An Epidemiological Study On Risk Factors Responsible For Enhanced Receptivity And Vulnerability To Malaria In Goa, India

Thesis Submitted To The
Goa University For The Degree Of

DOCTOR OF PHILOSOPHY

In

ZOOLOGY

By

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October 2008

ACKNOWLEDGEMENTS

I am highly indebted to my research guide Dr. Ashwani Kumar, Officer-in-Charge, National Institute of Malaria Research (ICMR), Field Station, Goa for his valuable guidance, unstinted encouragement, enthusiastic approach and moral support to my research work. I am immensely thankful for his helping attitude and timely requisite assistance provided throughout the duration of my research work and also for critically examining the manuscript in all aspects. The patience and untiring efforts put by him towards the work only made it possible to complete this research study.

I wish to express my gratitude to my subject expert, Prof. U. M. X. Sangodkar, Head, Department of Marine Science and Biotechnology, Goa University in providing the necessary guidance and valuable suggestions from time to time.

My sincere thanks to Prof. P. V. Dessai, Dean of Life Sciences, Prof. A. B. Shanbaug, Head, Department of Zoology and Prof. D. J. Bhat, Head, Department of Botany, Goa University for their advise and administrative support.

I am very much grateful to Dr. (Mrs.) Rajnanda Desai, Director of Health Services and Dr. Dipak Kabadi, Dy. Director, National Vector Borne Disease Control Programme, Directorate of Health Services, Government of Goa for their continuous and whole hearted support in completing my research work.

I wish to acknowledge Dr. A. V. Salelkar, Ex. Director, Dr. (Mrs.) Mathura Usgaonkar, Ex. Dy. Director NVBDCP, Dr. (Mrs.) Elmira Pereira, Health Officer, Dr. Jose D'sa, Health Officer, Dr. (Mrs.) Sunita Perni, Medical Officer and Mr. M. B. Kaliwal, State Entomologist, Directorate of Health Services, Goa for their support and co-operation.

I am sincerely thankful to Prof. A. P. Dash, Director, National Institute of Malaria Research (ICMR) Delhi for necessary permission, precious support and research facilities.

I am thankful to Dr. Ananda Helekar, Ex. Director of Health Services Government of Goa for encouragement and translation of the Portuguese literature into English which has been referred in this thesis.

My thanks are due to the staff of NVBDCP, Directorate of Health Services, Sharvashri Mahesh Virnodkar, Vishnudas Dhavjekar, Gurudas Morajkar, P. K. Devidas, Anthony Pereira, Chakrapani Narse and Damodar Mardolkar for their assistance in carrying out mosquito surveys I the field, collection of data and the laboratory work.

I am very much grateful to Dr. Rajpal S. Yadav, Officer-in-Charge, Field Station, Gujarat for helping me to carry out the incrimination studies of anopheline mosquito samples.

I express my gratitude to Dr. Hemant Kumar, Senior Research Scientist, NIMR for his advice and support, also my special thanks to Mr. Ajeet Mohanty, Assistant Research Scientist for helping in computer work as well as

photography. I also thank the staff of NIMR field station Goa, Mrs. Sushma Bhinge, Mrs. Maria Flavia Fernandes, Mrs. Smita Naik, Mr. Pratap Jhalmi, Mr. Arun Phadte, Mr. Udesh Kondvilkar, and Mrs. Ida Lobo for all their assistance and concern throughout the course of this study.

I am immensely grateful to the Vice-Chancellor, Registrar, Goa University for necessary permissions and to their staff, Mrs. Smita Kamat (Admn. III), Mrs. Sangeeta and Mrs Helen for their cooperation and administrative support.

I gratefully acknowledge the Department of Meteorology, Govt. of India, The Census Department, Govt. of India, Directorate of Archives of Goa, Directorate of Agriculture, Department of Forest, Department of Science and Technology, Government of Goa, Xavier Centre for Historical Research Goa, Goa University, Central Library Goa, NIMR Field Station-Goa, Research Institute for Development, Corporation of City of Panaji for providing the necessary literature, documents and data needed to support the research work.

My thanks are due to Shri Kiran Shirodkar who provided the mosquito magnet trapping device for collection of mosquito samples and to Mr. Xavier for drawing the PHC map of Goa.

I express my sincere gratitude to Mrs. Jyotsna Sarin for her most cherished contribution to this research study and without her co-operation it would have been difficult to meet the desired goal.

I am very much indebted to my family, especially my husband, Santosh who has been the most encouraging and supporting person behind me and to my children Sumegh, Srinivas and Pratik mutely coping with me throughout the research period.

This assignment could be completed only with the divine blessings of the Almighty. I thank you God for all your spiritual help and courage bestowed on me for the accomplishment of this endeavour.

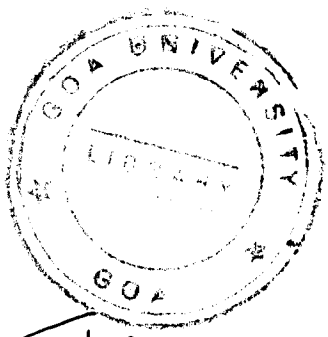
N.S. Korgaokar
22/10/08

Nandini S. Korgaokar

Certificate

This is to certify that the thesis entitled **'An Epidemiological Study on the Risk factors responsible for the enhanced receptivity and vulnerability to Malaria in Goa, India'** submitted by Ms. Nandini S. Korgaonkar for the award of the Doctor of Philosophy in Zoology is based on the results of investigations carried out by the candidate under our supervision. The thesis or any part thereof has not been previously submitted for any other degree or diploma of any University or Institute. The material obtained from other sources has been duly acknowledged in the thesis.

As per the reports received from the External Examiners, necessary changes have been incorporated in the Thesis.



30/9/09

22nd Oct. 2008

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Research Guide

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Statement

I hereby state that this thesis for the Ph.D. degree on **'An Epidemiological Study on the Risk factors responsible for the enhanced receptivity and vulnerability to Malaria in Goa, India'** is my original contribution and any part thereof has not been previously submitted for the award of any diploma/degree of any University or Institute. To the best of my knowledge, the present study is the first comprehensive study of its kind from the area.

The literature pertaining to the problem investigated has been duly cited. Facilities availed from other sources are duly acknowledged.

N.S. Korgaokar
22/10/08

(Nandini S. Korgaokar)

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Abbreviations

ABER	Annual Blood Examination Rate
Ae.	*Aedes*
An.	*Anopheles*
AFI	Annual Falciparum Incidence
API	Annual Parasite Incidence
AVI	Annual Vivax Incidence
BSC/E	Blood slides collected/examined
BCC	Behavioural Change Communication
CHC	Community Health Centre
CSP	Circum Sporozoite Protein
Cx.	*Culex*
EDCT	Early Detection and Complete Treatment
ELISA	Enzyme Linked Immuno Sorbent Assay
GR	Geographical Reconnaissance
HIB	Health Intelligence Bureau
IGR	Insect Growth Regulator
KAP	Knowledge, Aptitude and Practice
LPG	Liquid Petroleum Gas
MAP	Malaria Action Program
MLO	Mosquito Larvicidal Oil
MM™	Mosquito Magnet™

MST	Mass Suppressive Treatment
NIMR	National Institute of Malaria Research
NVBDCP	National Vector Borne Diseases Control Programme
PCR	Polymerase chain reaction
Pf	*Plasmodium falciparum*
PF%	Proportion of *P. falciparum*
PHC	Primary Health Centre
POP.	Population
Pv	*Plasmodium vivax*
PV%	Proportion of *P. vivax*
S. No.	Serial Number
SEAR	South East Asian Region
SFR	Slide Falciparum Rate
SPR	Slide Positivity Rate
SVR	Slide Vivax Rate
TM	Trademark
UHC	Urban Health Centre
WHO	World Health Organisation

Chapter 1: INTRODUCTION

There are more than 3200 species of mosquitoes distributed worldwide belonging to 37 well recognised genera. Their systematic position in animal kingdom is given below.

Phylum:	Arthropoda
Class:	Insecta
Sub class:	Pterygota
Division:	Endopterygota
Order:	Diptera (comprising two winged insects or true flies)
Sub division:	Nematocera
Super family:	Culicoidae
Family:	Culicidae

Mosquitoes exploit a variety of habitats as developmental sites for their immature forms and are ubiquitous in distribution except in extreme conditions like Arctic and Antarctic regions. They are well adapted to rural, forested, suburban and urban conditions although different species show predilection for different ecological niches. The females of all species except those of genus *Toxorhynchites* seek animal or human blood meal for the completion of their gonotrophic cycle i.e. for the production of eggs and are accordingly labelled as either zoophilic or anthrophilic. Mosquitoes exhibit clear host preference but may secure a blood meal from any alternate host if preferred host is not available. The females of some of the medically important genera particularly Anopheles, Culex, Aedes and Mansonia not only possess great nuisance potential but also transmit a variety of parasitic and pathogenic diseases of

great socio-economic importance to the man kind and these diseases have posed grave threat to human health over the centuries (Table 1.1).

Table: 1.1 Important Mosquito Genera responsible for the transmission of causative organisms of human diseases.

S. No.	Vector Genera	Causative Organism	Disease
1.	*Anopheles* spp. (about 50)	Protozoa : *(Plasmodium vivax, P. falciparum, P. ovale & P. malariae)*	Malaria
2.	*Aedes* spp.	Viruses	
		DEN group serotypes 1,2,3,4 (family Flaviviridae; Group B)	Dengue
		Yellow fever virus (family Flaviviridae; Group B)	Yellow Fever
3.	*Aedes* & *Culex* spp.	Viruses (Zoonotic)	
		California virus Group C	California Encephalitis
		Alpha virus Group A (family Togoviridae)	Eastern Equine-Encephalitis
		JE virus Group. A	Japanese Encephalitis
		St. Louis virus Group B (Flavivirus)	St. Louis Encephalitis
		West Nile virus Group B (Flavivirus)	West Nile Encephalitis
4.	*Culex, Aedes Anopheles* & *Mansonia* spp.	Nematodes *Wuchereria bancrofti, Brugia timori* & *B. malayi*)	Bancroftian Filariasis, Brugian Filariasis

Historically, malaria has been the greatest single cause of mortality in mankind, maiming and destroying number of civilisations and repulsing mightiest of the armies, a great demoraliser and a strong contributor to human misery and poverty (Kumar et. al. 2007). Malaria, often dubbed as the king of all ailments, is one of the humanity's worst diseases and also one among the top 10 killer diseases in the world (Sharma, 1999b). Currently, it threatens 2020 million (about 36%) people in the world. According to WHO estimates, there are about 300-500 million clinical cases and 1 million deaths attributed to malaria, especially among young children below 5 years of age annually and expectant mothers mostly in Africa, Asia and Latin America (http://www.who.com).

Malaria is prevalent in over 100 countries and *Plasmodium falciparum,* which causes severe/malignant malaria and most of malarial deaths, is transmitted in 92 countries. In the South East Asian Region of WHO, of the ~1.4 billion people living in 11 countries, 1.2 billion are exposed to the risk of malaria, mostly inhabiting India. However, South East Asia contributed only 3.04 million cases to the global burden of malaria. Of this, India alone contributed 76% of the total cases (Kumar, et. al. 2007). There are however estimated 15 million cases and 19,500 deaths due to malaria in India by WHO (SEARO) New Delhi. The National Anti Malaria Programme however reports only 1.5-3.0 million cases and 600-1700 deaths attributable to malaria annually (Sharma, 1999b). Epidemiological indices of malaria in India have been showing an increasing trend in the past three decades (Sharma, 1999a).

The state of Goa has become endemic to malaria. With an area of 3702 sq. kilometres, It is one of the smaller states of India located on the western

coast between Maharashtra and Karnataka. Goa has two districts and 11 'talukas' (=subdivisions of the district) comprising of 15 towns and 398 villages. Topographically, Goa can be broadly divided into three regions viz., hilly region in the East, middle intermediate region with plateaus and valleys in the middle and coastal plains interspersed with plateaus in the West.

Prior to the liberation of Goa in the year 1961, Malaria has been prevalent since many a centuries. Indeed epidemics of diseases, such as malaria and plague, were responsible for the shifting of the capital from Old Goa to Panaji. Besides, the city of Old Goa, the disease was widespread in the Quepem, Sanguem and Canacona 'Talukas' of the South Goa district (Gracias, 1994). The population of Goa decreased gradually during the early 20th Century due to malaria (de' Mello, 1933; de'Sa, 1919). The other published records reveal that the *Plasmodium vivax* and *Plasmodium falciparum* were the dominant species and the *P. malariae* was rare in Goa (de'Sa, 1919).

