IMPACT OF IRRIGATION SYSTEMS ON MALARIA AND RVF TRANSMISSION IN JIZAN, SAUDI ARABIA

Thesis submitted in accordance with the requirements of
the University of Liverpool
for the degree of Doctor in Philosophy

By

Mohammed Hassen Alzahrani

December 2006

ABSTRACT

A series of studies investigating the impact of irrigation projects on malaria and rift valley fever (RVF) were undertaken in Jizan province in Saudi Arabia, an area with moderate to high malaria endemicity and where RVF was first recorded in 2000. Studies on the mosquito vector populations in both irrigated and non-irrigated villages were carried out over a 12-month period from January to December 2004, by larval surveys and adult mosquito surveys using pyrethrum knockdown catches (PKD), CDC light-traps baited with dry ice. A geographic information system (GIS) was used to examine the geographical distribution of malaria and RVF in all selected villages, and to determine if the risk of disease was influenced by man-made water resources in the area. A KAP survey was undertaken to assess the knowledge, attitudes and practices of the local community regarding malaria and RVF and their mosquito vectors.

In total, 6,135 mosquito larvae belonging to three genera were collected during the study period, of which 2,637 were culicines and 3,498 were anophelines. Of these, *Culex tritaeniorhynchus* Say, the vector of RVF in Saudi Arabia, represented 74% of the total culicine catch, while *Anopheles dthali* comprised 50 % of the total anopheline, with the highest number collected from the irrigated sites. Overall, 22,825 adult mosquitoes were collected, and 19,887 were culicines: *Cx tritaeniorhynchus* Say and *Aedes vexans ssp. arabiensis* Patton were the most abundant (78 % and 18 % respectively), with the highest number collected from the irrigated area, 79% (n= 11875) and 19% (n=2850) of the total catch respectively. A total of 2938 anopheline adults were collected 53% (n=1574) were *An. dthali* Patton, 31% (n=924) were *An. pretoriensis* Theobald, and 7% (n=212) were *An. gambiae s.l.* Giles. Overall A significance t test show that there is no significant difference between irrigated and non-irrigated area in vector density ($P > 0.05$) while there was a significant difference between irrigated and non-irrigated area in malaria and RVF cases ($P < 0.05$).

A total of 413 household heads were interviewed: 231 (55.9%) in 3 villages in the irrigated areas and 182 (44.1%) in 3 villages in non-irrigated areas. Households in both villages were significantly different ($p<0.001$) in all characteristics studied. Also, there was a marked difference in the total number of RVF cases reported during the 2000 epidemic between irrigated villages and non-irrigated villages, with much higher numbers occurring in irrigated areas (254) compared with non-irrigated areas (13).

The GIS study showed that malaria positivity tended to be negatively correlated with the distance between houses and the nearest breeding sites and wadis in both irrigated non-irrigated villages. Overall, the households with RVF cases during the 2000 epidemic tended to have a higher mean malaria positivity score, and were, on average, closer to breeding sites and wadis, than those houses which did not have RVF cases in both irrigated villages and non-irrigated villages.

The current rapid growth in agriculture and irrigation projects in Saudi Arabia, with little or no attention for their health impact cannot be sustained. Studies to gain new insight on their potential impact on RVF and malaria transmission are urgent as there is rapid, often unplanned, expansion and this could alter vector-borne disease epidemiology. Our study in irrigated and non-irrigated areas contributed to this by highlighting several risk factors to be considered in further studie`s. It is considered that RVF and malaria transmission in irrigated areas can be ameliorated by control techniques, such as Insecticide-Treated Bednets, that are readily accepted by communities.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

First of all I want to express my sincere appreciation to my supervisor Dr Philip McCall for his encouragement, support, guidance and advice throughout this study. I am greatly to indebted to him for everything he taught me in the five years we worked together. His guidance will stay with me throughout my life.

Thanks to my advisory panel, Professor H Townson and Dr Guy Barnish for their advice and support. I would also like to thank Dr Amir Hassan, my second supervisor, on his help and support.

I owe my thanks to Dr Louise Kelly and Dr Ali Hassan for their support and help during the GIS work. I am greatly indebted to the field teams and technicians who assisted me in the survey in Saudi Arabia during the collection of the field study.

Thanks also to Gwen Finnegan for her invaluable secretarial and logistic support and to all my colleagues and staff in our research group. A special thanks to Drs Themba Mzilahowa and Eveline Klinkenberg for revealing the world of ELISA to me and an extra special thanks to Dr Adel Al-Sheikh for invaluable assistance in times of need.

Finally, great thanks and warm love to my wife Norah Alzahrani who left her work to support me and shared my difficulties. Also, many thanks to my kids Hassen, Hussam, Aymen and Yara who even participated and helped me to leave my mosquito traps clean and ready during rushed field work. Thanks to my mother, my sisters and friends for their continuous support and keeping my mind off work once in a while. A special thanks to Ahmed Al Sadi in Jizan region, without whom my field work would not have succeeded.

The study was funded by a scholarship from the Ministry of Health, Saudi Arabia.

ABBREVIATIONS

The following abbreviations appear in this thesis:

BB	Blocking Buffer
CDC	Centre of Disease Control and Prevention
ELIZA	Enzyme-Linked Immunosorbent Assay
FAO	Food and Agriculture Organization
GIS	Geographic Information System
GPS	Global Positioning System
HBI	Human blood Index
I	Irrigated area
IRS	Indoor residual spraying
ITNs	insecticide-treated bed nets
JDP	Jizan Dam Project
KAP	Knowledge, Attitude, and Practice
MOA	Ministry of Agriculture
MOH	Ministry of Health
N	Non-irrigated area
N/S	Not Significant
PBS	Phosphate Buffered Saline
PCR	Polymerase Chain Reaction
PKD	Pyrethrum Knockdown Caches
RVF	Rift Valley Fever
SD	Standard Deviation
WHO	World Health Organization
HIA	Health Impact Assessment
DHF	Dengue Haemorrhagic Fever
ESRI	Environmental Systems Research Institute

Chapter One: Introduction

1.1 Introduction

In the 120 years since mosquitoes were shown to transmit human disease, hundreds of viruses, bacteria, protozoa, and helminths have been found to require a haematophagous (blood-sucking) arthropod for transmission to vertebrate hosts (Gubler *et al.*, 1991). Historically, malaria, dengue, yellow fever, plague, filariasis, louse-borne typhus, trypanosomiasis, leishmaniasis, and other vector-borne diseases were responsible for more human disease and death in the 17th through to the early 20th centuries than all other causes combined (Gubler *et al.*, 1991).

Mosquitoes are hosts to a variety of pathogens and parasites, including viruses, bacteria, fungi, and nematodes. Approximately 430 species of mosquitoes of the genus *Anopheles* are recognised (Service & Townson, 2002). Around 70 species worldwide can transmit malaria, but of these only about 40 are vectors of major importance (Service & Townson, 2002). Mosquitoes also transmit the viruses responsible for Rift valley fever, yellow fever, dengue haemorrhagic fever and several forms of encephalitis (Clements, 1992).

Environmental change and ecological disturbance, due to both natural phenomena and human intervention, have exerted and continue to exert a marked influence on the emergence and proliferation of parasitic diseases (Patz *et al.* 2000). Deforestation and ensuing changes in land use, human settlement, commercial development, construction of roads, water control systems (dams, canals, irrigation systems, reservoirs), and climate, both alone and in combination, have been accompanied by global increases in morbidity and mortality from a number of emergent parasitic diseases (Lederberg *et al.*, 1992). Changes, such as agricultural practices and deforestation increase the risk for vector-borne disease transmission (Birley, 1991; Lederberg *et al.*, 1992). Many irrigation systems and dams have been built in the past 50 years without regard to their effect on vector-borne diseases. Similarly, tropical forests are being cleared at an increasing rate, and agricultural practices such as rice production have also increased. Reservoirs, irrigation canals, and dams are closely associated with parasitic disease.

The replacement of forests with crop farming, ranching, and raising of small animals can create a supportive habitat for parasites and their vectors. Introduction of non-native species, such as cattle, pigs, and chickens can result in either increased or decreased transmission of parasitic disease to humans (Service, 1991). With livestock to feed on, the vectors may reduce feeding on humans or, conversely, vectors may multiply and seek additional human blood-meals (Giglioli, 1963). With the larger reservoirs of infection, there is increased parasite transmission and, the humans not only become ill, but also further increase the parasite reservoirs.

Typically, larger breeding sites produce larger numbers of adult mosquitoes (Spiers, 2003). In the tropics, during construction of dams and canals, excavation pits provide breeding sites for mosquitoes. The range of water bodies that can support the developing larval and pupal stages of the main malaria vectors is broad, ranging from foot/ hoof prints to extensive irrigated rice fields covering hectares in area, although each species is considered to prefer certain site types where it appears to proliferate and compete best (Service & Townson, 2002). Tropical reservoirs and irrigation systems provide ideal sites for rapid reproduction and growth of fluke-transmitting aquatic snails (Patz *et al.*, 2000). Additional breeding sites are provided by creation of basin irrigation for rice, by poor drainage, and impounded water and seepage. Hydrological changes following irrigation development or dam construction may lead to a significant increase in the extent of mosquito breeding sites and in their seasonal duration. Thus seasonal transmission of a disease such as malaria may be extended. As each vector has its own peculiar biology and environmental requirements, therefore the detailed design of a water development project should take account of the attributes of local vector species (Birley 1991).

Understanding where mosquitoes breed and why they prefer certain water bodies over others is vital for the elaboration of sound mosquito control strategies and is particularly important in areas where large-scale irrigation is being practiced (Birley, 1991; Ijumba & Lindsay, 2001). The key questions that have to be answered when water management measures are considered for vector borne disease control are: What are the local vectors? Where do they breed? Are the breeding opportunities that are created in the irrigated area likely to contribute significantly to the overall vector abundance and disease transmission level? Vector ecology and disease transmission are dynamic and complex processes and it is sometimes difficult to draw general conclusions (Birley, 1991). This must be considered when reading examples from different countries.

1.2 Vector-borne disease and Irrigation in Jizan province, Saudi Arabia

Following the extensive malaria control programmes in Saudi Arabia, malaria is now restricted to the southwestern part of the country (Tihama). About 5% of the national population of Saudi Arabia are at risk (1.04 million). Jizan Region, in the SW of Saudi Arabia and bordering Yemen, is known to be the most malarious region in Saudi Arabia, accounting on average for 60-70% of all locally acquired malaria cases recorded during the period from 1983 to 2001 (Al Sheikh, 2004). In valleys and villages at the foothills of Sarawat Mountains in Jizan region where *P. falciparum* is common (over 90% of cases) and where rainfall is relatively abundant, malaria occurs at meso- to hyperendemic level (Al-Seghayer 1983; Al-Seghayer *et al.,* 1999). In addition to the imported and border malaria, two major technical problems now face malaria control programme in Saudi Arabia. (a) the already developed resistance of vectors to organochlorine insecticides and the expected resistance to the insecticides in use, and (b) *P. falciparum* resistance to chloroquine that showed progressive increase in recent years among locally acquired cases in areas bordering Yemen. With this situation, monitoring of both vector and parasite resistance must be regularly carried out with vigilance (Al-Seghayer *et al.,* 1999)

In mid-September 2000, it was confirmed that Rift Valley fever (RVF) infection had occurred in both humans and livestock in the Kingdom of Saudi Arabia (CDC, 2000a,b). This is the first time that RVF virus has been reported outside Africa and Madagascar. The epidemic appears to have started simultaneously in Jizan Dam area in the Jizan Region in the southwest, as well as in neighbouring Yemen, and to have continued until the end of November (CDC, 2000 a, b). Although the epidemic was centred in Jizan Region and northern Yemen, it subsequently extended northwards into the Aseer and Al Quenfadah health regions. It was concluded that both *Culex* (*Culex*) *tritaeniorhynchus* Giles and *Aedes vexans arabiensis* Patton were vectors of RVF in Saudi Arabia on grounds of abundance, distribution, preference for humans and sheep, the virus isolations and vector competence tests (Jupp *et al.,* 2002). In April 2004, the Saudi authorities lifted a 3-year-old ban on the movement of livestock between regions hit by Rift Valley Fever (RVF). The ban was imposed on animals in Jizan, the Tihama areas of Asir, Makkah Area (MOA, 2004). In September 2004 RVF occurred again in Jizan region. 5 cases of viral disease were detected during periodic examinations in

Jizan by the agriculture ministry. Four of the samples which tested positive are in Abu Arihs governorate and one in Al-Arid governorate, both governments are in Jizan Dam and Irrigation Project Area (MOA, 2004).

Wadi Jizan Dam (1703'N, 4258'E; 15 km east of Abu Arish, Jizan region) is probably the largest and most variable expanse of freshwater habitats in the southwestern provinces of Saudi Arabia. It was constructed to provide year-round water for irrigation purposes and for flood control. The reservoir is supplied by water from the major wadis and has a very large catchments area, extending south into Yemen. The depth of the reservoir has been reduced following sedimentation and, in flood periods, the reservoir can cover an area of 1,000 ha. Large quantities of silt have effectively cut off some pools and larger expanses of open water from the main reservoir; one can be regarded as an almost permanent lake of about 60 ha (MOA, 1995).

There is a major possible change in land use in Jizan Dam area. Intensive cultivation continues to increase as the local human population expands (Rahmah, 1994). Further development is likely along the newly built al-Arida road. The impact of water development schemes on health is unknown. The increase in the local human population poses the biggest threat of vector-borne diseases such as malaria and RVF as more and more land is cleared for housing and agriculture. Methods of cultivation, field and water surface sizes and typical circular thatched dwelling huts give the Jizan Dam area, including nearby Wadis an African character unique in Saudi (Rahmah, 1994).

1.3 Aims of the study

The overall aims of this study were:

- To measure the potential effect of water development schemes on vector-borne diseases through literature reviews on similar development projects.
- To conduct an assessment of the effect of irrigation systems on vector-borne diseases in the Jizan area.

- Through the findings of the study to make appropriate recommendations for mitigating measures where needed and to provide baseline information to prevent similar and additional problems from happening in similar irrigation systems elsewhere.

Specific objectives

Environmental factors: To investigate vector breeding and transmission sites associated with the irrigation system in Jizan area for malaria and RVF through vector sampling and direct observation.

Community vulnerability: To find out and compare the knowledge, attitudes and practices of households in man-made irrigated areas and in naturally irrigated areas with regard to malaria and RVF. To understand how community perceptions and behaviour may affect their vulnerability and to find out the magnitude of vulnerability and exposure through estimation of prevalence rates.

Chapter Two: Literature Review

2.1 Health impact of water resource development

Many diseases are associated with water either directly, such as the diarrhoeal diseases transmitted by ingestion of infected water, or indirectly, where a disease's intermediate hosts or vectors depend on water for their development. In the latter case, the abundance and the consequent prevalence of the disease are often inadvertently increased when water resources are developed. Vector-borne diseases in particular can become serious problems and predicting how such developments might affect vector populations, in order to ensure that negative outcomes can be avoided, is a crucial part of any new scheme.

Health Impact Assessment (HIA) is an approach that aims to identify, predict, safeguard and mitigate the impact of development projects on health; the assessment procedure involves identification of health hazards, interpretation of the health hazards as health risks attributable to the project and finally health risk management (Birley & Perelta, 1995). HIA can be defined as:-

> *An assessment of the change in health risk reasonably attributable to a project, programme or policy and undertaken for a specific purpose.*
> (Birley, 1995)

> and

> *The estimation of the effects of a specified action on the health of a defined population.*
> (Scott-Samuel, 1998)

Birley (1991, 1995, and 1996) conducted studies for predicting when vector-borne diseases might increase following water resource development and Hunter *et al.* (1993), investigated changes in parasitic diseases in the same situations.

The water-based and water-related vector-borne diseases are most likely to be found in areas where irrigation has introduced large new water surface areas (Tiffen, 1991). These include:

- Malaria
- Schistosomiasis
- Lymphatic filariasis
- Japanese encephalitis

2.2 Vector-borne disease

Insect vectors represent the largest group of disease transmitting agents. In most cases and for the most widespread diseases, mosquitoes are the main vectors. Among a wide range of vector-borne diseases, Birley (1995) named two diseases, malaria and lymphatic filariasis, as serious health hazards in the context of poor drainage. These and others, important in the Arabian Peninsula are reviewed here.

Malaria

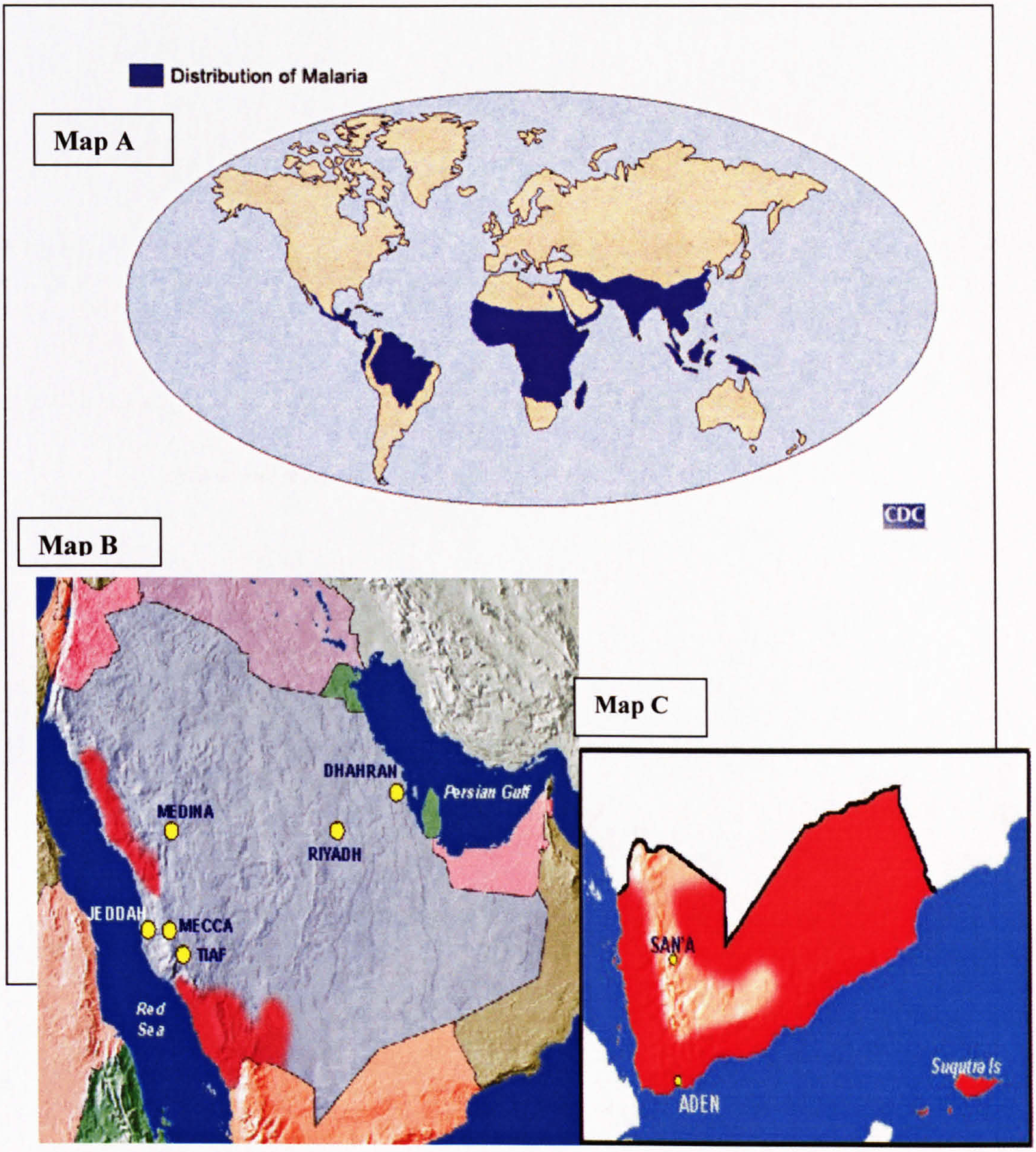
Malaria is the most common vector-borne disease worldwide, with 300-500 million clinical cases per year in some 100 countries (Seyoum *et al.*, 2003) (Figure 2.1). Global malaria mortality is estimated at 1.5-2.7 million (WHO, 1997). Malaria is one of the most serious health problems facing African countries and a major limitation on their socio-economic progress. Children under the age of five and pregnant women are most at risk. WHO (1997) reports that 90 percent of the global burden of this disease can be attributed to environmental factors, including land and water management.

Malaria is transmitted by anopheline mosquitoes. Approximately 430 species of anopheline mosquitoes are recognized; only about 70 are important vectors (Service & Townson, 2002). In each locality there are usually only one or two important species, each species having a unique combination of breeding-site preferences and other behaviours. Broadly speaking, malaria vectors 'prefer' to breed in relatively clean water (*i.e.* unpolluted or with lower organic content) and therefore malaria is most common in rural and peri-urban areas (Rozendaal, 1997; Service & Townson, 2002; Hay *et al*, 2005).

Many of the malaria parasite species and their vectors respond sharply to changes in the ecology of their habitat: deforestation, vegetation, density of human population, bodies of water and their locations and climate. For example, upsurges of malaria have been coincident with changes in land-use and human settlement subsequent to deforestation in Africa (Coluzzi *et al.*, 1979, 1985), Asia (Bunnag *et al.*, 1979), and Latin America (Kaplan *et al.*, 1980; Tadei *et al.*, 1998) Each *Anopheles* species occupies a unique ecological niche, and has a different level of vector competence.

Peri-urban areas represent pockets of rural environment within the larger urban conurbation. During the dry season many towns and cities practise irrigated agriculture. Malaria prevalence varies greatly from one district of a city to another, as a result of the mobility of the human population, the abundance of breeding sites for the mosquito, and the quality of housing and services (Rossi- Espagnet *et al.*, 1991; Atkinson and Merkle, 1993; Birley, 1995; Klinkenberg *et al.*, 2005a and 2005b).

Figure 2.1: Global Malaria Distribution; ***Map A*** shows global malaria distribution, Malaria is endemic in tropical and subtropical regions. ***Map B & C*** show location of malaria-affected areas in Saudi Arabia (map A) and Yemen (map B); substantial malaria risk is shaded in dark red. Source: (CDC graph 2003; WHO/RBM, 2002).



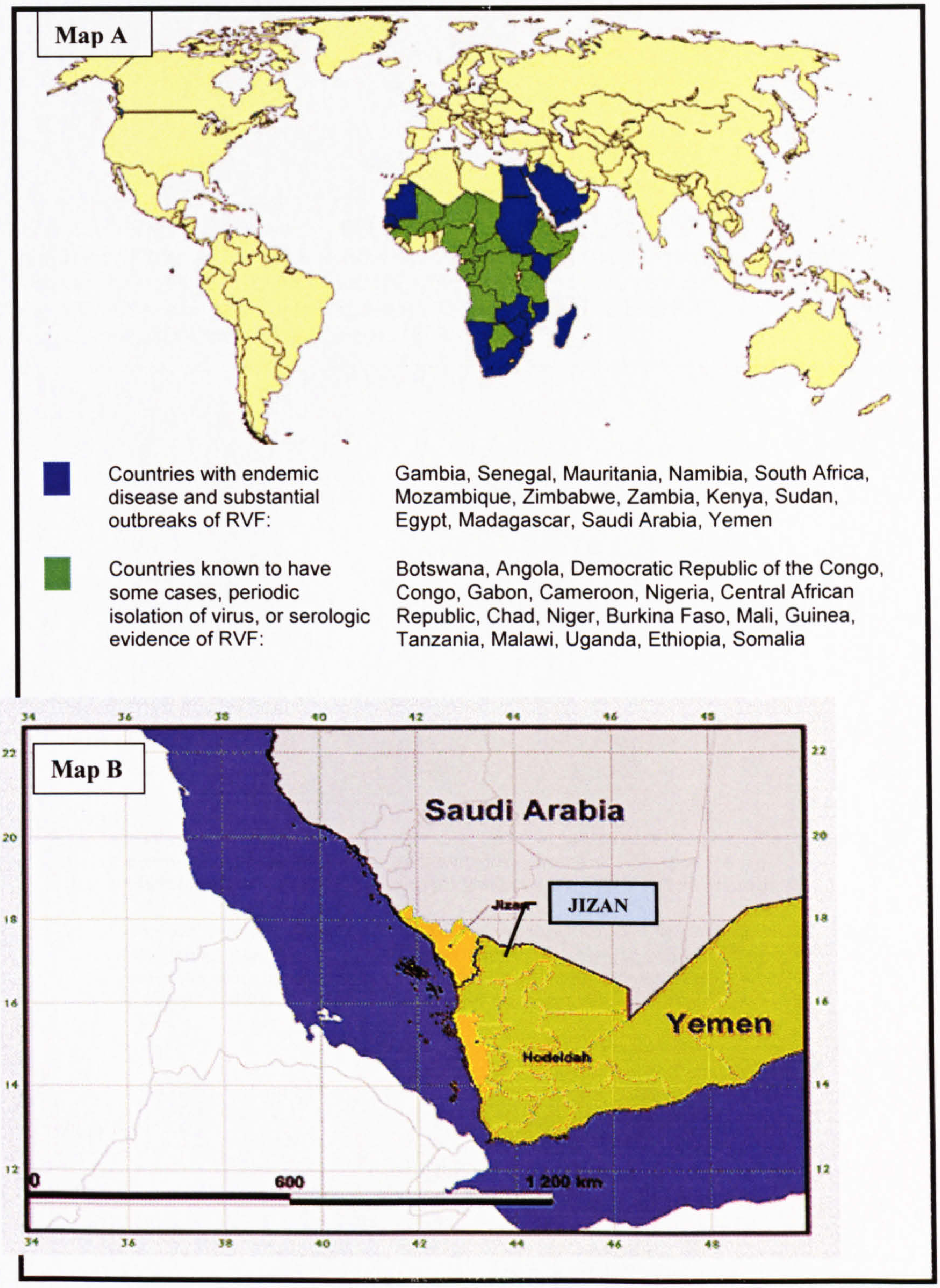
Rift Valley Fever (RVF)

Rift Valley Fever (RVF) is an acute viral disease that affects domestic animals (typically cattle, sheep, goats, buffalo and camels) and humans (WHO, 2000; Megan & Bailey, 1988). RVF has occurred most frequently in eastern and southern Africa (Figure 2.2) where sheep and cattle are raised, but the virus exists in most countries of reported in Saudi Arabia and subsequently Yemen. These cases represented the first Rift Valley fever cases identified outside Africa (Jupp *et al.*, 2002; Gubler, 2002).

RVF is a *phlebovirus* in the family Bunyaviridae. Epidemics typically occur in years with heavy rains (WHO, 1985b). Humans can get RVF infection either as the result of a mosquito bite or if they are exposed to blood or other fluids of infected animals (Wilson *et al.*, 1994).

The main vectors incriminated in transmission RVF in East and South Africa are the *Aedes* mosquitoes, especially *Aedes circumluteolus* and *Aedes mcintoshi*, in addition to *Aedes vexans* and *Aedes ochraceus* in Western Africa (Thonnon *et al.,* 1999). RVF virus has also been isolated from *Aedes dalzieli* (Balkhy & Memish, 2003).

Figure 2.2: World distribution of Rift Valley Fever (RVF).: ***Map A*** shows the world distribution of RVF in Eastern and Southern Africa and in Saudi Arabia and Yemen in Southwest Asia (for the first time outside Africa). ***Map B*** shows regions affected by RVF in 2000 in Saudi Arabia and Yemen. (Source CDC graph 2003 & EMPRES Transboundary Animal Diseases Bulletin Issue number: 15/ 3-4 – 2000).



🟦	Countries with endemic disease and substantial outbreaks of RVF:	Gambia, Senegal, Mauritania, Namibia, South Africa, Mozambique, Zimbabwe, Zambia, Kenya, Sudan, Egypt, Madagascar, Saudi Arabia, Yemen
🟩	Countries known to have some cases, periodic isolation of virus, or serologic evidence of RVF:	Botswana, Angola, Democratic Republic of the Congo, Congo, Gabon, Cameroon, Nigeria, Central African Republic, Chad, Niger, Burkina Faso, Mali, Guinea, Tanzania, Malawi, Uganda, Ethiopia, Somalia

Dengue and Dengue haemorrhagic Fever

Dengue is considered the most common human viral disease transmitted by arthropod vectors (Gubler, 2002). Annually there are an estimated 50 -100 million cases of DF, and 250,000 to 500,000 cases of dengue haemorrhagic fever (DHF) in the world (Solomon & Mallewa, 2001; Gubler, 2002) (Figure 2.3), involving more than 100 countries in Africa, the Americas, the Eastern Mediterranean, South-east Asia and Western Pacific (Figure 2.3).

Dengue virus infections may be asymptomatic or lead to a range of clinical presentations, even death. The dengue viruses belong to the genus *Flavivirus* (family Flaviviridae) (Solomon & Mallewa, 2001). There are four serotypes of dengue viruses transmitted by *Aedes* mosquitoes (Gubler, 1998 a & b).

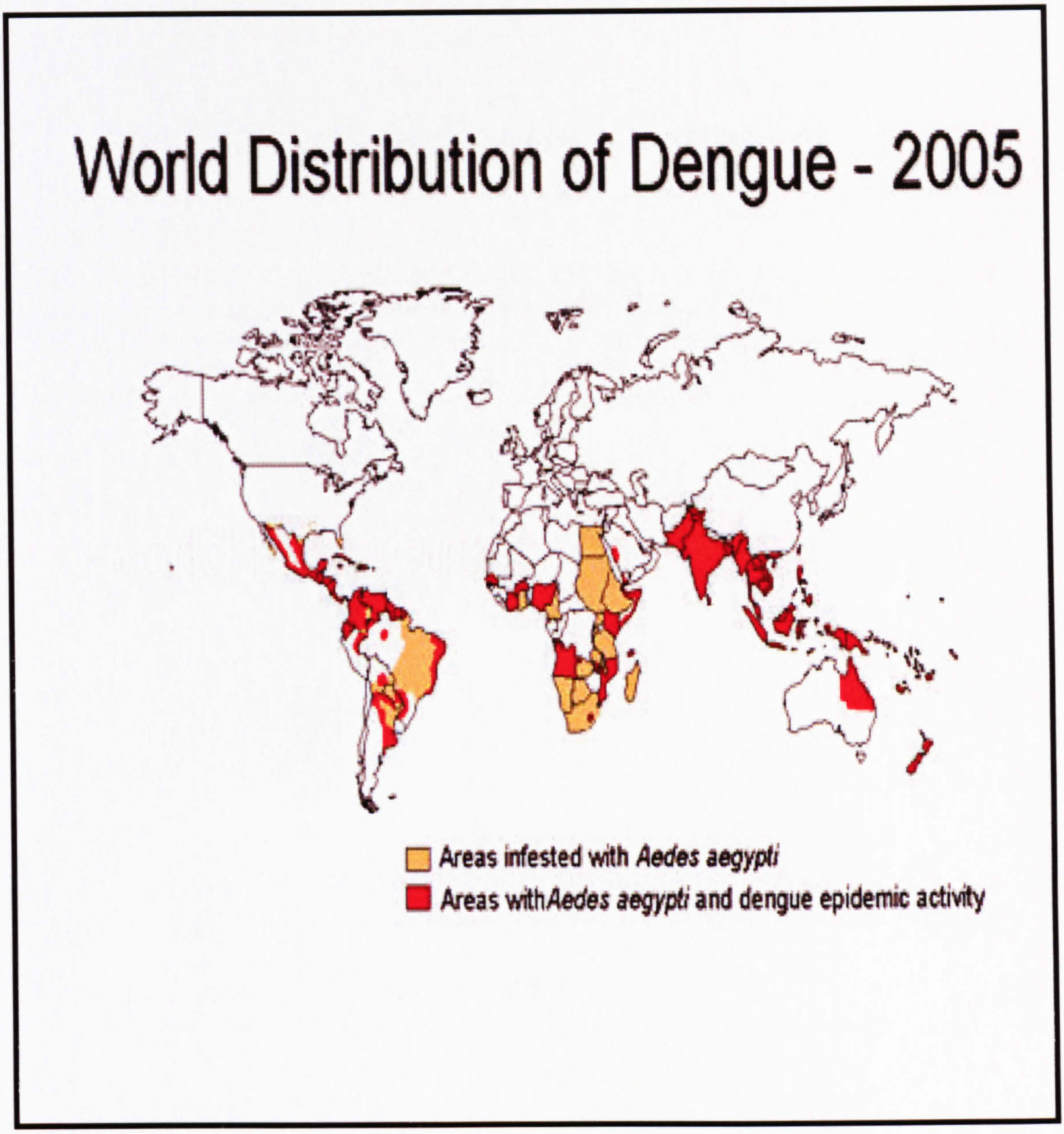
The main vectors of dengue are *Aedes aegypti* and to a lesser extent *Ae. albopictus.* The rainwater and drinking-water containers in which the vectors breed include tin cans, coconut husks, rubber tyres, water-storage jars and buckets. Leaf axils and tree holes are probably the natural habitats (Gubler & Clark, 1996; Guzman *et al.*, 2003).

There is no specific treatment for dengue fever: clinical management by experienced physicians prevents death of DHF patients. With appropriate intensive supportive therapy, mortality may be reduced to less than 1% (WHO, 1997). Vaccine development for dengue and DHF is difficult because any of four different viruses may cause disease, and because protection against only one or two dengue viruses could increase the risk of more serious disease (Saluzzo, 1996).

Yellow fever, also transmitted by *Ae. aegypti,* is frequently fatal but a good vaccine is available and outbreaks are currently very sporadic (Tiffen, 1991).

Intensified transmission of Japanese encephalitis (JE) has been observed in other parts of South-East Asia and the Western Pacific, most likely due to an expansion of irrigated agriculture and pig husbandry, as well as changing climatic factors. Water resource development and management, in particular flooded rice production systems, are considered among the chief causes for several JE outbreaks (Akiba *et al.*, 2001)

Figure 2.3: World distribution of Dengue and the primary mosquito vector, *Aedes aegypti* shows that Saudi Arabia and Yemen are infected with this disease. (Source Centers for Disease Control and Prevention (CDC))



Schistosomiasis

Schistosomiasis (Bilharzia) is caused by the digenetic blood trematodes, mainly *Schistosoma haematobium*, *S. mansoni* and *S japonicum*, when the free-swimming infective larvae penetrate human skin in water. Larvae develop in specific fresh-water snails of three genera, *Biomphalaria*, *Bulinus*, and *Oncomelania* (WHO, 1985a &

disease after malaria in terms of public health and economic impact in tropical and subtropical areas (WHO, 1985a). An estimated 200 million people are infected and transmission occurs in about 74 countries (Utzinger *et al.*, 2003). Water development projects, especially those associated with the irrigation of large areas, have often been linked to an increased incidence of schistosomiasis: intestinal schistosomiasis was unknown or infrequent in the Nile, Senegal and Volta deltas before the construction of the Aswan, Diama and Alosombo dams (Lines *et al.*, 1994; Birley, 1995).

Filariasis

About 100 million people are infected with filariasis worldwide (Ottesen *et al.*, 1997). The most important urban and periurban form is bancroftian filariasis, caused by a nematode parasite which is principally transmitted by the mosquito *Culex quinquefasciatus*. But also by *Anopheles* and *Aedes* spp. *Cx quinquefasciatus* is the vector in India, Urban East Africa, Haiti and part of Brazil (Gyapong *et al.*, 1996; Evans *et al.*, 1993). The mosquito breeds in water which is highly polluted with organic matter. Such water is characteristic of dense human settlement, mosquitoe breeding occurs in wet pit latrines, blocked sewage systems and drains, cesspits and septic tanks, often because the structures have been poorly designed, or because they are blocked by solid waste as a result of ineffective garbage-collection systems. Organically polluted, stagnant water accumulates behind the blockages (Rajagopalan *et al.*, 1990). Because of the association of the mosquito with polluted water, there is sometimes an irregular gradient in mosquito density from high densities in the city to low densities at the periphery. A study in India (Cairncross *et al.*, 1988) demonstrated the relative importance of different kinds of breeding site within one coastal town and this enabled control activities to be prioritised.

In rural areas, anopheline mosquitoes and *Mansonia sp.* mosquitoes are important vectors, in Africa and Asia. In West Africa and New Guinea anopheline mosquitoes are the filariasis vectors. In Polynesia *Aedes* species are the vectors of diurnally periodic *W. bancrofti*. *Mansonia* spp. are the main vectors of *Brugia malayi*.

Leishmaniasis

Visceral leishmaniasis is a severe parasitic disease caused by Protozoan parasites *Leishmania sp.* and transmitted by phlebotomine sandflies. The larvae of these flies are terrestrial but routes by which irrigation may have an impact on Leishmaniasis are described below.

In parts of the Middle East and Asia there is urban transmission of cutaneous leishmaniasis, or oriental sore. The vector, also a phlebotomine sandfly, appears to favour high-density, low quality housing and construction sites in dry cities and peri-urban areas. Cities from which it has been recorded include Kabul, Teheran and Aleppo. Different species of *Leishmania* have their main reservoir either in humans or various domestic or wild animals (Tiffen, 1991).

