkins, 1952).

Qualitative observations on collected and identified larvae in the study area showed variation among the anophelines in different breeding sites. *Anopheles arabiensis* was sampled from temporary breeding sites such as canals, excavation ditch and rain pool with emergent vegetation and sunlit. This species was known to exhibit a wide ecological range as its breeding habitat (Tulu, 1993). Considerably, larger numbers of larvae of this species were identified from stream margin, rain pool and swamp. This species seems to start breeding in the main rainy season in June, a time when temporarily breeding sites become abundant. Many earlier studies have indicated that it predominantly prefers temporary, clear and sun lit water bodies created mainly during rainy season (Gillies and De Meillon, 1968; Hopkins, 1952). Moreover, *An. christyi* larvae were abundant and collected from almost all kinds of breeding habitats such as artificial pond, swamp and stream margin. Unlike *An. arabiensis* it occurred throughout the survey period both in dry and wet seasons. The highest larval density of *An. arabiensis* was collected from excavation ditch and rain pool during the wet season. In contrast, *An. christyi* was abundantly obtained both during wet and dry season. But *An. cinerus* larvae were the least available during this survey. *Anopheles cinereus* was obtained rarely only in rain pool. It was commonly reported as a highland anopheline occurring in rain pools such as in Addis Ababa, 2457m; Entoto, 3000m (Ovazza and Neri, 1955; Giaquinto-Mira, 1950). Generally, larval densities of the anopheline species were closely associated with the availability of temporary suitable breeding places in different parts of the year, except *An. christyi* that breeds in permanent water body. Such habitat that favors the vector species was only observed at the peripheral site of the Town.

In addition, the present study confirmed that *An. christyi* tolerates pollution of breeding sites with organic substances. Since Akaki is an industrial town, industrial liquid waste and toxic substances are being dumped into Akaki River from these industries for the last three decades. For instance, a recent study that indirectly confirmed the occurrence of toxic substances in vegetables grown along the river banks in excess to its normal concentration is worth mentioning as an indicator of the occurrence of pollution in the area Akaki River (Fisseha Itanna, 1998). This is certainly due to breeding affinity of *An. gambiae* s. l. to sun lit, clear and small water collections. Earlier studies in Ethiopia have also confirmed that the larvae of *An. christyi* unusually tolerate relatively high levels of pollution (Ovazza *et al*., 1956 cited in Gillies and De Meillon, 1968). Another study also revealed that this species occurred in polluted sites in the Town of Dessie and the surrounding localities, Northern Ethiopia (Bevan, 1937). Hopkins (1952) reviewed the inhibitory effects of effluent from sugar factories, sisal and coffee waste to the breeding of *Anopheles* in other African countries. In contrast, *Anopheles christyi* was reported to tolerate a greater degree of organic pollution than other species of *Anopheles* including *An. gambiae* s. l. On the other hand, this pollution of the surrounding area including Akaki River could perhaps suppress the distribution of the main malaria vector, consequently, influencing the prevalence of malaria transmission in the Town.

Therefore, this ecological change might upset the breeding and survival of *An. gambiae*, the principal vector of malaria in Ethiopia that requires clear, small and sunlit breeding site.

Adult catches were more successful using human-bait, CDC light traps and space spray in which *An. arabiensis* was the most abundant followed by *An. christyi, An.*

pharoensis and *An. coustani.* However, the latter two species were only obtained by human-bait catches with very low density. The other two methods, aspirator and drop net collections, could not yield anophelines.

On the other hand, a total of 3498 adult culicines were caught, with about 30 folds of anophelines, in Akaki Town. A similar study in one of the African cities, urban area of Kinshasa, also indicated the low density of anophelines and predominance of culicines especially *Culex quinquefasciatus* (Coene, 1993). Several studies have indicated that this species greatly outnumbers malaria vectors, often by more than 100 to 1 in African towns and cities (Trape and Zoulani, 1987 cited in Coene, 1993). In the present study, no attempt was done to identify the culicines. However, it is likely that the majority were probably *Culex quinquefasciatus* since it commonly breeds in organically polluted waters in urban areas where it is a common biting nuisance including Ethiopia (Dr. Teshome, Pers. Comm.). Proliferation of adult anophelines was considered to be following the appearance of first rain and rise in ambient temperature. Therefore, variations of adult anopheline densities depend on availability of breeding sites.