The Portuguese Government in 1913 carried out anti-malaria campaigns to prevent and control malaria epidemics. Several measures were launched on war footing in the malaria affected areas. Research and investigations conducted by the erstwhile Portuguese Government showed that *Anopheles fluviatilis* was the predominant vector of malaria (Borcar et. al., 1967). It was found breeding in the slow moving streams/rivers of these hilly regions. The Portuguese government controlled malaria vectors by undertaking residual spraying of houses in the malaria affected areas and the incidence of malaria was brought down to a considerable extent.

In the mid 1970s, as in the rest of India, there was sudden resurgence of malaria in the rural areas of Quepem in Goa but it was quickly brought under

control in a couple of years. Thereafter the territory of Goa was practically free from malaria till the year 1985. However, malaria resurgence became perceptible in the year 1986 when Goa witnessed first outbreak of malaria in the coastal capital city, Panaji with the detection of 352 cases of malaria out of which only 1 *Plasmodium falciparum* case was detected and treated. In the year 1987, due to accelerated transmission in Panaji, there were 4416 cases out of which 7 were *P. falciparum*. The entomological investigations conducted by a team of experts from Malaria Research Centre, Delhi (now National Institute of Malaria Research) and National Anti Malaria Programme (now National Vector Borne Diseases Control Programme) revealed the presence of breeding of *Anopheles stephensi* in wells, construction sites and cement tanks, etc. (Narasimham and Khamre, 1987). *Anopheles stephensi* is a well recognized vector of urban malaria in India and in the neighbouring countries. In a classical study in the late 1980s, *Anopheles stephensi* has been found breeding in a variety of habitats in Panaji (Kumar et al. 1992). The resting behaviour has been studied and incrimination as vector has been done for the first time (Sumodan et al, 2004).

In the 1980s & 1990s, several malaria out breaks occurred in many coastal localities witnessing boom in the construction sector. Extensive breeding of *An. stephensi* in multi-storey construction complexes and aggregation of migratory labourers, who serve as source of plasmodial infection were considered as major cause of malaria outbreaks in the state of Goa (Kumar et al. 1991). The malaria situation worsened in Panaji and Candolim areas in the late 1980s. The Government of Goa requested the Malaria Research Centre (MRC), Field Station-Panaji under the aegis of ICMR to

implement Bio-environmental control measures in these areas involving source reduction/modification, larvivorous fishes and biolarvicides. The conventional methods of control i.e. DDT spraying and pyrethrum fogging proved inadequate and implementation of alternate control strategies was necessary. Large scale field trials were carried out by the MRC in Panaji in the year 1993 and in Candolim in 1994 with selective spraying of biolarvicides, *Bacillus sphaericus* and *B. thuringensis* var *israelensis* on *An. stephensi* larval habitats viz, curing waters, masonary tanks and sump tanks, etc, and extensive introduction of indigenous larvivorous fish *Aplocheilus blocki* in the wells, ponds and fountains. These intervention measures successfully curtailed transmission of malaria in both the areas (Kumar et al. 1994; Kumar et al. 1998). However, the results were short lived as the implementation of the bio environmental measures was discontinued in the subsequent years.

In late 1990s therefore, resurgence of malaria took place not only in Panaji and Candolim but also in the other adjoining areas. The highest incidence of malaria in the State was reported in the year 1998 when 25975 malaria cases were registered out of which 8694 were *P. falciparum* and there were 57 deaths attributed to malaria. Based on National Vector Borne Disease Control Programme criterion, the Government of Goa has declared Panaji, Margao, Candolim, Corlim and Aldona as malaria high risk areas (MAP, 1995). Thus in the last two decades malaria has emerged as a major public health problem in Goa which has threatened the tourism industry which is the mainstay of the economy of this small state.

The primary cause for malaria epidemic has been the large scale construction activities taking place in the coastal belt of Goa in the post

liberation era from 1961 to date and especially after the attainment of Statehood in the year 1987. Thus with the rapid pace of urbanisation and industrialisation, the areas along the coastal belt have become endemic to malaria. Malaria vector *An. stephensi* has predilection for breeding in stagnant waters in the construction complexes and has established itself well all along the coast (Kumar, 1991; Kumar et al. 1992). Due to the influx of large number of susceptible population on the one hand and the migrant labour from many hard core malarious areas of the country on the other, many different strains of parasites have been introduced in the areas having intense transmission where conducive malariogenic conditions have been created due to construction projects (Kumar, 1991; Prajapati et al. 2006). A recent study conducted in Goa also suggests that a high frequency of 69% and PCR corrected *P. falciparum* harbouring patients did not respond to the chloroquine treatment and hence the second line drug, ACT had to be introduced recently in Goa (NIMR, unpublished data; NVBDCP drug Policy-2008).

The current strategy for malaria control in Goa includes early detection and complete treatment (EDCT) of malaria cases, mass suppressive treatment (MST) in the affected areas, intensified anti larval measures with larvicides, Abate (Temephos), Baytex (Fenthion)/MLO (Mosquito larvicidal oil), introduction of larvivorous fish in mosquito breeding habitats, etc. anti adult measures with pyrethrum extract in the affected areas and health education aimed at behavioural change and lastly community participation (NVBDCP source). Despite all these anti malarial measures undertaken, the parasitic load continues to be high not only in the towns but also in villages along the coastal belt of Goa. Consequently, outbreaks of malaria are being reported regularly.

Focal malaria outbreaks have been reported from Vema, Cortalim, Benaulim, Sanguem and Canacona areas of the State in the recent years (State NVBDCP Data).

The transmission dynamics of malaria is dependent on both biotic and abiotic factors. The biotic factors includes, the malaria parasite species, human reservoir of infection and the number and prevalence of mosquito vector species. The abiotic factors include, vector breeding habitats, their variety and potential, climatic conditions which determine speed of mosquito immature development in the breeding habitats, pace of development of parasite in the adult vectors and longevity of mosquito vectors. These climatic abiotic factors are the rainfall, relative humidity and the temperature (both maximum and minimum).

It is well known that epidemiologically, malaria is a local and focal phenomenon and its distribution may vary considerably from place to place. The same degree of malaria control cannot be achieved simultaneously all over the State due to variation in the response to interventions and heterogeneity of epidemiological situations within the endemic foci.

In order to study the intricacies in the transmission dynamics of malaria in Goa, a detailed epidemiological study on the risk factors responsible for the enhanced receptivity and vulnerability to malaria was undertaken in Goa which is the subject of this thesis. The various objectives of this investigation are

1. Collection of vital information on physical maps, terrain features, soil type distribution, meteorological data, major developmental projects and construction activities, human migration, etc.

2. Collection of malaria information of the last one century from archives, National Vector Borne Diseases Control Programme (NVBDCP) Goa, other published works and electronic data bases.
3. Generation of Entomological information related to vector Anopheles mosquitoes by necessary adult and larval collections covering all possible breeding habitats in different ecotypes and biting behaviour on human hosts in both urban and rural areas.
4. Critical analysis of epidemiological data: Age and sex wise distribution of malaria and its seasonal distribution, relationship with weather parameters and other risk factors.
5. Stratification of the State based on epidemiological information generated according to the risk of malaria showing endemic zones, depicting vector and malaria distribution.
6. In depth analysis of various factors responsible for receptivity and vulnerability individually and collectively in relation to entomological and parasitological data in an attempt to identify the key factors responsible for sustained malaria transmission especially in Goa for the last two decades.
7. Formulation of appropriate cost effective and sustainable malaria control strategy suitable for different paradigms in Goa.

Chapter 2: REVIEW OF LITERATURE

The process of malaria transmission has been beautifully elucidated by Pampana (1969). He has compared malaria parasite with a seed, a mosquito with natural sower (rarely man as artificial sower with a infected syringe), and soil with another human being where the seed is sown i.e., a healthy person who received infection. In India, the epidemiology of malaria is very complex because of geo-ecological diversity, multi-ethnicity and wide distribution of nine anopheline vectors which transmit three Plasmodial species *P. falciparum*, *P. vivax* and *P. malariae*. The fourth human parasite species *P. ovale* is not known to be naturally transmitted in India. *Anopheles culicifacies* is widely distributed and is the principal vector of rural malaria. *An. stephensi* is the primary urban vector. *An. fluviatilis* is a vector in the hills foothills while *An. minimus*, *An. nivipes*, *An. philippinensis*, and *An. dirus* are vectors in the north east and An. sundaicus is restricted to Andaman and Car Nicobar islands. *An. annularis* and *An. varuna* act as secondary vectors with wide distribution in India (Kumar et al. 2007).

The biological challenges posed by Plasmodium-Anopheles system have, to a great extent, been compounded by the features of human behaviour and ecology. Thus malaria control efforts are not only hampered by biological phenomenon such as evolution of the drug resistance in the parasite and insecticide resistance in the vector but also by problems related to human ecology such as urban expansion, aggregation of labour, failure of radical treatment, the destruction of forest cover and so forth (Lal, 1998).

Malaria continues to be a major public health problem in India and the state of Goa is no exception. To understand the epidemiology of malaria one must have a thorough knowledge of the local determinants of malaria in an

endemic area. This knowledge is useful in the planning and evaluation of various control measures in the area (Pandhya, 1981).

A number of studies have been carried out to correlate environmental and behaviour risk factors with malaria incidence. In this chapter, the available literature has been reviewed from the past few decades to the more recent work on various aspects of malaria in relation to physiography, climatic conditions, demography particularly population migration, vector bionomics as well as control and epidemiology of malaria.

Physiographic features related to malaria vectors and disease endemicity

Gracias da Silva (1994) has written a historical review of Health and Hygiene spanning over 4 centuries from 1510 to1961 in Portuguese Colonial rule in Goa. From the Portuguese literature she has found that malaria was rampant in Goa during Portuguese regime. Epidemics of diseases such as malaria and plague were common and responsible for shifting of the capital of Goa from Old Goa town to Panaji. The author has also mentioned that dense and humid forests coupled with poor hygiene were the major causes of malaria and the consequent decay of Golden Goa. Dense forest particularly in the many areas of Sanguem 'taluka', stagnant pools of water in and around houses, unused wells and marshy areas along with poor sanitation were responsible for mosquito breeding that led to malaria epidemics in Goa.

Garcia (1958) also carried out studies on the Health Services in the areas of Portuguese occupation in India i.e. the territories of Goa, Daman and Diu. According to him, formerly, malaria was a real scourge in the territories of Goa especially in Old Goa, an important and popular trading town situated along the Malabar Coast. Malaria was most intense and serious problem in the

'talukas' of Quepem, Sanguem and Canacona in the Southern Goa. These places were of economic importance because of the agriculture and mining of ores. The then established Health Services carried out extensive surveys on malaria in these 'talukas'. Research and investigations conducted by them showed that *An. fluviatilis* was the predominant malaria vector which was found breeding in the slow moving streams/rivers and rice fields and supported malaria transmission in these hilly regions.

According to Borcar et al. (1967), malaria was prevalent in Goa, especially in the eastern hilly regions since very early times. It had caused havoc in the Sanguem 'taluka' in the early part of the nineteenth century. Topographically Goa has 3 longitudinal regions viz., (1) hilly region in the east, (2) the middle intermediate region and (3) the coastal region on the west. The hilly region comprised of the concelhos of Sattari, Sanguem and parts of Canacona with steep valleys and thick forests which were full of springs, streams, shallow water ponds, swamps and small irrigation canals which were ideal breeding places for the vector species of malaria. The average altitude of this hilly belt was 1000-4000 ft above mean sea level. The terrain of the intermediate region comprised of hillocks, forests and valleys where rain fed paddy cultivation was done. The altitude of most of the areas varied from 500–1000 ft above mean sea level. The coastal region had vast paddy fields and the altitude of this region was up to 500 ft above mean sea level. They found distribution of different anopheline mosquitoes at various altitudes. However, *An. fluviatilis* which was considered as the vector in Goa was collected from areas having altitude more than 500 ft above mean sea level.

D'Sa (1919) carried out investigations into high malaria endemicity in Sanguem taluka in Goa. According to him, though this region had rich natural resources in terms of forests and mines yet it was backward with a large number of huts of labourers. He found that malaria endemicity was high in the areas where no major agricultural activity was carried out and did not have proper water management. The spleen rate in children in these areas varied from 30% to 100%.