2.3 Irrigation and vector-borne disease

The risk that one or more of the diseases described above is introduced or has an increased impact following an irrigation development is increased in certain circumstances, typically in schemes where soils present drainage problems and drainage channels are absent or not well maintained or where rice or sugar-cane is cultivated; reservoirs constructed and borrow pits left with stagnant water; canals are unlined or have unchecked vegetation growth (Tiffen, 1991). Different types of crop irrigation has often been blamed for aggravating the health risks of local communities as it can provide habitats suitable for vector mosquitoes and the snail, intermediate hosts of schistosomiasis (Bradley, 1988; Gratz, 1988; Service, 1989; Hunter *et al.*, 1993; Birley, 1995 & 1999). Of these crops, rice is considered to pose the greatest danger to health since it is grown in flooded conditions, which provide ideal breeding sites for malaria mosquitoes.

2.3.1 Dams and reservoirs

The communicable diseases most often associated with reservoirs are malaria, schistosomiasis and onchocerciasis. Large engineering projects involving rivers have frequently led to explosive malaria epidemics during construction (Birley, 1995). Construction of dams and over 100 small dams in Cameroon has been blamed for increased prevalence of endemic diseases including malaria (Ripert & Raccurt, 1987). In the Uasin Gishu Highlands in Kenya, the building of dams was associated with increased malaria transmission (Khaemba *et al.*, 1994). A large study in the Ethiopian highlands showed there was increase in malaria in villages situated near dams compared to villages further away (Ghebreyesus *et al.*, 1999). Another example is the Mahaweli River, Sri Lanka where the natural flow in the upper reaches, was interrupted by dams and diversions and stream pools formed in the dry river-bed, in which malaria vectors bred,. A reservoir of infection was created by human circulation between lowland resettlement sites and riverine villages (Wyesundera, 1988).

Reservoirs constructed in peri-urban areas are likely to be for domestic water supply rather than hydropower generation, although both occur. Birley (1995) has reviewed the risks associated with such developments. There are important health hazards associated with the large bodies of water that are stored, diverted and discharged during dam construction and operation - land-use changes occur and many people are resettled, possibly with health consequences. Mosquitoes may breed in the shallow, sheltered margins of reservoirs. However there is much variation in scenarios between regions. In Africa, malaria mosquito breeding is also associated with numerous puddles on gently sloping shores, while in Asia, downstream pools in the riverbed tend to be more important. A small dam was built to regulate flow to the Edea hydroelectric plant in Cameroon. The shallow waters behind the dam soon contained abundant vegetation and larvae of the mosquito *Anopheles funestus*. The prevalence of *P. falciparum* malaria was high in surrounding villages and decreased with distance from the lake (Ripert & Raccurt, 1987).

Schistosomiasis and, to a lesser extent, dracunculiasis are commonly reported hazards of reservoir construction. The large reservoirs usually associated with hydro-power have many sheltered, shallow inlets where aquatic vegetation thrives. An increase in schistosomiasis has been observed across most of Sub-Saharan Africa where water development has taken place (Oomen *et al.*, 1990; Chimbari *et al.*, 2001) and therefore, fishing settlements are frequently vulnerable. The increases in prevalence have often been dramatic and the intense haematuria in children has caused public alarm (Hunter *et al.*, 1982). Urinary schistosomiasis was locally of low prevalence before the Akosombo Dam was built in Ghana. The reservoir attracted some 150,000 lakeside residents and there was an explosive increase in prevalence. Prevalence of the disease fell rapidly with distance from the lake shore, due to decreasing dependence on the lake for water needs (Hunter *et al.*, 1982). In contrast, schistosomiasis in Asia is often contained within small endemic foci and dam development has often proceeded without outbreaks of the disease (Utzinger *et al.*, 2005; Steinmann, 2006).

In South-east Asia and countries of the former U.S.S.R., *Opisthorchis sinensis* infection is associated with reservoir construction (WHO, 1992a).

Decomposing plant material often pollutes reservoir outflow. Pollution reduces access to potable water for downstream communities that rely on the river, promoting transmission of water-borne diseases. Reduced stream flows alter the replenishment rate of aquifers, affecting domestic water supply, and promoting saline intrusion on to irrigated lands. Reduced nutrient flows disrupt fisheries and reduce food security. When groundwater rose in Lower Egypt, as a result of the Aswan Dam, wastewater disposal was disrupted and aquifers became polluted (Egboka *et al.*, 1989).

2.3.2 Rice cultivation

Rice is an annual grass belonging to the genus *Oryza* that has two main species, each with a great number of varieties: *Oryza sativa* from Asia and *O. glaberrima* from West Africa (Ijumba & Lindsay, 2001). It is cultivated using one of two systems: upland (dry rice) or lowland (wet rice). Upland rice does not require flooding for its growth and can be cultivated like other cereal crops, even in mountainous areas. By contrast, lowland rice requires almost constant irrigation – intermitten irrigation is successfully used, especially in China, for mosquito control with highly prodective rice growing- and is generally maintained in 10-15 cm of water (Chandler, 1969; Grist, 1986) . Rice is the most common crop grown under irrigation, comprising about one-third of all irrigated crops grown in Africa (Ijumba & Lindsay, 2001).

Irrigated-rice cultivation, depending on the number of cropping cycles, may extend the breeding season of malaria mosquitoes and hence increase the annual duration of transmission (Ijumba and Lindsay, 2001). Moreover, in dry regions, irrigation will elevate relative humidity and aid survival of these vectors. Although *An. gambiae sensu lato* is often associated with irrigated rice, in certain situations *An. funestus* also thrives in paddy fields, especially in parts of Madagascar, while *Anopheles funestus* typically favours breeding sites shaded by vegetation and its presence tends to be indicative of more persistent wetland habitats (Gillies & De Meillon, 1968) In ricefields *An. funestus* occurs later in the growth of rice and when the land is fallow (Marrama *et al.*, 1995). Under some circumstances, however, *An. funestus* becomes excluded by well-managed irrigation schemes such as those maintained under guidance of the West African Rice Development Authority.In general, the predominant vector in irrigated rice systems is that found in surrounding areas, although there is at least one notable exception to this rule. The Mopti form of *An. gambiae sensu stricto* found in West Africa thrives in rice fields located in the northern fringes of the Sahel. Thus, in Burkina Faso this cytotype is common in the center of the rice fields, but at the edge of the irrigated area the Savanna form is more abundant (Robert *et al.*, 1989).

Irrigated rice fields represent ideal breeding sites for mosquitoes and they can generate large numbers of individuals, although smaller proportions are infective in rice field villages than in neighbouring communities (Ijumba and Lindsay, 2001). There is no simple association between irrigated rice fields and the degree of exposure to malaria parasites as measured using classical entomological methods. Thus, transmission intensity in irrigated settlements can appear higher, similar or less than in neighbouring villages outside the irrigation scheme. For example, in the rice-growing area of the Rusizi valley, Burundi, the vectorial capacity of *An. gambiae s. l.* was 150 times higher in the rice irrigation scheme than in adjacent area growing cotton. conversely, in the rice-growing areas of Bobo Dioulasso, Burkina Faso, the number of infective bites received in the local community was similar to that in the control area, whilst in the Lower-Moshi rice irrigation scheme, Tanzania, the number of infective bites was 2.6 times lower in an irrigation scheme than in a control village (Ijumba *et al.*, 1997). However, measurements of exposure may not accurately reflect the levels experienced by individuals in the study community. Mosquitoes collected on human baits or from light traps will overestimate true biting rates, particularly when large numbers of mosquitoes are biting, since people will often avoid receiving large numbers of bites by sleeping under a bednet or use some other means of protection (Lindsay *et al.*, 1989).

2.3.3 Irrigation of wheat and cotton

Whereas rice thrives in permanently inundated soils, crops such as wheat and cotton require less water and are susceptible to water logging. There have been reports that irrigation of crops, other than rice, has led to increased malaria transmission (Jobin, 1992; Hunter *et al.*, 1993; Jobin, 1995), and Ijumba and Lindsay (2001) reported on some well-documented studies of how irrigation of these crops affects malaria transmission in Africa.

An example is the Gezira-Managil irrigation scheme in Sudan (Jobin, 1995). This is the largest irrigation scheme in Africa and grew from 400 000 ha in 1925 to 880 000 ha by

1987. Cotton has been grown here since its inception. Later, wheat, sorghum, vegetables and eucalyptus were introduced during the rapid expansion programme of the late 1960s. Although low levels of malaria had always been associated with agricultural development in the Gezira, the expansion and intensification programme created new mosquito habitats and led to serious outbreaks of malaria (Oomen *et al.*, 1988). Fadel (1995) concluded that there were many factors that contributed to the rise in prevalence, primarily:

a- The increased acreage required for growing cotton and wheat provided additional breeding sites for malaria mosquitoes.

b- The pattern of transmission also changed since the irrigation of wheat during winter months led to a second seasonal peak in malaria. Wheat cultivation meant continuous irrigation from mid-October to the end of March, on land that had previously been left fallow, or planted with cattle fodder. Accordingly, irrigation of wheat occurred at a time when air temperatures allowed malaria transmission. Although malaria was found almost everywhere in the scheme, transmission was higher upstream where rainfall was heavier.

Excessive use of agricultural pesticides was blamed for causing insecticide resistance in *An. arabiensis*, the principal malaria vectors in the irrigation scheme (El Gaddal *et al.*, 1985; Oomen *et al.*, 1988; El Gaddal, 1991).

There is evidence that human factors exacerbated the problem of malaria. As many as 100 000 migrant labourers from neighbouring countries entered the scheme in search of employment in one season alone (Jobin, 1995). The high labour requirement attracted people from all over Sudan and neighbouring countries and many would have had little or no immunity, whilst others would carry their parasites with them, acting as reservoirs of infection (possibly a source of chloroquine-resistant strains of *P. falciparum*). Alternative drugs, such as Fansidar, for treating chloroquine-resistant cases were not readily available in the scheme area (El Gaddal, 1991).

The Hola cotton and vegetable irrigation scheme in the Lower Tana River Basin in Kenya is a 875-ha scheme established in the 1950s (Hunter *et al.*. 1993). Prevalence of malaria in this scheme was reported to be 54% higher than in surrounding, non-irrigated, areas resulting from an increased number of mosquito breeding sites. Indeed, malaria was reported to have increased so much as to compromise the economic objectives of the project (Thitai, 1991). Unfortunately in this case the socio-economic aspects of transmission were not described and it is not known what human factors may have contributed.

2.3.4 Sugarcane

A resurgence of malaria associated with sugarcane was reported in Swaziland (Packard, 1986). The study concluded that if care had been taken to maintain the irrigation system, malaria would not have been a problem. It was also thought that the problem was compounded by immigrants from neighbouring countries who brought with them new strains of malaria. Living conditions in workers camps were reported to have been very poor and neglected, and malaria treatment inadequate (Packard, 1986). Migrant labour movements were associated with maintenance and spread of chloroquine resistance in the scheme and other areas. In a study aimed at sugarcane plantation labourers at the Tanganyika Planting Company estates in Tanzania, it was found that prevalence of *P. falciparum* in school children was 37% (Mutabingwa *et al.*, 1986). The authors suggested that the prevalence was lower than expected because of frequent use of chloroquine and bednets by the population. More recently, the prevalence was found to have dropped to about 12%, compared with 29% in a nearby savannah village (Ijumba, 1997). Easy access to medical treatment and widespread use of bednets were identified as the key factors responsible for low malaria prevalence in the area. A study carried out in the Miwani sugar-belt in Kenya found a high sporozoite rate for *An. gambiae s. l.* of 6%, suggesting a high level of malaria transmission (Githeko *et al.*, 1993).

2.4 Irrigation and Disease Vectors

Understanding where mosquitoes breed and why they prefer certain water bodies over others is vital for the elaboration of sound mosquito control strategies and is particularly important in areas where large-scale irrigation is being practised (Birley, 1991; Ijumba & Lindsay, 2001).

The key questions that have to be answered when water management measures are being considered for vector borne disease control in rice agro-ecosystems are:

- What are the local vectors?

- Where do they breed?
- Are the breeding opportunities that are created in the irrigated area likely to contribute significantly to the overall vector abundance and disease transmission level?

Vector ecology and disease transmission are dynamic and complex processes and it is sometimes difficult to immediately draw reliable conclusions, particularly when applying to situations in different countries.

2.4.1 Water projects and vectors

Reservoirs, irrigation canals, and dams are closely associated with parasitic disease. Construction of reservoirs and canals can lead to a shift in intermediate host and vector populations, such as snails and mosquitoes, their larvae and their parasites. During construction of dams and canals, excavation pits can provide breeding sites for mosquitoes. Tropical reservoirs and irrigation systems provide ideal conditions for rapid reproduction and growth of fluke-transmitting aquatic snails. Additional breeding sites are provided by creation of basin irrigation for rice, by poor drainage, and impounded water and seepage (Patz *et al.,* 2000).

Hydrological changes following irrigation development or dam construction may lead to a significant increase in the extent of mosquito breeding sites and in their seasonal duration. Thus seasonal transmission of a disease such as malaria may be extended. As each vector has its own peculiar biology and environmental requirements, the detailed design of a water development project should take account of the attributes of local vector species (Birley, 1991).

Mosquito-borne disease

Different mosquito species vary in their habitat requirements, in both the larval and adult stages. Some species prefer sunlit pools with turbid water, with little or no emergent vegetation. Some larvae prefer clear water, inhabiting the edges of clean, clear, gently moving streams or, conversely, others thrive in irrigation and hydroelectric reservoirs with their frequent changes in water level, vertical shorelines, and emergent vegetation without organic material or salinity; others inhabit coastal areas with high salinity. In the Tenesses Valley in the USA in the 1930s-40s malaria mosquitoes (*An quadrimaculatus*) were controlled by fluctuation in the water level in reservoirs behind dams (see review in chapter by Curtis in forthcoming book on

Integrated Pest Management edited by Radcliffe & Hutchison, University of Minnesota. There are species, which require extensive vegetation cover and inhabit swamps and relatively permanent water-bodies with organic material.

Riverine pools, created by diversion of flow out of riverbeds, provide breeding in shallow, stagnant surface water exposed to sunlight. Deeply shaded pools, seepages in forests, footprints, mining pits and irrigation ditches, and excavated depressions in the open sunlight all provide areas for mosquitoes to deposit their eggs (WHO, 1982). Unfortunately, the wide variety of conditions under which at least a few species are able to thrive ensures that parasitic disease is throughout many regions of the world, especially in tropical areas (Patz *et al.*, 2000).

The characteristics of bodies of water, including their vegetation, play a role in determining which mosquito species inhabits an area. In Africa, A. *gambiae s.l.* prefers sunlit pools with turbid water with little or no emergent vegetation; *A. funestus* larvae prefer clear water, thriving in irrigation and hydroelectric reservoirs with their frequent changes in water level, around shorelines with vertical, emergent vegetation without organic material or salinity; *A. pharaoensis*, requiring extensive vegetation cover, inhabits swamps and relatively permanent water-bodies with organic material; *A. melas,* the coastal areas with high salinity (Patz *et al.*, 2000). Unfortunately, the wide variety of conditions under which at least one mosquito species with a malaria causing parasite can be found to thrive ensures that malaria remains endemic throughout Africa. In rural India, in the early stages of rice growth irrigation systems harbour *A. culicifacies*. In Sri Lanka, *An. Culicifacies* and *An subpictus* the vectors are not found in the irrigated fields or drains, but rather, in the riverine pools created by diversion of flow out of riverbeds, breeding primarily in shallow, stagnant surface water exposed to sunlight. *A. minimus* and *A. balabacensis* are the major malaria vectors in the hilly regions of Myanmar, Thailand, Vietnam, Laos and Cambodia. *An dirus* deposits its eggs in deeply shaded pools and seepages in the rain forests, in footprints, mining pits and irrigation ditches, and in excavated depressions in the open sunlight, while *A. minimus* larvae inhabit the edges of clean, clear, gently moving streams (WHO, 1982).

With reservoir development, mosquitoes which normally breed in small collections of water, such as *Anopheles gambiae* in Africa, may decrease in numbers as their numerous, separate habitats are submerged. On the other hand the shallow shoreline of a large water body may provide extensive new breeding sites. Weeds and aquatic vegetation invade the shallows, which provide refuges against waves, wind and current action and from predators. Deep reservoirs with regular shorelines and steeply sloped margins are likely to support far less mosquito breeding than shallow reservoirs with a long, irregular shoreline and gently sloped margins (Birley, 1991). Inadequate clearing of vegetation during construction may result in the accumulation of floating debris in inlets, the growth of aquatic vegetation and mosquito breeding. Systematic fluctuation in the water level as in the Tennessee Valley in the USA (see above) can do much to reduce vector breeding by stranding eggs, larvae and pupae but if temporary pools are created at the margins then important mosquito vectors may be encouraged to breed (Birley, 1991). Because of its widespread distribution and its importance, rice irrigation is a particularly important context.

Worldwide, over 140 million hectares are devoted to rice cultivation. Much of this area is found in countries of the tropics and subtropics where malaria still constitutes a serious human health problem. Only *An. culicifacies* sibling species E is found in Sri Lanka (Abhayawardana *et al.*. 1996). In India by contrast, this species is considered a rice-field breeder but not a vector. In India, malaria transmission is predominantly confined to the north of the country and the most important vectors are *An. culicifacies* sibling species A, C, D and E *An. nigerrimus, An. fluviatilis, An. stephensi* and *An. annularis* (Service, 1993). All except *An. stephensi* breed in rice fields to a greater or lesser extent. In contrast to the culicine vectors of Japanese encephalitis (JE), however, few anopheline vectors of malaria utilize rice fields per se as their main breeding habitat in India. The most commonly encountered breeding sites of malaria vectors are actually canals and fallow fields rather than rice fields under cultivation. Sharma and Mehrotra (1986) concluded that in India, rice cultivation has a very weak or no relationship to malaria transmission. In Madagascar the main vector of malaria is *An. funestus*, which almost exclusively breeds in rice fields in that country (Laventure *et al.*, 1996). However, the main vector of malaria in most of sub Saharan Africa, *An. gambiae s.l.*, has long been associated with rice cultivation (Surtees, 1970; Lindsay *et al.*. 1995). In Kenya, there was a 70-fold increase in the population of adult *An. gambiae* caught biting man on the Ahero irrigation scheme compared with an area of undisturbed settled agriculture (Surtees *et al.*, 1970).

Most vectors prefer sun exposed breeding habitats and therefore the numbers may decline when rice plants grow taller and the vegetation canopy closes. An example is *An. arabiensis,* which breeds in the early stages of the rice crop. The opposite can occur with anopheline mosquitoes that prefer shade. For example in California, rice fields with rapid early canopy development had greater populations of *An. freeborni* larvae than fields with more slowly developing vegetation canopies (Wood *et al.*, 1991). In Africa *An. gambiae* and *An. arabiensis* are often replaced by *An. funestus* when the canopy becomes more dense (Service, 1989b).

Early rice culture in Asia was small-scale, relying on manual irrigation from reservoirs (tanks), with seasonal flooding and drying. Good management of scarce water supplies appears to have been responsible for maintaining vector populations at low levels (Self & De Datta, 1988). In contrast, modern systems tend to be large, using large quantities of water diverted into water-scarce areas. In terms of food production they may be very successful, but there are often consequences in terms of human disease, and these potential negative effects are often overlooked during feasibility studies and environmental impact assessments. Furthermore, many schemes are poorly designed and constructed and this can lead to a proliferation of mosquito and other vector breeding sites. The improper elevation of canal beds, erosion from unlined canals and seepage from poorly designed and constructed canals can all lead to the creation of stagnant and sunlit pools which are often ideal mosquito breeding sites (Goonasekere & Amerasinghe, 1988).

Sandflies and leishmaniasis

The colonial desert rodents, *Meriones spp, Rhombomys opimus* and *Psammomys obesus* create ideal habitats for sandflies (in their relatively cool, moist burrows) across the entire Old World arid belt, from the northern edge of the Sahara desert to northern India and Mongolia (Warburg *et al.*., 1990). These animals provide a reservoir of leishmaniasis. In mountainous coffee-growing regions of Latin America, where there are large shade trees among the coffee plants, there are phlebotomine sand flies and leishmaniasis has become a serious problem (Warburg *et al.*, 1990). It is speculated that the sugar of the ripe coffee fruit may facilitate the development of *Leishmania* parasites in the vectors (Scorza *et al.*, 1985). Irrigation can lead to importation of the problem. In the Upper Nile province in southern Sudan, an area in which visceral lieshmaniasis had not been endemic, it has been suggested that an outbreak of leishmaniasis may have been attributable, in part, to a combination of the introduction of the parasite to a non-immune population by a large wave of immigrants from an area with endemic leishmaniasis and ecological changes favourable to the sand fly (Zijlstra *et al.*, 1991).

Agricultural development associated with water development affects the sandflies in two main ways. Ploughing and other land disturbances eliminate *Rhombomys* or *Psammomys*, which are the two main reservoir hosts of cutaneous leishmaniasis, but often encourage *Meriones sp.* to increase in numbers and therefore become more important Birley (1991). The second effect comes with the raising of the water table, which can lead to increases in sandfly populations. Female sandflies lay their eggs under stones or plants in flowing water (Birley, 1991).

Serious outbreaks of cutaneous leishmaniasis associated with water development projects have been reported from Libya, Saudi Arabia, USSR, Pakistan and India. In the formr USSR participation of public health engineers and landscape epidemiology teams in water development led to effective control and prevented outbreaks amongst labourers and settlers (Birley, 1991).

Snails and schistosomiasis

In the Nile Delta below Cairo and in the Sudan, the prevalence of schistosomiasis parallels the degree of irrigation intensity, as the snail is carried along with the water (Jobin, 1999). With the construction of the Roseires and Aswan Dams in Egypt, year-round irrigation became possible and snail populations grew. Schistosomiasis has prevailed throughout the Gezira irrigation system since 1970, when a storage dam was added to the original Gezira irrigation system of the central Sudan (Amin *et al.,* 1982). In Iran, construction of an improved irrigation system and a new canal system resulted in an upsurge in the prevalence of schistosomiasis, especially among those working and living within the immediate area (Jobin, 1999).

In China, subsequent to the first stage of the construction of the Three Gorges high dam on the Yangtze River, the snail distribution and annual prevalence of human schistosomiasis varied significantly in accordance with water levels in the Yangzte River. The density of the snails was related to the water table, annual rainfall, yearly evaporation and ground altitude (Xue *et al.,* 1999).

2.5 Benefits and drawbacks of irrigation

A good irrigation scheme will provide greater security of water supply over a longer period of the year. It will enable farmers to accept the risk of using a higher level of inputs, so that they can produce a larger volume and/or more valuable crops, to the benefit of both themselves and their country. Amongst the human health benefits should be improved diet resulting from an increased production of staple foods, new opportunities of growing fruits and vegetables and increased purchasing power for foods not produced on the farm. Improved incomes should also positively affect health status by enabling people to spend more on clothing, housing, recreation and health (Tiffen, 1991).

Other beneficial side effects of irrigation can be new fishing areas, the possible development of recreation areas alongside reservoirs and canals, and better facilities for feeding and watering the domestic livestock, which can also improve diet and income considerably. Unfortunately, almost nothing is known about the general impact on nutrition and health of specific agricultural projects, and this makes it difficult to quantify benefits (Lipton & de Kadt, 1988; Tiffen, 1991).

Irrigation development projects worldwide have been associated with negative impacts on human health, particularly with respect to vector-borne diseases (Hunter *et al.*, 1993; Birley, 1995; Birley & Lock, 1999). Evidence for a direct relationship between irrigation development and increased malaria transmission is inconsistent (Harrison & Scanlon, 1975; Oomen *et al.*, 1994; Ijumba & Lindsay, 2001), with increased transmission in some situations (Goonasekere & Amerasinghe, 1988) but not others (Boudin *et al.*, 1992).

Often health has either been ignored, or has been considered a separate item in the development of agricultural projects. Insufficient care has been taken to avoid the negative effects of irrigation on health. These occur because irrigation leads to changes in the distribution of areas of standing and flowing water and in the location of human settlements, and to a modified micro-climate (Tiffen, 1991).

The observation that ricefields frequently generate large numbers of mosquitoes suggests that malaria transmission will increase in local communities. However, there is an increasing body of evidence that indicates that this is not the case, at least in areas of stable transmission, where malaria may be less of a problem than in surrounding communities outside the ricefields. Also high vector density does not necessarily imply an increased risk of exposure to malaria parasites. In a study of two communities in the Vallée du Kou, Burkina Faso, malaria prevalence varied between 35-83% in the savannah and 16-36% in the rice-growing area (Boudin *et al.*, 1992). In the Lower Moshi rice irrigation scheme, Tanzania, malaria prevalence was four times lower in children living near irrigated rice cultivation compared with a nearby savannah village (Ijumba & Lindsay, 2001). When a large-scale rice irrigation scheme was introduced in The Gambia, there were anecdotal reports of increased malaria in local communities. However, on closer examination, it was apparent that there was less malaria near the ricefield than in other rural communities (Lindsay *et al.*., 1991). Another important finding from this study was that during the dry season there was 'anophelism without malaria'. Whilst enormous numbers of vectors were produced by the ricefields during the dry season there was little or no malaria in children. The main reason for this finding was probably related to the extremely high temperatures experienced during the dry season, often rising above 40°C during the day. Such exceptionally hot weather reduced the survival of adult mosquitoes and perhaps, more importantly, killed the developing parasites within the vector. The critical finding was that there were few infective mosquitoes during the hot, dry season.

This general observation that ricefields do not increase the risk of malaria, is also characteristic of some areas with exceptionally high numbers of mosquitoes. In The Gambia most *An. gambiae s.l.* breed on the edges of large pools bordering the River which generate large numbers of adult mosquitoes; interestingly villages closest to the breeding sites had less malaria than those further away (Thomas & Lindsay, 2000). Such effects also operate at a coarser spatial scale, with areas with the largest numbers of mosquitoes having less malaria than those with fewer mosquitoes (Thomson *et al.*, 1994).

Reasons for this protection are many and varied. One plausible explanation is that the introduction of irrigated-rice cultivation results in wealth creation in local communities and with this additional wealth, farmers make improvements to their homes, their standard of living rises and they have more disposable income with which to use to protect themselves from nuisance mosquitoes and malaria (Audibert *et al.*, 1990; Boudin *et al.*, 1992). In Kenya, it was found that at a certain threshold of income the situation becomes favourable for adoption of malaria control measures at a family level, and this went hand in hand with improvement of the living standard of the family or community. Therefore, a community with relatively higher economic development would be associated with greater use of anti-malarial measures, and also, within a community, wealthy individuals would be more likely to use such measures. Support for this also comes from studies that have shown that bednet ownership was related to wealth in The Gambia (D'Alessandro *et al.*, 1994) and Tanzania (D'Alessandro *et al.*, 1994)

Large-scale irrigated rice cultivation can result in several thousand mosquitoes entering a local house during the night. For most people such high biting rates are unacceptable and they will protect themselves by sleeping under bednets. Studies in The Gambia have shown that more people start using bednets when mosquito numbers begin to increase (Aikins *et al.*, 1993; Thomson *et al.*, 1994) Bednets in good condition reduce biting rates (Lindsay *et al.*. 1989) and can protect against malaria. Thus, it is likely that part of the association between rice and moderate malaria may be explained by the high bednet coverage in communities living near irrigated rice production. Thus, high net use has been reported from rice growing villages in Burkina Faso, Cameroon and The Gambia (Lindsay *et al.*, 1991).

Mosquitoes that find it difficult to feed on humans in such a situation may be displaced and feed on other animals, such as cattle. Such a marked shift in feeding behaviour was suggested as the reason for the low sporozoite rates found in three villages in the Senegal River delta where *An. gambiae s. l.*, *An. funestus* and *An. pharoensis* were vectors.

Widespread use of anti-malarials in ricefield communities and the existence of a well established health infrastructure may also contribute to the general lower level of malaria, although cloroquine is now obsolete because of widespread resistance – it has been replaced by artemisinin based combination therapy- will make control more difficult in the future. It is of course also important that irrigation schemes are well designed and maintained to reduce standing water to a minimum and thus limit the opportunities for mosquito breeding (Ijumba & Lindsay, 2001).

2.6 Immediate consequences of irrigation in previously arid areas

It is potentially dangerous when irrigation is introduced into areas of unstable malaria, sites with generally low levels of transmission and where people have little immunity against parasites. These communities are characterized by malaria being a threat to adults as well as children, unlike areas of stable transmission where malaria is largely a problem of children and primigravidae. This is a serious threat, especially as irrigation schemes are more likely to be introduced into dry areas, where transmission is likely to be low. In the highlands of Burundi, parasite prevalences were markedly higher in the Rusizi valley ricefields (24-69%), compared with nearby cotton-growing areas (5-30%) (Ijumba & Lindsay, 2001).

There are a number of possible reasons for this finding. It may have resulted from the large-scale migration of semi-immune or non-immunes moving into a malarious area. Following development of the irrigation scheme, more than 50 000 people, amounting to about 30% of the entire population, migrated from the mountains into the area (Hunter *et al.*, 1993). Such a large influx of people, if from non-endemic areas into an area of moderate transmission, where chloroquine and sulfadoxine and pyrimethamine resistance was widespread, could have resulted in increased malaria.

In the Mwea rice irrigation scheme in the Kenyan highlands, malaria prevalence was 26% higher than in the surrounding areas (Hunter *et al.*. 1993). Although anti-malarials were regularly given to children under 10-years-old, pregnant women and National Irrigation Board staff and their families, medical facilities were not readily accessible to some villages in the scheme because they were too far away, and protection against mosquitoes was minimal (Thitai, 1991).

In Madagascar the highlands were malaria free in the 19th century, but the disease became established when irrigated rice farming was introduced into the area (Carnevale *et al.*, 1999). Malaria had remained in check due to effective antimalaria control, although it has resurged in recent years several decades after the cessation of indoor-spraying with DDT. However it has now been brought back under control by reintroduction of DDT spraying.

2.7 Water resources in Saudi Arabia

As rainfall is irregular in Saudi Arabia, conservation and development of water sources was and is still one of the most important objectives of the Ministry of Agriculture. Heavy rainfall sometimes results in flash floods of short duration. Riverbeds remain dry for the rest of the time. Part of the surface runoff percolates through the sedimentary layers in the valleys and recharges the groundwater, but some is lost by evaporation (Audallah & Abderrahman, 1996). The largest quantity of runoff occurs in the southern and western region of Saudi Arabia and this represents 60% of the total runoff although it occurs in only 10% of the total area of the country (Audallah & Abderrahman, 1996). The remaining 40% of the total runoff occurs in the far south of the western coast (Tihama), which covers only 2% of the total area of the country. Total surface water resources have been estimated at 2.2 km^3/year, much of it infiltrating to recharge the aquifers: about 1 km^3 recharges the usable aquifers. The total groundwater reserves have been estimated at about 500 km^3, of which 340 km^3 are extractable at an acceptable cost (in view of the economic conditions of the country) (Ministry of Agriculture and Water, 1992).

Saudi Arabia is the largest producer of desalinated water from the sea. In 1992, there were 18 desalination and power plants on the western coast, with a total capacity of over 0.7 million m^3/day of water and 1286 MW of electricity, and four plants on the east coast, with a total capacity of over 1.1 million m^3/day of water and 1550 MW of electricity (Ministry of Agriculture and Water, 1992).

2.7.1 Dams in Saudi Arabia

By 1995, approximately 185 dams of various sizes were constructed for flood control and groundwater recharge with a combined storage capacity of 475 million m^3, and 45 new dams were planned (Ministry of Agriculture and water, 1995).

The basic objectives of building dams in Saudi Arabia were:

1. To recharge underground water in the dam area, and provide wells with water in the agricultural regions upstream of the dam.
2. Secure irrigation water for farming purposes.
3. Protecting cities and villages from the risks of torrents, dangers of floods and preserving the lives and properties of citizens.

Dams constructed by the Ministry are diverse and include the following main types:

1. Earth dams (Figure 2.4) are the most common dam made by either government or local people. Their design is suitable for dams up to 3m high. They are constructed simply by earth spreading. They are of special technical specifications built in well-compacted layers. The body of the dam is enclosed with stones or concrete to protect from erosion.
2. Rocky dams are a variant of the earth dam in which dumped rock takes the place of compacted earth fill. These consist of rocks of different sizes, stacked and compacted in layers. A concrete or earth partition is placed in the middle to prevent water leakage through the body of the dam.

Figure 2.4: Earth dams: They are usually made by local people to store water during the dry season (Feb-July) for agricultural purposes. Al-Megargumm, Jizan region, Saudi Arabia

3. Concrete dams are the most common dams built by The Ministry of Agriculture and Water for flood control and groundwater recharge. Concrete is made by mixing sand, cement, stones and water together to resist the forces on the dam. The Bisha dam in SW Saudi is an example of this type of dam (Figure 2.5). Its height from foundation is 106 m, crest length is 340 m and total storage capacity is 192 million m^3. It forms the largest lake in Saudi Arabia with an area of about 28 km^2.

4. Underground dams, which use a special technology and are rare worldwide. (Ministry of Agriculture and Water, 1995).

Dams differ markedly in storage capacity. The type of dam and its storage capacity are determined by the site and nature of each valley, and based on extensive preliminary studies (Ministry of Agriculture and Water, 1996 & 1995) conducted prior to the construction. These include:

1. Identification of the proper location of the dam, ensuring that the site is free from obstructions (e.g. roads, farms or other facilities); availability of suitable materials required for construction; preparation of contour plans of the dam area in order to specify the storage basin area; cross and longitudinal sections of the dam site.
2. Hydrological Studies, which determine the quantity of rainfall in the region, time cycle and floods in the valley. They also determine the area where water will collect by aerial mapping. Through such information and contour plans, the volume of water to be stored can be determined representing the storage capacity of the dam. This will determine the height of the dam wall, and required capacity of outlets to ensure safety in the event of floods.
3. Hydrological studies to identify the nature of the geological composition of the area to ensure strength and capability of foundations to withstand future loads and pressures.
4. Engineering and evaluation studies including identification of the type of the dam determined by the size of the valley, the storage capacity and proposed height of the dam wall, availability of materials required for construction, the nature of the geological composition of the dam, the purpose and viability of the dam followed by the preparation of final specifications and designs of the dam.

5. Studying the ecological consequences of building the dam with respect of the nature of valley, the vegetation and animal life, and to suggest appropriate solutions to prevent any adverse consequences.

Figure 2.5: Concrete dams: The Bisha dam in SW Saudi is an example of a concrete dam. These types of dams are built by the government for flood control and groundwater recharge. Its height from foundation is 106m; it is 340m wide with total storage capacity of 192 million m^3. It forms the largest lake in Saudi Arabia with an area of about 28 km^2. (Source Ministry of Agriculture 2000, Saudi Arabia)

2.7.2 Irrigation and drainage development

Soil surveys and classifications put the area of land suitable for irrigated agriculture at about 10 million ha (Department of Economic Studies and Statistics, 1989). All agriculture is irrigated and in 1996 the water managed area was estimated at about 1.6 million ha, all equipped for full/ partial control irrigation. Surface irrigation is practiced on the old agricultural lands, (cultivated prior to 1975), which represent about 34% of the irrigated area (Department of Economic Studies and Statistics. 1989; Audallah & Abderrahman, 1996).

Sprinkler irrigation is practiced on about 64% of the irrigated areas. The central pivot sprinkler system covers practically all the lands cropped with cereals. Normally, pumped groundwater from one deep well supplies one or two central pivots. The irrigation application efficiency of this method is estimated at between 70 and 85%. Groundwater is used on almost 96 % of the irrigated area, treated wastewater on 1 %.

The crop area has more than tripled between 1977 and 1996 (Ministry of Agriculture and water, 1996). In general, there is only one cropping season. The major irrigated crop is wheat. In 1996, it consumed almost 40% of the total quantity of irrigation water while it covered almost 62 % of the irrigated area. Other major crops are fodder, other cereals (particularly sorghum and barley), fruit trees and vegetables. Wheat, vegetables, fruits, dates and fodder are exported.

Waterlogging and drainage problems occur in the central and southern parts of the country (Ali *et al.*, 1991; Bahanshal, 1989), because of the existence of shallow, impervious layers. About 44,000 ha, or 2.7% of the irrigated area, have drainage facilities, mainly consisting simply of open drainage canals.

In several projects, such as the Al-Hassa irrigation project in the east, agricultural drainage water is reused for irrigation after blending with fresh groundwater. Old irrigation networks are replaced with concrete-lined canals (Ministry of Agriculture and water, 1987).

2.8. Vector-borne Diseases in Saudi Arabia

Malaria

Saudi Arabia with its diverse climatic, topographic and ecological features can support a wide variety of malaria epidemiological patterns. About 1.7 million of the population live in areas where malaria is transmitted. Except for the central part which is free of malaria, the rest of the country includes four malarious areas that differ in their epidemiological characteristics and mosquito vectors, though *An. sergentii*, which is extremely well adapted to desert conditions (Al-Seghayer *et al.*, 1999) occurs in all areas (Figure 2.6).

The first reliable data on malaria in Saudi Arabia came from Aramco (Arabian American Oil Company) in the eastern province in 1941. According to a malariometric survey carried out (Daggy, 1948) malaria at Al-Hassa was mesoendemic. It was the most significant health hazard and the leading cause of morbidity and mortality among the oil workers. Most of the cases came from the Al-Hassa oasis area. For the last thirty years no malaria cases have been detected, except for some imported cases each year from inside or outside the Kingdom of Saudi Arabia. *An. stephensi* is the recognised main malaria vector species predominating in the oases (Daggy, 1958; Bashwari *et al.*, 2001).