The build up of the man-biting densities of *An. arabiensis* and *An. christyi* was noted between June and October. This rise was partly due to the appearance of suitable breeding sites as already mentioned in larval collections. Appearance of the minor rains and increment of mean temperature during March through June was observed during this period. Then, peak biting occurred just after heavy rains from August to September, which declined immediately after. By October, the breeding habitats were completely dried up compared to the same month of the previous year.

Man-biting densities of *An. pharoensis* and *An. coustani* did not show a clear-cut seasonality, because of scarcity of these species in the area. The scarcity adults of *An. pharoensis* and *An. coustani* and their absence in larval stages may be due to the absence of permanent water bodies in higher altitudes suitable for breeding. *Anopheles pharoensis* is known to prefer permanent water bodies at lower altitudes (Gillies and De Meillon, 1968; Tulu, 1993).

Since *An. christyi* was found to breed in almost all the water collections investigated, its low biting density may be related to its poor anthropophilic behavior. It is believed to be predominantly zoophilic. For example, in Kenya and Rwanda only 12 % and 5% were positive for human blood, respectively while samples from Addis Ababa were nil (Gillies and De Meillon, 1968).

It is to be noticed that *An. arabiensis, An. chriysti* and *An. pharoensis* were the three important anthropophilic species in Akaki in their decreasing order. *Anopheles arabiensis* and *An. chriysti* fed both indoors and outdoors but were predominantly exophagic in their behavior. Similar observations have been reported in Ziway by Abose *et al.* (1998b) for *An. arabiensis. Anopheles arabiensis* however, fed predominantly indoors than outdoors in Gambella (Krafsur, 1977). In Gergedi (Upper Awash), Ameneshewa (1995) reported that biting behavior of *An. arabiensis* depends on availability of host whether outdoors or indoors and time of the evening. A higher degree of man-biting took place outdoors in the early hours of the evening and indoors during the rest of the night when most people are sleeping. However, a review by White (1974) has confirmed the predominant endophagic behavior of *An. arabiensis* in different African countries including Ethiopia. The reason for such variations in different areas is not quite clear, but might be due to several factors such as insecticide pressure, presence or absence of cattle in human dwellings (White, 1974; Bouma and Rowland, 1995; Hadis *et al.*, 1997).

With regards to *Anopheles pharoensis*, the species appeared to be more endophagic, although the number of specimen collected was very small. The species is more exophagic in Ziway area (Abose *et al.*, 1998b). But a similar study in Gambella has shown this species seemed ambivalent in choice of feeding sites, since 50% attacked man indoors and an equal proportion outside (Krafsur, 1977).

The biting periodicity of the anopheline mosquitoes over a 12-hrs period showed that feeding activities were considerably before mid-night, where little activity was observed after that. *Anopheles arabiensis* was characterized by maximum feeding between 18:00 and 21:00hrs and then declined sharply throughout the rest of the night both indoors and outdoors. An early peak biting activity was also observed in the same species in Ziway area (Abose *et al.*, 1998b). However, in Gambella, Krafsur (1977) reported peak feeding activity of *An. arabiensis* well after mid-night between 04:00 and 06:00hrs indoors. This difference in biting cycles for the same species in different areas might be due to variation in climatic factors in different areas.

The second abundant man-biting species encountered in Akaki was *An. christyi*. Like *An. arabiensis*, it predominantly fed outdoors with maximum biting activity between 18:00 and 21hrs. Small numbers were caught biting indoors.

The small number of *An. pharoensis* collected also peaked between 19:00 and 20:00hrs with no biting activity at all the rest of the night. Similar early peaks were also observed in Ziway (Abose *et al.*, 1998b) and Gambella (Krafsur, 1977).

Out of the total 43 *An. arabiensis* dissected, a very low parous rate of 2.3% was detected. None of the parous and nulliparous specimens were found to be infected with sporozoites.

Similarly, out of 49 *An. chriysti* dissected, only a small proportion (12.2%) was parous, still with no infection in both parous and nulliparous flies. Again, a total of only 2 *An. pharoensis* were dissected, of which none were parous and infected with sporozoites. A higher parity rate of 43.2% was detected for *An. arabiensis* in Ziway (Abose *et al.*, 1998b) showing that the species is old enough to efficiently transmit the disease. Short-lived breeding sites limited to the rainy season, after which the mosquitoes become scarce, may be due to the short breeding season cause the low parous rate in Akaki. In Geregedi, Ameneshewa (1995) found an average parous rate of for *An. arabiensis*, which exhibited seasonal tendencies, in general being greater in the wet season than in the dry season.