In Burundi, Coosemans et al. (1984) found high rates of malaria in less irrigated areas of the Rosizi valley. On the contrary, however, Gaddal et al. (1985) carried out studies on malaria control in the Gezia Managil irrigated scheme of Sudan and found that irrigated areas had more out breaks of malaria infections compared to that of less irrigated areas in Sudan.

Nagpal and Sharma (1986) carried out studies on incrimination of *Anopheles culicifacies* as vector of malaria in Orissa state of India. They have mentioned that topographically, Orissa has three main geographical regions having (1) hilly districts (2) plain districts and (3) coastal districts. The state was endemic to malaria with high incidence of *P. falciparum*. They undertook an extensive mosquito fauna survey covering all the three geographical areas in the entire state of Orissa. Results of the survey revealed only *An. culicifacies* among other anopheline mosquitoes were positive for the gut and gland infection. Their studies showed the prevalence of *An. culicifacies* in the villages in the hills, plains, coastal areas and urban areas. They also established its role in the transmission of malaria in Orissa. Many other studies, however, suggest that *An. fluviatilis* and *An. culicifacies* transmit malaria in hills and foothills and

plain areas respectively while *An. annularis* is also a vector of malaria in the coastal Orissa (Panigrahi 1942, White 1943, and Rao 1949).

Matola et al. (1987) carried out qualitative studies on climate change and malaria in the highland areas in Tanzania. They suspected that forest clearing was one of the key factors that was responsible for high malaria rates in the Usambara Mountains of Tanzania.

Kumar and Thavaselvam (1992) conducted a longitudinal study on breeding habitats and their contribution to *An. stephensi* in Panaji, Goa. They found that although most of the human inhabitation was on and around a hillock, topographically the breeding of this important urban malaria vector occurred practically in all areas viz., plain, foothill and hilly part of the city in a variety of habitats throughout the year.

Dutta et al. (1992) carried out a comprehensive study on the Anopheline fauna in parts of Tirap District in Arunachal Pradesh which was afflicted with high incidence of malaria. Deforestation and other developmental activities in addition to some other factors influenced gross ecological changes in this region. They found that the area was covered with deep forests and traversed by rivulets and hill streams. They captured seven species of mosquitoes, *An. philippinensis, An. dirus, An. minimus, An. culicifacies, An. maculatus, An. aconitus* and *An.annularis* in the foothills ranges (1000-1400 feet above sea level) in this district, which are recognised malaria vectors in India.

Tandon et al. (1995) carried out studies on the Anopheline fauna in Ajodhya hills of District Purulia in the West Bengal, India. Purulia was one of the malaria endemic districts of W. Bengal. In Ajodhya hills of this district, the disease posed a serious health problem and malaria transmission was

perennial. During the study they found that this hilly region was an elongated area lying between two valleys. Most of the land area was covered with forests and interspersed with many streams. There were a number of small springs and fissures in rocks through which water oozed out throughout the year. A river 'Subarnarekha' and tributary of river 'Damodar' ran along the western and northern borders of this hill. Entomological investigations revealed that the perennial transmission of malaria was due to high prevalence of vectors in the foothill areas of this region.

Chatterjee and Hati (1997) also carried out studies on incrimination of Malaria Vector on Ayodhya–Bagmundi range of Hills situated in the extreme west of Purulia district, West Bengal, India. This region was highly endemic for Malaria. During their study, they found that the average altitude of this hill area was 2200 ft above mean sea level. Most of the area was covered with dense moderate forests and sparsely inhabited. While carrying out search for anopheline vectors responsible for the transmission of malaria, they found that the fresh water pools, streams and small rain water collections provided breeding grounds for the malaria vectors in the region.

Sharma (1995) reported that in Malnad foothill areas of the Western Ghats, the evergreen forest belt of Karnataka, *An. fluviatilis* was the only vector which bred in the slow moving streams and maintained holoendemic malaria. This area had indigenous people who were chronic carriers of malaria and also there was high mortality in the infants, pregnant woman and non immune migrants.

Patz et al. (1998) conducted studies on climate change and malaria transmission in highland areas in Kenya. They found that soil moisture

correlated with the human–biting rate of malaria vectors with a two week time lag which was explained as the length of time it takes for mosquito larvae to develop into adults. They also found in the same study that soil moisture correlates with entomological inoculation rate, which are the product of the human-biting rate and the proportion of female mosquitoes carrying infective parasites (sporozoites) in their salivary glands ready to be delivered to the host with a six week time lag. Six weeks was the time period necessary for the development of the infective parasites in the mosquitoes plus the length of time the mosquito survived.

Malakooti et al. (1998) also carried out studies on climate change and malaria in highlands in Kenya. They found that deforestation might have been a reason behind changes in malaria transmission in the highlands.

Sharma et al. (1998) carried studies on the impact of Spherix (a formulation of *Bacillus sphaericus* B101, Serotype H5a, 5b) on the control of mosquito breeding in rural areas of Farrukhabad District in Uttar Pradesh. In some villages of this district, abnormal rise in malaria incidence was reported during the post monsoon period. During the survey, they observed that there was no river or irrigation canal in the selected villages. The terrain was plain Gangetic with sandy soil having high water absorption capacity and did not support mosquito breeding. However, extensive irrigation was done through the tube wells for the crops grown in the area. They found that crops such as potato and sunflower which required 5-6 times watering resulted in spillage of water and aggravated the mosquito problems in the area.

Singh et al. (1988) conducted studies on malaria outbreak in Kundam block, District Jabalpur in Madhya Pradesh. During the study, they found that

the topography of the area was mostly rocky with undulating terrain covered with thick forests. Most of the villages were located near the streams and remained cut off from other villages during rainy season. The rocky pools, rice fields, borrow pits, wells and seepage with rain water collections provided opportunities for the mosquito breeding. The investigations revealed that in spite of residual sprays carried out by the health authorities, the densities of malaria vectors in this region were high due to insecticide resistance and thus resulted in an outbreak in the area.

Mya et al. (2002) conducted studies of malaria in Yeasitkan village of lower Myanmar. During the survey carried out to identify the causes of malaria, they found that half of the total area in this village was covered by dense forest. They suggested that the prevalence of malaria vectors depends upon the distribution of forest. They also suggested the high incidence of malaria may be due to the presence of a big dam near the Yeasitkan village. This dam created conducive environment for mosquito breeding as well as the growth of vegetation which helped in increasing the mosquito densities.

Das et al. (1998) carried out studies on the mosquito fauna and breeding habitats of Anophelines in Car Nicobar Islands in India. This small flat island with an area of 127 sq. km. situated in the Bay of Bengal had posed a serious problem due to malaria. They found that the island was made up of corals. The island had 60 % of forest cover. There were seven live creeks; thick growth of mangroves, small streams emerged in northern and southern regions inside the jungle of the island influenced by tides, several water bodies and marshy areas. The results of their faunastic studies revealed that the above ideal environmental conditions along with suitable climatic conditions supported the

anopheline mosquito fauna especially the predominant vector, *An. sundaicus* and the malaria transmission in the area.

Pant et al, (1998) conducted studies on the prevalence of malaria and ABO Blood Groups in the sea port areas of Raigad district of Maharashtra. They confirmed the prevalence of malaria and distribution in various blood groups from the coastal region of Raigad district.-Shift from here

Das et al. (2002) in their studies carried out on mosquito fauna and breeding habitats of Anophelines in the Little Andaman and Nicobar Islands, India found that most of the areas of the Little Andaman were convered under thickly vegetated forest with tropical rain forest and natural vegetation. About 10% of the total area was covered by tidal flat areas, mangrove swamps and beaches and about 63% of the area was coastal plains. The central and southern portion of this island was undulating to moderately hilly area. The mangrove forests were wide spread along the coasts and in the estuaries of many creeks. The streams, forest nullahs, creeks, marshy area, mangroves and ponds were observed as the perennial sources of mosquito breeding. In their studies, they highlighted the breeding status of different Anopheles species in addition to *An. sundaicus* the malaria vector of this region.

Mohite et al. (2002) conducted studies on clinical analysis of malaria cases treated at MGM hospital, Navi Mumbai. The findings of the epidemiological study indicated that Navi Mumbai had higher mosquitogenic potential and incidence of malaria than other areas. There were about 136 quarries in the area. The land was marshy and low lying and resulted in the stagnation of water which was conducive for mosquito breeding along with other factors such as man made habitats created during construction activities,

small rain water collections, poor drainage facilities etc which helped in the transmission of malaria in the area.

Swarnakar and Dashora (2002) conducted longitudinal studies on prevalence of malaria vectors in Southern Rajasthan in India. This region experienced malaria epidemics. During the study, they found that the region was typically arid and semi arid consisting of dry sand desert areas interspersed with fertile plains and plateaus as well as forest clad hills. The Aravalis formed the main hill range of this region which was 1219 m above sea level. There were innumerable perennial and monsoon streams and lakes in the undulating landscape of hilly and plateau areas. On the basis of physiography and climate, Rajasthan was divided into four natural regions i.e., eastern plains, western desert plains, hilly regions and plateaus. With the introduction of Indira Gandhi Canal, the Western desert region was transformed into that of greenery. Similarly, Eastern plains and plateaus introduced with many irrigation schemes and industrial projects produced a very high potential of vector mosquitoes. However, their studies indicated that the prevalence of mosquito species was depended on the availability of natural breeding waters in an ecosystem. They found that along with other factors, the hilly and plateau areas which had many slow moving streams and stagnant water bodies provided facilities for the breeding of *An. fluviatilis* and *An. culicifacies* mosquitoes and supported the malaria transmission in the area.

Singh et al. (1989) carried out studies on bioenvironmental control measures of malaria in a tribal area of Mandla District in Madhya Pradesh, India. They found that had almost all villages were located either on low hillocks or in shallow valleys with a number of perennial streams and tributaries. There

were numerous natural depressions which resulted in stagnant water collections retained for long periods in the area. Primitive methods of rice cultivation were followed. Patches of swamps and seepage existed all along the streams and tributaries. Though rice was grown, there were no irrigation facilities. Their studies revealed that the Bizadandi block of District Mandla had high prevalence of malaria with high densities of *An. culcifacies* and *An. fluviatilis*. They found out the cause of potential mosquitogenic factors in the Bizadandi block were rocky hills which were subjected to continuous soil erosion thus providing breeding places to the vectors.

Dutta et al. (1989) carried out entomological studies to determine the prevalence of anopheline species *An. dirus* and their vectorial role in the transmission of malaria in the Northeast India. They studied a small foot hill area of Changlang district in Arunachal Pradesh. Close to this area were deep forests traversed by rivulets and hill streams. Small stagnant water pools and water collections in elephant's foot prints in open jungles supported the breeding of anopheline vector, *An. dirus* in the area indicating the high risk of acquiring malaria in the forest areas.

Yadav et al. (1989) carried out studies on the Anopheline Fauna of Kheda District in Gujarat. They found that several factors like perennial irrigation and multiple cropping coupled with increased water logging due to seepage and poor drainage resulted in extensive mosquitogenic conditions in the area. Vast ecological changes had taken place in the area due to intense irrigation and developmental projects. Results of their study on mosquito ecology in various types of aquatic habitats reported maximum number of

anopheline species recorded from the canal irrigated areas followed by the riverine areas and the non-canal irrigated areas.

Woube (1997) studied the geographical gistribution and gramatic increase in incidence of Malaria and consequences of the resettlement scheme in the Gambela area in SW Ethiopia. He found that the Gambela area was crossed by many rivers and streams. This vast area remained wet throughout the year. The geomorphology and flat topography of the area made it favourable for mosquito breeding through out the year. There was diversity in the topography of the land; the Eastern region had landscape of hills and valleys and was less conducive for larval development and low malaria endemicity. The middle flat landscape which had rivers, streams, small ponds and swampy areas favoured mosquito breeding and supported malaria transmission through out the year, however the Western landscape which was marshy and swampy with lakes and flooded areas was the most permanent malarious area. According to him, the clay soils were characterized by the physical (hard pan) and chemical (iron-magnesium-Fe_2Mg) properties which made them capable of holding water for sufficient periods of time favoured the development of mosquitoes. He pointed out that the geographical characteristics such as altitude, topography, surface water along with other factors were responsible for the rapid breeding of mosquitoes and spread of infectious disease in the area.