Figure 2.6: Distribution of malaria in Saudi Arabia.

In the eastern and northern parts where oasis malaria was endemic, local transmission has not occurred since 1972 (Al-Seghayer *et al.,* 1999; Bashwari *et al.*, 2001). However, with the abundance of anopheline vectors, mainly *An. stephensi* and *An superpictus* (Daggy, 1958), the continuous flow of parasitic carriers from malarious countries or from endemic areas within Saudi Arabia and the availability of non-immune humans, malaria may resurge if relaxation of control activities occurs. Moreover, if the situation in the Eastern Province is not well maintained, there is a risk of malaria outbreaks in such big cities as Dammam, Al-Hassa and Hofuf due to the ability of *An. stephensi* as a vector of urban malaria. Consequently, malaria surveillance in these areas remains high (Al-Seghayer, 1983; Al-Seghayer *et al.,* 1999).

In the western and southern parts, the geographic distribution of malaria was reduced to some foci inside remote valleys of Hijaz mountain range where rainfall is sufficient to provide abundant areas for breeding of the principal vectors, *An sergentii* and *An.*

arabiensis (Abdullah, 1995). Malaria control in such foci is difficult due to the nomadic movement and exophilic habit of the mosquito vectors.

In the south-western part especially in the valleys and villages in the foothills of Sarawat Mountains (Jizan and Aseer regions) where *P. falciparum* is common (over 90% of cases) and where rainfall is relatively abundant, malaria occurs at meso- to hyperendemic level (Al-Seghayer, 1983; Al-Seghayer *et al.,* 1999). In addition to the imported and border malaria, two major technical problems now face malaria control programme in Saudi Arabia:

(a) the already developed resistance of vectors to organochlorine insecticides and the expected resistance to the insecticides currently in use, and
(b) *P. falciparum* resistance to chloroquine, that has progressively increased in recent years, with some locally acquired cases in SW areas bordering Yemen. With this situation, monitoring of both vector and parasite resistance must be regularly carried out with vigilance (Al-Seghayer *et al.,* 1999)

The national antimalaria programme is under continuous evaluation and revision. Emphasis is placed on non-chemical measures for controlling malaria vectors such as environmental management and biological control to:

(a) reduce complete reliance on chemical insecticides due to their possible adverse effects on human health and environment in addition to the problem of vector resistance and

(b) to have efficient chemical agents available in emergency situations to assist in checking outbreaks of the disease. As malaria problems are often man-made, community participation in its control is of prime importance especially in vector control. Such participation is not yet fully achieved in Saudi, which represents a major challenge to the MOH control efforts (Al-Seghayer. *et al.*., 1999).

Following the extensive malaria control programmes described, malaria is now restricted to the southwestern part of the country (Tihama). About 5% of the national population of Saudi Arabia are at risk (1.04 million). The average number of cases per annum recorded in Saudi Arabia in the period from 1983 to 2001 was 15160 (Al-Seghayer *et al.*., 1999), ranging from 3074 in 2001 to 40,796 cases in 1998

Malaria in Jizan region

Jizan Region, in the SW of Saudi Arabia and bordering Yemen, is known to be the most malarious region in Saudi Arabia, accounting on average for 60-70% of all locally acquired malaria cases recorded during the period from 1983 to 2001 (Al Sheikh, 2004). Jizan Region is divided into four zones of differing endemicity:

1. Malaria free zone: Malaria is absent in mountain areas at 1500 metre above sea level, e.g. Feifa and Al Hasa areas. It is also absent in the Farasan Islands.

2. Low endemicity zone: Transmission in this zone is unstable and the area is subject to malaria epidemics. Periodic rains in the hills can lead to flooding in the wadis. This can leave water pockets suitable for breeding of mosquitoes on the coastal plain. In the past the spleen rate in this zone was found to be less than 10% (MOH, 1983; Ageel, 1990).

3. Moderate endemicity zone: Malaria incidence in this zone is also unstable. Most the inhabitants in this zone are exposed to malaria transmission during periods of up to six months every year, depending on the pattern and amount of rain. This zone includes the interior plains and foothills (Al Aridah, Harub, Samtah, Abu Arish, Al Raith, Sabya, Twowal, Itwad, Al Darb, Cuz, Kudmi, AlHakamyah, Shugayri, Al Salb, Dehama, Al Ghahma, Mislyah, Al Fateha, Al Ayah, Mawasam; In these places, the rainwater collects in wadis and in natural pans. This is also where most of the population of Jizan reside, especially along the wadis. The spleen rate in this zone was 10- 50% (MOH, 1983; Ageel, 1990).

4. High endemicity zone: Malaria in the Yemeni border areas is stable. Malaria cases reported from this zone constitute more than 50%of all cases reported in Jizan. Water suitable for mosquito breeding is available throughout the whole year. It is likely that malaria transmission continues throughout seven months of the year. This persists in most areas despite repeated control measures.

The malaria transmission season in Jizan extends from October to April with a prominent peak in January. The major factor that influences the extent and intensity of transmission season is rain (Ageel, 1990).

Malaria Vectors

Fifteen indigenous *Anopheles sp.* mosquito species are known to exist in Saudi Arabia (Al-Seghayer. *et al.*, 1999; Daggy, 1958) of which only three are primary malaria vectors: *An. stephensi* (Eastern province) and *An. superpictus* (Northern Province). Al Sheikh (2004) recently found that *An. arabiensis* is the only vector of malaria and the only member of the *An. gambiae* complex found in the Tihama area of Saudi Arabia and Yemen. In addition, *An. fluviatilis* (Eastern province) and *An. sergentii* (Eastern and Southern Provinces) are considered as secondary vectors (Daggy, 1958).

Rift Valley Fever

An outbreak of RVF occurred in 2000 in the Arabian Peninsula, in South-western Saudi Arabia, in Jizan Region (Jupp *et al.*, 2002) and in neighbouring Northern Yemen in Al Zohra district of Al Hudaydah Governorate (Balkhy & Memish, 2003). This was the first outbreak to occur outside the African Continent since RVF was recognised seventy years ago (Jupp *et al.*, 2002; Gubler, 2002).

The RVF outbreak in Saudi Arabia started in September 2000 and lasted until April 2001. The total number of cases identified serologically was 884, 98% of which occurred in Jizan and Asir Regions The case fatality rate was 14.0% (124/884) in Saudi Arabia and 11.1% (121/1087) in Yemen (Shoemaker *et al.*, 2002; Al-Hazmi *et al.*, 2003; Balkhy & Memish, 2003).

In September 2004 (during this study), RVF reappeared in South-western Saudi Arabia, in Jizan Region, with cases only in livestock with no cases reported among humans. Five cases of viral disease were detected during periodic examinations in Jizan (MoA, 2004). The 5 cases were in the Jizan dam area: 4 in Abu Areish governorate and one in Al-A'rida governorate.

RVF viruses in Saudi Arabia and Yemen were virtually identical to those identified in earlier East African outbreaks (Shoemaker *et al.*., 2002). In the Saudi Arabia RVF outbreak, *Aedes vexans spp. arabiensis* Patton and *Culex tritaeniorhynchus* Giles were identified as vectors (Jupp, *et al.*, 2002; Miller *et al.*, 2002).

Control of the epidemic was based on disease prevention in domestic animals in the peridomestic environment, by elimination of the infected animals and vaccination of uninfected. Mosquito control by larviciding, Indoor Residual Spraying (IRS) and space spraying using aircraft were also carried out. In September 2000, the Saudi Ministry of Health developed and implemented strict plans to prevent the appearance of this disease during the Hajj (pilgrimage) period. Annually, 2-3 million people from all over the world convene in the holy city of Mecca in the Western Province of Saudi Arabia to perform Hajj, part of which leads to the slaughtering of hundreds of thousands of livestock animals.

Dengue and Dengue Haemorrhagic Fever

Primary dengue, caused by one of the four serotypes, is usually a self-limiting febrile illness, but when infection with a second serogroup occurs DHF or dengue shock syndrome may ensue. In 1993, a fatal case of DHF occurred in a Saudi male in Jeddah, following the introduction of dengue to the region (Shaheen *et al.*, 1993 & Zaki, 1997).

Recently, the Ministry of Health reported 143 cases (4 deaths) in Jeddah in the first two months of 2006. This serious increase in the south western part of Saudi Arabia started in 2004 with 291 cases and continued with 305 cases in 2005 (MOH 2006).

The communicable diseases surveillance system in Yemen recently detected an outbreak of dengue 3 fever, which was confirmed by the US Naval Army Medical Research Unit 3 (NAMRU-3), Cairo, Egypt (WHO 2005). As of 17 April 2005, a total of 392 cases of dengue fever have been reported from Hodeida Governorate, Yemen: 172 from Hodeida City (8 deaths, Case-fatality rate [CFR]= 4.7%) and 100 from Zabeed City (7 deaths, CFR= 7%), while the other cases occurred in some 18 villages in the area (WHO, 2005).

Schistosomiasis

Schistosoma mansoni and *S. haematobium* are endemic in 12 provinces in the Kingdom of Saudi Arabia with the expansion of agricultural lands, which provide breeding grounds for snails (Sebai, 1988b). *S. mansoni* is prevalent in the highlands of the Western region and some parts of the Central and Northern regions whereas *S. haematobium* is mainly prevalent in Tihama areas, the lowland coastal plain in the west-southern region.

Transmission appears to be intense in the southwest region of the country, in which there are 23 dams (Ministry of Agriculture and Water 1995) and almost 2 million people are at risk of infection (Ashi. *et al.*, 1989; Ghandour *et al.*, 1999).

The geographical distribution and ecology of the snail intermediate hosts of these parasites, the prevalence, incidence and intensity of human infection, and the efficacy of several diagnostic tests have already been investigated in the Western region (Morad, Khan. 2001; Ghandour *et al.*, 1995, 1997; Amin, 1990; Magzoub & Kasim, 1980; Gremillion *et al.*. 1978; Alio, 1967; Arfaa, 1976). However, there have been few if any reports of human-water contact studies related to the transmission of schistosomiasis in Saudi Arabia.

The disease was until recently, an important public-health problem in most parts of the country. Between 1974 and 1977, the national ministry of health established centres in all endemic regions to carry out control programmes based on diagnosis, treatment of infected individuals and snail control (Amin & Ageel, 1997)

Leishmaniasis

Cutaneous leishmaniasis is a serious and increasing public health problem in the Kingdom of Saudi Arabia (Peter & Al-Zahrani, 1985). Biochemical typing of numerous isolates from patients with cutaneous leishmnaiasis revealed that *Leishmania major* is widespread in different parts of the country (Al-Zahrani *et al.*, 1989a).

Visceral leishmaniasis is endemic in southern Saudi Arabia (Peters & Al-Zahrani, 1987; Al-Zahrani *et al.*., 1988), mostly occurring in Jizan and Asir regions. Visceral leishmaniasis in southern Saudi Arabia affects predominantly infants and young children (Al-Zahrani *et al.*, 1989b).

Because of age distribution of cases, the disease in Saudi Arabia was thought to be similar to the Mediterranean variety; namely, a zoonosis for which canines are the main reservoir. However, studies identified the causative organism isolated from patients in southern Saudi Arabia as *L. donovani s.l.* zymodeme LON-42 (Al-Zahrani *et al.*, 1989b) This was isolated also in Yemen and eastern Ethiopia. The disease peaks in late spring and summer, then declines sharply in winter (Ibrahim, *et al.*, 1994).

Chapter Three: Description of the Study Sites and Mosquito Collection Methods

3.1 Study area:

The present study was conducted in Jizan Region in South-western Saudi Arabia.

3.1.1 Saudi Arabia

The Kingdom of Saudi Arabia comprises about four-fifths of the Arabian Peninsula, a land mass constituting a distinct geographical entity, bordered on the west by the Red Sea, on the south by the Indian Ocean and on the east by the Arabian Gulf (Figure 3.1).

Figure 3.1:Map of Saudi Arabia showing bordering countries and the main cities. Source; Magellan Geographix 1997 (www.map.com).

Geographically, Saudi Arabia is divided into four major regions. The first is the Central region, an elevated area in the heart of the Kingdom; secondly, there is the Western region, which lies along the Red Sea coast. The Southern region, in the southern Red Sea-Yemen border area, constitutes the third region. Fourthly, there is the Eastern region, the sandy and stormy eastern part of Saudi Arabia, the richest of all the regions in petroleum.

For administrative purposes, the Kingdom of Saudi Arabia is divided into 13 regions:

Riyadh Region
Makkah Region
Madinah Region
Qasim Region
Eastern Region
Asir Region
Tabouk Region
Hail Region
Northern Border Region
Jizan Region
Najran Region
Al-Baha Region
Al-Jouf Region

With the exception of the southern region (Asir, Jizan and Najran), Saudi Arabia has a desert climate characterised by extreme heat during the day (the average is 35°C during summer, reaching 49°C as maximum), an abrupt drop in temperature at night (the average is 23°C during winter reaching 4°C). Because of the influence of a subtropical high-pressure system and many fluctuations in elevation, there are considerable variation in temperature and humidity. The Relative Humidity ranges from 30% (the arid regions) to 95% (the costal regions). The average annual rainfall is between 7.5 and 15 cm, with the Southern Region (which is subject to Indian Ocean monsoons usually occurring between October and March) receiving the greatest amount, about 25-50 cm per annum (Al-Ohaydeb, 1992; Khoja & Farid,2000).

About 2% of the total land area is used for agriculture and forest covers about 3%. There are about 3,785 hectares planted with vegetable crops and 23285 hectares planted with trees, which include the date palm, an important food and cultural symbol. In Saudi Arabia there are about 13 million mature date palm (10% of the world supply). The other important cultivated crops and vegetables are millet, wheat, sorghum, and maize (Saudi MOH, 1983; FAO 2002).

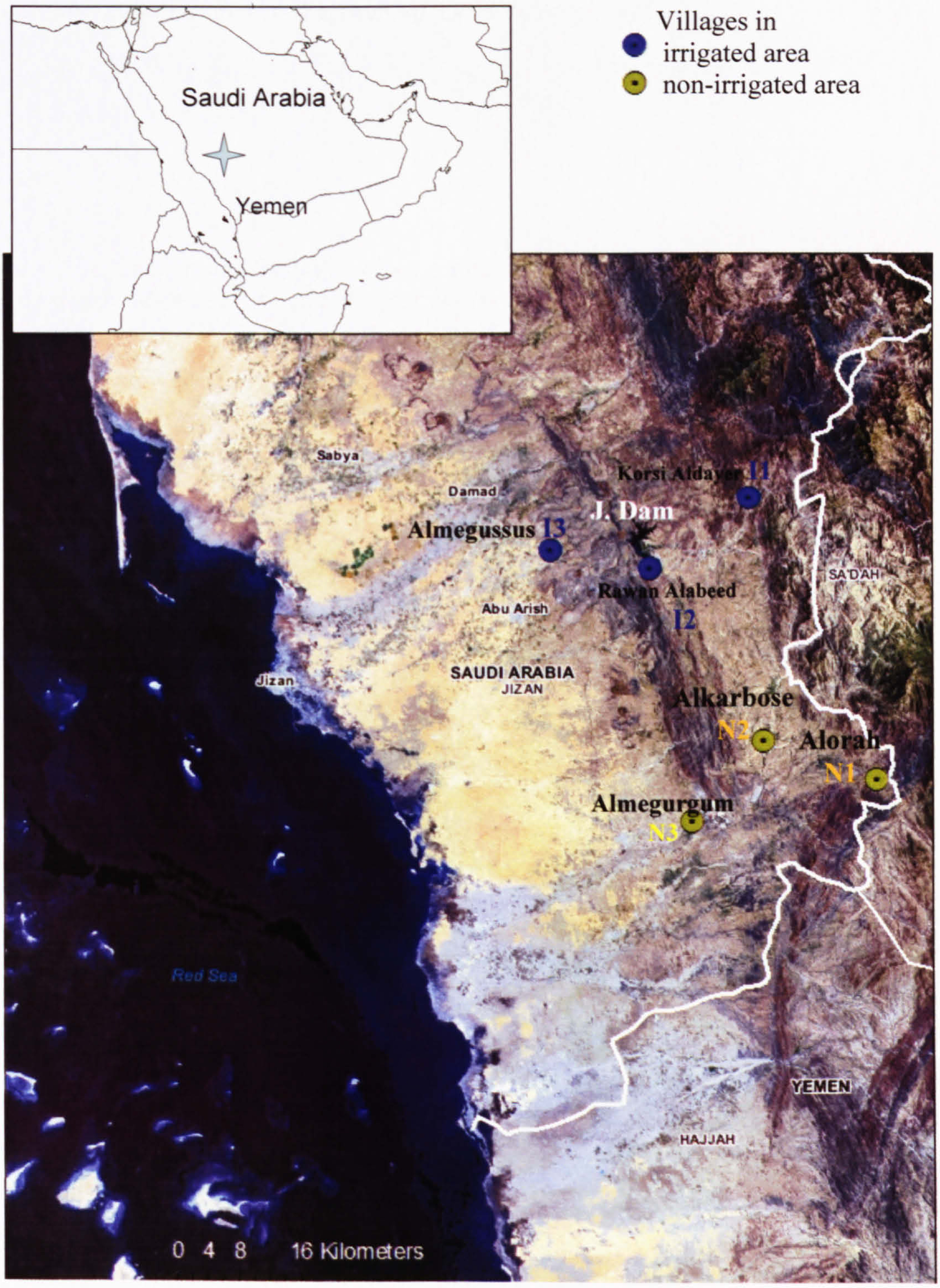
3.1.2 Jizan region

Jizan region lies in the southwest of the country, between 16° 12' and 18° 25' latitude north (Figure 3.2). It is bordered in the east by Sarawat Mountain, in the south by Arab Republic of Yemen and in the west by the Red sea. The total area of Jizan is about 22,000 square kilometres. The Jizan region runs along the Red Sea coast for almost 200 miles (300 km) and includes some 100 islands. In 2002, the population of the region was estimated as 1.3 million, with 30% concentrated in six major cities, and the remainder living in over 1000 villages. Most of these villages of 50-500 people are scattered in remote areas, without ease of access.

Jizan is one of the Kingdom's richest agricultural regions, remarkable for both the quality and variety of its agricultural produce. It is notable for its production of coffee beans, grain crops (barley, millet and wheat) and fruit (apples, bananas, grapes, lemons, mangoes, oranges, papayas, plums and tamarinds).

Topographically, Jizan is divided into three zones: the mountains in the east (rising to 2,500 meters above sea level), the foothills (400-600 meters above sea level) and the extensive plains (less than 400 meters) occupying the area between the foothills and the Red Sea (Ageel, 1990). The region is drained by several permanent wadis, which play a crucial role in providing perennial habitats for mosquitoes and several intermittent wadis, which are wet except in the dry season and which are important in increasing the number of breeding habitats and directly influence abundance of anopheline vectors. These wadis maintain a continuous steady flow into the foothill area (Al-Sharif, 1983; Ageel, 1990). During the period of heavy rains, the wadis may flood and water is carried along the entire wadis to the Red Sea. Thus water flow in these wadis is not stable and is subject to various fluctuations depending on the amount of rainfall in the mountains. Water run off these wadis ranges from steady flow, excessive flow or sweeping flood. Under these situations the breeding places are not constant or stable and continuously depend on the water flow in the wadi. Twenty major wadis that drain rainwater from the mountains into the Red Sea traverse Jizan. These wadis have hundreds of tributaries in the foothill areas (Ageel, 1990).

Figure 3.2: Location of six study villages in the Jizan Region of Saudi Arabia (3 in irrigated area and 3 in a non-irrigated area)



3.1.3 Study sites

Two areas were selected for the study: (see Figure 3.2)

(1) Three villages in the irrigated area (Jizan Dam and Irrigation Project in Wadi Jizan).

(2) Three villages in the control area (Khulab Valley), located 25 km from the irrigated area.

Collection sites were selected after surveillance of the Jizan Region. This revealed that the only suitable habitat for mosquito breeding existed in the wadis, which run from the Sarawat Mountain range down to the Red Sea. Wadi Jizan was then chosen as the main study area because:

(1) It had been associated with the RVF outbreak in 2000,

(2) Jizan Dam and Irrigation Project is located in the middle of Wadi Jizan.(Figure 3.3)

In the study sites, in Irrigation and non-irrigation areas, the population live mostly in villages, few of which have more than 500 inhabitants. Typically, the population of the villages ranges between 50 and 150. These small hamlets are widely scattered in the plain and foothill area. Nearly all the villages in the plain are situated along wadis and seldom lie further than 1km from the wadi. The natural vegetation along the wadis is dominated by *Acacia sp.* and *Tamarix sp.*. Income is derived from sheep grazing, commerce and the cultivation of sorghum. Each family maintains approximately 10 sheep or goats and one cow, but wealthy herdsmen may have hundreds and hire shepherds. Most villages have electricity and a proportion of the population live in air-conditioned rooms. A few inhabitants have electric generators that they utilize at night. Inhabitants who have no electricity or air-conditioning sleep outside nearly all the year round, but especially in the hot weather. Education is available for all levels until secondary school for boys and girls. Health services (primary health care centre and two general hospitals) are also available. Most health centers are provided with a laboratory, where the first line treatment of malaria cases is sought.

Figure 3.3: Jizan Dam; a typical swamp area susceptible to mosquito breeding.

Three villages were selected in the irrigated Area. These are Korsi Aldayer I1 and Rawan Alabeed I2 which are located above Jizan Dam while Almejussus I3 is located below Jizan dam (Figure 3.2 & Table 3.1). Jizan Irrigation Project is located in Almejussus area below the dam. Korsi Aldayer I1 and Rawan Alabeed I2 are a mountainous area intersected by 4 main wadis and their tributaries, and with many hills and stony projections, which reduce the available agricultural areas to patches of clay dependent on rain for cultivation of crops, mostly sorghum. Grazing grass is abundant during the rainy season. To the east lie the Saudi mountains (Sala, Abadel, Bani Kais, with peak of 2500 metres high), and beyond this range, are the range of Yemen mountains, in particular Menabbeh Mountain, which rises to more than 2500 metres.

Table 3.1: Study sites in the Irrigated Area, Jizan, Saudi Arabia

Villages	Location		Total No of House-holds	Altitude (m)
	Lat	Long		
Korsi Aldayer I1	17.10478333	43.10505	62	> 400
Rawan Alabeed I2	17.01873333	42.98621667	321	300-400
Almegussus I3	17.04406667	42.87516667	136	< 300
Total			519	

Table 3.2: Study sites in Non-Irrigated Area, Jizan, Saudi Arabia

Villages	Location		Total No of House-holds	Altitude (m)
	Lat	Long		
Alorah N1	16.77651667	43.24763333	102	> 400
Alkarbose N2	16.79778333	43.2058	218	300-400
Almugergum N3	16.72953333	43.04281667	196	< 300
Total			516	

3.2 Mosquito Sampling

Each site of these 6 sites (Figure 3.2) was sampled once/month and for entomological data three sampling methods were used: PKD (pyrethrum knockdown collection), CDC light traps, and larval sampling of breeding sites.

During the stages of the fieldwork, adult and larval mosquitoes were collected using different techniques to obtain information on density and seasonal abundance of vectors of malaria, Rift Valley fever and other mosquito-borne diseases

3.2.1 Sampling mosquito breeding sites

Surveys were carried out in all six selected villages during 2004 (Jan-Dec). Three local persons were trained as field worker assistants before starting the surveys in Malaria Centre in Jizan. Wadies near each village were sampled in over a length of 1 km. Natural collections of water in temporary pools that formed at the edge of the wadis as a result of overflow, seepage and receding water, water containers in or outside the houses, and wells were checked for the presence of mosquito larvae.

Because mosquito larvae are found in a wide variety of habitats, a number of different sampling techniques to determine their presence and density have been developed. The species of mosquitoes being looked for and the type of habitat being sampled, in part, determine the sampling method used. Thus, it was important that field personnel knew the preferred breeding habitats and seasonal occurrence of species known or suspected to be present within an area.

Many, if not all, of the published methods are described by Service (1993). Some methods used complex mechanical devices, but the most commonly used larval collection methods are the following:

a. Larval dipper
b. Larval net
c. Well net
d. A pipette

Larval Dipper

Mosquito larvae of most genera, particularly the common *Culex*, *Aedes* and *Anopheles*, are usually found at the water's surface and frequently next to vegetation or surface debris. In larger pools and ponds, they are usually near the margins, not in open, deep water. Dipping was concentrated around floating debris and aquatic and emergent vegetation. If there is a strong wind, dipping was done on the windward side of the habitat where larvae and pupae were most heavily concentrated. It is better to look for larvae before beginning to dip, if possible. If it was raining on the water's surface, the collector had to wait until the rain stopped. As many samples as possible were taken in order to obtain an accurate picture of the area's species composition.

Standard dippers (soup ladles) 350 ml, 13 cm diameter (Figure 3.4) were used to collect larvae from pools and ponds. A net was occasionally used to sample larvae. Collections were made following the protocols described in WHO (1975), by dipping the ladle gently into the water surface at an angle about 45 taking care not to disturb the larvae. Larvae and pupae were then transferred to tubes by means of a pipette. The number of dips in each type of breeding site was counted. Larvae were stored in labeled tubes containing water from the habitat, and transferred in a cool box to the laboratory at the Malaria Centre in Jizan.

Figure 3.4: Larval sampling using a dipper, Alorah, Jizan Region, Saudi Arabia

Larval net

A larval net consists of a fine mesh net, with a plastic bottle at the apex, and mounted on a wooden handle. To collect larvae and pupae, the water surface was swept by holding the net at an angle and moving it through the water. Larvae on the water surface were collected in the plastic bottle or tube.

Well Net

The well net was used for sampling from wells, steep sided pools, or from the dam-body tubes (concrete channels used for draining). This net is held at an angle by four strings and controlled by one long string. Asdft

A pipette

A pipette was used for collecting larvae from very small water bodies, e.g. tin cans or hoof-prints.

3.2.2 Sampling adult mosquitoes

Light Trap Collections

CDC light-traps baited with CO_2 (Figure 3.5) (Sudia & Chamberlain, 1962) operated from 6-V rechargeable gel-cell batteries were used to sample indoor and outdoor mosquitoes in each village houses and shelters. The body of the trap was made from a 15cm length of 8.25cm internal diameter. A slot on each side permitted the insertion of the motor support bracket for holding the motor. A 4-V bulb was mounted directly above the motor at the top of the trap body. Color-coded binding posts and 'snap-on' terminals permitted easy connection of leads from the battery and motor assembly. A detachable wire mesh screen was placed over the entrance of the trap to exclude large insects. A fine mesh cloth-collecting bag with a narrow neck was fitted to the end of the trap body. In bedrooms _where normally people don't use bednets _ or shelters with ceilings, it was suspended about 15cm below the ceiling, opposite a window and close to sleeper or animal. Light-traps were placed in 3-5 bedrooms or shelters. The traps were switched on at 1800 hr and switched off at 0700 hr. for certain collections, a 2 kilograms block of dry ice (CO_2) was wrapped in a plastic bag above the trap, mainly for outdoor collections. Five light traps were installed in houses or animals shelters once per month in each of the six sites. These collections were conducted from January – December 2004.

Figure 3.5: CDC light-traps baited with CO_2 used to sample outdoor mosquitoes in the Dam area, Rawan Alabeed, Jizan Region, Saudi Arabia.

Pyrethrum knockdown (PKD) collections

For blood-meal analysis for malaria and RVF vectors, pyrethrum Knockdown (PKD) collections were carried out in at least five houses every fortnight in during the wet season in each village. The routine for these collections in villages was the same, inhabitants were asked to leave their rooms and all easily removable objects such as small tables, chairs, exposed food and drinking water were removed. Followed the protocols of WHO (1972; 1992). In each room two assistants carefully laid white cotton sheets (2x4m) over the entire floors as well as over beds, large furniture and miscellaneous objects that were not easily removable (Figure 3.6). All doors and windows were closed and the bedroom sprayed by 3 people, two of whom remained inside, while the other stayed outside and sprayed along the open eaves gaps and other potential escape routes such as closed doors and windows. The spray was directed towards the roof and ceiling of bedrooms for about three minutes, after which the sprayers left the room and closed the door. Houses were sprayed the early morning between 0630 and 0900hr, with locally bought pyrethroid insecticide aerosol cans (RAID). RAID contains tetramethrin (0.15%), allerthrin (0.25%) and deltamethrin (0.015%). After about 10 minutes the door was opened, the sheets taken outside and mosquitoes picked up from the sheets using forceps. Mosquito were then placed in plastic Petri dishes on damp filter paper and moist cotton, and stored on ice in an insulated cool box for transportation to the laboratory. After completion of the spray collections, furniture and other objects that were removed from the room were returned. The name of the village, house number, time of spraying and the number of people who slept in the room, presence or absence of animals, and number and species of animals were recorded.

Figure 3.6: Using spry sheet collection (SSC) to collect mosquitoes from houses in Rawan village, Jizan, Saudi Arabia

Blood meal analysis indicates

Discovering the blood meal hosts of the local population of mosquitoes is important in determining how well they serve as a vector for diseases. Mosquitoes was collected in the rainy season 2004-2005 in both irrigation and non-irrigation areas mainly using PKD.

Collected mosquitoes were squashed on to a piece of filter paper. The filter paper was divided into 8-16 segments (Figure 3.7), the segments were numbered. The specimens were allowed to dry thoroughly before packing the filter paper for dispatch. If more than one filter paper was used, the filter papers should be separated from one another with a piece of grease-proof paper during packing; this is to avoid cross-contamination. The filter paper was placed in the plastic bag and then placed in the refrigerator.

The rest of the work was completed in Liverpool in the school laboratory in 2005. The following information was provided with each batch of blood-meal sample: a) locality/site of collection; b) mosquito species in relation to filter paper samples; c) animal hosts found at the site of collection; and d) date of collection.

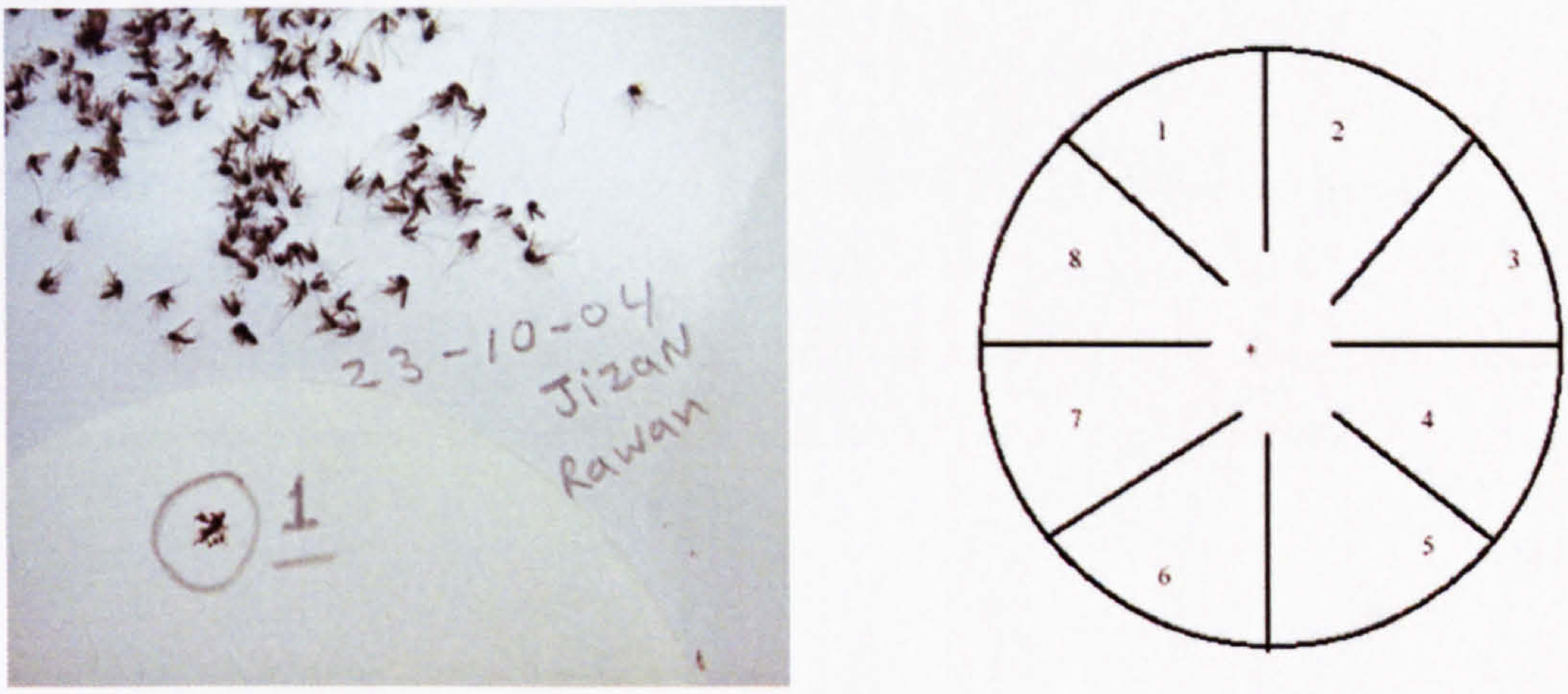


Figure 3.7: Shows how filter paper should be divided for blood-meal collection.

Transportation of Adults and Larvae to Lab

All adult mosquitoes were placed in plastic Petri dishes lined with damp filter paper, and then placed in a cool box and transported to the laboratory.

Wherever possible, larvae were transported alive to the laboratory. In rural areas the majority of journeys to the laboratory took from two to six hours, and tubes were opened every two hours to provide the specimens with fresh air.

Identification of collected mosquitoes

As larviciding with temephos in Jizan and all Tihamah areas occurs weekly, larvae collections in the present study always preceded this larviciding. Thus most of the larvae that were collected were at the first or second stages. Complete development in the laboratory to the later stages of larvae or adults was required for morphological identification. Anophelines and culicines (larvae and adult) were identified using the keys of Mattingly & Knight (1956), and DuBose & Curtin (1965). The key of Harbach (1985) was used for identification of *Culex* larvae and adults, and Glick (1992) was used for *Anopheles* adults. Samples of anophelines and culicines, were preserved in plastic bags containing silica gel and transferred to the Liverpool School of Tropical

Medicine for further analysis. Verification of identification were confirmed by Dr. Ralph Harbach at the Natural History Museum, London.

Chapter Four: Entomological surveys in irrigated and non-irrigated sites in Jizan

4.1 Introduction

Understanding where mosquitoes breed and why they prefer certain water bodies is essential for the execution of an effective mosquito control strategy. This need is particularly important in areas where large-scale irrigation exists (Birley, 1991; Ijumba & Lindsay, 2001).

Hydrological changes following irrigation development or dam construction may lead to a significant increase in the extent of mosquito breeding sites and/ or in their seasonal duration. Thus, seasonal transmission of a disease such as malaria may be extended. As each vector has its own peculiar biology and environmental requirements, the detailed design of a water development project should take account of the attributes of local vector species (Birley, 1991).

The immature stages of the important malaria vector *An. arabiensis* occur in a great variety of habitats, in small temporary, sunlit pools such as rain puddles, and in large permanent habitats such as rice fields and wells (Gillies & Coetzee, 1987). They can also be found in swamps formed by seepages alongside fields and irrigation canals, hoof and footprints and road ruts around rain water pools (Zahar, 1985; Bockarie *et al.*, 1993). Shililu *et al.* (2003) found *An. arabiensis* larvae in five of six aquatic habitats investigated in ponds, rain pools, streams/rivers, swamps and water supplies. In Yemen, *An. gambiae s.l* was found to breed in irrigation canals, riverbeds, water collections near pumps, storage tanks, artificial containers and basins (Al-Maktari & Bassiouny, 1999).

Recently, it was shown that *An. arabiensis* is the most important (and probably the only) malaria vector in Jizan Region, Saudi Arabia (Al Sheikh, 2004). *An. arabiensis* larvae were found to occur all year round with a peak occurring in November and December. Al Sheikh found that *An. arabiensis* occurred in many breeding habitats, but predominated in the temporary natural rain pools in wadis that formed after floods.

Other *Anopheles* species were also common in the region and *An. dthali* and *An. pretoriensis* were often found breeding with *An. arabiensis* (Al Sheikh, 2004).

Investigating the Rift Valley Fever epidemic of 2000, Jupp (2003) determined that both *Cx. tritaeniorhynchus* and *Ae. vexans arabiensis* were probably the most important vectors based on abundance, distribution and their preference for bloodfeeding on humans and sheep. The higher anti RVF virus immune rates in livestock resident in the foothills of the Sarawat Mountains in Saudi Arabia were believed to be related to the presence of the many agricultural fields in the terraces between the wadis in the foothills of the mountain range. The practice of temporary flooding of these crop and pasture fields provided an ideal habitat for oviposition and subsequent larval development of both species, but particularly the floodwater mosquito *Ae. v. arabiensis*. The latter would have been the first to appear in the area when the soil of these fields became inundated by the first rains. There is also the possibility that *Ae. v. arabiensis* will transmit the virus transovarially to the next generation when infected eggs hatch once the next season's rains arrive, in a manner similar to that shown previously in Kenya for *Ae. (Neomelaniconion) mcintoshi* (Linthicum et al., 1985). If so, this would have major implications for the future of RVF in the region.