From the present finding, the most important species that may be involved in the transmission of malaria in Akaki is *An. arabiensis* although it occurred in very small numbers and during the transmission season compared to other endemic areas elsewhere. The absence of sporozoite infection in the species could also be due to the very small number dissected as well as due to the detection method using microscopy. Immunological methods (e.g. ELISA) or molecular methods (PCR) are believed to be more sensitive and currently widely used (Bruce-Chawatt's, 1993; Coene, 1993; Ameneshewa (1995; Wilson *et al.*, 1998). *Anopheles arabiensis* is the most important vector of malaria in different regions of Ethiopia (Corradetti, 1939; Melville *et al.*, 1945; Giaquinto-Mira, 1950; Ovazza and Neri, 1955; Jolivet, 1959; Fountaine *et al.*, 1961

Rishikesh, 1966; O'Connor, 1967; White, 1974; 1980; Mekuria, 1983; Gebre-Mariam, 1984; Tulu, 1993; Ameneshewa, 1995; Abose *et al.*, 1998b).

Very low numbers of *An. pharoensis* were caught biting man in the study area, and thus may play no significant role in the transmission of malaria in Akaki. In other areas, such as in Ziway, the density of the species tends to increase as soon as the density of *An. arabiensis* drops during the dry season. It was thus suggested that it would take the role of main malaria transmission during the dry season as a secondary vector (Abose *et al.*, 1998b). The species usually occurs sympatrically with *An. gambiae* s. l. and is thought to play a secondary role in malaria transmission in Ethiopia and many other African countries (Mekuria, 1983; Service, 1993; Tulu, 1993; Ameneshewa, 1995).

Even though it occurred in low numbers, *An. christyi* was the second man- biting species in Akaki area. As in *An. arabiensis,* no infection was detected in the few specimen dissected. The species is regarded harmless with no epidemiological importance in malaria transmission in Ethiopia elsewhere. Previously it was recorded in many highland localities such as Gullale Torrent (2800m), Addis Ababa (Giaquinto-Mira, 1950). It was also collected around Ghibe River, southwestern Ethiopia, between altitude ranges of 1040 to 1140m (Tekie, 1991). Generally, this species is distributed in east African highlands from Ethiopia to Tanzania, Rwanda and Katanga, at altitudes ranging from 1400 to 2500m Gillett (1972), but also at Sudan border from 230m (Gilles and De Meillon, 1968). It is generally regarded as a zoophilic species, elsewhere (Gilles and De Meillon, 1968). However, in Akaki area, since it was the second abundant anthropophilic species, and was observed to breed throughout the year exploiting nearly all types of breeding habitats (especially along stream margins), its role as a potential vector of malaria cannot be ruled out, but requires further studies.

Anopheles coustani is one of the four anthropophilic species, but was the least in abundance in Akaki. Only, a single specimen was caught biting outdoors. It was previously reported being common in Akaki and Addis Ababa (Jolivet, 1959). In addition, a study conducted in Ghibe (southwestern Ethiopia) has shown that this species is less anthropophilic and more exophagic with no epidemiological significance (Tekie, 1989).

Overall, further and detailed studies are thus required on habits and habitats of *An. arabiensis, An. chriysti* and *An. pharoensis* to ascertain their exact role in malaria transmission in Akaki and surrounding areas.

Generally, malaria transmission is negatively associated with urbanization as was shown in Kinshasa (Coene, 1993. This is mainly due to overcrowding, elimination of breeding sites due to construction or pollution of the breeding places resulting to lower vector densities in urban centers. These mechanisms were believed to have played an important role to suppress mosquito density in Akaki area. However, malaria transmission could also be maintained for short period of time during the wet season as a result of the appearance of temporary breeding sites mainly at the periphery suitable for the vector species. Moreover, climatic changes could have partly played an important role in appearance of malaria outbreaks in Akaki during 1997/98. Studies show that changes in climatic factors, especially in temperature in highland areas of African countries, results in outbreaks of malaria (Lindsay and Martens, 1998).