Malhotra et al. (1992) carried out studies on enhancing the efficacy of *Gambusia affinis* to control mosquito breeding in Ponds in the Bhabar and Terai areas of district Nainital. Both these areas were well known for high transmission of *P. vivax* and *P. falciparum* malaria. During their study, they

found that the Bhabar area had scarce water resources as the soil was porous and had a high content of sand, pebbles and stones. This area was situated in the foothills with deposition of detritus material. According to them, the porous soil did not retain water long enough to support mosquito breeding. However, the transmission of the disease was supported by the malaria vector, *An. culicifacies* which was found breeding in innumerable small ponds/pokars in the area.

Dutta et al., (1997) carried out faunastic studies in Goalpara District of Assam which reported high incidence of Malaria. The malaria cases were reported mostly from the foothill areas bordering Meghalaya. The entomological studies conducted in the Agia PHC area of this district confirmed the role of *An. minimus* as a vector of malaria which was found in the foothill areas of this region.

Das et al. (1997) undertook epidemiological and entomological investigation of malaria outbreak at Tamulpur PHC, Assam. They found that the Tamulpur PHC, under Nalbari district lies on Northwest part of Assam and shared International border with Bhutan. The area was low lying. It was intersected by 'katcha' nallahs, streams having aquatic vegetations, ditches, ponds and paddy fields. During their surveys, they found profuse breeding of *An. culcifacies* and *An. minimus* in the slow flowing 'katcha' nallahs, streams and paddy fields and indicated their role as vectors causing malaria epidemic in the area.

In another study carried out by Shukla et al. (1998) on the bionomics of *An. fluviatilis* and its sibling species, it was found that in District Nainital in Uttar Pradesh, there were two long narrow belts of land with markedly different

physical features in the foothills of Himalayas. Immediately, touching the foot hills, was the Bhabar area which had a waterless belt of porous and sandy soil with a width ranging from 10 -15 km and adjoining to it was a wet belt having wet, clay like soil about 13-16 km wide known as Terai. They observed that the breeding of *An. fluviatilis* was supported by water sources in the Terai region which had artesian (irrigation) drains, streams and water reservoirs.

Yadav et al. (1997) conducted a longitudinal study on the mosquito breeding and resting in tree holes in forest ecosystem in Orissa. They found that though the tree holes supported the breeding of several mosquito species, mainly *Ae. albopictus* however a small population of the malaria vectors, *An. culicifacies* and *An. fluviatilis* was also found breeding in the tree holes in the forest ecosystem.

Meteorological factors and malaria

Pampana (1969) in his review on Malaria Eradication has mentioned that the three main climatic factors, temperature, precipitation and relative humidity affect malaria. Temperature affects many parts of the malaria life cycle. The duration of the extrinsic phase depends on temperature and on the species of the parasite the mosquito is carrying. The extrinsic phase takes least amount of time when the temperature is 27°C. Rainfall affects the malaria transmission as it increases relative humidity and modifies temperature, and also affects where and how much mosquito breeding can take place. Though relative humidity does not affect Plasmodium parasites, it affects the activity and survival of Anopheline mosquitoes, thereby affecting the malaria transmission. According to Pampana, it is believed that if the average monthly relative humidity falls below 60%, the life of the mosquito would be so shortened that there would be

no malaria transmission. Instead of changing the amount and rate of transmission of the vectors and parasites that already exist in a certain location, changing the climate of an area can allow the introduction of different vectors and parasites that may be more efficient. Since *P. malariae* and *P. ovale* have longer extrinsic cycles some mosquitoes do not live long enough to transmit them. However, if environmental conditions change in ways that would increase the survival time of those mosquitoes then they would be able to transmit other species of malaria that were not present in that area before.

Covell, 1928 in his review, on the basis of studies on treatment of malaria cases at various institutions in Bombay has explained about the seasonal distribution of malaria in Bombay. The lean malarious month of the year was usually March whereas the incidence was slightly higher in April, and remained practically constant throughout from April to June. The malaria season began in the latter half of July and from then increased steadily to its highest peak in October. The months of September and October were the two most malarious months. In November, the number of cases decreased rapidly and continued till the minimum number was reached in the month of March. The results of adult collections when compared revealed that until the latter part of June, the adult Anophelines of all species were extremely rare. However, the numbers began to increase at the beginning of July along with collection of the first infected specimen in the second week of July which indicated a significant correlation between the malaria incidence and vector.

Fontaine et al., (1959) carried out studies on malaria epidemic in Ethiopia in the year 1958. They found that the increasing temperature and relative humidity were responsible for the epidemics in the area. However,

Khaemba et al. (1994) in their studies on 'Malaria in a Newly Developed Highland Urban Area' claimed that increasing drug resistance was one factor responsible for the malaria epidemic.

Russell et al. (1963) in their review on Practical Malariology mentioned that the life cycle of *P. falciparum* is limited if the temperature is below 20°C. However, malaria transmission can still occur in areas colder than 20°C because Anophelines often live in houses, which tend to be warmer than external temperatures. Larval development of the mosquito also depends on temperature. Though some contend that the amount of rainfall may be secondary in its effects on malaria related to the number of rainy days or the degree of wetness they found that malaria was dependent on the ground water level in that area. According to them, winds may play both negative and positive roles in the malaria cycles as very strong winds can decrease biting or ovipostion by the mosquitoes, while at the same time extend the length of the flight of the mosquitoes. However, during the monsoons, winds have the potential to change the geographic distribution of mosquitoes and consequently transmission of malaria in newer areas.

Borcar et al. (1967) while carrying out malaria eradication campaign, found rainfall pattern varying in the three different regions of Goa. The annual rainfall in the hilly region usually varied from 184 to 212 inches, whereas the average rainfall in the middle intermediate region varied from 154 to 160 inches and in the coastal region it ranged from 128 to 142 inches. According to them, malaria transmission in Goa lasted from mid June to December with *An. fluviatilis* as the main malaria vector.

Loban & Polozok (1985) in their review on malaria stated that in countries with tropical climate malaria is transmitted all the year round, whereas in sub tropical and temperate zones transmission is limited to summer & autumn. The sporogony cycle in the female anopheline mosquito may be completed only at a temperature higher than 16°C and accelerates at higher temperature. In hot climatic conditions, digestion of blood by the female mosquitoes is faster and females feed more often on humans and produce more oocysts which accounts for higher intensity of infestation of the vector by sporozoites. This explains a high degree of malaria transmission in tropical and sub tropical countries wherein the ambient temperature creates optimal conditions for mosquitoes.

Matola et al. (1987) carried out studies on the changed pattern of malaria endemicity and transmission at Amano in the north eastern Tanzania. They suspected that climate change associated with forest clearing was related to the increased malaria rates in the Usambara Mountains of Tanzania.

Oaks et al. (1991) revealed that for a given Plasmodium species, if the temperature decreases, the number of days necessary to complete the extrinsic cycle increases. Since the *P. vivax* and *P. falciparum* have the shorter extrinsic incubation period they are more common than *P. ovale* and *P. malariae*. They opined that the Anopheline mosquitoes breed in water habitats requiring just the right amount of precipitation for mosquito breeding to occur.

Singh et al. (1995) in their studies on the longevity of a malaria vector *Anopheles culicifacies* Giles, 1901 in Doon Valley found that the mosquito survival was noted maximum at 10–13°C temperature and at 100% humidity and minimum at 20% humidity. The survival rate was found to increase from

minimum when the humidity increased from 40 to 80%. They inferred on basis of their laboratory evaluation that relative humidity, temperature and predation influenced the longevity of the vector, *An. culicifacies*.

Martens et al. (1995) carried out studies on the Potential Impact of Global climate change on malaria risk. They found that higher temperatures increase the number of blood meals that are taken as well as the number of times eggs are laid by the mosquitoes and thus help in population build up at faster rate. Therefore the rising temperatures may lead to acceleration of transmission of malaria in the regions where it was non existent due to lower temperatures.

Bouma and Vander Kaay (1996) carried out studies on the El Nino Oscillation and the historic malaria epidemics on the Indian subcontinent and Sri Lanka. According to them, climate to a large degree predicts the natural distribution of malaria.

Bouma et al. (1996) carried out studies on falciparum malaria and climate change in the North West Province of Pakistan. Based on their studies, they found that in the month of December, the climate parameters viz, rainfall along with humidity predicted malaria rates fairly well in the area.

Malakooti et al. (1997) carried out studies on Re-emergence of epidemic malaria in the highlands of western Kenya. They claimed that the climate was not the factor for malaria transmission in the area, as the average temperature and rainfall did not change during the time when the malaria rates changed. According to them, deforestation might have been the reason behind changes in malaria transmission intensity in that area.

Three studies on malaria epidemics were carried out in different parts of the highlands of Kenya. Kigotho (1997) carried out malaria studies in Kenyan highlands and found that increased rainfall was related to malaria epidemics. Woube (1997) carried out study on Geographical distribution and dramatic increases in the incidences of malaria and the consequences of the resettlement scheme in Gambela, SW Ethiopia. The epidemic of malaria was attributed to higher temperatures, rainfall and relative humidity as compared to the previous years in the area. However, Woube found that there was excess rainfall in 1993 but no malaria epidemic occurred, whereas in 1984-85 there was high malaria incidence but very little rainfall was reported in the same area. His study revealed that although the epidemic was associated with higher rainfall, it was not always true for that area.

Fonteneille et al. (1990) and Mouchet et al. (1997) carried out studies on malaria epidemics in Madagascar. They related the epidemics to the factors such as lack of anti-malaria medications, lack of control techniques and low levels of immunity in the population. However, a study carried out by de Zulueta, (1994) during a malaria epidemic in Madagascar showed that the epidemic was caused by anthropogenic climate changes although no statistics were presented in support of this assertion.

Marimbu et al. (1993) carried out studies on the contribution of environmental factors to malaria in Burundi. According to them, the increasing temperatures and malaria transmission were correlated in the Burundi area.

Freeman (1994) carried out studies on malaria outbreak in Manyuchi Dam, in Zimbabwe. He found that near the Manyuchi Dam, although many

other factors could also be contributing to the outbreak, higher winter temperature was one of the factors responsible for increase in malaria rates.

A large group of studies have related the El Nino Southern Oscillation (ENSO) to malaria epidemics. According to the studies carried out by Bouma et al. (1994); Kilian et al. (1999); Bouma and Van der Kaay (1995); Bouma et al. (1995) malaria epidemics in the former British Punjab, Pakistan, Sri Lanka, the highlands of Uganda, Columbia, Argentina, Ecuador, Peru and Bolivia, were proposed to be associated with ENSO cycles. Many areas which have experienced periodic malaria epidemics every five to eight years may have been related to the ENSO cycle.

Patz and Lindsay (1999) carried out studies on the impact of climate change on infectious diseases. According to them, the effects of temperature on both malaria vectors and parasites were easily seen in the latitudinal and altitudinal boundaries to malaria transmission. Many highland areas experienced malaria epidemics in the past few years as the boundaries were changing. From their studies, they hypothesized that the increasing temperatures along with many other compounding factors could be part of the reason for malaria transmission at high altitudes.

Githeko et al. (2000) assessed the evidence for the part and current impacts of inter annual and inter decadal climate variability of vector borne diseases on a continental basis with the aim of shedding light on the increased likelihood of climate change. As per their views, the average global temperature will rise by 1-3.5°C. This will increase the likelihood of many vector borne diseases in newer areas. Although investigations made on the climate change and the resurgence of malaria in the East African highlands by Hay et al. (2002)

has revealed that if climate was not changed at the study sites, then the other changes must have been responsible for the increase in malaria.

Kumar and Thavaselvam (1992) conducted a longitudinal study on the breeding of *An. stephensi* in different habitats in Panaji, Goa. In urban areas, this species was found breeding in a variety of domestic and peridomestic habitats and maintained malaria transmission at very low densities. Their studies on seasonal prevalence of *An. stephensi* immature breeding showed that breeding was detected throughout the year with a peak in June in different habitats. They also found that the breeding of *An. stephensi* was associated with the rainfall. With the onset of rains, the additional breeding habitats became available and intermittent rains and dry spells favourably supported vector breeding. However, when rainfall was continuous and heavy, the breeding potential was lowered due to the flushing effect.