Significant populations of *Cx. tritaeniorhynchus* probably remained in the Jizan Region after the 2000 rains ceased and the RVF epidemic waned, as by breeding in more permanent water it is not dependent on the flooding of agricultural fields. In this way *Cx. tritaeniorhynchus* could have continued to transmit virus infections after *Ae. v. arabiensis* had disappeared (Jupp *et al*, 2003).

Despite the importance of the various other mosquito species also known to occur in this region (Al Sheikh, 2004), and their potential as vectors for diseases such as yellow fever, dengue and other arboviruses, little is known about them locally. For example, *Aedes aegypti* was involved in transmission of dengue fever in 2000 in Jeddah city (Fakeeh & Zaki, 2001), but little is known of its distribution or habits in the region.

The data in this chapter derives from a comprehensive year-long study carried out to record the mosquito fauna breeding in irrigated and non-irrigated sites, with a view to determining the effects of irrigation activities on their abundance. Although all mosquitoes were investigated, the species associated with transmission of malaria and RVF were of particular interest.

4.2. Materials and Methods

4.2.1 Study sites

Entomological surveys were carried out in Jizan Region, Saudi Arabia, in a total of six villages: three villages classed as being in an irrigation area (Korsialdayer, Rawan Alabeed and Almegussus); three villages in a non-irrigated area (Alorah, Alkarbose and Almegurgum) (see Chapter 3 for full descriptions of each site).

4.2.2 Larval collections

Surveys were conducted over 12 months from January to December 2004 in the selected sites. Each site was sampled once per month. Three local persons were trained as field worker assistants before starting the surveys, and were based at the Malaria Centre in Jizan.

The wadis were sampled in stretches of approximately 1 km in length. Typical sites examined were static pools of water formed at the edges of the wadi flow and temporary pools resulting from overflow, seepage or receding water. Within nearby villages or farmland, all water bodies were examined for mosquitoes. All potential mosquito breeding sites were visited and checked for the presence of water on each visit. Those with water were examined for mosquitoes.

Standard dippers (soup ladles) of 350 ml volume (13cm diameter) were used to collect larvae from pools and ponds. A net was occasionally used to sample larvae. Collections were made following the protocols described in WHO (1975 and 1992). Thus, pools of 1m^2 in size were dipped five times. Larger pools were sampled with 10 dips.

4.2.3 Adult mosquito collection

Pyrethrum Knockdown (PKD) collections

Sampling was carried out during the rainy season (from September to December 2004) one time per month at each study site. On each visit, five houses were selected randomly in each site and PKD carried out between 0600 and 1000 hrs (for a description of the method (see Chapter 3).

CDC Light -trap collections with dry ice

Once per month light-traps (n=5) were placed in six randomly selected houses or animal shelters at each study site in both irrigated and non-irrigated villages and left to run from 1800 to 0600 hrs period from Jan to Dec 2004 (see Chapter 3).

For sampling exophilic mosquitoes, a 2kg block of dry ice was wrapped above the light-traps in a hessian bag. This method was carried out simultaneously with unbaited light traps in the same sites and at the same period.

Identification of mosquitoes

As larviciding with temephos in Jizan and all Tihamah areas occurs weekly, larvae collections in the present study always preceded this larviciding. Thus most of the larvae that were collected were at the first or second stages. Complete development in the laboratory to the later stages larvae or adults was required for morphological identification.

Anophelines and culicines (larvae and adult) were identified using the keys of Mattingly & Knight (1956), and DuBose & Curtin (1965). The key of Harbach (1985) was used for identification of *Culex* larvae and adults, and Glick (1992) was used for *Anopheles* adults. Samples of anophelines and culicines, were preserved in plastic bags containing silica gel and transferred to Liverpool School of Tropical Medicine for further analysis. Verification of identification was confirmed by Dr. Ralph Harbach at the Natural History Museum, London.

4.2.4 Identification of mosquito blood meals

A direct ELISA (Enzyme Linked Immunosorbent Assay; Beier, *et al.*, 1988) was used to identify the source of bloodmeals of mosquitoes collected by PKD. Each sample was tested for reactions to antisera for human, cattle, goat, sheep, dog, chicken, donkey and camel.

Blood squash spots of mosquito were cut out and placed in labelled 1.5 ml eppendorf tubes to which 500 µl of phosphate buffered saline (PBS) were added and incubated at 4°C overnight to elute blood. A 96 well polyvinyl chloride (PVC) microtitre plate (Nuclon Surface) was first loaded with blood sample extract (50 µl/ well). After an incubation of 3 hours at room temperature, the well contents were discarded and washed three times with PBS + 0.05% Tween 20 (PBS-Tween 20). Peroxidase conjugated IgG antibody (diluted at a ratio of 1:500 in blocking buffer) was added to wells (50 µl/ well) followed by another incubation period of 1 hour at room temperature. The blocking buffer contained sera of various possible potential hosts that were present in the collection area. The plates were then washed three times with PBS-Tween 20. Finally, 100 µl of substrate solution of ABTS (2,2' azino-bis 3-ethylbenzthiazoline-6-sulphonic acid) and hydrogen peroxide (Kirkegaard and Perry Laboratories, USA) mixed 1:1 immediately before use, was added to each well and allowed to develop. Positive specimens turned green and all the results were read visually after 30 minutes.

4.3. Results

4.3.1 Larval surveys

Mosquito larvae were found in all types of standing waters in all study sites: the edges of wadis and water puddles on dry riverbeds, rain pools, ponds, manmade pools (artificial pools), rocky pools, domestic water tanks, swamps, dams and wells. In total, 6,135 mosquito larvae belonging to three genera were collected at the three study sites during the entire period of study of 12 months (Jan to Dec 2004). Of these, 57% were anophelines typically found in wadis and rain pools..

Culicine larval composition

In total, 11 culicine species were found as larvae (Table 1). All these culicine species have been recorded in Saudi Arabia before (Mattingly and Knight 1956), but these are the first records from Jizan region for *Culex sitiens* Wiedemann, *Cx. duttoni* Theobald, *Cx. laticinctus* Edwards, *Cx. simpsoni* Theobald and *Cx. decens* Theobald

Out of 2637 culicine species collected in the larval stages, *Culex tritaeniorhynchus* alone represented 74% of the total, with the highest number collected from the irrigated site, Rawan Alabeed (47.7% of the total catch collected in the irrigated villages). This species was found at all six sites in all types of breeding sites including the more turbid pools.

In the irrigated area, a total of 1320 larvae of *Cx. tritaeniorhynchus* were found. Of these, 1140 (86 %) were collected from 2 villages located near the upper Jizan dam (Korsi Aldayer, n=510; 38%; and Rawan Alabeed, n=630; 47%). Only 180 (13%) *Cx. tritaeniorhynchus* larvae were recorded in Almejussus below the dam (table 4.2a).A significance t test show that there is no significant difference between irrigated and non-irrigated area in culicine larvae. The abundance of *Cx. tritaeniorhynchus* fluctuated over the months of study and was apparently related to rain fall in Korsi Aldayer, with the maximum in August 2004 (Figure 4.1). Interestingly, in Rawan Alabeed near the upper Jizan dam, close to the lake, fluctuations in the abundance of *Cx. tritaeniorhynchus* were apparently unrelated to rain fall; *e.g.* the monthly average density was 65 larvae/ dip in April 2004 and 24 larvae/dip in May 2004 with no rain fall during this period (Figure 4.1).

Aedes vexans ssp. arabiensis was the second most abundant species in the dam area in the larval stage, with the highest numbers collected from Rawan Alabeed at the irrigated area (n=173). However, no larvae were collected at non-irrigated villages. Most of the *Aedes* species were found after flooding in breeding pools.

Table 4.1: Culicines collected in the larval stage at all study sites in Jizan Region in the period from Jan to Dec 2004.

Species	Number of larvae collected	% of total catch
Cx. tritaeniorhynchus Giles	1957	74.21
Ae. vexans ssp. arabiensis	272	10.31
Cx. quinquefasciatus Say	142	5.38
Ae. vittatus Bigot	115	4.36
Ae. aegypti Linnaeus	28	1.06
Cx. sitiens Wiedemann *	51	1.93
Cx. duttoni Theobald *	33	1.25
Cx. laticinctus Edwards *	17	0.64
Cx. pipiens ssp	8	0.30
Cx. simpsoni Theobald *	7	0.27
Cx. decens Theobald *	7	0.27
All identified species	**2637**	

* These species have been recorded in Saudi Arabia before (Mattingly and Knight 1956), but were not recorded in Jizan region.

Table 4.2a: Culicines collected in the larval stage in the irrigated areas in Jizan Region in the period from Jan to Dec 2004.

	Number of larvae collected in the irrigated areas		
Species	**Korsi Aldayer**	**Rawan Alabeed**	**Almegussus**
Cx. tritaeniorhynchus	510	630	180
Cx. quinquefasciatus	0	42	85
Ae. vittatus	15	25	0
Ae. vexans ssp. arabiensis	0	173	99
Total	**525**	**870**	**364**

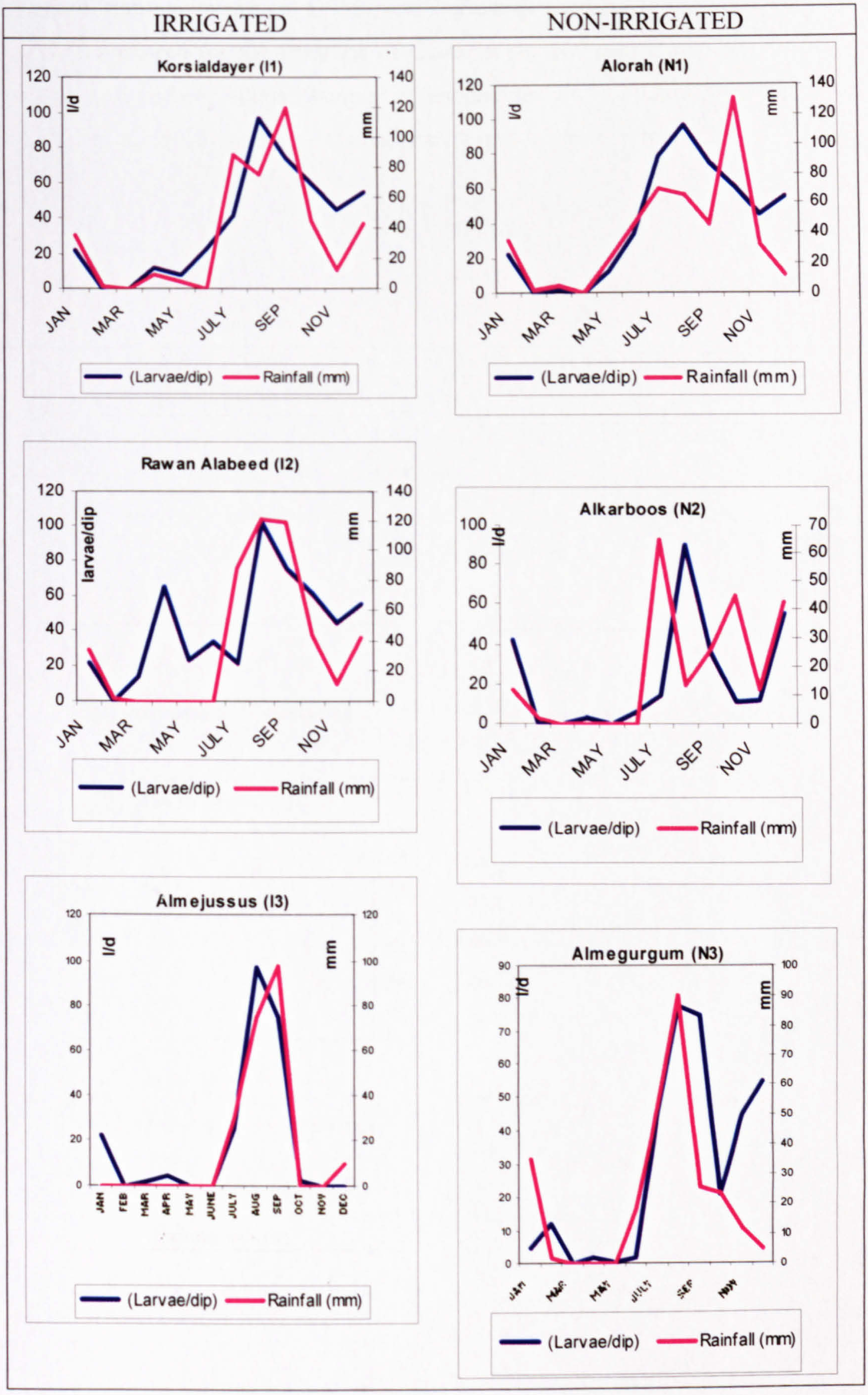


Figure 4.1: Monthly average density of larval *Cx. tritaeniorhynchus* collected in irrigated and non irrigated villages and monthly rainfall (mm) as recorded during the study period from Jan to Dec 2004

Table 4.2b: Culicines collected in the larval stage in the non-irrigated areas in Jizan Region during the period from Jan to Dec 2004.

Species	Number of larvae collected in non-irrigated areas		
	Alorah	**Alkarbose**	**Almegurgum**
Cx. tritaeniorhynchus	320	214	103
Cx. quinquefasciatus	15	0	0
Ae. vittatus	35	40	0
Ae. vexans ssp. arabiensis	0	0	0
Total	370	254	103

Anopheline larvae

In all study sites, larval stages of eight anopheline species were found (Table 4.3). Of 3498 anophelines collected in the larval stage, *An. dthali* comprised 50 % of the total, with the highest number collected from the irrigated site, Rawan Alabeed where 47.7% of the total catch collected in the irrigated villages was taken. *An. gambiae s.l.* comprised 9.43% of the total catch.(Figure 4.2, 4.3 and 4.4).

The majority of anophelines were collected at villages located at the upper part of wadis in both irrigated and non-irrigated areas: 77.3% of the total catch at the irrigated area was collected from Korsi Aldayer and 95% of the total catch at the non-irrigated area was collected from Alorah. Conversely, very few were collected at villages in the lower wadies: less than 1% of the total catch at the irrigated area was collected from Almegussus and less than 1% of total catch at non-irrigated area was collected from Almegergum.

In the middle reaches of wadis in irrigated and non-irrigated areas , 389 anopheline larvae were collected from Rawan Alabeed (upper Jizan dam in the irrigated area) compared with very few (n=65) collected from Alkarboos in the non-irrigated area (Table 4.4a & 4.4b). In the irrigated area, a total of 229 larvae of *An. gambiae s.l* were collected from 2 villages located above the Jizan dam (Korsi Aldayer n=151and Rawan Alabeed n=78) and with no *An. gambiae s.l* larvae recorded in Almejussus which is located below the dam (Table 4.4a). The abundance of *An. gambiae s.l.*

fluctuated throughout the study and was apparently related to rainfall in Korsi Aldayer, with the maximum in September 2004 (Figure 4.4). Interestingly, in Rawan Alabeed, located above the Jizan dam and very close to the dam lake, the abundance of *An. gambiae s.l* fluctuated over the months of study but was apparently unrelated to rain fall. In this village, the monthly average density of larval *An. gambiae s.l* was 1.3 larvae/dip in March 2004 although no rain fell from February to May 2004 (Figure 4.4). A significance t test show that there is no significant difference between irrigated and non-irrigated area in anopheline larvae.

In the non-irrigated area a total of 101 larvae of *An. gambiae s.l* were collected from Alorah in the upper part of the wadi and with no *An. gambiae s.l* larvae recorded in the other two villages (Alkarbose in the middle part of the wadi and Almugurgum in the lower part of the wadi) (Table 4.4b).

Table 4.3: Anophelines collected in the larval stage at all study sites in Jizan Region in the period from Jan to Dec 2004.

Species	Number of larvae collected	%
An. dthali Patton	1776	50.77
An. pretoriensis Theobald	1291	36.91
An. gambiae s.l. Giles	330	9.43
An. sergenti Theobald*	61	1.74
An. multicolor Cambouliou*	28	0.80
An. rhodesiensis rupicolus	6	0.17
An. turkhudi Liston*	6	0.17
Total	3498	100

* These species have been recorded in Saudi Arabia before (Mattingly and Knight 1956), but this is the first record in Jizan region.

Table 4.4a: Anophelines collected in the larval stage in the irrigated areas in Jizan Region in the period from Jan to Dec 2004.

Species	Number of larvae collected in the irrigated areas		
	Korsi Aldayer	Rawan Alabeed	Almegussus
An. dthali Patton	666	201	20
An. pretoriensis Theobald	582	110	0
An. gambiae s.l Giles	151	78	0
All identified species	1399	389	20

Table 4.4b: Anophelines collected in the larval stage in the non-irrigated areas in Jizan Region during the period from Jan to Dec 2004.

Species	Number of larvae collected in non-irrigated areas		
	Alorah	Alkarbose	Almegurgum
An. dthali Patton	801	24	10
An. pretoriensis Theobald	612	41	0
An. gambiae s.l Giles	101	0	0
All identified species	1514	65	10

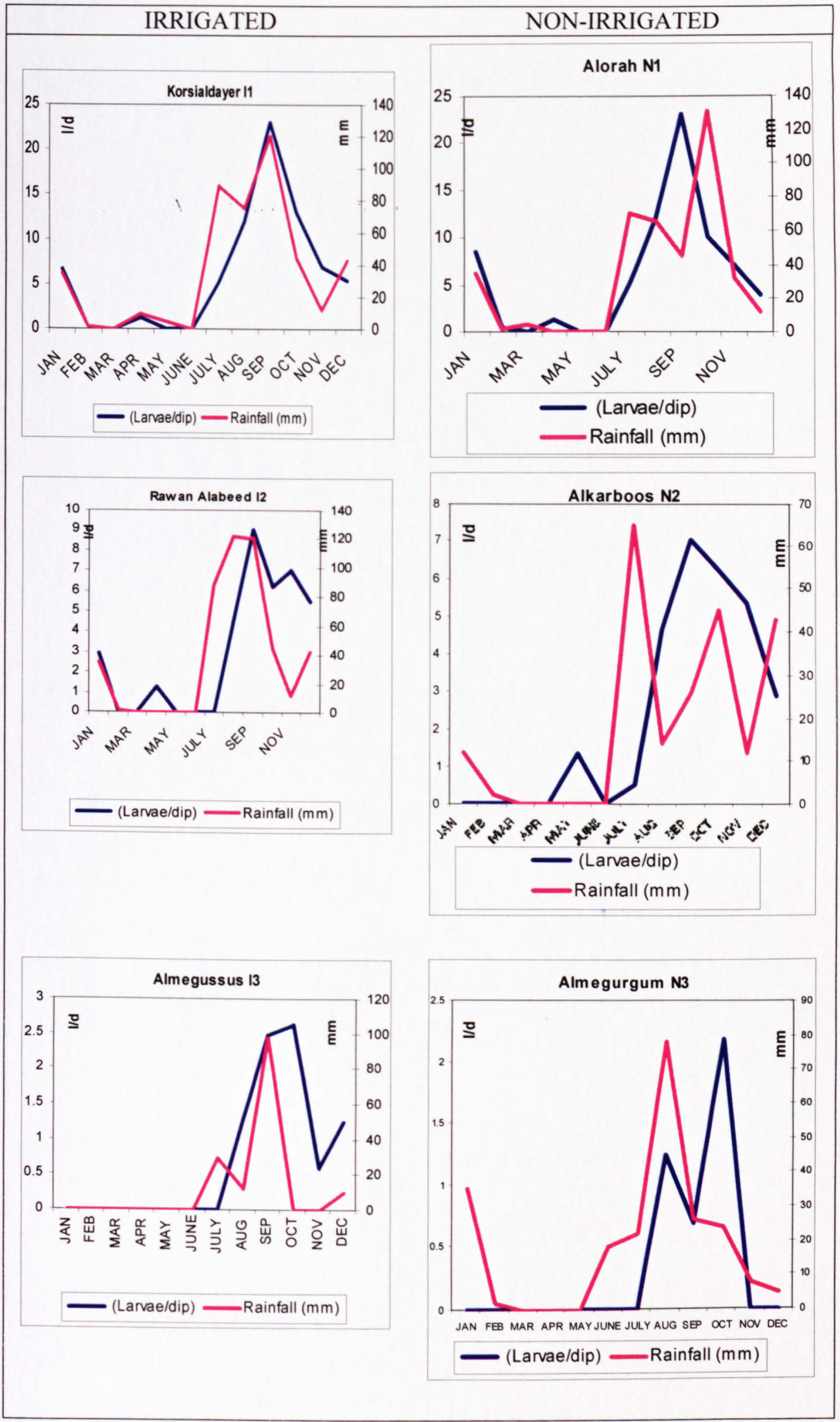


Figure 4.2: Monthly average density of larval *An. dthali* collected in irrigated and non irrigated villages and monthly rainfall (mm) as recorded during the study period from Jan to Dec 2004

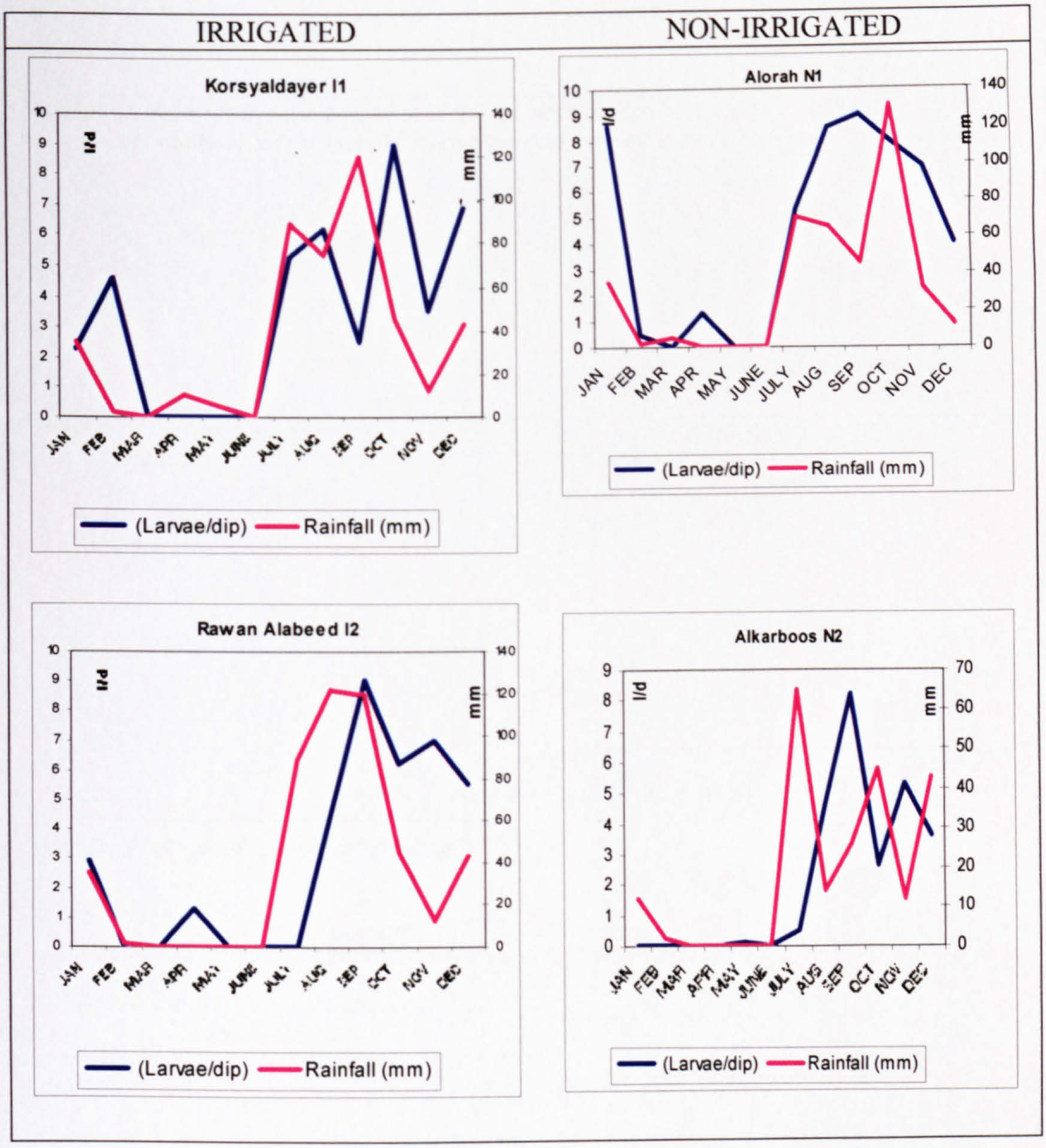


Figure 4.3: Monthly average density of *An. pretoriensis* larvae collected in irrigated and non irrigated villages and monthly rainfall (mm) as recorded during the study period from Jan to Dec 2004.

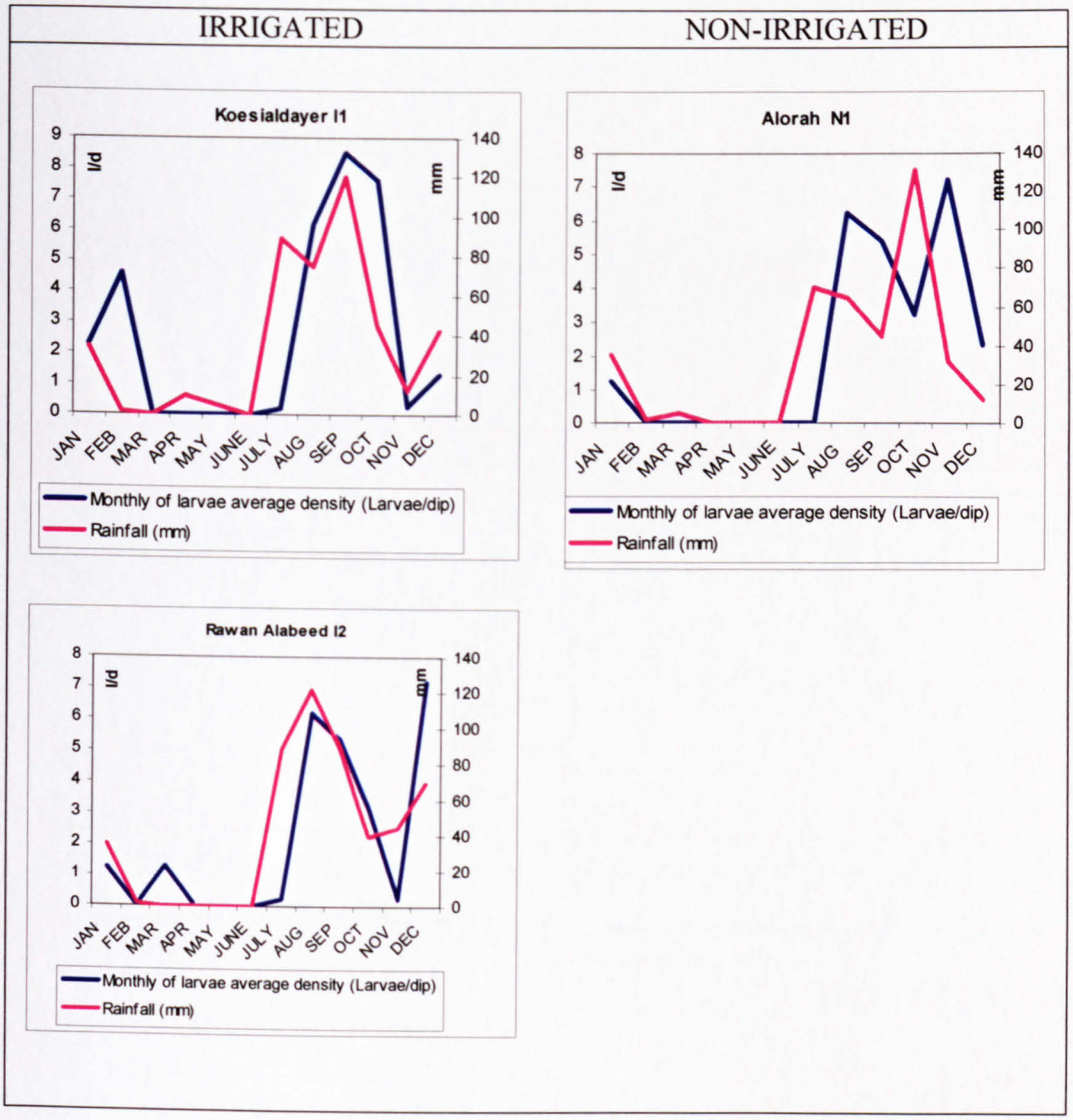


Figure 4.4: Monthly average density of larvae *An. gambiae s.l* collected in irrigated and non irrigated villages and monthly rainfall (mm) as recorded during the study period from Jan to Dec 2004.

4.3.2 Adult Mosquito survey

Culicines

Overall, 22,825 adult mosquitoes were collected over the entire study period using light traps baited with CO_2. Of these, 19,887 were culicines. *Culex tritaeniorhynchus* Say and *Aedes vexans ssp. arabiensis* Patton were the most abundant species among the culicines, 78 % and 18 % respectively, with the highest number collected from Rawan Alabeed near Jizan dam in the irrigated area, 79% (n= 11875) and 19% (n=2850) of the total catch respectively (Table 6a). A significance t test show that there is no significant difference between irrigated and non-irrigated area in culicine adults.

Anopheline species

A total of 2938 anopheline adults were collected during the study period (Jan –Dec 2004) (table 2). In adult collections, 53% (n=1574) were *An. dthali* Patton, 31% (n=924) were *An. pretoriensis* Theobald, and 7% (n=212) were *An. gambiae s.l.* Giles (collected in all six villages using a light trap baited with CO_2; Table 7).

Of all species of mosquito collected in this study, two anopheline species, *An. gambiae s.l.* and *An. dthali* are known vectors of malaria elsewhere. Only one anopheline species (*An. fluviatilis*) was recorded as adult but not as larvae. This was the first record of this species in Jizan region. A significance t test show that there is no significant difference between irrigated and non-irrigated area in anopheline adults.

Table 4.5: Adult culicines collected at all study sites in Jizan Region in the period from Jan to Dec 2004.

Species	Number of adults collected	% of total catch
Cx. tritaeniorhynchus	15506	78
Ae. vexans ssp. arabiensis	3607	18.4
Cx. quinquefasciatus	433	2.2
Ae. vittatus	317	1.6
Ae. aegypti	24	0.12
Total	19887	100

Table 4.6a: Adult culicines collected in the irrigated areas in Jizan Region in the period from Jan to Dec 2004.

	Number of adults collected in the irrigated areas		
Species	Korsi Aldayer	Rawan Alabeed	Almegussus
C. tritaeniorhynchus	808	11875	768
C. quinquefasciatus	0	139	202
Ae. vittatus	72	163	0
Ae. vexans ssp. arabiensis	225	2850	320
Total	1105	15027	1290

Table 4.6b: Adult culicines collected in the non-irrigated areas in Jizan Region in the period from Jan to Dec 2004.

	Number of adults collected in non-irrigated areas		
Species	Alorah	Alkarbose	Almegurgum
C. tritaeniorhynchus	1101	503	451
C. quinquefasciatus	92	0	0
Ae. vittatus	0	82	0
Ae. vexans ssp. arabiensis	114	98	0
Total	1307	683	451

Table 4.7: Adult anophelines collected at all study sites in Jizan Region in the period from Jan to Dec 2004.

Species	Number of adults collected	% of total catch
An. dthali	1574	53.57
An. pretoriensis	924	31.45
An. gambiae s.l.	212	7.22
An. multicolor	182	6.19
An. sergenti	32	1.1
An. fluviatilis *	14	0.5
Total	2938	100

* These species have been recorded in Saudi Arabia before (Mattingly and Knight 1956), but it is the first record in Jizan region.

Table 4.8a: Adult anophelines collected in the irrigated areas in Jizan Region in the period from Jan to Dec 2004.

	Number of adults collected in the irrigated areas		
Species	Korsi Aldayer	Rawan Alabeed	Almegussus
An. dthali Patton	630	203	25
An. pretoriensis Theobald	422	112	0
An. gambiae Giles	99	48	0
Total	1151	363	25

Table 4.8b: Adult anophelines collected in the non-irrigated areas in Jizan Region in the period from Jan to Dec 2004.

Species	Number of adults collected in non-irrigated areas		
	Alorah	Alkarbose	Almegurgum
An. dthali Patton	704	12	0
An. pretoriensis Theobald	390	0	0
An. gambiae Giles	65	0	0
Total	1159	12	0

4.3.3 Bloodmeal analysis

A total of 761 mosquito bloodmeal specimens were stored from PKD collections from both irrigated (445) and non-irrigated (316) areas and assayed by ELISA. Table 4.9 & 4.10 summarise the results of culicine and anopheline species analysed from irrigated and non-irrigated areas.

In both irrigated and non-irrigated areas humans were the most common bloodmeal source in all species. In the irrigated area human bloodmeals in culicines were lower than in the non-irrigated area combined 47% (n=174) in irrigated area with 79 % (n=228) in non-irrigated area but was not statistically significantly different from zero. The human blood feeding rates were approximately the same for anopheline species 82% (n=54) in non-irrigated area with 96 % (n=27) in non-irrigated area.

Table 4.9a: Numbers of *Cx. tritaeniorhynchus* and *Ae. v. arabiensis* bloodmeals identified by ELISA in irrigated areas. 'Unidentified' are bloodmeals that were negative in all ELISAs.

Irrigated Area	Mosquito bloodmeal source										
	No. tested	Human	Cattle (bovine)	Sheep	Goat	Dog	Chicken	Human +sheep	Human +goat	Human +dog	Human +chicken	un-identified
Cx. tritaeniorhynchus (%)	258	111(43)	21(8)	36(14)	29(11)	21(8)	18(7)	4(1.5)	0	6(2.3)	4(1.5)	6(2.3)
Ae. v. arabiensis (%)	109	63 (58)	10(9)	2(2)	11(10)	5(4.5)	2(2)	2(2)	1(0.9)	1(0.9)	0	2(2)
Total	367	174(47)	31(8)	38(10)	40(11)	26(7)	20(5)	6(2)	1(0)	7(2)	4(1)	8(3)

Table 4.9b: Numbers of *Cx. tritaeniorhynchus* and *Ae. v. arabiensis* bloodmeal identified by ELISA for non-irrigated areas. 'Unidentified' are bloodmeals that were negative in all ELISAs.

Non-irrigated Area	Mosquito Bloodmeal Source							
	No. tested	Human	Cattle (bovine)	Sheep	Goat	Dog	Chicken	unidentified
Cx. tritaeniorhynchus (%)	275	216(78)	19(7)	3(1)	20(7)	7(2.5)	8(2.5)	2(1)
Ae. v. arabiensis (%)	13	12(92)	1(8)	0	0	0	0	0
Total	288	228(79)	20(7)	3(1)	20(7)	7(2)	8(3)	2(1)

Table 4.10a: Numbers of *An. dthali* and *An. gambiae s.l.* bloodmeals identified by ELISA in irrigated areas.

	Mosquito bloodmeal source			
	No. tested	Human	Cattle (bovine)	unidentified
An. dthali (%)	50	46 (92)	2 (4)	2 (4)
An. gambiae s.l. (%)	28	18 (64)	10 (36)	0
Total	**78**	**54 (82)**	**12 (15)**	**2 (2.5)**

Table 10b: *An. dthali* and *An. gambiae s.l.* bloodmeals identified by ELISA in non-irrigated areas.

	No. tested	Human	unidentified
An. dthali	16	15 (94)	1 (6)
An. gambiae s.l.	12	12 (100)	0
Total	**28**	**27 (96)**	**1 (4)**

4.4 Discussion

The results from the entomological surveys indicated that, in both irrigated and non-irrigated areas, the *Culex* spp. and *Anopheles* spp. vectors of both RVF and malaria were found breeding in several sites in both areas. Many more breeding sites were found in irrigated areas, A significance t test show that there is no significant difference between irrigated and non-irrigated area. Seasonal rain usually increases the numbers of mosquito breeding sites, while higher relative humidity and growth of vegetation cover provided a cool shaded environment for the development of aquatic stages and aided the survival of young adults (Evans, 1938; Igbinosa, 1989; Okogun *et al.*, 2003). Most of the sources of breeding sites in the areas of study were wadis, which were dry during much of study period due to the low rainfall. The total amount of rainfall recorded in the study period (Jan. to Dec. 2004) was 182.2mm and during 3 months (May, June, July) there was no rainfall.

Most larvae, both anophelines and culicines, were collected from irrigated areas. There is no significant difference between irrigated and non-irrigated area. In the middle reaches of wadis in irrigated and non-irrigated areas, 389 anopheline larvae were collected from Rawan Alabeed I2 (upper Jizan dam in the irrigated area) compared with very few (n=65) collected from Alkarboos N2 in the non-irrigated area (Table 4.4a & 4.4b). This can most likely be attributed to the number of breeding sites available at each site: at Rawan Alabeed (I2) there was Jizan Dam Lake and Jizan Wadi providing perennial sources for breeding but at Alkarboos N3, the non-irrigated area, there was only one perennial wadi (Khulab Wadi) witch remained dry until the seasonal rains. This could explain why *Cx. tritaeniorhynchus* and *Aedes vexans ssp. arabiensis* (vectors of RVF) were the most abundant species in the irrigated area in the larval stage, with the highest numbers collected from Rawan Alabeed I2 at the irrigated area (n=630 and n=173) respectively (Table 4.2a). Very few *Cx. tritaeniorhynchus* (n=214) and no *Aedes vexans ssp. arabiensis* were collected from Alkarboos N2 in the non-irrigated area (n=0) (Table 4.2b).