7. CONCLUSIONS AND RECOMMENDATIONS

The present study focused on the elucidation of malaria transmission and determination of its prevalence in highland urban area, Akaki Town, Central Ethiopia, during the peak malaria transmission season. The status of malaria transmission was assessed, anopheline vector species involved were studied and review of records of health institutions was conducted. The conclusions and recommendations from this survey are given below.

7.1 CONCLUSION

1. Malaria is one of the major causes of morbidity congesting health services of Addis Ababa due to *Plasmodium* species, *P. vivax*, *P. falciparum* and *P. malariae*, in order of their prevalence.
2. Due to lack of information on geographical origin of reviewed malaria cases the presence of active malaria transmission in Addis Ababa could not go beyond suspicion.
3. The presence of autochthonous malaria transmission with a low prevalence (3.7%) was determined in Akaki Town due to *P. vivax* and *P. falciparum*.
4. Five anopheline species were identified in Akaki, *viz. An. arabiensis*, *An. christyi*, *An. coustani*, *An. pharoensis* and *An. cinereus*, of which the first two were the predominantly anthropophilic.
5. The occurrence of malaria epidemic in October1997 through February 1998 in Akaki and its surroundings is partly considered to be due to rise in mean temperature and abnormal rainfall that overlapped with global climatic changes during this period.

6. From the current KAPs survey, most of the households of the study population identified the role of mosquitoes in transmitting malaria and control measures.
7. The urban ecology of Akaki is believed to have negatively influenced the vector breeding and malaria transmission following the wet season for short period of time.

7.2 RECOMMENDATIONS

1. Detailed and frequent longitudinal entomological and parasitological observations using immunological techniques are required to elucidate the status of malaria in Akaki and the environs.
2. Further investigation is required to redefine the epidemiological importance of *An. christyi* in malaria transmission.

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APPENDIX

1. Species and age distribution of malaria cases seen at out-patient department at health institutions in Addis Ababa City administration, July 1993 to June 19999.

	1993					1994					1995				
Age	<1	1-4	5-14	15+	T	<1	1-4	5-14	15+	T	<1	1-4	5-14	15+	T
P. v.	0	0	1	1	2	0	0	1	1	2	0	0	0	1	1
P. m	0	0	0	4	4	0	0	0	0	0	0	0	0	0	0
P. f	0	0	0	1	1	0	0	2	0	2	0	0	0	2	2
O.M	1	2	43	66	112	0	2	14	77	93	1	1	31	144	177
Total	**1**	**2**	**44**	**72**	**119**	**0**	**2**	**17**	**78**	**97**	**1**	**1**	**31**	**147**	**180**

contd.

	1996					1997					1998				
Age	<1	1-4	5-14	15+	T	<1	1-4	5-14	15+	T	<1	1-4	5-14	15+	T
P. v.	3	64	219	1972	2258	31	155	433	3707	4326	35	136	497	4305	4973
P.m.	0	2	3	184	189	0	6	5	458	469	5	12	93	410	520
P. f.	3	34	147	2278	2462	7	65	248	1512	1832	15	60	233	2103	2411
O.M	1	12	49	424	486	0	17	135	653	805	3	12	293	1448	1756
Total	**7**	**112**	**418**	**4858**	**5395**	**38**	**243**	**821**	**6330**	**7432**	**58**	**220**	**1116**	**8266**	**9660**

1999					
Age	<1	1-4	5-14	15+	T
P. v.	59	112	743	2052	2966
P.m.	14	4	0	26	44
P. f.	1	31	121	706	859
O.M.	5	8	474	1667	2154
Total	**79**	**155**	**1338**	**4451**	**6023**

P. v.= *Plasmodium vivax*, P. m.= *Plasmodium malariae*,
P. f.= *Plasmodium falciparum*, O.M= Other unspecified Malaria (or clinically treated to malaria)
Source: Planning and Programming Department,
Addis Ababa Health Bureau, Addis Ababa

2. A questionnaire to collect data on malaria prevalence in Akaki Town and the surrounding areas.

1. Address: Woreda ____ Kebele_____ Ketena (Zone)_____House No._____
2. Identification: Household_________________Age____ Sex ____Religion___

   Educational status (illiterate, read and write only, elementary, junior, high school, higher institutions, others(specify)

   Ethnic group _______Occupation(Government employee, Farmer, merchant, Others(specify)__________Monthly income (Birr)_______.
3. Family size______

   Family members (specify): Age Sex Slide No. Result

   1.______________________ ____ ____ _______ _____

   2.______________________ ____ ____ _______ _____

   3.______________________ ____ ____ _______ _____

   4.______________________ ____ ____ _______ _____

   etc...
4. Type of housing: (thatched top, corrugated tin top)
5. Travel history to malaria endemic areas within the last two weeks: (Yes, No).
6. How does malaria transmitted from one person to another? ____________, _____________.
7. Health unit for treatment of malaria ______________, ______________, ___________.
8. How do you prevent and control malaria ______________, _____________, ___________.
9. History of malaria ____.