Tandon et al. (1995) in Purulia, West Bengal found that the anopheline density was highest during the summer and lowest in the monsoons which they attributed to extremely inclement weather due to heavy rains and frequent Northwest winds. Their investigations revealed that out of the six vector species, *An. culicifacies* was predominant and was found in sufficiently high density during the summer and the monsoons, whereas the prevalence of *An. fluviaitilis* was relatively low in the corresponding seasons, though a considerable increase in the density of this species was noticed in the winter.

Singh et al. (1988) investigated malaria outbreak in Kundam block of Jabalpur District in Madhya Pradesh, India. They found that during the period of outbreak, there was heavy rainfall in the months of late August and September which resulted in creation of vast areas for mosquito breeding. Though

systematic meteorological records were not available, information gathered from sources revealed that the average rainfall in the area was about 1400 mm. The rainy season began from June and lasted till the end of September. Total rainy days varied from 60-70. The minimum and maximum temperatures during winter and summer were in the range of 5-25°C and 25-42°C respectively. The results of their study showed that with the onset of winter, downward trend of *An. culicifacies* and *An. fluviatilis*, densities was observed, whereas an increasing trend in the density of the secondary vector *An. annularis* was observed during that period of the year due to the favourable weather conditions.

Studies of Mohite et al. (2002) conducted on epidemiological and clinical analysis of confirmed malaria cases treated at MGM Hospital, Navi Mumbai showed high prevalence of malaria reported every month in this city. A good number of malaria cases were reported during the rainy season from July to November which was the peak transmission season. According to them, the high incidence of malaria in the region was due to the prevailing climatic conditions viz., the rainfall, and suitable temperature in winter (20°C to 30°C) which was favourable to the parasite growth and humidity more than 60% that favoured the longevity and activity of mosquitoes. Other factors such as man-made water habitats in construction sites, water accumulation in low lying areas, rain water collections, etc. made conditions conducive for vector breeding. As a result, high incidence of malaria was reported in the rainy as well as post rainy seasons i.e., from July to November.

Sharma et al. (1998) carried out studies to assess the impact of Spherix (*Bacillus sphaericus* B-101, Serotype H5a, 5b) spraying on the control of

malaria vector *An. culicifacies* breeding in Rural Areas of Farukkhabad District, Uttar Pradesh. During their survey, they found that the average annual rainfall in the area for two consecutive years 1993 and 1994 was 450 mm. The number of rainy days was 37 and 45 during these two years respectively with small precipitations in the beginning of the year. The temperature ranged from 6 to 45°C and the months of May and June were the hottest. Results revealed that during the first six months of the study i.e. from April to September 1993, the densities of total mosquitoes and of anophelines remained low in the experimental area as compared to the control area. Thereafter, the densities were comparable. The higher mosquito vector densities during July and August 1994 were attributed to high rainfall (522.4 mm) and more number of rainy days (30) as compared to the corresponding months of the previous year in which only 112.4 mm rainfall in the 18 rainy days was recorded. The anopheline mosquitoes including the malaria vector *An. culicifacies* attained high densities and peak during the monsoon season i.e. from July to October.

Das et al. (1998) reported that the in Car Nicobar Island, India tropical conditions existed as the climate was hot and humid with the temperature varying from 25 to 32°C and relative humidity from 70 to 90% which were conducive for *An. sundaicus* prolification and malaria transmission. The annual rainfall in this island ranged from 2500 to 4000mm distributed mainly from May to December and was very less from January to April. In a mosquito fauna study carried out by Das et al. (2002) in Little Andaman Island, India they observed that climate of the Little Andamans was conducive for mosquito breeding and proliferation especially of the vector *An. sundaicus*.

Bryan et al. (1996) studied malaria transmission in relation to climate changes in Australia. Although endemic malaria was eradicated from Australia by the year 1981, the transmission of imported cases occurred and natural vectors *An. hilli* and *An. farauti* sensu lato still existed in the country. They investigated the present and future distribution of *An. farauti* sensu stricto (s.s.) or number one of the three species belonging to *An. farauti sensu* lato an important vector with the CLIMEX (climate matching model) and the method of Hutchinson to infer meteorological data. The potential distribution of *An. farauti* s.s. was estimated under the recent climate change scenario for the year 2030, with an increase of 1.5°C in temperature and 10% rise in summer rainfall in northern Australia. They predicted that the potential distribution of *An. farauti* s.s. would extend further over 800 km towards south thus encompassing more non endemic areas under the risk of malaria transmission.

Dev et al. (2003) illustrated malaria transmission dynamics in the North Eastern region of India by plotting the malaria parasitic incidence data of a selected model PHC of Kamrup district of Assam in relation to meteorological indices for four years (1991-94). They found that malaria was prevalent during all months of the year and there were distinct peaks noticed between May to September marking high transmission periods. During the peak transmission period the relative humidity was 63% to 89% and the difference between maximum (33°C) and minimum (22°C) temperatures were uniform and less marked thus rendering the environment conducive for vector proliferation and longevity. In April there was a gradual increase in the number of malaria cases (largely *P. falciparum*) followed by a steep rise in June/July. Thereafter, there was a steady decline till September/October, which corresponded to the

cessation of monsoons. In the winter season, though there was a further decline in number of cases, low levels of transmission continued. The infant parasite rate for all the months of the year supported by entomological findings affirmed the perennial transmission in the region.

Kamal and Das (2001) carried out the correlation of climatic factors and the incidence of malaria in the tribal villages of Darrang district, Assam which experienced persistent transmission of malaria. They found that the climate was hot and humid for most part of the year except from November to February which was the cold season. High rainfall during the transmission period was responsible for increased breeding places of *An. minimus*, the malaria vector of this region. Their findings revealed a positive correlation between rainy months and high malaria incidence (coefficient equal to 0.649). This coupled with favourable temperature and humidity led to heavy transmission of the disease in the area.

Yan et al. (2005) in their climatic studies carried out in Kenya have found that open, treeless habitats experience warmer mid day temperatures than forested habitats and also affect indoor hut temperatures. As a result, the gonotrophic cycle of female *An. gambiae* when compared with forest sites was shortened by 2.6 days and 2.9 days during the dry and rainy seasons respectively.

Patz and Olson (2006) carried out studies on malaria risk in relation to temperatures in the East African highlands. They found that the minimum temperature for development of parasites of *P. falciparum* and *P. vivax* was approximately 18°C and 15°C respectively. However, the spread of malaria was limited at higher altitudes owing to low temperatures as the altitude increased.

According to Bodker et al. (2003) there was a relationship between increasing altitude and decreasing mosquito abundance in Africa highlands. They found that changing landscapes could significantly affect local weather more acutely than long term climate change. However, Gibbs et al. (2005) found that land cover change could influence microclimatic conditions, including temperature, evaporation and surface run off. These were all keys to determine mosquito abundance and survivorship.

Similar findings have been documented in Uganda by Wilson et al. (2000). They found that the temperatures were higher in communities bordering cultivated fields compared with those adjacent to natural wetlands, and the number of *An. gambiae* s.l. per house increased along with minimum temperature after adjustment for potential confounding variables.

Munga et al. (2006) also observed that the higher maximum and mean temperatures of aquatic breeding sites found in farmlands had hastened larval development and adult mosquito population rates.

Pascual et al. (2006) in their studies on warming trends and malaria in the East African highlands observed the "biological amplification" of temperature effects. They found that a mere half degree centigrade increase in temperature trend could translate into a 30% to 100% increase in mosquito abundance.

Malaria in relation to Developmental Activities

Besides climatic factors, other factors such as urbanization, irrigation, agricultural practices, deforestation, etc. often confound the effect of meteorological variables on malaria, it is therefore important to understand them and their relationship with malaria.

Covell, 1928 in his review on malaria in Bombay mentions that *An. stephensi* which is the transmitter of urban malaria in India, held the same position as of *An. bifurcatus* in Palestine. It bred in unprotected cisterns not only in Bombay but in every town of India provided with a piped water supply which was followed by an increase in malaria incidence. According to him, the importance of this fact should be widely made known to all hydraulic engineers with regards to malaria control, which otherwise would pose grave danger just as in the case when irrigation projects are not accompanied by adequate schemes of drainage.

Pattanayak et al. (1985) in their studies on malaria paradigms in India and control strategies state that more and more dwellers in periurban areas are becoming exposed to a high risk of malaria.

Sharma et al. (1985) carried out studies on malaria in hutments of Delhi. They had found malaria was one of the most common causes of morbidity and the hutments constituted an important source of infection. The infection had also spread to other localities with improved sanitation and higher standards of living. According to them, the malaria incidence was due to rapid industrialization, large scale construction activities and employment opportunities which induced people to move to Delhi in large numbers. Many labour groups came from malaria endemic states, including regions with high P. falciparum incidence and also from regions having chloroquine resistance to P. falciparum. They stayed in temporary hutments in clusters and were scattered all over Delhi. These hutments had high malariogenic potential and poor sanitation facilities. They incriminated *An. stephensi* as the malaria vector that was found breeding in and around the construction sites and close to hutments

in Delhi and the species indeed was responsible for malaria out breaks in the area.

Similar studies were carried out by Dhir (1969) and Choudhary (1984) reporting outbreak of malaria in Delhi caused by breeding of *An. stephensi* in construction sites. Pattanayak et al. (1977) in their study had also described the association of *An. stephensi* with local outbreaks of malaria in construction complexes in Delhi.

According to Kondrashin (1992) the urban population of the countries of Southeast Asia constituted about 23% of the total population, the highest being in India (25%) and the lowest in Bhutan (6.4%). However, it has been estimated that the urban population of Southeast Asia Region would reach 52% of the total population by 2025. The problem of urban malaria was confined mainly to the Indian sub continent. *An. stephensi* is the principal vector in urban areas of India. In the mid 1970's, urban malaria constituted not less than 10% of total malaria incidence in the country. Urban malaria constitutes about 50% of total malaria cases in Tamil Nadu state while 66% of total malaria cases of West Bengal state were contributed by Calcutta city itself.

Kondrachine and Trigg (1997) in their global review of malaria mention that urban dwellers of all age groups are under the risk of malaria in certain areas in South Asia (e.g. India, Pakistan) and Africa (e.g. Congo, Zaire). *Anopheles stephensi* is fully adapted to the urban environment, except for some cities of South Asia where malaria transmission does not occur even in well established densely populated areas. However, many tropical cities are surrounded by rapidly growing slums, such periurban areas leads to increased

malaria transmission. Urban and periurban areas contribute to 10 to 20% to the overall malaria incidence in certain countries.

A study conducted by Sharma S.N. (1993) in Faridabad showed that Faridabad town contributed 38.7% of total malaria and 38.2% *Pf* malaria in the entire Faridabad district. Malaria could also be an occupational hazard for the construction workers who live close to the construction complex in the hutment and are exposed to the vector bites that may be breeding in the stagnant water in these complexes. The work force itself serves as reservoir of infection. For example, in Delhi Adak et al. (1994) studied outbreak of malaria in a hotel construction site and found SPR of 60.1% SFR of 44.1 % and Pf% of 73.5.

According to Kumar (1997), towns contribute about 15% of total malaria in India. In 1982, malaria problem in labour hutment in Delhi was investigated and it was found that 39.6% fever cases had malaria of which 16.3% had *P. falciparum* infections. Age and sex wise distribution showed that malaria was prevalent in all age classes of both sexes (Sharma et al. 1985a). While overall infant parasite rate was 7.83%, it was as high as 94.1% in age group of 15-24 years.

Martens and Hall (2001) in their studies on malaria related with population move and transmission mention that the world's urban population is growing at four times the rate of the rural population. Urban pull is prevalent throughout the developing world, with rural-to-urban migration taking place faster than ever before. Sub-Saharan Africa is the most rapidly urbanizing region in the world, and the urban population in India has doubled in the last 2 decades. Although water pollution in urban areas usually leads to decreases in

vector populations, however some vectors, such as *An. arabiensis* in the forest belt of West Africa, may adapt to breeding in polluted waters. In Asia, *An. stephensi* is proving adaptable to urban conditions, and in India it is a well-established vector of urban malaria. In urban areas of India, water is not supplied regularly and is stored in houses, providing extensive breeding places for *An. stephensi* in overhead tanks and cisterns. In the peri-urban areas, where 25% to 40% of the urban population lives in poor housing without proper water supply and drainage, another vector, *An. culcifacies*, also transmits malaria. When accompanied by adequate housing and sanitation, urbanization leads to a decrease in malaria through reductions in human-vector contact and vector breeding sites. However, in developing countries, rapid, unregulated urbanization often leads to an increase in or resumption of malaria transmission because of poor housing and sanitation, lack of proper drainage of surface water, and use of unprotected water reservoirs that increases human-vector contact and vector breeding.