Interestingly, in irrigated areas the abundance of larval *An. arabiensis* (and other anophelines) and *Cx. tritaeniorhynchus* (and other culicines) was not correlated with rainfall while in non-irrigated areas the abundance of larvae of the two species was correlated with rainfall. In Rawan Alabeed (I2), located in upper Jizan dam area and very close to the Dam Lake, the abundance of *An. gambiae s.l* and *Cx. tritaeniorhynchus* fluctuated over the months of study but was apparently unrelated to rainfall. In this village, the monthly average density of larval *An. gambiae s.l* was 1.3 larvae/dip and of larval *Cx. tritaeniorhynchus* was 65 larvae/dip in March 2004 although no rain fell from February to May 2004 (Figure 4.1). This was most likely because the dam lake and the irrigation project created additional suitable breeding sites for this species. Study in Saudi Arabia, Jizan region to determine the vectors of RVF found that more breeding sites were found in the Jizan dam area providing good mosquito larval habitats (Jupp *et al.,* 2002). Thus, *An. arabiensis* (and other anophelines) was able to breed in every month even in the dry months. The resultant vector abundance, all year round breeding (except in April May and June) and the intrinsic high vectorial capacity of *An. arabiensis* account for the endemicity of malaria in this area (Al Sheikh, 2004). This indicates the need for mosquito control during the wet seasons in irrigated areas.

Other *Anopheles* species, particularly *An. dthali* and *An. pretoriensis*, were abundant and widespread in the upper part of the wadis of both irrigated and non-irrigated areas (Korsi Aldayer I1 and Alorah I2 respectively (Table 4.8a & b). Both species co-existed with *An. arabiensis* larvae in some of their habitats. In Eritrea, Shililu *et al.* (2003) found *An. pretoriensis* in dams, streams, and river pools, while *An. dthali* occurred in streams and river pools.

The present survey found eleven culicines breeding at the study sites in irrigated and non-irrigated areas of Jizan region, with a great abundance of *Culex tritaeniorhynchus* (74%), with the highest numbers collected from the irrigated site, Rawan Alabeed (47.7% of the total catch collected in the irrigated villages). This species was found at all six sites in all types of breeding sites including the more turbid pools.

Culicines were the most abundant species collected as adults in irrigated and non-irrigated areas (87%). The public health importance of most of these culicine species is unknown. However, two species (*Aedes vexans ssp. arabiensis* and *Culex tritaeniorhynchus*) were involved in the 2000 outbreak of RVF in the region, particularly at Jizan Dam area (Jupp *et al.*, 2002). *Culex tritaeniorhynchus* Say and *Aedes vexans ssp. arabiensis* Patton were the most abundant species among the culicines (78 % and 18 % respectively), with the highest number collected from Rawan Alabeed near Jizan dam in the irrigated area, 79% (n= 11875) and 19% (n=2850) of the total catch respectively (Table 6a).

The floodwater species, *Aedes vexans*, was implicated in the transmission of RVF in 1998 in Senegal (Balkhy & Memish, 2003). *Aedes vexans ssp. arabiensis* as well as *Aedes vittatus* and *Aedes caspius* were found in the present study in pools created after a recent flood. These findings are consistent with the study of Miller *et al.* (2002) in Southwestern Saudi Arabia and with that of Jupp *et al.* (2002) in Jizan Region.

Although it was the most common species, *Culex tritaeniorhynchus* has not been implicated in the transmission of RVF in Africa but this may be because it does not occur at high densities in countries on that continent (Jupp *et al.*, 2002). However, it is an important vector of the *Flavivirus* Japanese encephalitis in India and the Far East (Jupp *et al.*, 2002). Despite the importance of the other culicine species as potential vectors for many diseases such as yellow fever, dengue fever, and other arboviruses (Igbinosa, 1989; Okogun *et al.*, 2003), little is known about their roles locally. *Aedes aegypti* was involved in transmission of dengue fever in 2000 in Jeddah city (Fakeeh & Zaki, 2001), and occurrance of dengue in Yemen indicates the importance of *Ae aegypti* as a vector is likely to be on the increase in this region (Jimenez *et al.*, 1984).

The low number of adult anophelines particularly *An. arabiensis*, collected in irrigated and non-irrigated villages may have been the result of the intensive use of insecticides (malathion, cypermethrin, temephos, lambdacyhalothrin, pirimiphos methyl) in the Tihama of Saudi Arabia, which were being used in response to the RVF epidemic of 2000 (Al Sheikh, 2004). Conversely, the large number of culicines collected may indicate the ineffectiveness of the control measures used in controlling these species, some of which are known RVF vectors.

In addition to the widespread use of insecticides, the shortage in rain during the study period (as compared with previous four years) was one of the limitations of adult vector density in both irrigated and non-irrigated areas. Clearly, the amount of rain (in irrigated and non-irrigated areas) and the creation of additional breeding sites (in irrigated areas) can influence the quantity and quality of breeding sites available for breeding of *An. arabiensis*. In the dry savanna of Africa, vector species can have seasonal fluctuations in abundance, declining to low levels in dry seasons (Taylor *et al.*, 1993; Charlwood *et al.*, 1995; Lemasson *et al.*, 1997; Simard *et al.*, 2000). ELISA test results showed the two anophelines (*An. dthali and An. arabiensis)* fed predominantly on humans (82 % in irrigated area and 96 % in non-irrigated area) (table 4.10a). The other blood meals were taken from cattle, mainly by *An. arabiensis* (36%) in the irrigated area. The domestic animals found in both areas were mainly goats, sheep, cattle, camel and donkey. Although cows were available in both areas, there were more cows in irrigated areas (estimated at 250 compared to 30 cows or less in the non-irrigated area). The presence of domestic animals has been associated with a decrease in malaria transmission rates due to zoophilic deviation (Bruce-Chwatt & Garrett, 1966). In some parts of Africa, zooprophylaxis is used and cattle are intentionally kept near or inside houses to divert mosquitoes from humans to cattle (Burkot *et al.*, 1988). It was suggested that cattle could play a role in reducing transmission of malaria by *An. arabiensis* by distracting the vector from humans (Hadis *et al.*, 1997) with the fact that cattle hoof prints create more breeding sites. In East Africa *An. arabiensis* shows a preference for feeding on cattle, sheep, goats and donkeys (White 1974; Garrett-Jones *et al.*, 1980). All these hosts were common in our study in the irrigated area. In Kenya *An. arabiansis* has been reported to move into houses after feeding outside on cattle (Petraca et al., 1991; Githeko *et al.*, 1992). McCall *et al.* (2001) also showed that a high proportion of *An. arabiansis* resting inside human habitations in northern Tanzania had fed on cattle.

For control measures, preventing mosquito feeding on animals by application of insecticide on domestic animals might also be useful (Hewitt & Rowland, 1999; Rowland *et al.*, 2001).

A factor that may lead to the development of resistance in Saudi Arabia could be agriculture, which apart from being dependent on a continuous supply of water and nutrients, also uses high inputs of pesticides as crop cultivation in irrigated areas is intensive. This high pesticide use in farming could favour selection for resistance to pesticide used in public health (Herath & Joshi 1989, Diabate *et al.* 2002). In the country the high use of mosquito insecticide could add to this selection pressure. No insecticide resistance tests were carried out in this study to show if there is a significant difference between irrigated and non-irrigated areas, so additional studies are needed to investigate this matter. Al Sheikh (2004) reported that *An arabiensis* in this area were fully susceptible to pyrethroids.

4.5 Conclusions

1- This study in irrigated and non-irrigated areas in Jizan, Saudi Arabia identified the presence of seven anopheline and eleven culicine species. All these species have been recorded before in Saudi Arabia, but 3 anopheline and 5 culicine were reported for the first time in Jizan region. Also, of these, two anopheline species, are known vectors of malaria here, *An. arabiensis*, and elsewhere *An. dthali*, while three culicine species are known vectors of Rift Valley Fever (*Aedes vexans ssp. arabiensis*, *Culex tritaeniorhynchus*) and dengue fever (*Aedes aegypti*) in the Region.

2- The study showed that in irrigated areas, suitable and additional breeding sites for many of these species exists during the wet season. The variety of the sites means that effective larval vector control of malaria and RVF diseases would be extremely difficult.

3- For the ELISA test carried out in this study show that there is no significant difference between irrigated and non-irrigated area in feeding behaviour. tables 4.9 a and b show only 7-9% of feeds were in cattle in irrigated and non-irrigated areas so it seems unlikely that distraction by cattle would be important. .

Chapter Five: A survey of Malaria and RVF Knowledge, Attitude and Practice In the Study Areas

5.1 Introduction

The magnitude of hazards in terms of health risks is influenced by three factors and their interaction: environmental factors, community vulnerability and capability of health protection agencies (Birley 1995). Community vulnerability involves identification of the communities that may be exposed to the health hazards and why they are vulnerable. The success of vector-borne disease control programmes at present relies heavily on community perceptions and practices in the transmission, treatment and control of the disease (Agyepong *et al.,* 1992). Inappropriate behaviour or incorrect beliefs can interfere with the effectiveness of a control measure, such as vector control or chemotherapy. These issues are particularly important in tropical areas where vector-borne disease control options may be limited because of parasite and vector resistance to drugs and insecticides, respectively (Wakgari *et al.*, 2003)

Household interview surveys of people's perceived morbidity, their use of health services and health status of a population have been adopted in many programmes in developing countries since the 1950's (Kroeger 1983). Demand for knowledge of what people perceive is steadily on the increase by many new programmes. Environmental modification and any associated morbidity can influence perception of an illness by an infected population and ultimately influence behavioural patterns adopted by communities (Huang and Manderson 1992). A KAP community survey can reveal the relationship between human behaviour and a health hazard and provides information on community vulnerability within a specific environmental and cultural setting.

The views of the community should be sought and incorporated into any proposed control measures. However, there had been no previous studies done on community knowledge and perception of malaria in Jizan, Saudi Arabia. Therefore, the present study within the irrigated and non-irrigated areas was undertaken to assess the knowledge, attitudes and practices of a rural community on malaria and RVF and the mosquito vector. The information generated in the current study would help in designing and evaluating malaria control strategies.

5.2. Materials and Methods

5.2.1 Study sites

Household questionnaire surveys were carried out in Jizan Region, Saudi Arabia, at three villages within the irrigation area: Korsialdayer, Rawan Alabeed and Almegussus, and at three villages in the non-irrigated area: Alorah, Alkarbose and Almegurgum (see Chapter 3 for full description of each site).

5.2.2. Household questionnaire surveys

Household questionnaire surveys were done in the selected 6 villages (3 villages in the irrigated area and 3 villages in the non-irrigated area) to record household characteristics, use of preventive measures and behavioural practices such as sitting or sleeping outside at night. The questionnaire was pre-tested in a neighbouring non-study village and adjusted accordingly before being applied in this study.

The questionnaires were usually addressed to the father in the household as he was expected to best know the health history of the household members and also it is not possible to interview women in Saudi Arabia. People who were part of the same family but did not sleep in the house were not included.

Proportionate sampling was used to randomly select 65% of households in each village for participation in the survey. Table 2 provides the names of the four selected villages, their characteristics, total number of households, and the number of households sampled.

5.2.3 Data analysis

For household surveys, collected data sets were entered, managed and analysed using the computer software package SPSS. Chi-square tests were used to assess statistical significance of differences

5.3 Results

A total of 413 household heads were interviewed: 231 (55.9%) in 3 villages in the irrigated areas and 182 (44.1%) in 3 villages in non-irrigated areas, comprising 86 (20.8%) in the upper parts of wadis in irrigated and non-irrigated areas, 194 (47%) in the middle part and 133 (32.2%) in the lower part of wadis. The number of people sleeping in the houses ranged from 1 to 34 persons (mean (SD) = 9.32 (4.54) in 1 to 25 bedrooms (mean = 4.58 bedrooms; SD=2.88).

5.3.1 Knowledge about causes of malaria and RVF

In the irrigated area and non-irrigated area about 87 % and 86 % respectively associated malaria with the bite of mosquitoes, while the other respondents associated it with exposure to cold, wet weather or change in weather and dirty stagnant water. The majority of these respondents were in villages located at the upper part of wadis in both areas; in Korsi Aldayer 92.5 % (irrigated) and in Alorah 91.3 (non-irrigated) (Table 5.1). For RVF, the percent of respondents who associated RVF with the bite of mosquitoes was lower, only 73.6 % in irrigated villages associated the causes of RVF to the bite of a mosquito and 65.4 % in non-irrigated areas (Table 5.1&5.2).

Table 5.1: Knowledge about causes of malaria and RVF in irrigated villages, Jizan, Saudi Arabia

Variables	Frequency (%)			
	Korsi Aldayer n= 40	Rawan Alabeed n= 126	Almegussus n=65	**Irrigated areas** (All 3 villages) n=226
Cause of malaria /				
Mentioned mosquito				
Yes	37 (92.5)	106 (84.1)	58 (89.2)	201 (87)
No	3 (7.50)	15 (11.9)	7 (10.8)	25 (10.8)
Don't know	0	1 (.8)	0	1 (.4)
Cause of RVF /				
Mentioned mosquito				
Yes	35 (87.5)	84 (66.7)	51 (78.5)	170 (73.6)
No	3 (7.5)	26.2 (28.2)	14 (21.5)	50 (21.6)
Don't know	1 (2.5)	0	0	1 (.4)

Table 5.2: Knowledge about causes of malaria and RVF in non-irrigated villages Jizan, Saudi Arabia

Variables	Frequency (%)			
	Alorah n= 46	Alkarbose n= 67	Almegergum n= 68	**Non-irrigated areas** (All 3 villages) n= 187
Cause of malaria /				
Mentioned mosquito				
Yes	42 (91.3)	56 (82.4)	59 (86.8)	157 (86.30
No	4 (8.7)	10 (14.70	9 (13.2)	23 (12.6)
Don't know	0	1 (1.5)	0	1 (.5)
Cause of RVF /				
Mentioned mosquito				
Yes	28 (60.9)	46 (67.6)	45 (66.2)	119 (65.4)
No	13 (28.3)	17 (25)	21 (30.9)	51 (28)
Don't know	4 (8.7)	1 (1.5)	1 (1.5)	6 (3.3)

5.3.2 Knowledge and attitude about transmission of malaria & RVF

Regarding malaria & RVF transmission, when asked about how someone is infected with malaria and RVF, 33.3 % in irrigated villages mentioned the bite of infective mosquitoes; the majority was in Almigussus (66.2 %), located in lower Jizan dam

(Table 5.3). In non-irrigated villages when asked about how someone is infected with malaria and RVF, only 27 % mentioned the bite of infective mosquitoes compared with 33.3 % in irrigated areas (Table 5.4). In irrigated and non-irrigated villages, 80.5 % and 65.3 % respectively believed that most mosquitoes biting of humans occurred in the wet season (Table 5.3 & 5.4).

Table 5.3: Knowledge and attitudes regarding malaria & RVF transmission and the habits of mosquitoes in irrigated villages, Jizan, Saudi Arabia.

Variables	Frequency (%)			
	Korsi Aldayer n= 40	Rawan Alabeed n= 126	Almegussus n=65	**Irrigated areas (All 3 villages)** n=226
Are mosquitoes a problem for your households?				
Yes	35 (87.5)	107 (84.9)	57 (87.7)	199 (86.1)
No	3 (7.5)	15 (11.9)	6 (9.2)	24 (10.4)
Don't know	2 (5)	4 (3.2)	2 (3.1)	8 (3.5)
Do you know of any diseases transmitted by mosquitoes				
Malaria	8 (20)	80 (63.5)	16 (24.6)	104 (45)
RFV	5 (12.5)	7 (5.6)	1 (1.5)	13 (5.6)
Malaria & RVF	23 (57.5)	11 (8.7)	43 (66.2)	77 (33.3)
Don't know	3 (7.5)	28 (22.2)	4 (6.2)	35 (15.2)
Other			1 (1.5)	1 (.4)
What time of year does most mosquitoe biting occur?				
Wet	30 (75)	98 (65.8)	58 (89.2)	186 (65.3)
Dry	2 (5)	8 (6.2)	1 (1.5)	11 (4.5)
All year	5 (12.5)	26(24)	2 (3.1)	32 (15)
Don't know	3 (7.5)	10 (7.9)	3 (4.6)	16 (6.9)
Other			1 (1.5)	1 (.4)

Table 5.4: knowledge and attitude regarding malaria & RVF transmission and the habits of mosquito vector in non-irrigated villages, Jizan, Saudi Arabia.

Variables	Frequency (%)			
	Alorah n= 46	Alkarbose n= 67	Almegergum n= 68	**Non-irrigated areas** (All 3 villages) n= 187
Are mosquitoes a problem for your households?				
Yes	42 (91.3)	63 (92.6)	57 (83.8)	162 (89)
No	4 (8.7)	3 (4.4)	11 (16.2)	18 (9.9)
Don't know		2 (2.9)		2 (1.1)
Do you know of any diseases transmitted by mosquitoes				
Malaria	19 (41.3)	28 (41.2)	31 (45.6)	78 (40.9)
RFV	5 (10.9)	14 (20.6)	3 (4.4)	22 (12.1)
Malaria & RVF	15 (32.6)	15 (22.1)	20 (29.4)	50 (27.5)
Don't know	6 (130	8 (11.8)	12 (17.6)	26 (14.3)
Other		3 (4.4)	2 (2.9)	5 (2.7)
What time of year does most mosquitoe biting occur?				
Wet	42 (91.3)	60 (88.2)	60 (88.2)	162 (89)
Dry	1 (2.2)	3 (4.4)	0	4 (2.2)
All year	1 (2.2)	3 (4.4)	6 (8.8)	10 (5.5)
Don't know	2 (4.3)	2 (2.9)	2 (2.9)	6 (3.3)
Other				

5.3.3 Knowledge and attitude about preventability of, and preventive methods for malaria & RVF

Malaria was thought to be preventable by about 64 % of the respondents in both irrigated and non-irrigated villages (Table 5.5 & 5.6). In irrigated villages, among those who believed that malaria is preventable, 53.7% reported insecticidal aerosol cans, 48.5 % indicated bed-nets as preventive methods and 43.7 % mentioned netting for windows (Table 5.5). In non-irrigated villages 60 % reported netting for windows, 41.9% indicated aerosol cans, and only 29.92% indicated bed-nets as preventive methods (Table 5.6). Proportions mentioning bed nets were not differ significantly between irrigated and non-irrigated areas.

Further enquiries about using bed-nets as prevention method in the study areas shows that 20 % and 8% in irrigated and non-irrigated villages respectively, did not know where they could obtain a bed-net (Table 5.5&5.6), while 36 % and 20% in irrigated and non-irrigated villages respectively, believed that using bed-nets is not necessary as preventive methods. Over 26% in irrigated villages believed that bed-nets were expensive and 17.6 in non-irrigated villages reported that using a bed-net was inconvenient. Insecticide treatment of nets ensures that they are effective even if torn and that a treated net does not divert mosquitoes to people without nets.

Table 5.5: Knowledge and attitude about preventability and preventive methods of malaria & RVF in irrigated villages, Jizan, Saudi Arabia.

Variables	Frequency (%)			
	Korsi Aldayer n= 40	Rawan Alabeed n= 126	Almegussus n=65	Irrigated areas (All 3 villages) n=226
Malaria is preventable				
Yes	23 (57.5)	79 (62.7)	45 (69.2)	147 (63.6)
No	14 (35)	32 (25.4)	19 (29.2)	65 (28.1)
Don't know	3 (7.5)	12 (9.5)	1 (1.5)	16 (6.9)
RVF is preventable				
Yes	26 (65)	57 (45.2)	42 (64.6)	125 (54.1)
No	9 (22.5)	35 (27.8)	22 (33.8)	66 (28.6)
Don't know	5 (12.5)	33 (26.2)	1 (1.5)	38 (16.5)
Preventive methods				
netting for windows	24 (60)	42 (33)	32 (49.2)	101 (43.7)
Bed-nets	6 (15)	82 (65)	12 (18.5)	110 (48.5)
coils	4 (10)	2 (1.6)	6 (9.2)	26 (11.3)
Aerosol cans	6 (15)	0 (0)	12 (20)	124 (53.7)
Why do you not use a bed-net?				
not necessary	14 (34)	46 (36.5)	30 (46.2)	83 (35.9)
expensive	12 (30)	43 (34.1)	13 (20)	62 (26.8)
inconvenient	4 (10)	18 (15)	4 (6.2)	7 (3)
don't know	10 (25)	6 (4.8)	13 (20)	15 (6.5)
other	1(1)	12 (10)	7 (9)	3 (1.3)
Do you know where you can obtain a bed-net				
Yes	20 (50)	107 (84.9)	39(60)	166 (71.9)
No	13 (32.5)	9 (7.1)	26 (40)	48 (20.8)
Don't know	4 (10)	6 (4.8)	0	12 (5)
Other	3 (7.5)	3 (2.8)	0	7 (2.5)

Table 5.6: Knowledge and attitude about preventability and preventive methods of malaria & RVF in non-irrigated villages, Jizan, Saudi Arabia.

Variables	Frequency (%)			
	Alorah n= 46	Alkarbose n= 67	Almegergum n= 68	Non-irrigated areas (All 3 villages) n= 187
Malaria is preventable				
Yes	32 (69.6)	40 (58.8)	44 (64.7)	116 (63.7)
No	13 (28.3)	25 (36.8)	20 (29.4)	58 (31.9)
Don't know	1 (2.2)	1 (1.5)	4 (5.9)	6 (3.3)
RVF is preventable				
Yes	27 (58.7)	36 (52.9)	28 (41.2)	91 (50)
No	16 (34.8)	28 (41.2)	24 (35.3)	68 (37.4)
Don't know	2 (4.3)	3 (4.4)	14 (20.6)	19 (10.4)
Preventive methods				
netting for windows	32 969.6)	38 (55.9)	39 (57.4)	109 (59.9)
Bed-nets	12 (26)	16 (23.8)	28 (41.2)	56 (29.92)
coils	3 (6.5)	14 (20.6)	15 (22.1)	32 (17.6)
Aerosol cans	41 (89.1)	53 (77.9)	55 (80.9)	149 (41.9)
Why do you not use a bed-net?				
not necessary	10 (21.7)	11 (16.2)	16 (23.5)	37 (20.8)
expensive	4 (8.7)	12 (17.6)	12 917.6)	28 (15.4)
inconvenient	14 (30.4)	9 (13.2)	9 913.2)	32 (17.6)
don't know	0	6 (8.8)	5 (7.4)	11 (6)
other	2 (4.3)	0	5 (7.4)	7 (3.8)
Do you know where you can obtain a bed-net				
Yes	34 (73.9)	62 (91.20)	60 (88.2)	156 (85.7)
No	7 (15.2)	3 (4.4)	5 (7.4)	15 (8.2)
Don't know	3 (6.5)	1 (1.5)	2 (2.9)	1 (.5)

5.3.4 Household characteristics

Table 5.7 shows household characteristics in two villages in the irrigated area, Rawan Alabeed located above Jizan dam and Almegussus located below the Jizan dam. Households in both villages were significantly different (Chi-square test; $p<0.001$) in all characteristics studied except % living in compound house.

Table 5.7: Household characteristics of the study population in two villages in the irrigated area, Rawan Alabeed (above Jizan dam) and Almegussus (below the Jizan dam).

Household characteristics	Rawan Alabeed n= 126 Above Jizan dam	Almegussus n=65 Below the Jizan dam
% living in compound house	3.2	1.5
% no flooring cover	81	7.7
% with toilet	21.4	92.3
% with access to piped water	6.3	86.2
% with air conditioning	43.7	98.5
% have attended school	49.2	90.8
% sleeping outside	54	10.8

5.3.5 Malaria and RVF

There was a marked difference in the total number of malaria cases during the previous 7 years (1998-2004) between irrigated villages and non-irrigated villages (Figure 5.1). Testing significance of difference between I1 vs N1, I2 vs N2 and I3 vs N3 in each of the 7 years show that there was a significant difference in number of malaria cases. A total of 1343 and 832 malaria cases were reported in irrigated and non-irrigated villages respectively. In the middle parts of wadis in both irrigated and non-irrigated areas, Rawan Alabeed (located in the irrigated area and within the dam area) reported a much larger number of malaria cases (n=493) compared with Alkarbose (n=123) located in the middle part of the wadi in the non-irrigated area.

Also, there was a marked difference in the total number of RVF cases reported during the 2000 epidemic between both irrigated villages and non-irrigated villages, with much higher numbers occurring in irrigated areas (254) compared with non-irrigated areas (13) (Figure 5.2). Among all villages in irrigated and non-irrigated areas Rawan Alabeed reported the highest number of RVF cases (Figure 5.2).

Figure 5.1: Total Number of malaria cases in the study area for the last 7 years (1998-2004). Irrigated villages; I1= Korsi Aldayer, I2= Rawan Alabeed, I3= Almejussus. Non-irrigated villages; N1=Alorah, N2= Alkarbose and N3= Almegurgum.

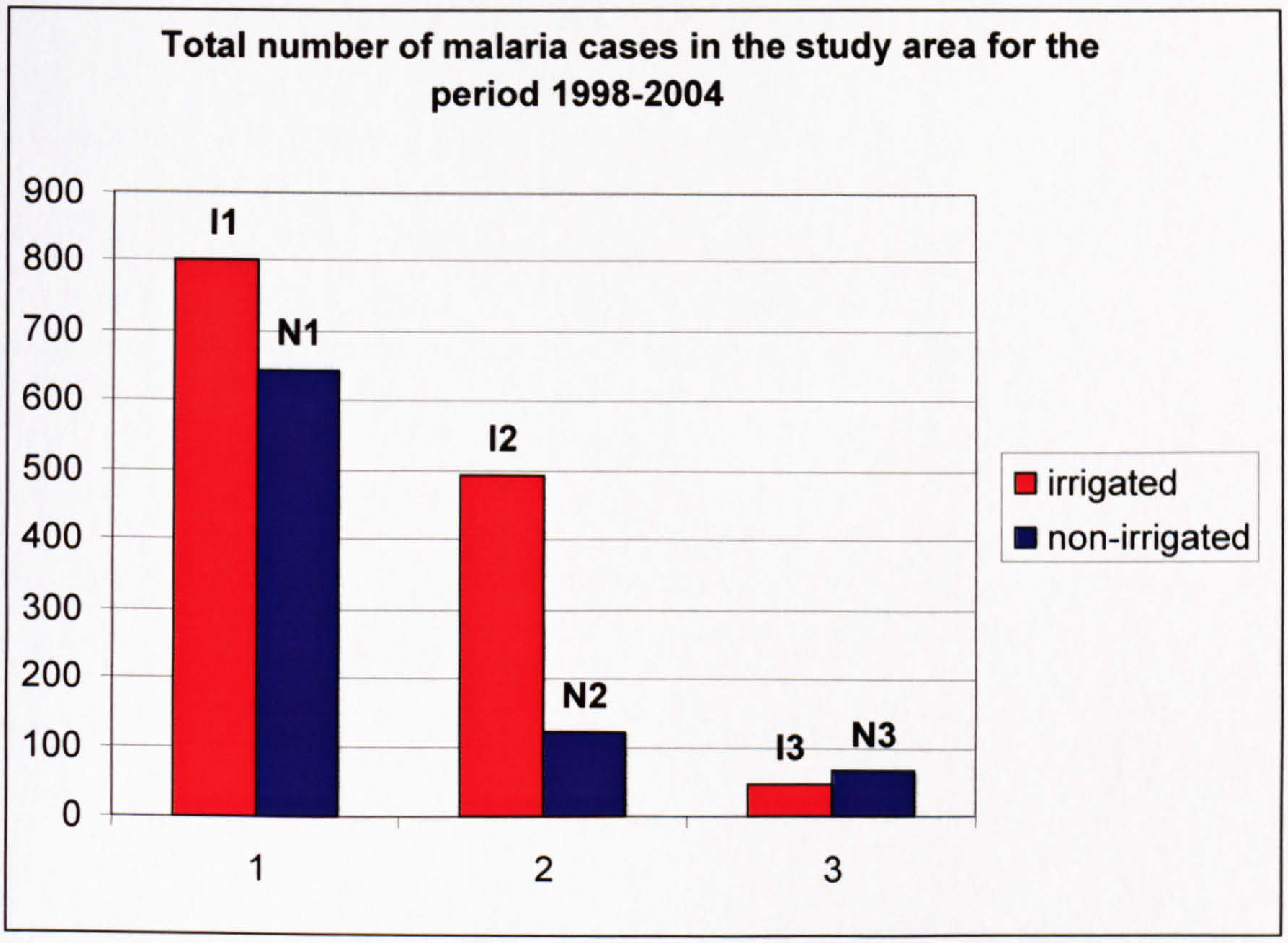
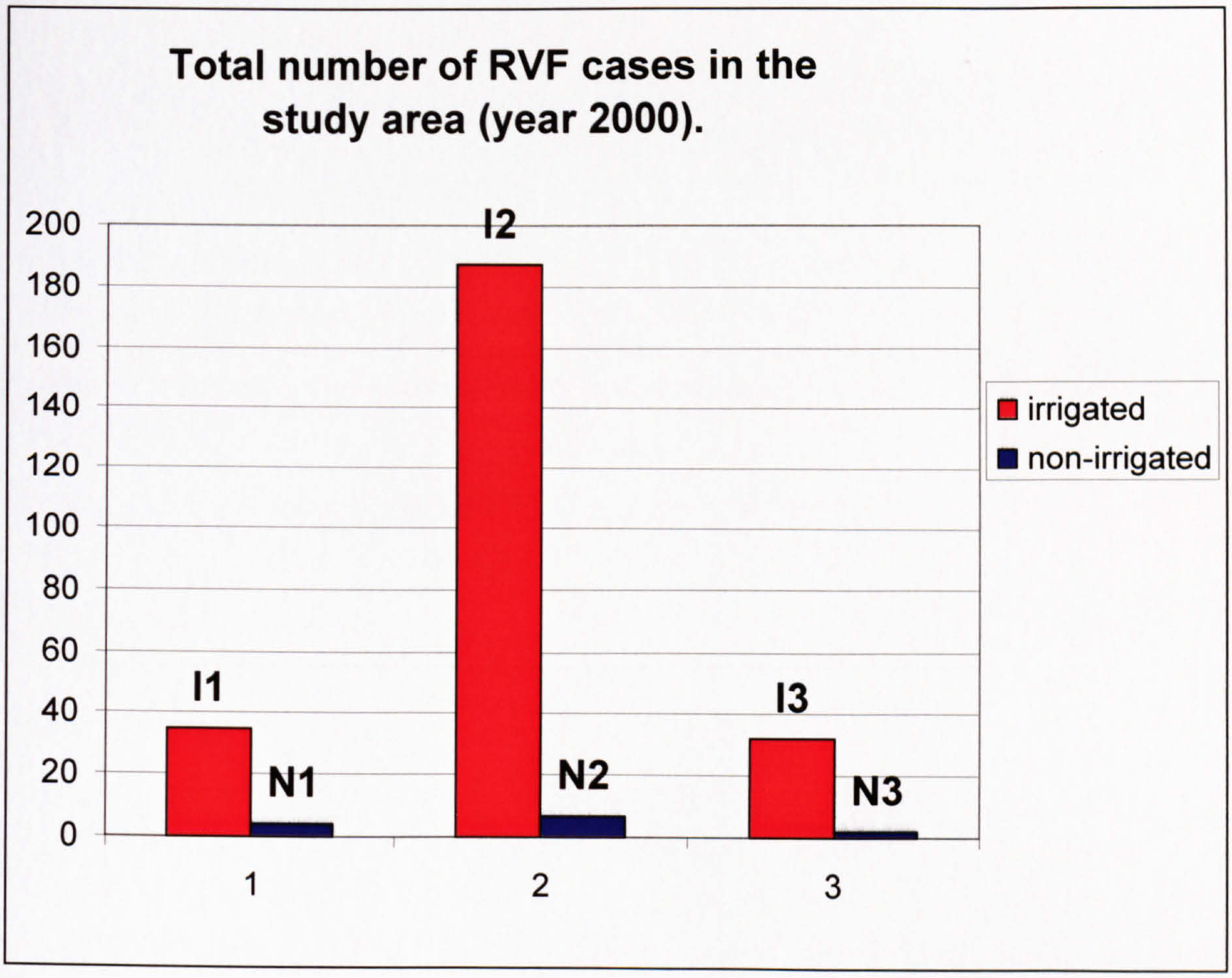


Figure 5.2: Total number of RVF cases during 2000 in the study area. Irrigated villages; I1= Korsi Aldayer, I2= Rawan Alabeed, I3= Almejussus. Non-irrigated villages; N1=Alorah, N2= Alkarbose and N3= Almegurgum.



5.4 Discussion

The present study is the first one in Saudi Arabia to try to understand how community perceptions and behaviour may affect vulnerability with regard to malaria and RFV.

With respect to the causes of malaria, in the irrigated areas more of the study subjects implicated mosquito bite as a possible cause of malaria and indicated that people are infected with malaria by the bite of infected mosquitoes. About 80% of the informants in irrigated areas knew that mosquitoes transmit malaria (all informants who mentioned malaria or mentioned malaria and RVF) as compared with 65 % in non-irrigated areas. This awareness in the present study is much higher than the level noted in other studies conducted in central Ethiopia (Wakgari *et al.*, 2003) and a similar study carried out in Kenya (Ongore *et al.*, 1989). This could possibly be due to the increase in awareness of the importance of mosquitoes, after the RVF epidemic of 2000. In non-irrigated areas, awareness was significantly lower than the level noted in irrigated villages, where only 65% of the informants in non-irrigated areas knew that mosquitoes transmit malaria. This could probably be due to the very low number of cases of RVF reported in non-irrigated villages and it is likely that the villages would not have heard about it.

Our study found that villages located below the Jizan dam such as Almegussus were wealthier than villages located above the dam. We found that household in both villages were significantly different ($p<0.001$) in almost all characteristics studied (Table 5.7). This was possibly a result of the earlier period when the Saudi government financed compensation for farmers below the dam who gave land to the Jizan Dam Irrigation Project 20 years ago. This in fact plays a significant role in the impact of an irrigation project such as the Jizan dam on the community wealth.

On the preventability of malaria, however, most of the present study population believed that malaria is a preventable disease. This could be explained by the the long term activities of the Malaria Control Programme to prevent and control the disease in the area over the last 30 years (Al-Seghayer, 1983; Al-Seghayer. *et al*, 1999) might have enhanced their knowledge on the preventability of malaria and the preventive measures. In the village located in the irrigated area below Jizan dam (Almejussus), this difference could also be attributed to the educational status of the present study population (90% attended school) compared to the much lower rate of school attendance (30%) in the above mentioned project in central Ethiopia (Wakgari *et al.*, 2003) and (16%) (Ongore *et al.*, 1989). While in the village located above Jizan dam and within the dam area (Rawan Alabeed) less than 50 % had attended school.

A review by Worrall *et al.* (2002) suggested that use of and expenditure on malaria prevention methods to be higher among those of higher Socio-economic status (SES) since they are likely to have more disposable income to spend on items which are often considered luxuries. Much of the evidence on use of and expenditure on malaria prevention is focused around using of Insecticide treated nets, though there is some limited evidence relating to other interventions (Worrall, *et al.* 2002). In our study in non-irrigated villages we found that malaria prevention is focused on netting for windows (60%) and only 29.92 % indicated bed-nets as preventive methods comparing with 48.5% in irrigated villages (there was no significant defrence). That may have resulted from a campaign to promote use of Insecticide Treated Nets (ITNs) after the 2000 RVF epidemic that focussed only on those areas which reported the highest number of RVF cases (*i.e.* irrigated areas). The evidence suggests that the poor are less likely to use preventive measures, especially the most effective ones. They are also less likely to use preventive methods in the most effective or appropriate manner. Generally, the level of expenditure on prevention methods is positively correlated with income, wealth or other proxy measures of SES such as education, however the mentioned review (Worrall et al. 2002) suggest that the relationships are not always clear. It seems that when the poor do choose to invest in malaria prevention, they suffer a greater relative burden of this expenditure (in terms of the share of total household expenditure) and its opportunity cost.

In our study we found that community in Rawan Alabeed and Korsi Aldayer which were located in the irrigated areas above the dam and in non-irrigated villages are at higher risk for contracting malaria and RVF than Almegussus village which is located below the dam. This means that in our study we found that poorer populations may be at higher risk for contracting malaria and RVF than wealthy populations. In other studies the evidence regarding the distribution of malaria incidence between poor and less poor population groups is mixed and often contradictory (Worrall et al. 2002).

In this study like most of other related studies, we found that the availability of electricity at home was positively related to knowledge of mosquito ecology, which could be partly explained by the availability of information from television at home. On the other hand availability of electricity at home is not always positively related to preventive measures such as using air conditioning (AC) or Insecticide Treated Nets (INTs). In wealthy villages located below the dam (Almegussus), we found 98% of households with air conditioning comparing with only 43% in villages above the dam (Rawan Alabeed) even though there is electricity in both villages.