3. Average relative humidity of 12 hours readings (18:00 to 06:00hrs) of the study area, Akaki Town, from October 1999 to October 2000.

Time	position	Oct 1999	Nov. 1999	Dec. 1999	Jan. 2000	Feb. 2000	Mar. 2000	Jun 2000	Jul 2000	Aug 2000	Sep. 2000	Oct. 2000
18-19	in	80	64	49	28	27	45	87	89	70	76	64
	out	79	67	48	14	29	46	86	81	74	94	74
19-20	in	73	49	55	29	35	41	89	75	83	68	68
	out	80	59	61	18	32	46	92	83	88	73	80
20-21	in	75	63	48	30	35	46	90	79	74	71	72
	out	85	67	52	19	41	46	88	82	88	78	80
21-22	in	77	68	56	19	43	44	85	73	89	70	70
	out	84	63	48	27	37	45	94	94	84	73	82
22-23	in	83	63	54	23	31	44	88	78	79	74	74
	out	85	70	58	31	39	49	86	75	84	88	86
23-24	in	81	57	55	25	33	43	76	66	74	76	76
	out	81	72	64	28	44	53	88	82	78	90	88
01-02	in	86	70	55	32	34	46	79	69	70	75	79
	out	86	80	58	36	47	51	91	88	74	87	86
02-03	in	87	67	54	32	39	46	82	77	63	77	82
	out	84	76	61	44	44	53	76	74	72	86	84
03-04	in	83	70	48	49	39	48	81	77	72	68	75
	out	76	78	65	48	43	55	83	79	65	75	81
04-05	in	78	71	44	51	55	49	90	83	70	66	68
	out	88	75	61	55	42	58	82	84	64	72	76
05-06	in	81	70	47	50	43	48	82	73	68	67	66
	out	89	80	62	55	40	60	80	80	64	71	70

4. Meteorological conditions prevailing in Akaki Town between 1965 and 2000.

Year	Rainfall	RH	Temperature		
			maximum	minimum	mean
1965	938.5	57	23.4	7.5	15.5
1966	1326	61	23.4	8.1	15.4
1967	1239	63	22.6	8.1	15.4
1968	1259.6	62	23.4	7.9	15.7
1969	1463.7	62	22.7	8.9	15.8
1970	1216.8	60	22.8	8.8	15.8
1971	2010	60	22.3	8.5	15.4
1972	2113	61	22.7	8.9	15.8
1973	___	57	23.2	8.6	15.9
1974	2060.9	58	22.3	8.1	15.2
1975	1301.7	62	22.8	8.8	15.8
1976	1163	59	22.6	8.9	15.8
1977	1483	63	22.5	9.4	16
1978	1110.7	59	22.8	8.2	15.5
1979	1095.8	60	22.9	8.4	15.7
1980	1167.8	59	23.1	9	16.1
1981	1197.6	60	23	9	16
1982	964.1	63	22.7	9.2	16
1983	1116.3	65	23	9.4	16.2
1984	954.1	61	23.2	8.4	15.8
1985	1084.9	67	22.7	8.8	15.8
1986	1024.5	68	22.6	7.7	15.2
1987	1130.5	66	23.2	9.8	16.5
1988	1112.5	66	22.9	9.2	16.1
1989	1185.5	64	22.8	9	15.9
1990	1050.7	67	23.2	9	16.1
1991	994	55	23.5	9.4	16.5
1992	855.5	62	23.1	9.4	16.3
1993	966.4	63	23	9.1	16.1
1994	791.4	61	23	8.9	16.4
1995	911.9	70	23.7	9.7	16.7
1996	1112.2	69	23.5	9.3	16.4
1997	853.5	61	24	9.9	17
1998	1070.8	67	23.8	10.2	17
1999	954.5	57	23.8	8.9	16.4
2000	885.3	63	21.4	8.0	17