Sharma (1996a) carried out studies on Re-emergence of malaria in India. According to him, in India with industrialization, urbanization has followed. In the eradication era, urban areas had not experienced much malaria in the past and so limited efforts were made for controlling malaria in those areas. In the 1990s, however due to an increase in industrial growth, many forest areas where malaria was endemic were cleared and those areas were developed. Since, these areas were easily accessible, migration of non–immune people in those areas created an environment for malaria epidemics.

Sharma (1996b) also highlighted the impact of ecological changes on vector borne diseases and mentioned that the expansion of urban areas was

unplanned and poor people lived in unsanitary conditions. This created the right environment for malaria epidemics, caused by increase in *An. culicifacies* breeding in clean rain waters on the ground surface and An. stephensi breeding in wells as well as in intradomestic containers. The author opined that the expansion of *An. stephensi*, distribution in urban areas was related to the spread of piped water systems throughout the country over the past four decades in more and more towns and peri–urban areas.

Sethi et al. (1990) carried out studies on the role of migratory population in maintaining endemicity of malaria in metropolitan cities of India. According to them, peri–urban malaria was a new malaria paradigm as migrants often had chronic malaria and with poor environmental conditions in their temporary settlements, they fostered the mosquito breeding and malaria transmission in the urban areas.

Kumar (1997) wrote a review on Urban Malaria and its control in India. According to the author, malaria has emerged as a major public health problem in many small, medium and metropolitan cities in India. It had assumed serious proportions in the states of West Bengal, Andhra Pradesh, Gujarat, Rajasthan, Tamil Nadu, Maharashtra and Goa. Many major towns viz; Ahmedabad, Baroda, Chandigarh (UT), Delhi and Chennai have also reported increased incidence of malaria due to urbanization. In most of these places, the two vectors involved in the transmission of malaria were the type form of *An. stephensi* in the core area of the cities supplemented by *An. culicifacies* in the peri–urban areas. These two potent vectors complimented each other's role in maintaining malaria transmission in and around cities. The author summarises that urban malaria is essentially a man-made problem which is the outcome of

rapid and haphazard expansion of the cities, inadequate piped water supply, and storage of water in cisterns, disuse or scarce use of wells, developmental activities and aggregation of migrant labour and over all population movement.

Kumar et al. (1991) carried out a study on Malaria related to construction activities in Panaji, the capital city of Goa which had experienced a severe outbreak of malaria in 1986 and the following years. The focus of malaria which was initially confined to a labour camp near a major construction site in the Campal area had gradually spread to the entire city in 1987. The survey in these labour camps revealed that most of the construction workers had migrated from states outside Goa and were residing in hutments close to the construction sites where *An. stephensi* breeding occurred in masonary tanks and curing as well as rain water collections occurred. The study showed that the tropical aggregation of labourers and the buildings under construction were the main problem areas which enhanced vulnerability and receptivity of area and created malaria foci. Inference was that the wards of the city which had accelerated construction activity had many fold malaria (x14) than others which had lesser amount of construction activity.

Sharma (1996b) carried out relative studies on ecological changes and vector borne diseases. He found that *An. culicifacies* took over *An. fluviatilis* when irrigation was implemented in an area in Uttar Pradesh and created more problems as *An. culicifacies* was resistant to DDT and HCH. Similarly the Sardar Sarovar irrigation Project on the River Narmada, which was intended to irrigate 1.8 million hectares in drought prone areas of Gujarat and Rajasthan, also caused the invasion of *An. culicifacies* and *An. fluviatilis*, thereby extending

the malaria season and changed the area into an endemic malaria region with a ten to fifteen fold increase in malaria.

Tyagi and Chaudhary (1997) carried out studies on malaria in the Thar Desert. Many different canal projects carried out in the area stimulated agricultural production through increased irrigation. They found that due to seepages from the canals, 860 hectares of land was permanently inundated, 1000 hectares was converted to marshy land, and there was a rise in water table along with growth of hydroponic weeds, which increased the preferred breeding grounds of *An. culicifacies*. Earlier, the same area which was dominated by An. stephensi, a desert species, was now found with *An. culcifacies* breeding in and around the canal areas. According to them, the increase in malaria was due to the mismanagement of the widespread developmental activities of canal based irrigation in the area.

Sharma and Hamzakoya (2001) carried out larval studies in Lakshadweep Island, in India which was endemic for malaria. During the survey they found that the topographical features of the Lakshadweep Islands were devoid of any natural breeding sites like streams, swamps and marshes thus restricting the diversity of mosquito fauna. However, only those mosquito species could become endemic which could afford to breed in man–made habitats. According to them, *An. stephensi* (type form) the vector of urban malaria had posed an immediate threat not only to the Lakshadweep islands but also to the adjoining Maldives Islands. It showed a southward geographical spread on the Indian mainland due to rapid urbanization and water storage practices.

Population Migration and Malaria

Kondrashin (1992) while reviewing the malaria situation in the WHO South East Asia Region opined that the exact extent of population movement was not known, however it was estimated that the degree of internal migration within India was much greater and amounted to not less than 15 to 20% of the total population every year. Migration of population was viewed as a serious public health problem because it usually increased the spread of disease. The uncontrolled population movement caused operational constraints thus resulting in obstructing malaria control measures, development and spread of resistant malaria, establishment of urban malaria and changing epidemiological pattern of the disease. Unemployment was one of the major factors in the malarious country contributing to the phenomenon of population movement and was closely related to malaria problem. The enormous increase in population had resulted in increasing the number of landless farmer and promoting migration to urban areas or to those areas with previously uncultivated lands. It was observed that the risk of acquiring malaria was considerably higher among mobile workers and among those exposed to mosquito bites in the open air on account of their occupation. Malaria epidemics occurred mainly among non-immunes when they moved into highly malarious areas as was seen in Myanmar and Thailand. Malaria epidemics were also reported particularly in areas in Nepal where population movement and developmental activities took place and were instrumental in the re-establishment of malaria endemicity in areas previously freed from malaria.

Kumar et al. (1991) while carrying out studies on malaria related to construction activities in Panaji, Goa had found that the construction activity in

Panaji had increased enormously during 1980s. Survey in the labour camps revealed that the labourers had migrated from 13 states of India of which 72.5% were only from Karnataka state belonging to Bijapur, Hubli, Dharwad and Belgaum districts and resided in hutments close to the construction sites. A large number of malaria cases were found amongst the labourers who had come from many malaria endemic areas and were engaged in the construction of multi-storeyed complexes and construction of two bridges in the capital city. Some of these labourers revisited their homes once in six months or once every year or once in two years, etc and also frequently moved within Goa. The mosquito surveys in different construction sites revealed extensive An. stephensi breeding in the different habitats at the construction sites. The study showed that the migrant labourers were a major vulnerable risk group for contracting malaria in their place of work.

Migration and tropical aggregation of labour are common in developmental projects i.e. Railways, Dams, irrigation canals, etc., wars, famines floods, strifes, gem mining and in International border areas especially in the South East Asia.

Geographical Reconnaissance of breeding habitats of Mosquito immature

Larval Sampling of Mosquito immature breeding habitats: According to Oaks et al. (1991) a little is known about the biology of the aquatic phase of Anopheline mosquito breeding. However, there are innumerable studies on breeding ecology of mosquitoes in larval habitats. Nagpal and Sharma (1995) have described that different Anopheline mosquitoes prefer different types of water bodies in which they breed.

Gupta et al. (1992) carried out longitudinal studies on the Intra domestic mosquito breeding sources and their management in Nadiad taluka of Kheda district, Gujarat. Their search of intradomestic breeding sources revealed the breeding of seven mosquito species, viz., *An. culicifacies*, *An. stephensi*, *An. annularis*, *An. subpictus*, *An. barbirostis*, *Cx. quinquefasciatus* and *Ae. aegypti*. Both *An. culicifacies* and *An. stephensi* were observed breeding in intradomestic containers regularly in spite of the free access to peripheral breeding sources. *An. stephensi* was found pre-dominantly breeding in almost all types of containers, which indicated the potential and preference of *An. stephensi* to breed in intradomestic water collections particularly in urban or semi urban areas and its role in the transmission of the disease.

Mariappan et al. (1992) carried out extensive surveys to find the magnitude of vector breeding in the city of Cochin in Kerala. They checked various habitats such as cement tanks, wells, ponds, canals, cess pools, water meter chambers and miscellaneous peridometsic habitats such as tree holes, tree stumps, containers, tyres, mud pots, flower pots, grinding stones, etc. Among these, cement tanks, overhead tanks and wells were found to support the breeding of *An. stephensi*. Out of the 2581 wells and 2128 cement tanks examined, 59 wells and 39 cement tanks respectively were found to support heavy breeding of An. stephensi. According to them, owing to the availability of piped water supply, the number of disused wells was increasing in the town and these were more prone to breeding of *An. stephensi* more than other habitats.

Mukhopadhyay et al. (1997) carried out longitudinal studies on the epidemiological status of Malaria in Calcutta Municipal Corporation in West Bengal. Since 1990, this city showed remarkable increasing trend of *P.*

falciparum cases and deaths due to malaria. They carried out monthly larval breeding surveys in fixed hundred houses in the area. Results revealed that the vector An. stephensi was found breeding through out the year in water reservoirs. However, maximum breeding was encountered in the rainy season in a wide range of water collections. The larvae on emergence into adult mosquitoes were identified with the help of standard keys to determine the Breteau and Container index of *An. stephensi*. The larval indices on comparing with the month wise malaria data collected from the study area indicated that the malaria incidence and breeding index coincided and had direct correlation.

Sharma and Hamzakoya (2001) while carrying out studies on the geographical spread of *An. stephensi* and *Ae. aegypti* in Lakshadweep Islands of India, carried out larval surveys in the two islands of Agatti and Kavarathi to ascertain the status of malaria and to collect the information on the prevalence of vectors. Their findings revealed the presence of 5 mosquito species, viz., *An. stephensi* (type form), *An. varuna*, *Cx. quinquefasciatus*, *Ae. aegypti* and *Ae. albopictus. An. stephensi* was found breeding in small cement tanks containing clean/turbid water attached to mosques/community lavatories, whereas *An. varuna* occupied draw wells as their breeding sites. This study revealed the permanent foot hold of the *An. stephensi* which was found breeding in a large number of community and rain harvesting cement storage tanks.

Dev et al. (2003) in their review of malaria transmission in the North-eastern region of India concluded that in this terrain mosquito breeding was recorded in a wide variety of habitats including pools, wells, and roadside puddles, cut bamboos, paddy fields and streams. However the breeding of the vector *An. minimus* was recorded throughout the year in slow moving

streams/streamlets with grassy banks along with *An. fluviatilis* and *An. culicifacies*. The monsoon species *An. dirus* breeding was reported in pools/rain water collections in the deep jungles.

Prasad et al. (1992) carried out vector surveillance while investigating malaria epidemic on Baniyani district of Uttar Pradesh. They found 12 small ponds, 33 wells and one minor drain around the village. There was no river or canal and the area was not water logged. None of the ponds, wells checked for mosquito breeding were positive for mosquito larvae. However, anopheline mosquito breeding was encountered in the water collections in the rice fields and tube well tanks. Three anopheline species, *An. culicifacies*, *An. annularis* and *An. subpictus* were found. On larval sampling carried out, larval densities of 78 and 241/5 dips were found in rice fields and tube well tanks respectively.

Uprety et al. (1983) carried out mosquito breeding survey in 14 localities of Delhi wjich was struck by a fever epidemic. They found that the main areas affected were urban central parts which were thickly populated, as well as the peripheral parts of Delhi. The breeding of Anopheles larvae along with Aedes larvae was confined to the overhead tanks (OHT). Most of the tanks were poorly maintained, not cleaned for a long-time, the lids were broken or left open, some were not in use and had rain water in them. Some of the tanks were not accessible being placed very high on roof tops with no ladders for inspection. Results of the survey revealed that the mosquito breeding occurred in the OHTs throughout urban Delhi. Out of 1,644 cement and steel overhead tanks checked, 339 tanks were found breeding with Aedine larvae and 23 were found with mix breeding of *An. stephensi* and *Ae. aegypti* larvae. No other mosquito species was found breeding in the overhead tanks. Their studies

revealed that overhead tanks were a permanent source of mosquito breeding. The intensity of breeding per tank varied considerably from 10-20 larvae to a few thousands.