Statistical analysis regarding the impact of the community perceptions and behaviour on actual malaria incidence, however, was not feasible due to the limited number of malaria cases in 2004. This study was conducted following the extensive use of pesticides after the 2000 epidemic of RVF in Saudi Arabia when only a few malaria cases were found in the study sites. However, based on the very high number of RVF cases reported in the study areas in 2000 and on all the reported and observed behaviour changes, it is reasonable to expect that self-protection from mosquito bites improved among participants in irrigated villages, and thus educational would probably have a positive impact on mosquito-borne disease prevention. Recently, free provision of 38 million Long Lasting Insecticidal Nets in very poor countries such as Niger, Togo, Eritrea and Sierra Leone. Since money has been found for this, surely Saudi Arabia could do the same in the small part of the country which remains malaria affected.

Chapter Six: Exploration of risk factors associated with the geographical distribution of malaria and RVF

6.1 Introduction

Vector-borne diseases are complex diseases and their incidence is a function of the interaction between the vector, the parasite or virus, humans or animals, and the environment. Different mosquito species have different habitat preferences e.g. rice fields, plantations, forests, forest fringes, foothills, etc., and many of these features can be identified by satellite images (Sithiprasasna, *et al.*, 2003). The physical environment also plays a significant role in the distribution of species (Claborn *et al.*, 2002)

Geographic information systems (GIS) are computerized systems utilized to process and manage spatial data. A GIS is capable of integrating topographical maps, satellite images, and aerial photos with attribute data such as demographic and socioeconomic characteristics and disease incidence. The systems have been used widely to produce maps of disease distribution and for analyzing spatial patterns in disease distribution (Beyers *et al.*, 1996; Brooker *et al.*, 2000; Cattani *et al.*, 2001; Cherkasskiy 1999; Kitron 1998; Moncayo *et al.*, 2000; Omumbo 1998). These maps have been used as tools for developing control and intervention strategies.

In Saudi Arabia, GIS tools have not yet been used to investigate patterns of malaria or other vector-borne diseases. Linking disease incidence data with environmental, population, socioeconomic and entomological features on a GIS platform can elucidate important risk factors as shown by some studies in other epidemiological settings of Asia, Africa and the Americas. For example, a study in China found that malaria was mainly influenced by the physical environment, the presence of efficient vector species and mobile populations along the area bordering neighbouring countries (Hu *et al.* 1998). Another study in Thailand, utilizing spatial analysis to explain malaria and dengue patterns, revealed that the two diseases exhibited great seasonal variations, but were associated with provincial economic status. Consequently, both diseases required different demands on the use of control resources (Indaratna *et al.* 1998). In Gujarat, India, application of GIS techniques revealed the importance of a high water table, soil types, irrigated agriculture and water quality (Srivastava *et al.* 1999).

In Africa, GIS has been used to generate models of malaria occurrence (Craig, *et al.*, 1999; MARA, 1998), seasonality (Hay *et al*, 1998) and transmission intensity (Kleinschmidt *et al.*, 2000; Rogers *et al.*, 2002) using climatic and remotely sensed data. The outputs of such models have been combined with population data (Snow et *al.*, 1999) to estimate population exposure, mortality and morbidity and to analyse and project (Lindsay & Martens, 1998) the effects of climate change on malaria. GIS has been used to map malaria vectors (Smith *et al.*, 1995; Coetzee *et al.*, 2000), vector habitats (Minakawa, *et al.*, 1999) and infection. It has also been used in the management and control of malaria (Martin, *et al.*, 2002).

Sipe & Dale (2003) concluded that the challenges in using GIS for malaria research can be organized in three areas. The first relates to data concerns. Without adequate data, GIS is not very useful. Specific problem areas include: accurate data on the disease and how it is reported; basic environmental data on vegetation, land uses, topography, rainfall and demographic data on the movement of people. The second area relates to technology – specifically computer hardware, GIS software and training. The third area concerns methods – assuming the previous data and technological problems have been resolved.

In general, malaria transmission is related to rainfall patterns, it can vary greatly in time and space. Research in the dry zone of Sri Lanka has suggested that the linkage between malaria and rainfall might have weakened and that it has been complicated due to ecological transformations (van der Hoek *et al.* 1997). Apart from rainfall and river-flow velocities, several other malaria risk factors have been identified, *e.g.*, utilization of control measures (van der Hoek *et al.* 1998), socioeconomic status (Klinkenberg *et al*, 2005) age and gender (Mendis *et al.* 1990; van der Hoek *et al.* 1998), human migration (Klinkenberg, 2001), as well as type and location of housing (Gamage-Mendis *et al.* 1991; van der Hoek *et al.* 1998). Because of spatial and temporal variation of malaria transmission, it is important to better understand and quantify the underlying risk factors, so that control efforts can be targeted to the high-risk areas. For spatial risk analysis and predictive forecasting, GIS and remote sensing (RS) have become increasingly important.

This study set out to use GIS tools to examine the geographical distribution of malaria and RVF in irrigated and non-irrigated villages, and to determine if the risk of disease is related to the location of mosquito breeding sites and the proximity of the man-made water resources in the area.

6.2. Materials and Methods

6.2.1 Study sites

Disease data were collected, and entomological and environmental surveys carried out in the three study villages in the irrigated area of the Jizan Region, Korsi Aldayer, Rawan Alabeed and Almegussus; and in the three study villages in the non-irrigated area, Alorah, Alkarbose and Almegurgum (see Chapter 3 for map and full description of each site).

6.2.2 Geographic information system database

The study sites and survey data within each village were mapped using a handheld Geographical Positioning System (Magellan, Meridian GPS). The database was built using the software ArcGIS 9.1 (ESRI, Redlands, CA). A digital map of the study area was used as the base map to which all data were spatially linked.

6.2.3 Data sources

Disease: Data on malaria were based on the Ministry of Health (MOH) parasite prevalence records from 1998 to 2004. A score for malaria positivity was calculated for each house involved in the study (random selection). For any given year, a house was considered malaria-positive if at least one malaria case was officially recorded by MOH. The score for malaria positivity was calculated as the number of years a house was scored positive for malaria during the previous seven years, i.e. number of malaria positive years divided by the number of years (n=7) (x100 to give a percentage). Data on RVF were cross-sectional and based on the 2000 epidemic. Data were obtained from the health centre in each village, and the risk (presence or absence of cases) recorded at the same houses where the malaria positivity was determined.

Entomological: Data on the main mosquito breeding sites in each of the six villages were based on the entomological surveys carried out during the study period (Jan to Dec). The collection methods and results of these surveys have already been described and presented in chapter four. However, for the purposes of this chapter, the exact co-ordinates (latitude and longitude) of the main breeding sites within each village were geo-referenced and mapped using ArcGIS 9.1.

Environmental: In each village, the distance (in metres) between selected houses and the nearest breeding site and the nearest wadi (the main water sources) were calculated using the ArcGIS 9.1, except in Rawan Alabeed, an irrigated area, where the distance between houses and the dam lake was calculated as the lake was the main water resource in this village. The location of wadis within each village was determined from satellite images (Google Earth) and imported into ArcGIS 9.1.

6.2.4 Data analyses

To determine the geographical distribution of malaria and RVF in each of the six study villages, data were first imported into ArcGIS. The relationship between the household malaria positivity score and the presence/absence of RVF were visualized and compared to the geo-referenced breeding sites and wadis. Distances were measured between each household and the nearest breeding site and wadi. All data were exported to a database for statistical analysis in SPSS..

Bivariate correlations were used to examine the relationship between the household malaria positivity score and distance between the nearest breeding sites and nearest wadis. As RVF is a dichotomous variable (yes/no), the differences in the mean malaria positivity, distances to nearest breeding site and nearest wadi were examined using the student t-test.

6.3 Results

Overall, malaria positivity was negatively correlated with the distance between houses and the nearest breeding sites and Wadis in both irrigated villages (Table 6.1) and non-irrigated villages (Table 6.3). The geographical distribution of malaria positivity and the location of the main breeding sites and wadis in each village are shown in Figures 6.1 and 6.2. Overall, the households with RVF cases during the 2000 epidemic had a higher mean malaria positivity score, and were, on average, closer to breeding sites and wadis, than those houses which did not have RVF cases in both irrigated villages (Table 6.2) and non-irrigated villages (Table 6.4).

6.3.1 Irrigated Areas

Malaria, RVF and breeding sites and wadis

In the village Korsi Aldayer (I1), malaria was negatively correlated with distance to the nearest breeding sites ($r=-0.62$, $P \leq 0.01$), but positively correlated with the nearest wadi ($r=0.28$) (Table 6.1). There was no relationship in this village between the breeding sites and wadis ($r=0.11$). Overall the mean malaria positivity was 48.9%, while the average distance between the houses and breeding sites, and the houses and wadis was 31m and 293m, respectively. There were significant differences between RVF positive and negative households with a significantly lower malaria positivity (3 times lower) and longer distance (2 times longer) to breeding sites in RVF positive houses compared to houses with no RVF cases recorded (Table 6.2).

In the village Rawan Alabeed (I2), the malaria positivity scores were negatively correlated with the distance to the nearest breeding sites ($r=-0.69$) and the nearest wadi ($r=-0.62$) (Table 6.1). In this village the breeding sites and wadis were significantly positively correlated with each other ($r=0.72$). Overall the mean malaria positivity was 29.1% and the distance between the houses and breeding sites and wadis were 56m and 731m, respectively. There were significant differences between RVF positive and negative households with a significantly higher malaria positivity (3.4 times higher) and shorter distance (2.5 times shorter) to breeding sites and wadis in RVF positive houses compared to houses with no RVF cases recorded (Table 6.2).

In the village Almegussus (I3), the malaria positivity scores were negatively correlated with the distance to the nearest breeding sites (r=-0.38) and the nearest wadi (r=-0.23 and not statistically significantly different from zero) (Table 6.1). In this village the breeding sites and wadis were significantly positively correlated with each other (r=0.63). Overall the mean malaria positivity was 26.5%, while the average distance between the houses and breeding sites, and the houses and wadis was 31m and 396 m, respectively. There were significant differences between RVF positive and negative households with a significantly higher malaria positivity (4 times higher) and shorter distance (1.8 times shorter) to breeding sites in RVF positive houses compared to houses with no RVF cases recorded (Table 6.2).

Table 6.1: Bivariate correlations between malaria positivity, and the distance between houses and nearest breeding sites, and nearest Wadi/dam lake (main water course) in the irrigated sites.

Korsi Aldayer I1

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.616(**)	1	
Distance to nearest Wadi	.281	.111	1

Rawan Alabeed I2

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.690(**)	1	
Distance to nearest Wadi	-.617(**)	.715(**)	1

Almegussus I3

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.379(*)	1	
Distance to nearest Wadi	-.232	.628(**)	1

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 6.2: Comparison the mean malaria positivity, distance to breeding site and wadis in households with and without RVF in irrigated villages

Korsi Aldayer **I1**

	RFV YES (n=20)	RFV NO (n=13)	P value
Malaria	26.8%	83%	<0.001**
Distance to nearest breeding site	39m	18m	0.002*
Distance to nearest Wadi	281m	310m	N/S

Rawan Alabeed I2

	RFV YES (n=33)	RFV NO (n=13)	P value
Malaria	37.2%	10.8%	<0.001**
Distance to nearest breeding site	38m	94m	<0.001**
Distance to nearest Wadi	713m	769m	<0.001**

Almegussus I3

	RFV YES (n=16)	RFV NO (n=16)	P value
Malaria	42.4%	10.5%	<0.001**
Distance to nearest breeding site	22m	39m	0.017*
Distance to nearest Wadi	392m	401m	N/S

** P-value significant at the 0.01 level (2-tailed).
* P-value significant at the 0.05 level (2-tailed).
N/S = not significant

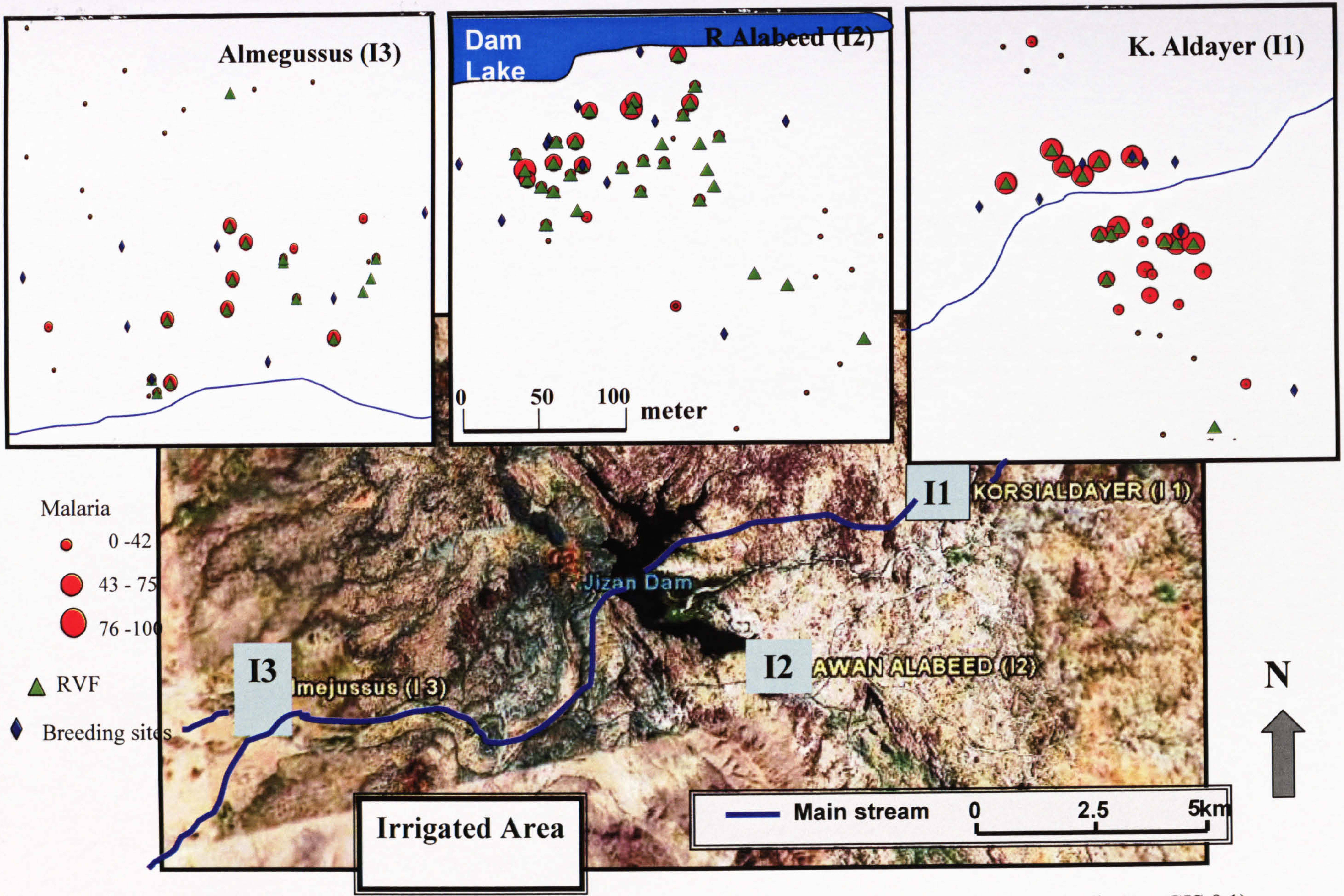


Figure. 6.1 : Map of irrigation villages showing malaria positivity, RFV (Y/N), breeding sites and Wadis (Arc GIS 9.1).

6.3.2 Non-irrigated Areas

Malaria, RVF and breeding sites and wadis

In the village Alorah (N1), malaria was negatively correlated with the distance to the nearest breeding sites (r=-0.48) and the nearest wadi (r=-0.29 and not statistically significantly different from zero) (Table 6.3). In this village the breeding sites and wadis were not correlated with each other (r=0.06). Overall the mean malaria positivity was 48.3 % and the distance between the houses and breeding sites and wadis were 34m and 144m, respectively. There were significant differences between RVF positive and negative households with a significantly higher malaria positivity (1.7 times higher) in RVF positive houses compared to houses with no RVF cases recorded (Table 6.4).

In the village Alkarbose (N2), the malaria positivity scores were negatively correlated with the distance to the nearest breeding sites (r=-0.82, $P \leq 0.01$) and the nearest wadi (r=-0.82) (Table 6.3). In this village the breeding sites and wadis were significantly positively correlated with each other (r=0.99). Overall the mean malaria positivity was 35.5% and the distance between the houses and breeding sites and wadis were 53m and 1372m, respectively. There were no significant differences between RVF positive and negative households in malaria positivity was or the distance to breeding sites in RVF positive houses compared to houses with no RVF cases recorded (Table 6.4).

In the village Almegurgum (N3), the malaria positivity scores was negatively correlated with the distance to the nearest breeding sites (r=-0.71) and the nearest wadi (r=-0.61) (Table 6.3). In this village the breeding sites and wadis were significantly positively correlated with each other (r=0.78). Overall the mean malaria positivity, the distance between the houses and breeding sites and wadis were 31.8%, 51m and 344m, respectively. There were significant differences between RVF positive and negative households with significantly higher malaria positivity (1.7 times higher) and shorter distance (2.5 times shorter) to breeding sites and wadis (1.2 times short) in RVF positive houses compared to houses with no RVF cases recorded (Table 6.4).

Table 6.3: Bivariate correlations between malaria positivity, and the distance between houses and nearest breeding sites, and nearest Wadi/dam lake (main water course) in the non-irrigated area.

Alorah N1

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.481(**)	1	
Distance to nearest Wadi	-.291	-.065	1

Alkarbose N2

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.823(**)	1	
Distance to nearest Wadi	-.823(**)	.990(**)	1

Almegurgum N3

	Malaria	Distance to nearest breeding site	Distance to nearest Wadi
Malaria	1		
Distance to nearest breeding site	-.711(**)	1	
Distance to nearest Wadi	-.613(**)	.783(**)	1

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 6.4: Comparison the mean malaria positivity, distance to breeding site and wadis in households with and without RVF in non-irrigated villages

Alorah N1

	RFV YES (n=4)	RFV NO (n=32)	P value
Malaria	74.5%	45.0%	0.039*
Distance to nearest breeding site	15m	37m	N/S
Distance to nearest Wadi	126m	146m	N/S

Alkarbose N2

	RFV YES (n=4)	RFV NO (n=31)	P value
Malaria	46%	34.1%	N/S
Distance to nearest breeding site	23m	56m	N/S
Distance to nearest Wadi	1339m	1376m	N/S

Almegurgum N3

	RFV YES (n=14)	RFV NO (n=23)	P value
Malaria	45.5%	23.4%	0.009
Distance to nearest breeding site	26m	66m	<0.001
Distance to nearest Wadi	309m	365m	N/S

** P-value significant at the 0.01 level (2-tailed).
* P-value significant at the 0.05 level (2-tailed).
N/S = not significant

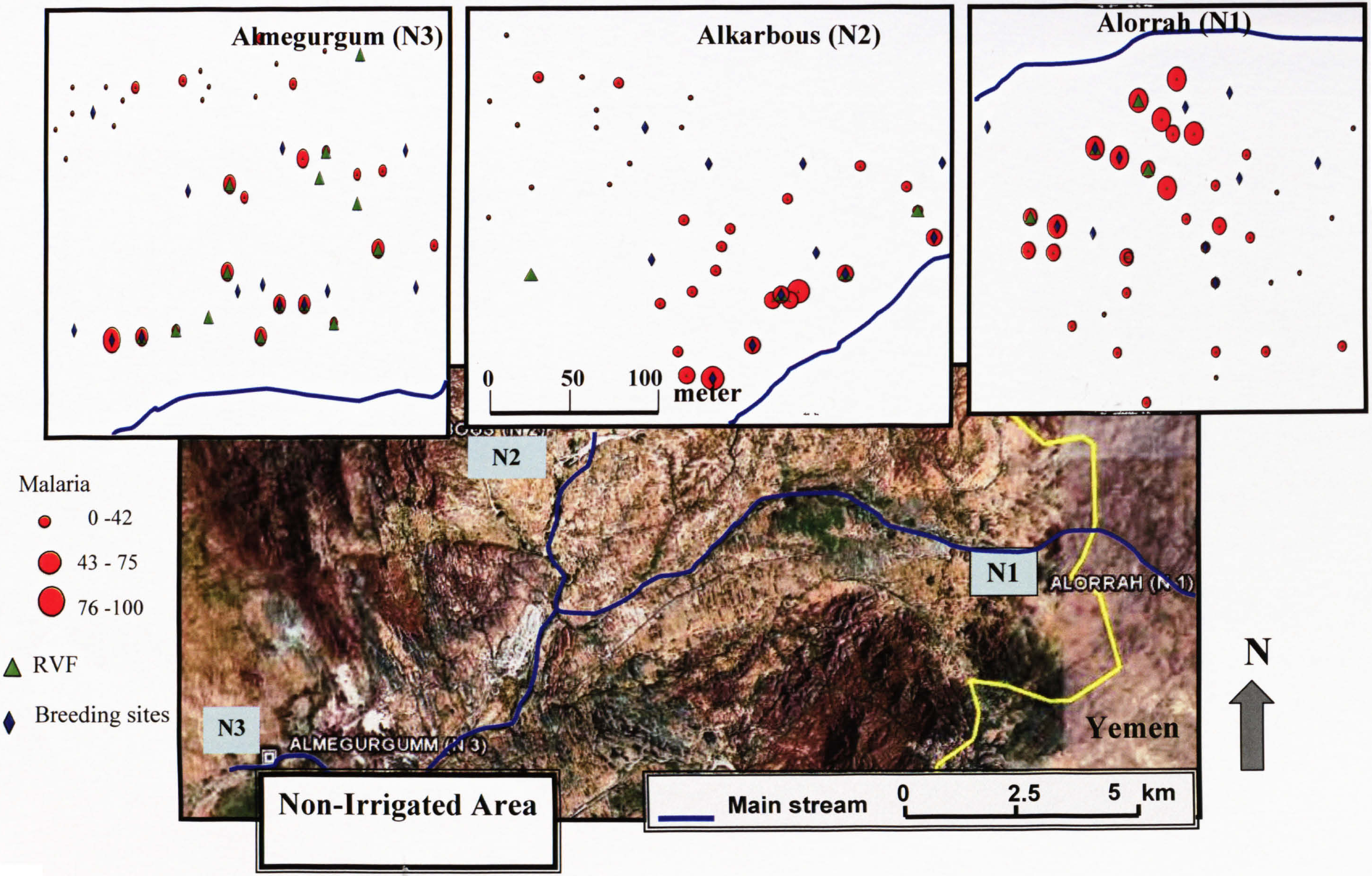


Figure. 6.2 : Map of non- irrigation villages showing malaria positivity, RFV (Y/N), breeding sites and Wadis (Arc GIS 9.1).

6.4 Discussion

In this chapter disease data and entomological and environmental data have been examined concurrently to better understand the relationship between malaria and RVF and environmental factors influencing their distribution in irrigated (Jizan Dam area) and non-irrigated villages in the Jizan Region of Saudi Arabia. Vector ecology and disease transmission are dynamic and complex processes and it is sometimes difficult to immediately draw reliable conclusions, particularly when applying to situations in different countries (Birley, 1991). Studies similar to the present one have been made in other parts of the world to determine the impact of irrigation projects on malaria. In Cameroon, construction of dams has been blamed for increased prevalence of endemic diseases including malaria (Ripert & Raccurt, 1987). In Kenya, the building of dams was associated with increased malaria transmission (Khaemba *et al.*, 1994

Malaria positively was in some cases negativity correlated with distance to breeding sites and wadi (water sources) suggesting that the closer the household, the higher the risk. These findings are consistent with other studies (Ripert & Raccurt, 1987; Ghebreyesus *et al.*, 1999) and further support the value in collecting on-ground/field data to define the risk of disease within communities. In Cameroon, a small dam was built to regulate flow to the Edea hydroelectric plant in Cameroon (Ripert & Raccurt, 1987). The shallow waters behind the dam soon contained abundant vegetation and larvae of the mosquito *Anopheles funestus*. The prevalence of *P. falciparum* malaria was high in surrounding villages and decreased with distance from the lake (Ripert & Raccurt, 1987). A large study in the Ethiopian highlands showed there was increase in malaria in villages situated near dams compared to villages further away (Ghebreyesus *et al.*, 1999). In Africa, malaria is not the only vector-borne disease associated with distance from dam lake. A study on urinary schistosomiasis in Ghana found that prevalence of the disease fell rapidly with distance from the lake shore, due to decreasing dependence of the lake for water needs (Hunter *et al.*, 1982). Our results support findings of previous research in Asia (Bergquist *et al.*, 2001; Srivastava *et al.*, 1999) and Mediterranean countries (Hassan *et al.*, 2003) that environmental factors are important determinants of vector-borne disease risk. In India the geographic information system was used as a tool to study malaria recepictivity in India. The study found that malaria was associated with high water-table (Srivastava *et al.*, 1999).

The mean distances to breeding site may also help to define the "distance" of risk of malaria and RVF. In both irrigated & non-irrigated areas the mean distance ranges from about 30-50 meters. This has direct implications for control & those houses closest to breeding sites can be targeted by mosquito control and intervention programs/strategies.

The relationship between RVF and malaria positivity and distance to breeding sites and wadi determined during this study were positive in all villages except one village Korsi Aldayer in the irrigated area. This may be related to our finding in the KAP survey when we found that villages located below Jizan dam such as Almegussus were wealthier than villages located above the dam. This was possibly a result of the earlier period when the Saudi government financed compensation for farmers below the dam who gave land to the Jizan Dam Irrigation Project 20 years ago. This in fact play a significant role on impact of irrigation project such as Jizan dam on the community wealth. Overall there was a higher mean malaria positivity in households which reported RVF cases during the 2000 epidemic, which suggest that the epidemiology of these two disease in Jizan Area are related. The fact that both diseases have positive associations with the breeding sites and wadis suggests that the different vectors for each disease share the same breeding sites. This means that any breeding sites for malaria vectors may also be effective against RVF vectors too.

This study sets the stage for the development of a more comprehensive database on impact of malaria, RVF and other vector-borne diseases in Saudi Arabia. Our findings also provide the basic framework for developing an early warning system for malaria and RVF in Saudi Arabia through monitoring of vector distribution and mapping these data in relation to environmental variables. Moreover, the successful cooperation experienced throughout this investigation between health authorities and research institutions should be repeated to include other important diseases and should be expanded to include Regional cooperation in the fight against vector-borne diseases of Regional interest.

Chapter Seven: General Discussion and Conclusions

Malaria and Rift Valley fever (RVF) are two of the important diseases in South-western Saudi Arabia. Malaria used to have a wide distribution in the country in the past, but as a result of the extensive malaria control programmes, the disease has receded and is restricted now to the south west, where 60-70% of total cases are recorded. In mid-September *2000, RVF occurred in both humans and livestock in* the Saudi Arabia for the first time (CDC, 2000a,b), and the first time that RVF had been reported outside Africa and Madagascar. The epidemic appears to have started simultaneously in the Jizan Dam area in the Jizan Region in the southwest, as well as in neighbouring Yemen, and to have continued until the end of November (CDC, 2000 a, b). A re-emergence of RVF was recorded among animals in September 2004, when 4 of the 5 cases reported were located in the Jizan dam area (MOA, 2004).

It appeared that the irrigation systems have the potential to create breeding sites, resulting in increased abundance of mosquitoes, including increases in malaria and RVF vector density. The communicable diseases most often associated with reservoirs are malaria, schistosomiasis and large engineering projects involving rivers have frequently led to explosive malaria epidemics during construction (Birley, 1995). Construction of small dams in Cameroon has been blamed for increased prevalence of endemic diseases including malaria (Ripert & Raccurt, 1987).

In Saudi Arabia approximately 185 dams of various sizes exist, constructed for flood control and groundwater recharge, and tens of new dams are planned (Ministry of Agriculture and Water, 1995). Construction of dams is based on extensive preliminary studies such as identification of the proper location of the dam, hydrological studies, engineering and evaluation studies including identification of the type of the dam and ecological studies to suggest appropriate solutions to prevent any adverse consequences (Ministry of Agriculture and Water, 1996 & 1995). Interestingly there is little attention for any health studies.

The movements of human populations into Saudi Arabia from neighboring countries to work as a farmers constitute an important social factor that has a direct bearing on transmitted malaria and RVF and other vector-borne diseases and in the planning of vector control measures. The constant influx of a workforce from neighboring Yemen, where malaria is endemic and where RVF and Dengue also occur, continuously brings a source of infection into the area. During the present study period (Jan-Dec 2004) for instance, the number of imported cases in Jean region that originated in Yemen (n = 215) was approximately half that of the locally acquired cases during the same period (MOH, 2004). Moreover, immigrant laborers from East Africa coming from countries known to be endemic for vector-borne diseases may also be another factor that has a direct bearing on transmission of these diseases.

Humidity and temperature are important factors influencing the transmission of malaria. The development of both vector and parasite is temperature dependant, and both of % humidity and % relative humidity affect mosquito survival. The ideal conditions for malaria transmission are when the mean temperature is within the range of 20°C – 30°C, while the mean relative humidity is at least 60% (Snow & Gilles, 2002). The climate in irrigated and non-irrigated areas was found to be favourable for malaria transmission during the wet season. The relative humidity was above 50% at any time and anywhere in this area and the temperature to support transmission occurred in the wet season. Thus transmission in Jizan is perennial. Rainfall in the area is discontinuous and irregular.

Within the Tihama, human settlements follow the watercourses of seasonal streams. The population inhabiting the endemic area resides in small hamlets, widely scattered across a large area. Some inhabited areas are inaccessible and rarely reached by any of the control measures applied by either the Ministry of Health (malaria control) or Ministry of Agriculture (RVF control). Interestingly, people in the rural areas sleep outdoors near their huts during the summer where man-vector contact would increase from the mosquitoes that come to bite animals, and as the numbers of animals are greater in irrigated areas than in non-irrigated areas there will be increased risk of RVF in irrigated area than in non-irrigated areas but animals may divert biting away from humans. ITNs, suspended over the outdoor beds, would be useful for such behaviour and provide protection from mosquito bites.

In irrigated areas, vector control strategies aimed at reducing vector density through larviciding, would be extremely difficult to implement and unlikely to succeed because of the variety and difficulty of locating the many breeding sites. Conversely, there is evidence that indoor residual spraying IRS appeared to be sufficient in controlling indoor resting mosquitoes (Al Sheikh, 2004). Additionally, insecticide treated bednets (ITNs) are likely to be useful and a good alternative to IRS. Lambdacyhalothrin and other pyrethroids remain effective in controlling *An. arabiensis* in the Tihama area, but resistance to the larvicidal insecticide temephos is appearing in *An. arabiensis* (Al Sheikh, 2004). Larval control could be added in certain areas, although breeding sites are transitory and a large and consistent community effort would be needed. For the irrigated areas, additional measures could be taken to minimize breeding in the irrigation structures and further studies are needed to investigate the role of the farm areas in providing resting/ breeding sites. Irrigation projects also has clear proven benefits in terms of food security and provision of jobs and livelihoods, therefore farming should be promoted but care should be taken to minimize any potential anopheline breeding but as mintiond above this would be extremely difficult to implement.

There is a need to carry out longitudinal studies to further investigate the effect of annual variation on risk factors and malaria and RVF prevalence. In addition similar studies should be conducted in other irrigated area in Saudi Arabia to study the association with irrigation.

The study revealed a number of risk factors for irrigated areas in Saudi Arabia. How broadly applicable to other parts of the world these finding are needs to be further investigated. The baseline information using GIS is now available and it would be good to map all the houses and do randomized selection of households in future longitudinal surveys. Such studies should be extended to include other part of neighbouring regions in Saudi Arabia (such as Aseer region) and in Yemen. This study sets the stage for the development of a more comprehensive database on impact of malaria, RVF and other vector-borne diseases in Saudi Arabia. Our findings also provide the basic framework for developing an early warning system for malaria and RVF in Saudi Arabia through monitoring of vector distribution and mapping these data in relation to environmental variables. Moreover, the successful cooperation experienced throughout this investigation between health authorities and research institutions should be repeated to include other important diseases and should be expanded to include Regional cooperation in the fight against vector-borne diseases of Regional interest.

The current rapid growth in agriculture and irrigation projects, with little or no attention for their health impact cannot be sustained. Studies to gain new insight on impact of RVF and malaria transmission are urgent as there is rapid, often unplanned, expansion and this could alter vector-borne disease epidemiology. Our study in irrigated and non-irrigated areas contributed to this by highlighting several risk factors to be considered in further studies. Free provision of 38 million Long Lasting Insecticidal Nets in very poor countries such as Niger, Togo, Eritrea and Sierra Leone. Since money has been found for this, surely Saudi Arabia could do the same in the small part of the country which remains malaria affected. It seems that the best prospect for reducing RVF and malaria transmission in this area will be proven control techniques that are readily accepted, such as ITNs

REFERENCES

Abdallah E. Dabbagh and Wali A. Abderrahman. (1996).
Management of groundwater resources in Saudi Arabia under various irrigation water use scenarios. *Arabian Journal of Science and Engineering.* **11** : 182-199.

Abderrahman W A. (1988).
Water management plan for the Al-Hassa Irrigation and Drainage Project in Saudi Arabia, *Agricultural Water Managemen, Saudi Arabia.* **13** : 185-194.

Abdullah M. A. R. and A. I. Merdan. (1995).
Distribution and ecology of the mosquito fauna in the southwestern Saudi Arabia. *Journal of the Egyptian Society of Parasitology.* 25(3): 815-37.

Abdullah, M., & Merdan, A. (1995).
Distribution and Ecology of mosquito Fauna in the Southwestern Saudi Arabia. *Journal of the Egyptian society of Parasitology,* **25(3):** 815-837.

Abdulrahman, A., Alrajhi, A., Rahim, I., Akood, M., & Hazmi, M. (1999). *Chloroquine-Resistant Plasmodium falciparum* Cerebral Malaria in Chloroquine-Susceptible Area. *The Journal of Infectious Diseases, **180:*** 1738-1741.

Abhayawardana, T. A.; R. K. C. Dilrukshi; and S. R. E. Wijesuriya. (1996). Cytotaxonomical examination for sibling species in the taxon Anopheles culicifacies Giles in Sri Lanka. *Indian Journal of Malariology* 33:74-80.

Aboud, M. (2003).
Ecology and population structure of *Anopheles arabiensis* in Sudan. PhD Thesis, Liverpool University, Liverpool.

Abulfatih, H.A. (1981).
Wild plants of Abha and its surrounding survey of Abha. . Lake. *J. Saudi Arabia. Nat. hist.* Soc. **25**: 17-22.

Acree, F., Turner, R. B., Gouck, H.K., Beroza, M., Smith, M. (1968).
L-lactic Acid: A Mosquito Attractant Isolated from Humans. *Science,* **161**: 1346-47.

Adams et al. (1998a).
Principles of Neurology, 6th Ed, p751; *Lancet* pr 11; **351**(9109): 1094-7.

Ageel, A. (1990).
Changing Epidemiological Pattern of Malaria during the period from 1981-1989 in Gizan Province-Saudi Arabia with Particular Reference to Control Measures. Msc Thesis, Military Medical Academy, Cairo, Cairo.

Ageel, A., & Amin, M. (1997).
Integration of schistosomiasis-control activities into the primary-health-care system in the Gizan Region, Saudi Arabia. *Annals of Tropical Medicine and Parasitology,* **91(8):** 907-915.

Agyepong, IA. (1992)
Malaria: Ethnomedical perceptions and practice in an Adange farming community and implications for control. *Soc. Sci. Med.*; 35(2):131- 137.

Ahmed K. (2000)
More deaths from rift valley fever in Saudi Arabia and Yemen. *Lacet,* 3564, (9239): 1420.

Aikins, M., Pickering, H., Alonso, P.L., D'Alessandro, U., Lindsay, S.W., Todd, J., Greenwood, B.M. (1993).
Perceptions of the causes of malaria and of its treatment and prevention in the study area. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **87,** 25 30.

Al-Arishi, H., El Awad, A., & Al Bishi, L. (2001).
Chloroquine-resistant *Plasmodium falciparum* malaria among children seen in regional hospital, Tabuk, Saudi Arabia. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **95(4):** 439-440.

Al-Hazmi, M., Ayoola, E., Abdurahman, M., Banzal, S., Ashraf, J., El-Bushra, A., Abdullah, M., Aboo, H., Elamin, A., Al-Sammani, E., Gadour, M., Menon, C., Hamza, M., Rahim, I., Hafez, M., & Jambavalikar, M. (2003).
Epidemic Rift Valley Fever in Saudi Arabia: A Clinical Study of Severe Illness in Human. *Clinical Infectious Diseases,* **36:** 245-252.

Ali A. Al Jaloud. (1991).
Agriculture and fertilizer use in Saudi Arabia. Research Institute of Natural Resources and Environment. Country paper for expert consultation on fertigation/chemigation, Cairo, Egypt, 8-11 September 1991.

Ali, A., Nanar, J., & Xue, R. (1995).
Comparative toxicity of selected larvicides and insect growth regulator to a Florida laboratory population of *Aedes albopictus. Journal of the American Mosquito Control Association,* **11(1):** 72-76.