Biswas et al. (1992) carried out a year long surveillance of *An. stephensi* larvae in and around a fixed number of human dwellings (100 nos.) in an area of persistent malaria transmission in South Calcutta. They found that the area was characterized by 1-3 storey brick built houses with 2-3 masonry tanks within roofed structures on the ground floor of almost all houses and also some tanks outside the houses. All types of water containers in and around the selected houses were searched for *An. stephensi* larvae once a month. The larval sampling was carried out by dipping and pipetting. They found that masonry tanks (42.8%) were the major breeding source of the vector species. The other important categories of *An. stephensi* breeding containers were earthen pitchers (14.3%), tin drums (6.7%), tin cans (6.7%), plastic flower vases (6.1%), earthen barrels (3.8%), earthen flower pots (3.8%), plastic buckets (3.5%), and overhead tanks (3.5%) which showed that the vector species had a greater preference for outdoor man made water bodies than indoor ones. The average number of breeding containers per positive house was lowest (1.1) in December and highest (4.1) in August. The house index, container index and Breteau index of *An. stephensi* calculated during sampling of immature stages showed that both house index and container index remained uniform throughout the year however, the breteau index i.e., number of breeding container per 100 houses, showed a wide variation. The index was lowest (13) in January, started increasing (25) with the onset of summer (March) and reached its highest peak (58) in August which was the month of

highest transmission in Calcutta. Their studies indicated that though, breteau index is recognized as the most suitable as indicator of the larval population of *Ae. aegypti*, this index could also be used for the assessment of *An. stephensi* larval populations.

Singh and Nagpal (1985) carried out studies on mosquito fauna of Mandla district in Jabalpur. Malaria was one of the major health problems among the tribals which constituted 60% of the population in the area. Larval surveys revealed heavy breeding of anophelines in rivers, pits and intradomestic containers. These breeding sites were commonly encountered in all the villages surveyed. The surveys revealed that the density of immatures was very high in the river/stream. Most of the mosquito larvae were of *An. culicifacies* which indicated its role as a vector in malaria transmission in the area.

Singh et al. (1985) carried out larval surveys in the Mandla district of Madhya Pradesh having high incidence of malaria. Immatures were collected from ponds, rivers, streams, pools pits and wells etc. from the area. The identification of the mosquito fauna revealed 12 species of genus Anopheles, 2 species of Aedes, 1 species of Armigeres and 2 species each of genus Culex and Mansonia. It was noted that most prevalent species among the anophelines collections was *An. culicifacies* (79%) followed by *An. annularis* (14.9%) and *An. subpictus* (3.7%) respectively. *An. culicifacies* was considered as the most likely vector of malaria in this district.

Kumar and Thavaselvam (1992) conducted a longitudinal study of breeding habitats and their contribution to *An. stephensi* in Panaji, Goa. Their results showed that 1.1%(747) of the 67,360 breeding sites searched contained

An. stephensi immatures and the overall positivity varied from 0.4% to 3.5% with a peak in June. The habitat wise proportion of *An. stephensi* breeding in wells was 0.1 to 4.1%, curing water in construction sites 0.6 to 9.0%, groundwater tanks 0 to 1.4%, tyres 0 to 8.9%, barrels and tins 0 to 5.4% and intradomestic container 0 to1.9% in different months. A variety of habitats supported *An. stephensi* breeding alone or with other species (interspecific association) such as *An. subpictus*, *An. vagus*, *An. barbirostris*, *Cx. quinquefasciatus*, *Cx. vishnui*, *Ae. aegypti*, *Ae. albopictus* and *Ae. vittatus*. Their studies revealed that in most of the habitats, *An. stephensi* breeding was detected throughout the year in variable proportions, though the positivity increased in the month of April, peaked in June followed by a decline in July and August due to continuous heavy rains followed by low grade breeding till the month of March.

Adult Catches and Biting Rhythm of Mosquitoes

Rao (1984) in his book 'The Anophelines of India' mentions that anopheline mosquitoes, except for a few species occurring in the deep shade of the forest, take their blood meals at night time. They feed on man, cattle and other domestic animals, the animals of the forest including monkeys and perhaps birds. According to him, females of anophelines in India bite mainly at night but occasional observations have been made during day light hours also. These species differ considerably in their biting rhythms. Some species bite early and others bite late though there are innate differences between different species yet the behaviour of the same species could also be influenced by seasonal factors. Though biting may occur throughout the night on a small scale, there are distinct peak biting times.

Many anopheline species were recorded from Goa by James and Liston (1911), de' Melo and de' Sa (1921), Borcar (1952) and de' Silva (1952), Borcar et al. (1967). They were *An. aconitus, An. annularis, An. aitkeni, An. barbirostris, An. culicifacies, An. culiciformis, An. karwari, An. maculatus, An. minimus, An. philippinensis, An. pulcherrimus, An. subpictus, An. fluviatilis, An. hyrcanus, An. jamesi, An. tesselatus, An. varuna,* and *An. vagus.* After the inception of the Malaria Eradication Programme a systematic collection of anopheline mosquitoes was carried out which also revealed the presence of additional species viz; *An. jeyporiensis, An. kochi, An. majidi, An. palidus, An. stephensi and An. theobaldi* (Borcar et al. 1969).

Ghosh et al. (1985) undertook a study to investigate the probable role of *An. annularis* as a principal of vector of malaria in rural W. Bengal. They carried all night landing mosquito collection on human baits, placed indoors and outdoors from 18.00 to 06.00 hours twice in a month for one year in a village endemic for malaria. Results showed *An. vagus* (0.70%), *An. annularis* (0.44%), *An. subpitcus* (0.43%) and *An. hyracanus* (0.10%) came in contact with human bait at night. Out of the total number of 5428 *An. annularis* caught both from cattle sheds and human habitation only one mosquito dissected, was found with sporozoites. They found natural infections in *An. annularis* only whereas no infection was detected in *An. vagus* and *An. subpictus.* Their studies were in conformity to earlier authors, Covell (1927), Timber (1935) who had incriminated *An. annularis* as the malaria vector and thus confirmed its role in malaria transmission in rural areas of W. Bengal.

Kumar et al. (1995) carried out longitudinal studies on biting behaviour of vectors on human baits from 18.00 to 06.00 hrs in Goa. During the 75 all night

mosquito collections six disease vectors species viz, *An. stephensi, Culex quinquefasciatus, Culex vishnui, Culex pseudovishnui, Culex tritaeniorhynchus* and *Aedes aegypti* were collected. *Anopheles stephensi* was the only malaria vector collected from the urban localities of Panaji and Bambolim. It was found active throughout the night feeding in small proportions (7.2 to 8%) at dusk, with peak biting observed (68.8%) between 22 to 24 hrs which further remarkably declined till 05.00 hrs with nil % in early morning except for a very few females caught biting between 5 to 6 hrs in the early morning. Analysis of season wise data showed that crepuscular biting of *An. stephensi* was more pronounced (29.4%) during the pre-monsoon period (February-May) and comparatively less (17.2%) during the monsoon period (June–Sept.) and least (7.4%) in the post monsoon period. The biting rhythms of *An. stephensi* was found to be trimodal with its first peak in the month of April with an average of 3.0 mosquitoes/bait with the second and highest peak in the month of June with 4.4 mosquitoes/ bait and the third peak during October with 2.66 mosquitoes/bait.

Sumodan et al. (2004) conducted studies on the resting behaviour and malaria vector incrimination of *An. stephensi* in Goa. The study was carried in three malaria endemic coastal towns of Goa urban and sub urban viz; Panaji, Porvorim and Calangute. The results showed that in well built houses, 67 hours of collections indoors did not yield a single *An. stephensi* mosquito, although other species were encountered. However, collections in the construction sites and from worker's huts for 151 hours yielded 38 *An. stephensi* females resting in 5 types of surfaces such as unplastered surfaces, plastered surfaces, bamboo or wood surfaces, metal surfaces and others at a height varying from

30cm to 2.4 meters from the ground or water. Most of the mosquitoes were collected from galvanized iron sheets and from unplastered brick walls. Out of the 37 mosquitoes tested for the presence of Circumsporozoite protein (CSP) by ELISA technique, one was found to be *P. falciparum* CSP positive. It was concluded from the study that *An. stephensi* showed considerable diversity of resting places in Goa but did not rest indoors in the well built permanent houses. Similar observations were made earlier by Hati et al. (1987) in Calcutta, India.

Dev et al. (2003) carried out studies on malaria transmission in the Northeastern region of India. They identified a total of 23 different anopheline species during the year round collection from various ecotypes. Of the total species collected, *An. minimus* and *An. hyrcanus* group of species constituted a fair proportion of the fauna. Except the *An. fluviatilis*, all other species were found in the cattle sheds. They reviewed the feeding habits of the anopheline mosquitoes and their role as vectors. Majority of the species were collected during evening collections from cattle sheds while *An. minimus*, the major incriminated vector species was most abundant in the indoor day resting catches from human dwellings and night biting catches over human bait. All these species were widely prevalent from June to October except *An. fluviatilis* which was found during the post monsoon season only. The host blood meal analysis of the anophelines revealed that most species were zoophilic and cattle biting except *An. minimus* which was attracted to human host and had an anthropophilic index as high as 93%. During the whole night bait catches, *An. minimus* fed throughout the night and the feeding was more pronounced between 01.00 to 04.00 hrs and its biting rate was 13.72 mosquitoes per

person per night. Other species including *An. philippinensis* and *An. dirus* were also collected over human bait but in less numbers.

Vishwanathan et al. (1943, 1944) in their observations, found the *An. fluviatilis* biting mostly during the first quarter of the night in North Kanara District. However, Brooke Worth (1953), Bhombore et al. (1956) found biting of *An. fluviatilis* occurring much later in the night in Old Mysore state which was about 200 kms south in the same Western Ghats.

Vishwanathan et al. (1955) carried out critical studies over a period of about 100 nights near Pune and exemplified the typical behaviour of *An. culicifacies* species. They constructed special huts in which careful observations were made. A calf was tethered in the huts at night. They found that over 67 percent of the females entered and took blood meals before midnight. They observed that *An. culicifacies* bites mostly in the earlier part of the night i.e. prior to midnight though some degree of biting continues throughout the night.

Reisen and Aslamkhan (1978) in their studies near Lahore observed that there were innate differences in the biting rhythms among mosquitoes, though seasons also brought about marked variations. In their collections, they found that the *An. culicifacies* biting took place mostly in the first segment of the night during the cooler months i.e. from November to March, it then shifted to the 2nd and 3rd segments during the hot months i.e. during April/May and September/October and during mid summer i.e. June to August, biting was entirely arrhythmic and occurred through out the night, Whereas the biting rhythm of *An. annularis* was found throughout the year during the 1st and 2nd segment of the night but a slight shift occurred covering a little earlier period

during cold weather. In case of *An. stephensi*, it was found feeding took place mostly before midnight and was markedly crepuscular in periods of low ambient temperature. They postulated the possibility of genetic factors which influenced the behaviour and the changes in the degree of anthropophilism and endophagy among different populations of anophelines and adenine species of mosquitoes.

Nursing et al. (1934) in Old Mysore found a bimodal rhythm of *An. stephensi* biting rhythm with one peak between 21.00 and 24.00 hours and another between 04.00 to 06.00 hours. Deburca and Jacob (1947) however observed that the species could also bite during day time even at 09.00 hours and also in the evenings in the open.

According to Rao (1961a) the biting of *An. sundaicus* took place in the first half of the night rather than in the second half. When the species occurred in large numbers, it was found biting throughout the night and some even fed in early daylight hours. However, Sundaraman et al. (1957) observed in Indonesia that most of the feeding of *An. sundaicus* occurred during the second and third quarters of the night.

Sharma et al. (1993) carried out studies on role of *An. culicifacies* and *An. stephensi* in malaria transmission in urban Delhi. Their findings revealed that both *An. culicifacies* and *An. stephensi* prevailed throughout the year in peri urban areas with higher densities during the post monsoon months.