Alio I S. (1967).
Epidemiology of schistosomiasis in Saudi Arabia with an emphasis on geographic distribution pattern. Ph.D. theses, Colombia university, New York.

Al-Madani, A. (1989).
Control of schistosomiasis in Saudi Arabia. A multidisciplinary approach. *Journal of the Egyptian society of Parasitology,* **19**(2 Suppl): 879-886.

Al-Madani, A. (1991).
Problems in the control of schistosomiasis in Asir Province, Saudi Arabia. *Journal of Community Health,* **16(3):** 143-149.

Al-Maktari, M., & Bassiouny, H. (1999).
Bionomics of Anopheline vectors in Zabid District, Al-Hodeidah, Governorate, Republic of Yemen. *Eastern Mediterranean Health Journal,* **5(4):** 698-705.

Al-Maktari, M., & Bassiouny, H. (2003a).
Malaria status in Al-Hodeidah Governorate, Republic of Yemen. Part II: Human factors causing the persistence of chloroquine resistance *P. falciparum* local strain. *Journal of the Egyptian Society of Parasitology,* **33(3):** 829-839.

Al-Maktari, M., Bassiouny, H., Al-Hamd, Z., Assabri, A., El-Massry, A., & Shatat, H. (2003b).
Malaria status in Al-Hodeidah Governorate, Yemen: malariometric parasitic survey & chloroquine resistance *P. falciparum* local strain. *Journal of the Egyptian Society of Parasitology,* **33(2):** 361-372.

Al-Ohaydeb, E. (1992).
"Distribution of Rainfall in Southwestern of Saudi Arabia," Institute of Researches and Arabic Studies, Cairo.

Al-Orainey, I., Gassim, I., Singh, L., Ibrahim, B., Ukabam, S., Gonchikar, D., & Shekhawat, B. (1994).
Visceral Leishmaniasis in Gizan, Saudi Arabia. *Annals of Saudi Medicine,* **14(5):** 396-398.

Al-Qurashi, A., Ghandour, A., Osman, M., & Al-Juma, M. (2000).
Dissemination in cutaneous leishmaniasis due to *Leishmania major* in different ethnic group in Saudi Arabia. *International Journal of Dermatology,* **39:** 832-836.

Al-Seghayer S M (1983).
Control of malaria in the kKingdom of Saudi Arabia. Postgraduate Diploma Theses. University of Leeds, UK. 100 pp.

Al-Seghayer S M, Kenawy M A, Ali OT. (1999).
Malaria in the Kingdom of Saudi Arabia epidemiology and control. *Scintific J of King Faisal University*; [Febuary Special issue]: 6-20.

Al-Sharif, A. (1983).
"Geography of Kingdom of Saudi Arabia. The second part: Southwestern Region of Saudi Arabia," Mareekh, Riyadh.

Al-Sheikh, A. (2004).
Studies on the ecology, vectorial Role and population structure of *Anopheles arabiansis* in the Tihama region of Saudi Arabia and Yemen. PhD Thesis, Liverpool University, Liverpool.

Al-Soghayer, S., Kenway, M., & Ali, O. (1999).
Malaria in the Kingdom of Saudi Arabia: Epidemiology and Control. *Scientific Journal of King Faisal University,* February Special Issue: 6-20.

Al-Zahrani M A, Peters W, and Evans D A. (1988).
Visceral leishmaniasis in man and dogs in south-west Saudi Arabia.*Trans R Soc Trop Med Hyg.* 82(6):857.

Alzahrani M A. et al. (1989a).
Leishmania infecting man and wild animals in Saudi Arabia. 6. Cutaneous leishmaniasis of man in the south-west. *Trans R Soc Trop Med Hyg.* 83(5):621-8.

Al-Zahrani M A. et al. (1989b).
Leishmania infecting man and wild animals in Saudi Arabia. 5. Diversity of parasites causing visceral leishmaniasis in man and dogs in the south-west. Trans R Soc Trop Med Hyg. 1989 Jul-Aug;83(4):503-9.

Al-Zahrani M A. et al. (1992).
Leishmania infecting man and wild animals in Saudi Arabia. 9. The black rat (Rattus rattus) a probable reservoir of visceral leishmaniasis in Gizan province, south-west Saudi Arabia.*Trans R Soc Trop Med Hyg.* 86(5):513-4.

Al-Zahrani, M., Peters, W., & Evans, D. (1988).
Visceral leishmaniasis in man and dogs in South-west Saudi Arabia. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **82:** 857.

Al-Zahrani, M., Peters, W., Evans, D., Smith, V., & Chin, C. (1989a).
Leishmania infecting man and wild animals in Saudi Arabia 6. Cutaneous leishmaniasis of man in the south-west. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **83(5):** 621-628.

Al-Zahrani, M., Peters, W., Evans, D., Smith, V., & Chin, C. (1989b).
Leishmania infecting man and wild animals in Saudi Arabia. 5. Diversity of parasites causing visceral leishmaniasis in man and dogs in the south west. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **83:** 503-510.

Amin M A, Ageel A R. (1997).
Integration of schistosomiasis-control activities into the primary-health-care system in the Gizan region, Saudi Arabia. *Ann Trop Med Parasitol.* 91(8):907-15.

Amin M A. et al. (1990).
Schistosomiasis and control activities in Gizan region of Saudi Arabia. *J Egypt Soc Parasitol.* 20(1):397-409.

Amin M, Fenwick A, Teesdale C, McLaren M. (1982).
The assessment of a 3 year snail control programme in the Gezira irrigated area Sudan. Ann Trop Med Hygiene Parasitol;76:557-80.

Arfaa F. (1976).
Studies on schistosomiasis in Saudi Arabia. *Am J Trop Med Hyg.* 25(2):295-8.

Ashi J. et al.(1989).
Progress achieved in the control of schistosomiasis in Saudi. Arabia.*J Trop Med Hyg.* 92(1):27-31.

Asnis D, Conetta R, Waldmon G, et al. (1999).
Outbreak of West Nile-like viral encephalitis: New York.*MMWR Morb Mortal Wkly Rep,* 48: 845-49.

Atkinson, S. and Merkle, A. (Eds) (1993).
Urban Health in Africa. International Institute for Environment and Development, London.

Audallah E. Dabbagh and Wali A. Abderrahman. (1996).
Management of groundwater resources in Saudi Arabia under various irrigation water use scenarios. *Arabian Journal of Science and Engineering.* 15(1):3 –15.

Audibert, M., Josseran, R., Josse, R., Adjidji, A. (1990)
Irrigation, schistosomiasis, and malaria in the Logone Valley, Cameroon. *American Journal of Tropical Medicine and Hygiene,* 42, 550 560.

Bahanshal. (1989). Agricultural and water resources in the Kingdom of Saudi Arabia. King Saud University.

Balkhy, H., & Memish, Z. (2003).
Rift Valley fever: an uninvited zoonosis in the Arabian Peninsula. *International Journal of Antimicrobial Agents,* **21:** 153-157.

Bashwari L A. et al. (2001).
Epidemiological profile of malaria in a university hospital in the eastern region of Saudi Arabia. *Saudi Med J.* 22(2):133-8.

Beyers N, Gie RP, Zietsman HL, Kunneke M, Hauman J, Tatley M, Donald PR
1996) The use of a geographical information system (GIS) to evaluate

the distribution of tuberculosis in a highincidence community. *S Afr Med J* , 86:40-1, 44.

Bergquist R, Utzinger J, Xiao S, N'Goran EK, , Tanner M.The potential of artemether for the control of schistosomiasis. (2001). Int J Parasitol. Dec;31(14):1549-62. Review.

Birley MH and Lock K. (1999).
The Health Impacts of Periurban natural resource development. Liverpool: Liverpool School of Tropical Medicine.

Birley, M. H. (1991).
Guidelines for forecasting the vector-borne disease implications of water resources development. Geneva, World Health Organization.

Birley, M. H. (1995).
The health impact assessment of development projects. London, HMSO.

Birley, M. H., R. Bos *et al.* (1996).
"A multi-sectoral task-based course: Health opportunities in water resources development." Education for Health: Change in Training and Practice 91: 71-83.

Birley, M.H., and Peralta, G.L. (1995)
Health impact assessment of development projects, pp. 153-170 in Vanclay, F., and Bronstein, D.A. (eds.) Environmental and Social Impact Assessment, John Wiley and Sons Ltd., Chichester.

Boudin, C., Robert, V., Carnevale, P., Ambroise-Thomas, P. (1992)
Epidemiology of *Plasmodium falciparum* in a rice field and a savanna area in Burkina Faso. Comparative study on the acquired immunoprotection in native populations. *Acta Tropica*, 51, 103-111.

Bradley, D.J. (1988).
The Epidemiology of Ricefield-Associated Diseases. International Rice Research Institute in collaboration with WHO/FAO/UNEP, Panel of Experts on Environmental Mangement for Vector Control.

Bres PLJ. (1986).
A century of progress in combating yellow fever. *Bull World Health Organ*, 64, 775-86.

Briggs, D.J. & Elliott, P. (1995)
The use of geographical information systems in studies on environment and health. *World Health Stat. Quart.*, 48, 85-94.

Brooker S, Rowlands M, Haller L, Savioli L, Bundy DA (2000)
Towards an atlas of human helminth infection in sub-Saharan Africa: the use of geographical information systems (GIS). *Parasitol Today* 2000, 16:303-307.

Bruce-Chwatt L.J.; Garrett B. (1966)
Ten years study (1955-64) of host selection by anopheline mosquitos. *Bull.Wld Hlth Org.*, **35:** 405-39.

Buei, K., Nakajima, S., Ito, S., et al. (1986).
Ecological studies on the over wintering of mosquitoes, especially of *Culex tritaeniorhynchus* Giles, in Oska prefecture. 1. Notes on the dry ice- and emergence- trapping in spring at terraced rice field areas, 1967-1975. *Jap. J. Sanit. Zool.*, 37, 333-40. (In Japanese, English summary).

Bunnag T, Sornmani S, Phinichpongse S, Harinasuta C. (1979)
Surveillance of water-borne parasitic infections and studies on the impact of ecological changes on vector mosquitoes of malaria after dam construction, 21st SEAMEO-TROPMED Seminar: environmental impact on human health in southeast and east Asia. Tokyo: Tsukuba,.

Buttiker. (1981).
Observation on urban mosquitoes in Saudi Arabia, *Fauna of Saudi Arabia.* **2**: 472-479.

Cairncross, S., Rajavel, A., Vanamail, P., Subramaniam, S., Pailly, K., Ramaiah, K., Amalraj, D., Mariappan, T. and Srinivasan, R. (1988).
Engineering, mosquitoes and filariasis: a case report. *Journal of Tropical Medicine and Hygiene*, **91**, 101–106.

Cattani P, Jannin J, Lucas P (2001)
Sleeping sickness surveillance: an essential step towards elimination. *Trop Med Int Health*, **6**:348-361.

Cherkasskiy BL(1999)
A national register of historic and contemporary anthrax foci. *J Appl Microbiol*, **87**:192-195.

CDC. (2000a). Update: outbreak of Rift Valley fever—Saudi Arabia, August–November 2000. *MMWR Morb Mortal Wkly Rep.* 49:982–5.

CDC. (1998)
Rift Valley fever---East Africa, 1997--1998. *MMWR*, 47:261-4.

CDC. (2000b).
Outbreak of Rift Valley fever—Saudi Arabia, August–October, 2000. *MMWR Morb Mortal Wkly Rep.* 49:905.

Chandler, J., Hill, M., & Highton, R. (1976).
The use of light traps for long-term surveillance of mosquitoes of epidemiological importance on the Kano Plain, Kenya. *East African Medical journal,* **53(10):** 596-600.

Charlwood, J., Alecrim, W., Fe, N., Mangabeira, J., & Martins, V. (1995).
A field trail with Lambda-cyhalothrin (ICON) for the intradomiciliary control of malaria transmitted by *Anopheles darlingi* Root in Rondonia, Brazil. *Acta Tropica,* **60:** 3-13.

Charlwood, J.D. & Edoh D. (1996)
Polymerase chain reaction used to describe larval habitat use by *Anopheles gambiae* complex (Diptera: Culicidae) in the environs of Ifakara, Tanzania. *Journal of Medical Entomology*, **33**, 202-4.

Cherkasskiy BL(1999)
A national register of historic and contemporary anthrax foci. *J Appl Microbiol*, **87**:192-195.

Chimbari , L., Engels, D., Montresor, A., & Savioli, L. (2000).
The global status of schistosomiasis and its control. *Acta Tropica,* **77:** 41-51.

Claborn DM, Hshieh PB, Roberts DR, Klein TA, Zeichner BC, Andre RG. (2002)
Environmental factors associated with larval habitats of malaria vectors in northern Kyunggi Province, Republic of Korea. J Am Mosq Control Assoc.;**18**:178–185

Claborn, D. M., Sad DF. (2002).
Environmental factors associated with larval habitats of malaria vectors in northern Kyunggi Province, Republic of Korea. *Journal of the American Mosquito Control Association.*

Clarke, S.E., Bøgh, C., Brown, R.C. *et al.* (2002)
Risk of malaria attacks in Gambian children is greater away from malaria vector breeding sites. *Trans. Roy Soc Trop. Med. Hyg.*, **96**, 499-506.

Clements A. N. (1963).
The physiology of Mosquitoes. Vol. 17, pp 4-30. Oxford: Pergamon Press.

Clements A. N. (1992).
The biology of mosquitoes. Vol. 1, pp 1-12, 220-24. London: Chapman & Hall.

Coetzee M, Craig M and le Sueur D (2000)
Distribution of African malaria mosquitoes belonging to the *Anopheles gambiae* complex. *Parasitol Today*, **16**:74-7.

Coluzzi M, Petrarca V. Di Deco. M.A. (1985)
Chromosomal inversion intergradation and incipient speciation in Anopheles gambiae. Bull Zool;52:45-63.

Coluzzi M, Sabatini A, Petrarca V, Di Deco MA. (1979)
Chromosomal differentiation and adaptation to human environments in the *Anopheles gambiae* complex. Trans R Soc Trop Med Hyg;73(5):483-97.

Craig MH, Snow RW and le Sueur D (1999)
A climate-based distribution model of malaria transmission in sub-Saharan Africa. *Parasitol Today*, **15**:105-11.

Daggy R H. 1958.
Malaria in oases of eastern Saudi Arabian. Am J Trop Med Hyg. 8:223-291.

Department of Economic Studies and Statistics. (1989). Agricultural Sector Development: Graphical Indicators. Ministry of Agriculture and Water.

Diabate, A., Baldet, T., Chandre, F., Dabire, K., Simard, F., Ouedraogo, J., Guillet, P., & Hougard, J. (2002).
First report of a *kdr* mutation in *Anopheles arabiensis* from Burkina Faso, West Africa. *Journal of the American Mosquito Control Association*, **20(2)**: 195-196.

Doumenge, LP., Mott, K.E., Cheung, C., Villenave, D., Chapuis, 0., Perrin, M.F. and Reaud Thomas, G., (1987).
Atlas of the Global Distribution of Schistosomiasis, CEGET/CNRS - WHO, Talence/Geneva.

DuBose, W., & Curtin, T. (1965).
Identification Keys to the Adult and Larval Mosquitoes of the Mediterranean Area. *Journal of Medical Entomology*, **1(4)**: 349-355.

Egboka, B. C. E., Nwankwor, G. I., Orajaka, I. P. and Ejiofor, A. O. (1989).
Principles and problems of environmental pollution of groundwater resources with case examples from developing countries. *Environmental Health Perspectives*, **83**, 39–68.

El Gaddal, A.A., Haridi, A.A.M., Hassan, F.T., Hussein, H. 1985
Malaria control in the Gezira-Managil irrigated scheme of the Sudan. *Journal of Tropical Medicine and Hygiene*, **88**, 153 159.

Emran M A. (1978).
Report on general review of experience of the health impacts of water resources development projects in Kingdom of Saudi Arabia. Seminar on the prevention and control of vector-borne diseases development projects. Alexandria / Khartoum. WHO.

Evans DB, Gelband H, Vlassoff C. (1993)
Social and economic factors and the control of lymphatic filariasis: a review. *Acta Trop*, 53:1-26.

Evans, A. (1938). "Mosquitoes of The Ethiopian Region II: Anophelini," Oxford University Press, London.

Fadel, M. (1995).
MSc Study on Jazira Project in Sudan. Khartoom University.

Fakeeh M, Zaki A M. (2001).
Virologic and serologic surveillance for dengue fever in Jeddah, SaudiArabia, 1994-1999. *Am J Trop Med Hyg.* 65(6):764-7.

FAO, (2002).
Food and Agriculture Organization of the United Nation (FAO). *FAOSTAT on-line statistical service*, Rome.

Fontenille W E. (1988).
MSc thesis, Rice field and malaria in Asia, Sri Lanka, MOH project.

Gajdusek, D. C. (1978).
Introduction of *Taenia solium* into West New Guinea with a note on an epidemic of burns from cysticercus epilepsy in the Ekari people of the Wissel Lakes area. *Papua New Guinea Medical Journal*, **21**, 329–342.

Gamage-Mendis, A. C.; Carter, R.; Mendis, C.; De Zoysa, A. P. K.; Herath, P. R. J.; Mendis, K. N. (1991)
Clustering of malaria infection within an endemic population: Risk of malaria associated with the type of housing construction. *American Journal of Tropical Medicine and Hygiene* 45:77-85.

Ghandour A M. et al. (1995).
Epidemiological studies on Schistosoma mansoni infection in the western region of Saudi Arabia using the potassium hydroxide stool digestion technique*J Trop Med Hyg.* 98(1):57-63.

Ghandour A M. et al. (1997).
Rectosigmoid bilharzioma causing intestinal obstruction. *J Pediatr Surg.* 32(4):631-3.

Ghandour A M. et al. (1999).
Epidemiological study on the transmission of schistosomiasis in Saudi Arabia (western region). *Ann Trop Med Parasitol.* 93(2):193-5.

Ghebreyesus TA, Haile M, Witten KH, Getachew A, Yohannes AM, Yohannes M, Teklehaimanot HD, Lindsay SW, Byass P. (1999).
Incidence of malaria among hildren living near dams in northern Ethiopia: community based incidence survey. *BMJ.* Sep 11;319(7211):663-6.

Ghebreyesus, T.A., Haile, M., Witten, K.H., Getachew, A., Medhin, A., Yohannes, M., Teklehaimanot, H.D., Lindsay, S.W., Byass, P. (2000)
Household risk factors for malaria among children in the Ethiopian Highlands. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 94, 17 21.

Gillies, M., & D. M. (1968).
A study of the age-composition of populations of *Anopheles gambiae* Giles and *A. funestus* Giles in North-Eastern Tanzania. *Bulletin of Entomological Research,* **56(2):** 237-262.

Gillies, M.T & M. Coetzee. (1987).
A supplement to the Anophelinae of Africa south of the Sahara (Afrotropical Region). *The South African Institute for Medical Research*, pub no. 55.

Githeko, A., Brandling-Bennett, A., Beier, M., Atieli, F., Owaga, M., & Collins, F. (1992).
The reservoir of *Plasmodium falciparum* malaria in a holo-endemic area of western Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **86(4):** 355-358.

Githeko, A.K., Service, M.W., Mbogo, C.M., Atieli, F.K., Juma, F.O. (1993)
Plasmodium falciparum sporozoite and entomological inoculation rates at the Ahero irrigation scheme and the Miwani sugar-belt in western Kenya . *Annals of Tropical Medicine and Parasitology*, 87, 379 391.

Glick, J. (1992).
Illustrated key to the female *Anopheles* of southwestern Asia and Egypt. *Mosquito Systematics,* **24(2):** 125-153.

Goonasekere, K. G. A.; and F. P. Amerasinghe. (1988).
Planning, design, and operation of rice irrigation schemes - their impact on mosquito-borne diseases. In *Vector-borne disease control in humans through rice agroecosystem management.* Manila, Philippines: International Rice Research Institute.

Gratz, N., & Pal, R. (1988).
Malaria vector control: larviciding. Pp. 1213–1226. *In* "Malaria: Principles and practice of malariology" (W. Wernsdorfer & I. McGregor, Eds.), Churchill Livingstone, Edinburgh, UK.

Gremillion D H. et al. (1978).
Schistosomiasis in Saudi Arabian recruits. A morbidity study based on quantitative egg excretion. *Am J Trop Med Hyg.* 27(5):924-7.

Gubler, D. (1998a).
Dengue and Dengue Haemorrhagic Fever. *Clinical Microbiology Reviews,* **11(3):** 480-49.

Gubler, D. (1998b).
Resurgent Vector-Borne Diseases as a Global Health Problem. *Emerging Infectious Diseases,* **4(3):** 422-450.

Gubler, D. (2002).
The Global Emergence/Resurgence of Arboviral Diseases As Public Health Problems. *Archives of Medical Research,* **33:** 330-342.

Gubler, DJ. (1989).
Aedes aegypti and Aedes aegypti-borne disease control in the 1990s. *Am J Trop Med Hyg,* 40:571-578.

Gunawan, S., Subianto, D. B. and Tumada, L. R. (1976).
Taeniasis and cysticercosis in the Pania Lakes area of Irian Jaya. *Bulletin Penelitian Kesehaten. Health Studies in Indonesia,* **4,** 9–17.

Gyapong JO, Gyapong M, Evans DB, Aikins MK, Adjei S:
The economic burden of lymphatic filariasis in northern Ghana. *Ann Trop Med Parasitol* 1996, 90:39-48. 2.

Harbach R. E. (1985).
Pictorial keys to the genera of mosquitoes, subgenera of *Culex* and the species of *Culex* (*Culex*) occurring in southwestern Asia and Egypt, with a note on the sub generic placement of Culex deserticola (Diptera: Culicidae). *Mosquito Systematics.* 17(2) 83-108.

Harrison, B.A. & Scanlon, J.E. (1975)
Medical Entomology Studies - II: The subgenus *Anopheles* in Thailand. *Contributions of the American Entomological Institute,* **12,** 1-307.

Hassan M, El-Motaiem M, Afify H, Abaza B, El-Shafei M, Massoud AM. (2003). In vitro effect of Mirazid on Schistosoma mansoni worms.J Egypt Soc Parasitol. 2003 Dec;33(3):999-1008.

Hay SI, Snow RW and Rogers DJ (1998)
Predicting malaria seasons in Kenya using multitemporal meteorological satellite sensor data. *Trans R Soc Trop Med Hyg,* **92:**12-20.

Henry, M.C., Dossou Yovo, J., Nzeyimana, I., Diarassouba, S., Akodo, E., Teuscher, T., Carnevale, P. (1998). Impact of rice cultivation systems on malaria incidence in the savanna of northern Côte d'Ivoire. 2nd European Conference on Tropical Medicine. Liverpool School of Tropical Medicine, Liverpool, U.K.

Herath, P.R.J. and G.P. Joshi. 1989. Pesticide selection pressure on *Anopheles subpictus* in Sri Lanka: Comparison with two other Sri Lankan anophelines. Trans. R. Soc. Trop. Med. Hyg. 83: 565-567.

Hewitt, S., & Rowland, M. (1999).
Control of zoophilic malaria vectors by applying pyrethroid insecticides to cattle. *Tropical Medicine and International Health,* **4**(7): 481-486.

Hightower, A.W., Ombok, M., Otieno, R., *et al.* (1998)
A geographic information system applied to a malaria field study in western Kenya. *Am. J. Trop. Med. Hyg.*, 58, 266-272.

Hii, J. L. K., Smith, T., Mai, A., Mellor, S., Lewis, D., Alexander, N., and Alpers, M. P. (1997).
Spatial and temporal variation in abundance of *Anopheles* (Diptera: Culicidae) in a malaria endemic area in Papua New Guinea. *J. Med. Entomol.* 34, 193-205.

Hommel D., Heraud JM., Hulin A.and Talarmin A. (2000)
Association of Tonate virus (subtype IIIB of the Venezuelan equine encephalitis complex) with encephalitis in a human. *Clin Infect Dis,* 30(1): 188-90.

Hoogstral, H., Meegan, J.M., Khalid G.M. and Adham, F.K. (1979).
The rift valley fever epizootic in Egypt (1977-1978). 2- Ecology and entomological studies. *Trans. Roy Soc. Trop. Med. Hyg.* **73**: 624-29.

Hu, H.; Singhasivanon, P.; Salazar, N. P.; Thimasarn, K.; Li, X.; Wu, Y.; Yang, H.; Zhu, D.; Supajev, S.; Looarecsuwan S. (1998)
Factors influencing malaria endemicity in Yunnan Province, PR China (analysis of spatial pattern by GIS). *Southeast Asian Journal of Tropical Medicine and Public Health* 29:191-200.

Huang, Y, and L Manderson. (1992).
Schistosomiasis and the social patterning of infection. *Acta Tropica* 51: 175-194.

Hubalek Z, Halouzka J. (1999).
West Nile fever: a reemerging mosquito-borne viral disease in Europe. *Emerg Inf Dis*, **5**: 643-50.

Huggins JW. (1989) Prospects for treatment of viral hemorrhagic fevers with ribavirin, a broad- spectrum antiviral drug. *Reviews of Infectious Diseases*; **11**(suppl): S750--S761.

Hunter, J.M.L., Rey, L., Chu, K.Y., Adekolu-John, E.O., Mott, K.E. (1993).
Parasitic Diseases in Water Resources Development. The Need for Intersectoral Negotiation. World Health Organization, Geneva.

Ibrahim O A. et al. (1994).
Visceral Lishmaniasis in Gizan, Saudi Arabia. *Ann Saudi Med.* 14(5):396-398

Igbinosa, I. (1989).
Investigations on the breeding site preferences of mosquitoes in Ekpoma, Nigeria. *Journal of Applied Entomology,* **107:** 325-330.

Indaratna, K.; Hutubessy, R.; Chupraphawan, S.; Sukapurana, C.; Tao, J.; Chunsutthiwat, S.;
himasarn, malaria information system for malaria research and control in South Africa. *Health Place*, **8**:227-36.

Ijumba, J.N. & Lindsay, S.W. (2001)
Impact of irrigation on malaria in Africa: paddies paradox. *Medical and Veterinary Entomology*, **15**, 1-11.

Jeronimo, S., Oliveira, R., Mackay, S., Costa, R., Sweet, J., Nascimento, E., Luz, K., Fernandes, M., Jernigan, J. and Pearson, R. (1994). An urban outbreak of visceral leishmaniasis in Natal, Brazil.

Jobin W. (1999).
Ecological design and health impacts of large dams, canals, and irrigation systems. London: E&F.N. Spon.

Jobin, W.R. 1995*Malaria Prevention in the Planning of Irrigation Systems. 1995 Costs.* Blue Nile Associates, Foxboro, MA, U.S.A. Jul iano, B.O. (1995). *Rice in Human Nutrition.* International Rice Research Institute/Food and Agricultural Organization of the United Nations, Rome.

Jonathan A. Patza, Thaddeus K. Graczykb, Nina Gellera, Amy Y. Vittor.(2000). Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology* 30 (2000) 1395-1405.

Jupp P G. et al. (2002).
The 2000 epidemic of Rift Valley fever in Saudi Arabia: mosquito vector studies. *Med Vet Entomol.* **16**(3):245-52.

K.; Crissman, L. (1998).
Application of geographical information systems to co-analysis of disease and economic resources: Dengue and malaria in Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health* **29**:669-676.

Kaplan JE, Larrick JW, Yost J, et al.
Infectious disease patterns in the Waorani, an isolated Amerindian population. Am J Trop Med Hyg 1980;29(2):298-312.

Kay BH, Nam VS, Tien TV, *et al.*. (2002)
Control of *Aedes* vectors of dengue in three provinces of Vietnam by use of *Mesocyclops* (Copepoda) and community-based methods validated by entomologic, clinical, and serological surveillance. *Am. J. Trop. Med. Hyg.*, **66**, 40-48.

Khaemba, B.M., Mutani, A., Bett, M.K. (1994)
Studies of anopheline mosquitoes transmitting malaria in a newly developed highland urban area: a case study of Moi University and its environs. *East African Medicine*, **71**, 159 164.

Khan, Abdul A., Maibach, H.I., Strauss, W.G., Fenley, W.R. (1965).
Screening Humans for Degrees of Attractiveness to Mosquitoes. *J. Econ. Entomol*, **58**: 694-697.

Killeen GF, Knols BG & Gu W. (2003)
Taking malaria transmission out of the bottle: implications of mosquito dispersal for vector-control interventions. *Lancet Inf. Dis.,* **3**, 297-303.

Killeen GF. (2003)
Following in Soper's footsteps: northeast Brazil 63 years after eradication of *Anopheles gambiae*. *Lancet Inf. Dis.* **3**, 663-6.

Kitron U(1998)
Landscape ecology and epidemiology of vectorborne diseases: tools for spatial analysis. *J Med Entomol*, **35**:435-445.

Kleinschmidt I, Bagayoko M, Clarke GP, Craig M and Le Sueur D (2000)
A spatial statistical approach to malaria mapping. *Int J Epidemiol*, **29**:355-61.

Klinkenberg, E., McCall, P.J., Hastings, I. M., Wilson, M. D., Amerasinghe, F. P. and Donnelly M. J. (2005a)
High malaria prevalence and urban agriculture in Accra, Ghana
Emerging Infectious Diseases, **11**, 8, 1290-1293.

Klinkenberg, Brian. (Editor). (2005ab).
E-Flora BC: Electronic Atlas of the Plants of British Columbia [www.eflora.bc.ca]. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia, Vancouver.

Klinkenberg, E. (2001)
Malaria risk mapping in Sri Lanka: Results from the Uda Walawe area. Proceedings of a health workshop in Embilipitiya, Sri Lanka, March 29th 2001. IWMI Working Paper 21. Colombo, Sri Lanka: International Water Management Institute.

Klinkenberg, E. (2001)
Malaria risk mapping in Sri Lanka: Results from the Uda Walawe area. Proceedings of a health workshop in Embilipitiya, Sri Lanka, March 29th 2001. IWMI Working Paper 21. Colombo, Sri Lanka: International Water Management Institute.

Kroeger, A. 1983.
Health interview in development countries: A review of the methods and results. I. J .Epd. 12: 465-481.

Laventure T. (1996).
PhD study. Rice field and malaria vectors in Asia, Sri Lanka, MOH project.

Lemasson, J., Fontenille, D., Lochouarn, L., Dia, I., Simard, F., Ba, K., Diop, A., Diatta, M., & Molez, J. (1997).
Comparison of behaviour and vector efficiency of *Anopheles gambiae* and *An. arabiensis* (Diptera: Culicidae) in Barkedji, a Sahelian area of Senegal. *Journal Medical Entomology,* 34(4): 396-403.

Lindsay SW and Martens WJ (1998)
Malaria in the African highlands: past, present and future. *Bull World Health Organ,* 76:33-45.

Lindsay, S.W., J. R. M. Armstrong Schellenberg; H. A. Zeiler; R. J. Daly; F. M. Salum; and H. A. Wilkins. (1995).

Lindsay, S.W., Wilkins, H.A., Zieler, H.A., Daly, R.J., Petrarca, V., Byass, P. (1991) Ability of *Anopheles gambiae* mosquitoes to transmit malaria during the dry and wet seasons in an area of irrigated rice cultivation in The Gambia . *Journal of Tropical Medicine and Hygiene*, 94, 313 324.

Lines, J., Harpham, T., Leake, C. and Schofield, C. (1994).
Trends, priorities and policy directions in the control of vector-borne diseases in urban environments. *Health Policy and Planning*, 9, 113–129.

Linthicum, K. J. et al (1985)
Journal of the American Mosquito Control Association,1: 93.

Lipton, M. and de Kadt, E., (1988).
Agriculture - Health Linkages. WHO offset Publication No. 104, World Health Organization, Geneva.

Louise Seka. (2003).
Living in the paddies: a social science perspective on how inland valley irrigated rice cultivation affects malaria in Northern Cote d'Ivoire. *Tropical Medicine and International Health.* Volume 8, Issue 5, Page 459.

Magzoub M, Kasim A A. (1980)
Schistosomiasis in Saudi Arabia. *Ann Trop Med Parasitol.* 74(5):511-3.malaria information system for malaria research and control in South Africa. *Health Place*, 8:227-36.

MARA (1998)
Towards an Atlas of malaria risk in Africa: First technical report of the MARA/ARMA collaboration. *Durban*, Marrama, L., Jambou, R., Rakotoarivony, I., Leong Pock Tsi, J., Duchemin, J., Laventure, S., Mouchet, J., & Roux, J. (1995).

Malaria transmission in Southern Madagascar: influence of the environment and hydroagricultural works in sub-arid and humid regions. Entomological investigations. *Acta Tropica*,89(2):193-203.

Marshall, L. (1988).
The natural history of larval mosquito habitats. Pp 3-14. London: Academic Press.

Martin C, Curtis B, Fraser C and Sharp B (2002)
The use of a GIS-basedmalaria information system for malaria research and control in South Africa. *Health Place*, 8:227-36.

Mattingly, P.F. and Knight K.L. (1956).
The mosquitoes of Arabia. *Bull. Brit. Mus. Nat. Hist.* (Ent.) 4: 91-141.

McCall, P., Mosha, F., Njunwa, K., & Sherlock, K. (2001).
Evidence for memorized site-fidelity in *Anopheles arabiensis*. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 95(6): 587-590.

Megan JM, Bailey CL. (1988)
Rift Valley Fever. In: Monath T, editor. Arboviruses: Epidemiology and Ecology. Vol IV. Boca Raton: CRC Press; p. 51-75.

Mendis, C.; Gamage-Mendis, A. C.; de Zoysa, A. P. K. ; Abhayawardena, T. A. ; Carter, R. ; Herath, P. R. J.; Mendis, K. N. (1990).
Characteristics of malaria transmission in Kataragama, Sri Lanka: A focus for immuno-epidemiological studies. *American Journal of Tropical Medicine and Hygiene* 42:298-308.

Meslin, F. (1992).
Surveillance and control of emerging zoonoses. *World Health Statistics Quarterly*, 45, 200–207.

Miller B R. et al. (2002).
Isolation and genetic characterization of Rift Valley fever virus from Aedes vexans arabiensis, Kingdom of Saudi Arabia. *Emerg Infect Dis.* 8(12):1492-4.

Minakawa N, Mutero CM, Githure JI, Beier JC and Yan G (1999)
Spatial distribution and habitat characterization of anopheline mosquito larvae in Western Kenya. *Am J Trop Med Hyg*, 61:1010-6.

Minakawa N, Seda P, Yan G. (2002)
Influence of host and larval habitat distribution on the abundance of African malaria vectors in western Kenya. *Am. J. Trop. Med. Hyg.*, 67, 32-8.

Minakawa, N., Mutero, C.M., Githure, J.I., *et al.* (1999)
Spatial distribution and habitat characterization of anopheline mosquito

larvae in Western Kenya. *Am. J. Trop. Med. Hyg.*, **61**, 1010-6.

Ministry of Agriculture and Water (1987).
Technical Annual Report 1986-1987. Al-Hassa Regional Agricultural Research Centre.

Ministry of Agriculture and Water. (1970).
Wadi Jizan Development Project, Malaki Dam. General Report.

Ministry of Agriculture and Water. (1990).
Wadi Jizan *Operation & Maintenance project.* Wadi Jizan Dam.

Ministry of Agriculture and Water. (1995).
Dams in The Kingdom of Saudi Arabia. Projects Execution Department.

Ministry of Agriculture and Water. (1996).
Water Projects In The Kingdom of Saudi Arabia. Projects Execution Department.

Ministry of Agriculture and Water. (1992).
Agricultural statistical yearbook.

Ministry of Health, Saudi Arabia. (2000).
Annual Report year 2000.

MOH (1988). General Directory of Agriculture and Water in Bishah Region.(1988).
Annual Report 1987-1988.

Mohammed A N. (1992).
Sediment transport in Saudi Arabia, Deposition Behind Jizan Dam. [abstract]. King Saud University.

Monath, T.P. (1991)
Yellow fever: Epidemics and research in the last forty years and prospects for the future. *Am J Trop Med Hyg*, **45**,1-43.

Monath, T.P.(1994).
Dengue: the risk to developed and developing countries. *Proc Natl Acad Sci* USA, **91**, 2395-400.

Moncayo AC., Edman JD., Finn JT. (2000).
Application of geographic information technology in determining risk of eastern equine encephalomyelitis virus transmission. *J Am Mosq Control Assoc*, **16**(1): 28-35.

Morad N A, Khan A R. (2001).
Clinicopathological patterns and distribution of schistomsomiasis in Asir region, Kingdom of Saudi Arabia.*Saudi Med J.* 22(6):520-2.

Mutabingwa, T.K., Kilimali, V.A.E.B., Kilama, W.L. (1986)

Chloroquine-resistant *Plasmodium falciparum* at the Tanganyika Planting Company (TPC) sugar estate, Moshi, Tanzania . *East African Medical Journal*, 3, 26 30.

Mwabu, G.M. (1991)
Economic development and malaria prevalence. An empirical analysis with reference to Kenya. *Malaria and Development in Africa. A Cross-Sectoral Approach*, pp. 167 180. United States Agency for International Development, Africa Bureau, Washington DC.

Mzilahowa, T (2005)
Malaria transmission intensity and the population structure of Plasmodium falciparum in the lower Shire Valley, southern Malawi. PhD thesis.

Oberste MS., Schmura SM., Weaver SC. *Et al.* (1999).
Geographic distribution of Venezuelan equine encephalitis virus subtype IE genotypes in Central America and Mexico. *Am J Trop Med Hyg*, 60(4): 630-4.

Okogun, G., Nwoke, B., Okere, A., Anosike, J., & Esekhegbe, A. (2003). Epidemiological implications of preferences of breeding sites of mosquito species in Midwestern Nigeria. *Annals of Agricultural and Environmental Medicine,* 10(2): 217-222.

Omumbo J, Ouma J, Rapuoda B, Craig MH, le Sueur D, Snow RW (1998)
Mapping malaria transmission intensity using geographical information systems (GIS): an example from Kenya. *Ann Trop Med Parasitol*, 92:7-21.

Oomen, J.M.V., de Wolf, J., Jobin, W.R. (1988)
Health and Irrigation. Incorporation of Disease-Control Measures in Irrigation, a Multi-Faceted Task in Design, Construction, Operation. International Institute for Land Reclamation and Improvement /ILRI, Wageningen, The Netherlands.

Ottesen EA, Duke BO, Karam M, Behbehani K:
Strategies and tools for the control/elimination of lymphatic filariasis. Bull World Health Organ 1997; 75(6): 491-503.

Packard, R.M. (1986)
Agricultural development, migrant labour and the resurgence of malaria in Swaziland. *Social Science and Medicine*, 22, 861 867.

Patz JA, Graczyk TK, Geller N, Vittor AY. (2000).
Effects of environmental change on emerging parasitic diseases. *Int J Parasitol.* Nov;30(12-13):1395-405.

Peters W, Al-zahrani M A. (1987).

Zoonotic cutaneous leishmaniasis in Saudi Arabia: lesions healing naturally in man followed by a second infection with the same zymodeme of Leishmania major.Trans R Soc Trop Med Hyg. 79(3):363-5.

Petrarca, V., Beier, J., Onyango, F., Koros, J., Asiago, C., Koech, D., &Roberts, C. (1991).
Species composition of the *Anopheles gambiae* complex (diptera: Culicidae) at two sites in western Kenya. *Journal of Medical Entomology,* 28(3): 307-313.

Rahmah T. Study of Jizan dam, Saudi Arabia. Msc Thesis, King Saud University, Riyadh, Saudi Arabia. 1994.

Rajagopalan PK, Das PK, Paniker KN, Reuben R, Rao DR, Self LS, Lines JD. Environmental and water management for mosquito control. In: Curtis CF, editor. Appropriate technology in vector control. Boca Raton, FL: CRC Press, 1990. pp. 121-38.

Renaud De Plaen, Robert Geneau, Thomas Teuscher, Amalaman Koutoua, Marie-Exposure of Gambian children to Anopheles gambiae malaria vectors in an irrigated rice production area. *Medical and Veterinary Entomology* 9: 50-58.

Ribeiro, J.M.C., Seulu, F., Abose, T., *et al.* (1996)
Temporal and spatial distribution of anopheline mosquitoes in an Ethiopian village: implications for malaria control strategies. *Bull. WHO,* 74, 299-305.

Richard N., T-W-Fiennes. (1978).
Zoonoses and the origins and ecology of human disease. Pp 53-54.London: Academic Press.

Ripert, C. & Raccurt (1987)
The impact of small dams on parasitic diseases in Cameroon. *Parasitology Today,* 3, 287 289.

Robert, V., Awono-Ambene, H., & Thioulouse, J. (1998).
Ecology of larval mosquitoes, with special reference to *Anopheles arabiensis* (Diptera: Culcidae) in market-garden wells in urban Dakar, Senegal. *Journal of Medical Entomology,* 35(6): 948-955.

Rogers DJ, Randolph SE, Snow RW and Hay SI (2002)
Satellite imagery in the study and forecast of malaria. *Nature* 2002, 415:710-5 42.

Rossi-Espagnet, A., Goldstein, G. and Tabibzadeh, I. (1991).
Urbanisation and health in developing countries: a challenge of health for all. *World Health Statistics Quarterly,* 44, 187–244.

Rowland, M., Durrani, N., Kenward, M., Mohammed, N., Urahman, *H., & Hewitt,* S. (2001).
Control of malaria in Pakistan by applying deltamethrin insecticide to cattle: a community-randomised trial. *Lancet,* 357(9271): 1837-1841.

Rozendaal, J. (1997).
"Vector control: methods for use by individuals and communities".
World Health Organization (WHO), Geneva.

Said B A. (1999). Geography of Saudi Arabia. [in Arabic]. King Saud University. Pp 139-142.

Said, B.A. (1993).
Geography of Saudi Arabia [in Arabic]. 1993. pp 139-148.

Saluzzo JF and Dodet, B. (1996).
Factors in the emergence of arbovirus diseases. Pp 83-90, 143-157. Amesterdam, Oxford: Elsevier.

Saudi MOH. (1998). Annual reports. Ministry of Health, Riyadh, Saudi Arabia.

Saudi MOH. (1999). Annual reports. Ministry of Health, Riyadh, Saudi Arabia.

Seyoum A, Killeen GF, Kabiru EW, Knols BG, Hassanali A . (2003).
Field efficacy of thermally expelled or live potted repellent plants against African malaria vectors in western Kenya.Trop Med Int Health. 2003 Nov;8(11):1005-11.

Scorza JV, Castillo L, Rezzano S, Marquez M, Marquez C. El papel d cafeto en la endemicidad de la leishmaniasis cutanea en Venezuela. Bol Direcc Malar Saneam amb 1985;25:82-88.

Scott, J.A, Brogdon, WG & Collins, FH. (1993).
Identification of single specimens in the *Anopheles gambiae* complex by the polymerase chain reaction. *Am. J. Trop. Med. Hyg.*, 49: 520-529.

Scott-Samuel. (1998). Health impact assessment--theory into practice.J Epidemiol Community Health. 1998 Nov;52(11):704-5.

Sebai Z A. (1988a).
Malaria in Saudi Arabia. *Trop Doct. 18(4):183-8.*

Sebai, Z A. (1988b).
Schistosomiasis in Saudi Arabia. *Ann Saudi Med.* 8(3);169-74.

Sebesta; and L. Legters. (1991).
Distinguishing high and low anopheline-producing rice fields using remote sensing and GIS technologies. *Preventive Veterinary Medicine* 11: 277-28

Self, L. S.; H. K. Shin; K. H. Kim; K. W. Lee; C. Y. Chow; and H.K. Hong. (1973). Ecological studies on Culex tritaeniorhynchus as a vector of Japanese encephalitis. *Bulletin of the World Health Organization* 49: 41-47.

Service M.W and H. Townson (2002)
The *Anopheles* Vector. In Essential Malariology. Warrell DA and HM Gilles ed. London, Arnold.

Service M.W. *(1993)*
Mosquito Ecology: Field sampling methods. Elsevier Applied Science. 2nd Edition.

Service, M. (1970a).
A battery-operated light-trap for sampling mosquito populations. *Bulletin of the World Health Organization,* **43:** 635-641.

Service, M. (1971).
Studies on Sampling Larval Populations of the *Anopheles gambiae* Complex. *Bulletin of the World Health Organization,* **45:** 169-180.

Service, M. (1976).

"Mosquito Ecology," John Wiley & Sons, New York.

Service, M. (1977).
Mortalities of the immature stages of species B of the *Anopheles gambiae* complex in Kenya: comparison between rice fields and temporary pools, identification of predators, and effects of insecticidal spraying. *Journal of Medical Entomology,* **13(4-5):** 535-545.

Service, M. (1986).
The enzyme-linked immunosorbent assay (ELISA) test for the identification of blood-meals of haematophagous insects. *Bulletin of Entomological Research,* **76:** 321-330.

Service, M. (1993).
"Mosquito ecology field sampling methods," Elsevier Applied Science, London.

Service, M. (2000).

"Medical Entomology for students," Cambridge University Press, Cambridge.

Service, M. W. (1993).
The Anopheles vector. In *Essential malariology*, eds., H. M. Gilles, and D. A. Warrell. London: Edward Arnold.

Service, M., & Townson, H. (2002).

The *Anopheles* Vectors. *In* "Essential Malariology" (D. Warrell, & H. Gilles, Eds.), Arnold, London.

Service, M., Joshi, G., & Pradhan, G. (1978).
A survey of *Anopheles gambiae* (sp. A) and *An. arabiensis* (sp. B) of the *Anopheles gambiae* Giles complex in the Kisumu area of Kenya following insecticidal spraying with OMS-43 (fenitrothion). *Annals of Tropical Medicine and Parasitology,* **72:** 377-386.

Service, M.W. (1993).
Mosquito ecology field sampling methods. Snd edn., pp76-289. London, Elsevier Applied Scince.

Shaheen FAM, Sheariya F, Amuesi I. *et al.* (1993).
Successful management of Crimean-Congo hemorrhagic fever complicated by acute renal failure. *Saudi Kidney Dis Trans Bull,* 1993;4:148-52.

Sharma, V. P.; and K. N. Mehrotra. (1986).
Malaria resurgence in India: a critical study. *Social Science and Medicine* 22: 835-845.

Shililu, J., Ghebremeskel, T., Seulu, F., Mengistu, S., Fekadu, H., Zerom, M., Asmelash, G., Sintasath, D., Mbogo, C., Githure, J., Brantly, E., Beier, J., & Novak, R. (2004).
Seasonal abundance, vector behavior, and malaria parasite transmission in Eritrea. *Journal of the American Mosquitoes Control Association,* **20(2):** 155-164.

Shililu, J., Ghebremeskel, T., Seulu, F., Mengistu, S., Fekadu, H., Zerom, M., Ghebregziabiher, A., Sintasath, D., Bretas, G., Mbogo, C., Githure, J., Brantly, E., Novak, R., & Beier. J. (2003).
Larval habitat diversity and ecology of anopheline larvae in Eritrea. *Journal of Medical Entomology,* **40(6):** 921-929.

Shoemaker, T., Boulianne, C., Vincent, M., Pezzanite, L., Al-Qahtani, M., Al-Mazrou, Y., Khan, A., Rollin, P., Swanepoel, R., Ksiazek, T., & Nichol, S. (2002).
Genetic Analysis of Virsus Associated with Emergence of Rift. *Journal of Medical Entomology,* 40(6): 921-929.

Simard, F., Lehmann, T., Lemasson, J., Diatta, M., & Fontenille, D. (2000).
Persistence of *Anopheles arabiensis* during the severe dry season conditions in Senegal: an indirectet approach using microsatellite loci. *Insect Molecular Biology,* **9(5):** 467-479.

Sipe NG, Dale P (2003)
Challenges in using geographic information systems (GIS) to understand and control malaria in Indonesia. *Malar J.* Nov 4;2(1):36.

Sir R.C. (1960). *Aedes aegypti* (L.): The yellow fever mosquito. Pp 77-80. London:The Syndics of the Cambridge University Press.

Sithiprasasna, R., K.J. Linthicum, G.J. Liu, J.W. Jones, and P.Singhasivanon. 2003. Some entomological observations on temporal and spatial distribution on malaria vectors in three villages in northwestern Thailand using a Geographic Information System (GIS). Southeast Asian J. Trop. Med. Publ. Hlth. 34: 505-516.

Smith T, Charlwood JD, Takken W, Tanner M and Spiegelhalter DJ (1995) Mapping the densities of malaria vectors within a single village. *Acta Trop*, **59**:1-18.

Snow RW, Craig MH, Deichman U and Le Sueur D (1999) A continental risk map for malaria mortality among African children. *ParasitolToday* 1999, **15**:99-104.

Solomon, T., & Mallewa, M. (2001). Dengue and Other Emerging Flaviviruses. Review Article. *Journal of Infection,* **42:** 104-115.

Spiers, AA. (2003). *Seasonality and life history traits of the Anopheles gambiae complex in Malawi.* PhD Thesis University of Liverpool..

Srivastava, A.; Nagpal, B. N.; Saxena, R.; Sharma, V. P. (1999). Geographic information system as a tool to study malaria receptivity in Nadiad Taluka, Kheda district, Gujarat, India. *Southeast Asian Journal of Tropical Medicine and Public Health* **30**: 650-656.

Steinmann, P., Keiser, J., Bos, R., Tanner, M. & Utzinger, J. (2006). Schistosomiasis and water resources development: systematic review, meta-analysis and estimates of peoples. *Lancet Infect. Dis.* **6**, 411-425.

Sudia W. D. and Chammberlain. (1996). Battery operated light trap, an improved model. *Mosq. News*, **22**: 126-129.

Surtees, G.; D. I. H. Simpson; and E.T.W. Bowen. (1970). Ricefield development and arbovirus epidemiology, Kano Plain, Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 64: 511-518.

Tadei WP, Dutary Thatcher B, Santos JMM, et al.(1998). Ecological observations on Anopheline vectors of malaria in the Brazilian Amazon. Am J Trop Med Hyg;59(2):325-35.

Tanser, F.C. & le Sueur, D. (2002) The application of geographical information systems to important public health problems in Africa. *Int. J. Health Geog.,,* **1**, 4.

Taylor, C., Toure, Y., Coluzzi, M., & Petrarca, V. (1993).
Effective population size and persistence of *Anopheles arabiensis* during the dry season in west Africa. *Medical and Veterinary Entomology,* **7**: 351-357.

Thitia W E. (1991)
MSc thesis, research on irrigation project located in irrigation area Kenea. Khartoom University.

Thomas, C.J. & Lindsay, S.W. (2000)
Local-scale variation in malaria infection amongst rural Gambian children estimated by satellite remote sensing. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **94**, 159 163.

Thompson, R. C. A. (1979).
Biology and speciation of *Echinococcus granulosus. Australian Veterinary Journal*, **55**, 93–98.

Thompson, R., Begtrup, K., Cuamba, N., *et al.* (1997)
The Matola malaria project: a temporal and spatial study of malaria transmission and disease in suburban Maputo, Mozambique. *Am. J. Trop. Med. Hyg.*, **57**, 550-9.

Thomson, M.C., D'Alessandro, U., Bennetts, S., Connor, S.J., Langerock, P., Jawara, M., Todd, J., Greenwood, B.M. (1994)
Malaria prevalence is inversely related to vector density in The Gambia, West Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **88**, 638 643.

Thonnon, J., Picquet, M., Thiongane, Y., Lo, M., Sylla, R., & Vercruysse, J. (1999).
Rift Valley fever surveillance in the lower Senegal River basin: update 10 years after the epidemic. *Tropical Medicine and International Health,* **4(8)**: 580-585.

Tiffen, M., (1991).
Guidelines for the incorporation of health safeguards into irrigation projects through intersectoral cooperation. PEEM Guidelines series 1. Document WHO/CWS/91.2, World Health Organization, Geneva.

Trape, J.-F., Lefebvre-Zante, E., Legros, F., *et al.* (1992).
Vector density gradients and the epidemiology of urban malaria in Dakar, Senegal. *Am. J. Trop. Med. Hyg.*, 47, 181-189.

Tsai TF, Popovici F, Cernescu C, Campbell GL, Nedelcu NI. (1998)
West Nile encephalitis epidemic in southeastern Romania. *Lancet*, **352**: 767-71.

Utzinger, J., Bergquist, R., Shu-Hua, X., Singer, B., & Tanner, M. (2003).
Sustainable schistosomiasis control--the way forward. *Lancet*, **362(9399)**: 1932-1934.

Van der Hoek, W.; Konradsen, F.; Dijkstra, D.S.; Amerasinghe, P. H.; Amerasinghe F. P. (1998).
Risk factors for malaria: A microepidemiological study in a village in Sri Lanka. *Transactions of the Royal Society of Tropical Medicine and Hygiene* **92**:265-269.

Vaughn D W and C H Hoke. (1992).
The epidemiology of Japanese encephalitis: Prospects for prevention. Epidemiologic Review. 14: 197-221.

Vine, M.F., Degnan, D. & Hanchette, C. (1998)
Geographic information systems: their use in environmental epidemiologic research. *Env. Health Persp.*, **105**, 7-16.

Vu SN, Nguyen TY, Tran VP, *et al.* (2005).
Elimination of dengue by community programs using *Mesocyclops* (Copepoda) against *Aedes aegypti* in central Vietnam. *Am. J. Trop. Med. Hyg.*, **72**, 67-73.

Wakgari Deressa, Ahmed Ali, Fikre Enquoselassie. Knowledge, Attitude and Practice About Malaria, the Mosquito and Antimalarial Drugs in a Rural Community. *Ethiop. J. Health Dev.* 2003; 17(2):99-104).

Warburg A, Montoya-Lerma J, Jaramillo C, Cruz-Ruiz AL, Ostrovska K. (1990)
Leishmaniasis vector potential Lutzomyiaspp. In Colombian coffee plantation. Med Vet Ent;5:9-16.

Warrell D A. (1993).
Leishmaniasis, malaria and schistosomiasis in Saudi Arabia. *Saudi Med J.* **14**:203-208.

White, G. (1974).
Anopheles gambiae complex and disease transmission in Africa. *Transactions of the Royal Society of Tropical Medicine and Hygiene,* **68(4)**: 278-301.

WHO, (1985a).
The control of schistosomiasis. *World Health Organization Technical Report Series no. 728*, Geneva.

WHO, (1990).
Control of the leishmaniasis. *World Health Oraganization Technical Report Series no. 793*, Geneva.

WHO, (1992).
"*Entomological field techniques for malaria control.* Part I & II. Learner's Guide," World Health Orgainization, Geneva.

WHO, (1992a).
Vector resistance to pesticides. 15th report of the export committee on vector biology and control., *WHO Technical Report Series no. 818*, Geneva.

WHO, (1995).
Vector control for malaria and other mosquito-borne diseases. *World Health Organization Technical Report Series no. 857.*, pp. 1–91, Geneva.

WHO, (1999)
The world health report 1999; making a difference, World Health Organization, Geneva

WHO, (2001).
Water-related Diseases (Schistosomiasis). World Health Organization, Geneva.

WHO, (2002).
Leishmaniasis Fact Sheet. World Health Organization, Geneva.

WHO, 1986 in Georghiou G., & Lagunes-Tejeda, A. (1991).
The Occurrence of Resistance to Pesticides in Arthropods: An Index of Cases reported through 1989.

WHO. (1975).
Manual on practical entomology in malaria – Part 2, Methods and techniques, WHO, Geneva.

WHO. (1992).
Entomological field techniques for malaria control. Part 1. WHO, Geneva.

WHO. (1997).
Dengue haemorrhagic fever: diagnosis treatment and control, 2nd edn., 3-11. WHO, Geneva.

WHO. (1975).
Manual on Practical Entomology. Part II. Methods and Techniques Geneva: World Health Organisation.

WHO. (1994).
Japanese encephalitis. Weekly Epidemiological Record 69: 113-118.

WHO.(2000)
Rift Valley Fever. Fact sheet no. 207. World Health Organization.

WHO/CDS, (2002a).
Malaria entomology and vector control part I, World Health Organization, Geneva.

WHO/CDS, (2002b).
Malaria Vector Control: Decision making criteria and procedures for judicious use of insectides, Geneva.

WHO/CDS/CPE/PVC, (2001).
Insecticide Resistance Monitoring in Desease Vectors. Procedures and conditions for supply of test kits, WHO, Malaysia.

WHO/*EMRO, (2001).*
National Malaria Programme Manager's Meeting on *RBM* Damascus, Syria. Regional Office of the Eastern Mediterranean (EMRO), Cairo, Egypt.

WHO/EMRO, (2002).
Report on the second intercountry meeting of National Malaria Programme Managers, Muscat, Oman. Regional Office of the Eastern Mediterranean (EMRO), Cairo, Egypt.

WHO/FAO/UNEP, (1987)
Effects of agricultural development. On Vector-Borne Diseases. Working papers of 7th Annual Meeting, Joint WHO/FAO/UNEP Panel of Experts on Environmental Management for Vector Control. World Health Organization, Geneva

WHO/FAO/UNEP, (1990).
Water Resources Development and Vector-Borne Diseases in Kenya. World Health Organisation, Geneva.

Wills W. M. et al. (1985):
Sindbis virus isolations from Saudi Arabian mosquitoes. Trans. *Roy. Soc. Trop. Med. Hyg.* 79: 63-66.

Wilson, M., Chapman, L., & Hall, D. (1994).
Rift Valley Fever in rural Northern Senegal: human risk factors and potential vectors. *American Journal of Tropical Medicine and Hygiene,* 50(6): 663-675.

Wood, B.; R. Washino; L. Beck; K. Hibbard; M. Pitcairn; D. Roberts; E. Rejmankova; J. Paris; C. Hacker; J. Salute; P. (1991).
Spectral and spatial characterization of rice field mosquito habitat. Int. J. Remote Sens. 12(3):621-626.

World Health Organisation. Manual on environmental management for mosquito control. Offset Publication Number 66. Geneva: World Health Organisation, 1982.

World Health Organization (1992a).
Our Planet, Our Health. Commission on Health and Environment, WHO, Geneva.

World Health Organization (1997).
Health and Environment in Sustainable Development: Five Years after the Earth Summit. WHO, Geneva.

World Health Organization, (1989b).
Geographical distribution of arthropod-borne diseases and their principal vectors, Document WHQ/VBC/ 89.967, WHO, Geneva.

Worrall E., Basu S., and Hanson K. (2002)
The relationship between socioeconomic status and malaria: a review of literature. Background paper for a meeting on "Ensuring that malaria control interventions reach the poor, HEFP, LSHTM & the World Bank, September 5-6th (unpublished).

Wyesundera, M. S. (1988).
Malaria outbreaks in new foci in Sri Lanka. *Parasitology Today*, 4, 147–150.

Xu XJ, Yang XX, Dai YH, Yu GY, Chen LY, Su ZM. (1999).
Impact of environmental change and schistosomiasis transmission in the middle reaches of the Yangtze River following the Three Gorges construction project. Southeast Asian J Trop Med Public Health;30(3):549-55.

Zaki AM. (1997)
Isolation of a flavivirus related to the tick-borne encephalitis complex from human cases in Saudi Arabia.Trans R Soc Trop Med Hyg; 91:179–81.

Zijlstra EE, Ali MA, el-Hassan AM, et al. Kala-azar in displaced people from southern Sudan: epidemiological, clinical and therapeutic ®ndings. Trans R Soc Trop Med Hyg 1991;85(3):365-9.

APPENDIX

QUESTIONNARE KAP STUDY

(Code for CLOSE questions: 1=Yes; 2=No; 8=don't know; 9= No answer)

Date .... Interviewer: ID No |__|__|__|__|__|__|__|__|

GPS_CODE: N |__________________| W |__________________|

---

1. a. How many people sleep in this HH? | |
   b. How many children are between 0 and 5 years of age? | |
   c. How many children are between 0 and 10 years of age? | |

2. a. Housing type? Compound [ ] self-contained [ ] storey building [ ]

Wall type	mud [ ]	brick-blocks [ ]	wood [ ]	
Roof	tiles [ ]	sheets [ ]	slates [ ]	
Ceiling	yes [ ]	no [ ]		
Floor	cement [ ]	wood [ ]	earth [ ]	
Flooring cover	nothing [ ]	tiles-terazo [ ]	carpet [ ]	vinyl [ ]

other, specify..................

b. How many bedrooms do you have in your house?

c. What is the source of drinking water for your household?
Piped water [ ] private well [ ] public well [ ] public tap [ ] public borehole [ ] tanker/truck [ ] river/stream [ ] other, specify...............

d. What toilet facility do you use?
Part 1. Private [ ] shared [ ]
Part 2. WC [ ] pit latrine [ ] VIP latrine [ ] bucket latrine [ ] Free range (push) [ ] Other, specify.........................

3. a) Do you have any of the following items?
(Code Income ranking: 0=High; 1=Middle; 2=Low)

Item	Present yes/no
Electricity	
Bicycle	
Motorcycle	
Radio	
Television	
Car	
Fan	
Fridge	
AC	

b) Do you have a domestic worker not related to the head of the household?
(1=yes; 2=no; 8= Don't know) | | Dom

4. Have you ever attended school?
If YES, what was the last grade you completed?
(0=Not attended/illiterate; 1=primary; 2=JSS/MLC; 3=SSS/A'level; 4=graduate/certificate)

5. What are the common illnesses in this village?

6. Are fever a problem for you? (1=Yes; 2=No; 8= Don't Know)

MALARIA

7. Is malaria a problem for your household? (1=Yes; 2=No; 8= Don't Know)

8. How can you get malaria?...

9. Mentioned mosquitoes (1=Yes; 2=No)

10. Whom does it affect most? (1=All; 2=Adults; 3=Child; 8=Don't know; 9=No)

11. How do you know someone has malaria?

	Hot head	☐	Weakness	☐
	Hot body	☐	Lethargic	☐
	Diarrhoea	☐	Muscle pain	☐
Dizziness ☐	Joint pain	☐		
Code for these:	Cough/chest	☐	Head ache	☐
1= Mentioned	Coma	☐	Sleepy	☐
2= Not mentioned	Death	☐	Can't sleep	☐
	Vomiting	☐	Body pain	☐
	Yellow eyes	☐	Cold sweat	☐
	Constipation	☐	No appetite	☐
	Other	☐	Don't Know	☐
	Fever	☐	Yellow urine	☐

12. Can you prevent yourself (or your household) from getting malaria?
If yes how?

RIFT VALLEY FEVER (RVF)

13. Is RFV a problem for your household? (1=Yes; 2=No; 8= Don't Know) ☐
14. How can you get RFV?...

15. Mentioned mosquitoes (1=Yes; 2=No) ☐

16. Whom does it affect most? (1=All; 2=Adults; 3=Child; 8=Don't know; 9=No) ☐

17. How do you know someone has RFV?

	Hot head	☐	Weakness	☐
	Hot body	☐	Lethargic	☐
	Diarrhoea	☐	Muscle pain	☐
Code for these:	Dizziness	☐	Joint pain	☐
1= Mentioned	Cough/chest	☐	Head ache	☐
2= Not mentioned	Coma	☐	Sleepy	☐
	Death	☐	Can't sleep	☐

Vomiting ☐
Yellow eyes ☐
Constipation ☐
Other ☐
Fever ☐
Body pain ☐
Cold sweat ☐
No appetite ☐
Don't Know ☐
Yellow urine ☐

18. Can you prevent yourself (or your household) from getting RFV? ☐
If yes how?

MOSQUITOES

19. a) Do you have a problem with biting insects? (1=Yes; 2=No; 8= Don't Know)
b) what kind of insects do you have?

Bees ☐
lice ☐
Mosquitoes ☐
Horseflies ☐
Tsetse ☐
blowflies ☐
tabanidae ☐
sandflies ☐
Others ☐

20. Where do mosquitoes come from? ☐

21. In which places (in the village/fields) do they mostly bite? ☐

22. What time of year do they mostly bite? (1=wet; 2=dry; 3=all year) ☐

23. How often do they get bitten? (every night=1; Once a week=2; Once a month=3)

24. Do you know of any diseases transmitted by mosquitoes?

25. Do you sit outside during the evenings? ☐

26. Do you sleep outside?

27.

28. Are mosquitoes a problem for your households? ☐
(1=yes; 2=No; 8= Don't know)

29. Do you protect your self from mosquitoes? ☐
(1=yes; 2=No; 8= Don't know)

a. If No ask why not? ☐ not necessary ☐ expensive ☐ inconvenient ☐ don't know how ☐ Other, specify...............

b. If Yes fill table:

Trap doors/netting for windows		All or bedrooms	
Bednet		Who sleep under	

		Please ask to see net, status, impregnated	
Coils		How often used and how many	
Bum herbs		How often?	
Aerosol cans		How often?	
Others		Specify	

Check if any of above mentioned are in the house? | | Check
(1=yes; 2=no; 9=not checked)

30. a. IF NO USE OF BEDNET ASK (check 29a NO or in table no use of net?

b. Why do you not use a bednet?

c. If mentioned costs in b. please ask: are there apart from costs other reasons for not using bednets?

d. Do you know where you can obtain a bednet? Where?

e. If you where given a bednet, who would sleep under it?

HEALTH CENTER

31. a. Have you or anyone in your house, had fever recently? | |

b. If yes, what was it?

c. How did you know?
[ ] symptoms tell [ ] doctor judgement [ ] other, specify

d. What did you do?
[ ] to clinic [ ] bought drugs [ ] nothing [ ] other, please specify.........

e. If to clinic was a blood-film made (If MALARIA)? (yes/no) | |

f. If drug what did you take (If MALARIA)? | |
(1=Chloroquine; 2=Fansidar; 3= Paracetamol; 4= Artesunate; 5=Other, specify; 3=Non; 8=Don't know)

g. Where did you get the drugs? | |
[ ] doctors receipt at health centre/pharmacy [ ] at pharmacy without receipt
[ ] others, specify...............

h. If a health centre, which one?

Appendix B

KAP questionnaire in Arabic (study area language)

استبيان

وزارة الصحة

الباحث/ محمد حسن الزهراني
جامعة ليفربول - بريطانيا

2005م

الملحق الثقافي السعودي ببريطانيا

الباحث يقدم

شكره وتقديره لكل من يتعاون معه في إتمام هذا البحث

استبيان

==========

اسم القرية: ....
التاريخ: .... اسم القائم بالعمل:...........................
أسم مركز الرعاية: .... رقم المنزل الصحي:...........................

==

.1
(أ) كم عدد الأشخاص الذين ينامون في هذا البيت؟ ....
(ب) كم عدد الأطفال بين سن صفر إلى 5 سنوات؟ ....
(ت) كم عدد الأطفال بين سن 5-10 سنوات؟ ....

.2
(أ) نوع المسكن؟
عمارة ( ) أخرى( ) ما هي............ منزل شخصي ( ) مجمع ( )
(ب) نوع الجدار؟
طوب( ) خشب( ) أخرى( ) ما هي............ حجر( ) طين( )
(ت) نوع السقف؟
لوح أو شراع( ) طوب احمر قرميد( ) خرسانة( )
حجر( ) أخرى ( ) ما هي .... أغصان مقطوعة ( )
(ث) الأرضية؟
تراب ( ) أخرى ( ) ما هي .... خشب ( ) إسمنت ( )
(ج) غطاء الأرضية؟
أخرى ( ) ما هي .... سجاد( ) بدون غطاء ( )
(ح) كم عدد الغرف في مسكنك؟ ( )
(خ) ما هو مصدر الماء في منزلك؟
بئر خزان حنفية عام( ) بئر عام ( ) بئر خاص ( ) شبكة مياه ( )
وايت صهريج ( ) مياه الوادي ( ) ارتوازي عمومي( ) بئر ارتوازي خاص ( )
أخرى ( ) ما هي ....
(د) مكان قضاء الحاجة ؟
مرحاض حفرة ( ) مرحاض متكامل ( ) الخلاء ( ) أخرى ( ) ما هي ....

.3
(أ) هل تملك أي من الأشياء التالية؟

الغرض	موجود: نعم / لا	الغرض	موجود: نعم / لا
كهرباء		مروحة	
راديو		ثلاجة	
تلفزيون		غسالة	
مكيف		سيارة	

(ب) هل لديك عمال ليسوا ذو قرابة لك؟
لا اعرف ( ) لا ( ) نعم ( )

4. هل أنت متعلم؟
نعم ( ) لا( )

إذا كان نعم أي مستوى تعليمي؟

أخرى ( ) ما ثانوي ( ) جامعي ( ) ابتدائي ( ) متوسط ( )

هي.........

5. ما هي الأمراض الشائعة في هذه القرية؟

....

....

6. هل الحمى تمثل مشكلة لك؟

لا اعرف ( ) لا ( ) نعم ( )

الملاريا

7. هل الملاريا تمثل مشكلة لك؟

لا اعرف ( ) لا ( ) نعم ( )

8. في رأيك كيف ممكن نصاب بالملاريا؟

....

....

لا ( ) نعم ( ) 9. أثناء إجابته ذكر البعوض؟

10. من اكثر فئات الأعمار عرضة للملاريا؟

لا اعرف ( ) الصغار ( ) الكبار ( ) الكل ( )

11. كيف تعرف شخص انه مصاب بالملاريا؟ 1= ذكره , 2= لم يذكره

حرارة في الرأس		**خمول**			
حرارة في الجسم		**ألم عضلي**		**اصفرار في العين**	
إسهال		**ألم مفاصل**		**إمساك**	
دوخة		**وجع راس**		**حمى**	
سعال		**نعسان**		**ضعف عام**	
غيبوبة		**لا يستطيع النوم**		**فقدان الشهية**	
موت		**ألم في الجسم**		**اصفرار البول**	
تطريش		**تعرق (خروج العرق)**		**لا اعرف**	

12. هل تستطيع تحمي نفسك أو عائلتك من الإصابة بالملاريا؟ إذا ممكن كيف؟

....

....

حمى الوادي المتصدع

13. هل حمى الوادي المتصدع تمثل مشكلة لك؟

لا اعرف ( ) لا ( ) نعم ( )

14. في رأيك كيف ممكن نصاب بالمتصدع؟

....

....

لا ( ) نعم ( ) 15. أثناء إجابته ذكر البعوض؟

16. من اكثر فئات الأعمار عرضة للمتصدع؟

لا اعرف ( ) الصغار ( ) الكبار ( ) الكل ( )

17. كيف تعرف شخص انه مصاب بالمتصدع؟ 1= ذكره , 2= لم يذكره

حرارة في الرأس		**خمول**			

حرارة في الجسم		ألم عضلي		اصفرار في العين	
إسهال		ألم مفاصل		إمساك	
دوخة		وجع راس		حمى	
سعال		نعسان		ضعف عام	
غيبوبة		لا يستطيع النوم		فقدان الشهية	
موت		ألم في الجسم		اصفرار البول	
تطريش		تعرق (خروج العرق)		لا اعرف	

18. هل تستطيع تحمي نفسك أو عائلتك من الإصابة بالمتصدع؟ إذا ممكن كيف؟

....

....

البعوض

19. (ا) هل تعاني من الحشرات؟
لا أعرف ( ) لا ( ) نعم ( )
(ت) ما نوع الحشرات المتواجدة؟
ذباب ( ) بعوض( ) نمل ( ) نحل( )
أخرى ( ) ما هي .... ذبابة الرمل ( )

20. من أين يأتي البعوض؟

....

....

21. في أي الأماكن يكثر تواجد البعوض سواء في القرية أو الحقول؟

....

....

22. ما هي الفترة التي يكثر فيها البعوض خلال السنة؟

....

....

23. كم مرة عادة تتعرضون للدغ البعوض؟
مرة في الشهر( ) مرة في الأسبوع ( ) يوميا ( )
24. هل تعرف أي مرض ممكن ينقله البعوض؟

....

25. هل تجلسون في الخارج خلال المساء؟

....

26. هل تنامون بالخارج؟

....

27. هل البعوض يسبب مشكلة لكم؟
لا اعرف ( ) لا ( ) نعم ( )

28. (أ) هل تحمي نفسك من البعوض؟
لا اعرف ( ) لا ( ) نعم ( )
(ب) إذا إذا الإجابة " لا" فاسأل لماذا؟
لا غير مريح ( ) غالي ( ) غير ضروري ( )
أخرى ( ) ما هي .... اعرف ( )

(ث) إذا الإجابة بنعم فأملا الجدول؟

الوسيلة	( )	سؤال	إجابة
شبك على الشبابيك		كل البيت أو فقط غرف النوم	....
ناموسيات		من ينام تحتها؟ فضلا اطلب ترى الناموسيات , حالتها, مشبعة بالمبيد أم لا؟	....
زيوت نباتية		كم مرة؟	....
الرش بالمبيد		كم مرة؟	....
أخرى		حددها	....

فضلا تأكد من أن أي مما ذكر أعلاه موجود في المنزل؟

الناموسيات

29. (أ) إذا لا يستخدم الناموسية فاسأل الآتي: (تأكد من إجابة 29أ (لا) أو في الجدول أعلاه لا يستخدم الناموسية؟

(ت) لماذا لا تستخدم الناموسية؟

....

....

....

(ث) إذا ذكر السعر في الفقرة ب فاسأل: هل هناك أسباب أخرى غير السعر لا تجعلك تستخدم الناموسية؟

....

....

....

(ج) هل تعرف من أين يمكن الحصول على الناموسية؟

....

....

....

(ح) إذا أعطيتم ناموسية من سينام تحتها؟

....

....

المركز الصحي

لا ( )   30. (أ) هل أنت أو أحد أفراد عائلتك كان لديه حمى قريباً؟   نعم ( )

(ب)إذا نعم ماذا كان المرض؟

....

(ت) كيف عرفت؟

أخرى ( ) ما هي .... طبيب المركز الصحي ( ) الأعراض ( )

(ث) ماذا فعلت؟

لا شيء ( )　　اشتريت علاج ( )　　ذهبت للمركز الصحي ( )

أخرى ( ) ما هي..

(ج) إذا المركز الصحي هل أجري للمريض فحص دم للملاريا؟

لا اعرف ( )　　لا ( )　　نعم ( )

(ح) إذا أعطى علاج ما ذا كان العلاج (إذا كان ملاريا) ؟

فيفادول ( )　　فانسيدار( )　　كلوروكين ( )

لا اعرف ( )　　أخرى ( ) حدد ....　　ارتيزون ( )

(خ) من أين حصلت على العلاج؟

من الصيدلية بدون وصفة ( )　　وصفة طبية من مركز الرعاية ( )

أخرى ( ) حدد..................................

(د) إذا من مركز الرعاية ما اسمه؟