Bhatt et al. (1994) carried out studies on biology of malaria vectors in Kheda district in Central Gujarat in order to understand the vector behaviour in the wake of ecological changes and their role in malaria transmission in the area. In 70 all night bovine bait trap collections; they collected 41,552

anophelines with *An. culicifacies*, *An. fluviatilis* and *An. stephensi* accounting for 5.57%, 0.32% and 0.42% respectively. Most biting of *An. culicifacies* occurred in winter during the first quarter of the night which shifted to the second and third quarters during hot and rainy seasons, whereas biting took place in varying magnitudes from dusk to dawn throughout the year. *An. fluviatilis* exhibited no definitely rhythm in its feeding activity, however during rainy season, 71% of the specimens were collected in the first half of the night with a peak between 20.00 and 21.00 hours. Similar observations were made in Madhya Pradesh (1987). The third vector, *An. stephensi* was observed biting mostly before midnight. During hot and cold seasons, the maximum biting activity took place in the first quarter of the night and continued till third and fourth quarters, though at a very low rate. Similar findings were also reported by Reisen and Aslamkhan (1978).

Chatterjee and Hati (1995) in their studies carried out in different areas indicated that seasonal prevalence of *An. stephensi* varied widely. In Calcutta, in W. Bengal, of the 927 *An. stephensi* captured from six collection stations on human baits, the maximum number (725, 78.2%) was obtained in the rainy season and only 140 (14.4%) and 62 (6.68) were captured in the winter and summers seasons respectively. These findings also tallied with the findings of man landing collections conducted by Mukhopadhay and Hati (1978) and Mukhopadhay (1980) when 20, 5 and 2 mosquitoes were collected in the rainy, winter and summer seasons respectively. However, two earlier observations of Rao (1946) and Bhatia et al. (1958) revealed that in Madras, the maximum abundance of *An. stephensi* was observed in the winter season (976) followed by in the rainy (678) and summer seasons, whereas in Delhi, maximum

prevalence was in the summer (1577) followed by in the rainy and winter seasons. In Mandora, Haryana, the highest collection was reported in the month of February (Subbarao et al. 1984). In Pakistan, through a release and recapture experiment, maximum prevalence was noted in the month of November & December (Reisen and Aslamkhan 1979). In Bandar Abbas this species was active throughout the year with bimodal peaks one in April-May and the other in August–September which were not observed elsewhere (Manouchahri et al. 1976).

Devi and Jauhari (2006) carried out studies to evaluate the relationship between *An. fluviatilis* & *An. stephensi* catches & the prevalence of malaria in Dehradun district (Uttaranchal). Results indicated that the correlation between vector density and monthly parasite incidence was higher in monsoons and post monsoon months than the other months suggesting that with the rise in density of *An. stephensi*, the number of cases increased. The density of An. stephensi showed significantly high correlation ($r = 0.819$; $P<0.001$) whereas *An. fluviatilis* showed a slight variation in this type of relationship. Both temperature and rainfall were found to be positively correlated with malaria incidence. Their findings showed that both *An. fluviatilis* & *An. stephensi* played a significant role in malaria transmission in Kalsi area of Dehradun.

Malaria Epidemiology studies

Kondrashin (1992) reviewed the malaria situation in the WHO South East Asia Region. According to him, the coastal areas support different vectors of malaria such as *An. sundaicus* in Bangladesh, *An. annularis* in Orissa and *An. culicifacies* in eastern coastal areas of India, etc. The diversity of landscape along with variation in the climate and economic activities of the population

determine the zonal and intra-zonal distribution of malaria in this region. The coasts which are greatly influenced by the large biomass determine the natural drainage system; the latter in turn facilitate the mosquitogenic potential. The plains have open terrain systems, in turn attract the largest concentration of human population both in urban and rural areas, and are thus exposed to extreme climatic variations, produce unstable malaria systems which are prone to malaria epidemics at periodic intervals. Whereas, the foothill regions support malaria systems with *P. falciparum* predominance and the hilly regions which are 3000 ft above m.s.l. with rich flora and fauna and criss-crossed by perennial hill streams support long lived vector populations and thus give rise to hyperendemic types of malaria.

Mukhopadhyay et al. (1997) carried out malaria epidemiological studies in Calcutta Municipal Corporation to assess the actual situation of malaria in the city. A ward with population of 20,000 reporting large number of malaria cases, especially *P. falciparum* was selected for the study. The malaria cases including of *P. falciparum* were detected throughout the year. Results showed that from January 1995 to July 1996 out of 8432 blood slides collected, 4045 (48%) slides were found positive for malaria. The highest SPR (69.4%) was recorded in the month of February 1995 and a decline (27.5%) was noted in the corresponding month of 1996. They attributed the decline in SPR to the constant surveillance and treatment of malaria cases and mass awareness created amongst the locals. The peak period of malaria when maximum number of cases were recorded was from July to November, 1995.

Kamal and Das (2001) studied epidemiological situation due to persistent transmission of malaria in a tribal village of Darrang district, Assam.

The study conducted from April 1994 to March 1995 revealed that out of a total of 1122 blood smears collected from fever cases, 193 were positive for malaria parasites with a slide positive rate (SPR) of 17.2%, slide falciparum rate (SfR) of 15.77%, slide vivax rate (SvR) of 1.25% and mixed infections (*Pf* and *Pv*) of 1.05%. It was evident from the study that the malaria incidence due to *P. falciparum* was considerably higher than *P. vivax*. Malaria cases were recorded in all the months of the year indicating perennial transmission. The monthly parasite incidence indicated that May to October was the peak transmission period, while rest of the months was the low transmission period. A positive correlation between rainy months and high malaria incidence was observed (correlation co-efficient, r = 0.64989). *An. minimus* was incriminated as a major malaria vector in this region with high densities recorded from human dwellings in the study villages. According to them high morbidity and persistent transmission of malaria was due to poor surveillance, difficult terrain and favourable climatic conditions conducive for mosquito breeding and survival coupled with low socio-economic conditions in this region.

Sharma et al. (1985) carried out parasitological surveys in the itinerant labour camps of Delhi. Results of one year study of daily surveillance in the 12 hutments showed that the fever rate in the community was very high and showed great variation between the months. *P. vivax* cases were reported from early spring and reached high numbers in August-September, and gradually declined with simultaneous increase in falciparum cases which peaked in September and October, and declined with the onset of extreme winter. Out of 7191 blood smears collected and examined, 2851 (SPR:36.6%) were found positive for malaria, of which 2386 (83.7%) were *P. vivax* positive, 454 (15.9%)

were *P. falciparum* positive and 11 (0.4%) with mix infection of both malarial parasites.

Kumar et al. (2007) carried out a retrospective analysis of burden of malaria in India. According to them as per NVBDCP records, the distribution of malaria in most states of India showed API less than 2, and regions with API from 2-5 were scattered, where as the states of Rajasthan, Gujarat, Karnataka, Goa, Southern Madhya Pradesh, Chhattisgarh, Jharkhand, Orissa and in North Eastern states the API was more than 5. The Annual blood examination rate which indicates the quality of surveillance system was an average 9% in India for the year 2004 as against 10% prescribed by the national programme. The study revealed that of all the states, Orissa state contributed 25% of the total of 1.5-2 million reported annual malaria cases and 39.5% of the total *P. falciparum* malaria cases and 30% of the deaths attributed to malaria in the country.

Malaria incidence in different ages and sexes

Srivastava et al. (1995) in their report on malaria in Buhari PHC of Surat have distributed malaria according to <1, 1-4, 5-9, 10-14, 15-29 and >30 years age groups in both sexes. They showed that while in male children of 1-4 year age, SPR was 80%, it was 21.92 % in >30 years adults. Almost similar trend was noticed in females in different age classes. On the other hand Shukla et al. (2002) investigated outbreak of malaria in Moradabad, U.P. and distributed malaria cases age-wise together for both sexes. The age groups were <1, 1-5, 5-15, 15-25, 25-50 and 51 & above and found SPR of 80% in infants which declined gradually over other age classes to 57.1% in the age group of > 51 years.

Dhiman et al.,(2001) chose yet another classification of age groups to group malaria cases in Bahraich district of Uttar Pradesh and their age classes were <5 years (SPR 19.2%), 6-14 (28.84%), 15-25 years (12.5%) and > 25years (39.4%) which means malaria showed increasing trend with age which was contrary to the earlier studies referred above. Yadav et al. (1993) in a study carried out in Shankargarh in Allahabad district, it was found that malaria was high in all the age groups of both sexes e.g. 47% amongst infants and 50% in children of 1-4 year age followed by 57% in 4-8 years, 57% in 8-14 years and 52% above 14 years 9. They also found that *Pf* gametocytaemia ranged from 15.7 to 24.8% amongst these patients and only 56% were symptomatic cases.

Prakash et al. (1997a), in a village based study in Sonitpur in Assam, have reported high prevalence of malaria with SPR ranging from 39.7 to 50% and spleen rate in children <10 years 51.3%. The *P. falciparum* proportion varied from 95 to 100%. In Kamrup district of Assam, Dev and Sharma (1995) reported perennial transmission of malaria with SPR ranging from 22.9% to 36.5% with proportion of Pf 74%. High incidence of malaria was reported in all the months amongst all age groups including infants.

In Morigaon district of Assam, malaria outbreak was investigated by Dev et al. (2001). They found that 68% of the blood smears were positive for malaria (*Pf.* 87%). Age and sex wise distribution of malaria cases detected in mass survey revealed that 44% children below 4 years age had malaria while 45% in the age group 5-14 and 38% from 15 and above age group suffered from malaria.

In a study carried out in ethnic communities in Assam and Arunachal Pradesh, Dutta et al. (1999) found that incidence was quite high amongst tribals with proportion of *P. falciparum* 80%. The slide positivity for malaria in apparently healthy school going children was 7.25 to 17.46%. Problem of malaria was high in infants and children (44.11%) in Rabha, Bodokachari area and decreased with the age (14.7%). Whereas, it was high in children <10 years of age (21.09%) and then reduced in 10-20 years age group (11.4%) followed by another rise in >20 years adults (24.4%) in Karbi ethnic communities. In Arunachalis, on the other hand, it was 25.27% in children <10 years (25.3%) followed by 42.62% in 10-20 year of age and then declined once again to 20.3% in > 20 years of age. Dutta et al., (1991) conducted a study on epidemiological situation of malaria in Tengakhat PHC in Dibrugarh district in Assam. In this area, they found that malaria was seasonal (1987-89: SPR ranged from 12.9 to 28.5% and SFR from 10.78 to 25.01%) and all age groups suffered from malaria. The attack rate (Cases per 1000 pop.) was the least (9.07) in infants but highest in children (53.98%) and in the higher age groups it ranged from 11.97 to 35.19%. They found that An. dirus was the principal vector of malaria in this area.

Dutta and Bhattacharya [(1990) conducted a malaria survey in some parts of Namsang circle of Tirap district, Arunachal Pradesh and found that SPR was 26.84% in a sample of 190 blood smears examined and SFR was 21.05%. They analyzed malaria according to age groups <1, 1-10, 11-20, 21-30, 31-50 and >51 years in both sexes and found that while SPR was nil in

infants and low in persons >50 years of age, it gradually increased up to 30 years of age.

A study conducted by Das et al. (2000) on epidemiology of malaria in tribal Rajmahal Range, Bihar showed that the slide positivity rate was 25.1% and Pf% was 64.2. Age wise distribution showed that SPR in children was 25% and it increased to 34.4% in 6-10 years age group and 37.7% in 11-15 years age group. In Lakhimpur district, Assam, Das et al., [35] found that in forest fringed villages the SPR was 46.5%, SFR 28.1% while Pf% was 60.4%. Malaria greatly affected children below 5 years (SPR:47.6%), and in the higher age groups SPR ranged from 30.9% to 64.3% showing thereby alarming situation created by the outbreak of malaria. Prakash et al. (1997b) studied malaria problem in forest fringed areas in Dibrugarh district Assam and found that SPR% was 47, SFR was 39.0% while Pf% was 83.1. Age and sex wise distribution showed that infants suffered the maximum in this area (SPR: 69.2%) while malaria problem was also acute in other age groups (SPR range 36.1 to 60.7%).

Mohapatra et al. (1998) have highlighted the importance of younger age groups during epidemic in Tamalpur, Assam and found out that the children between 3 and 12 years of age who were treated and recovered continued to harbour gametocytes and transmit malaria as gametocyte reservoirs. Kamal and Das (2001) found in Darang district of Assam that peak transmission of malaria was between May and October and SPR ranged from 2.3-45.67% in different months with predominance of *P. falciparum* (91.7%) as found in other

studies. The worst affected age groups were 0-1 and 21-30 years although all the age groups suffered from malaria (SPR 11.65% to 19.09%).

Kondrashin (1992) reviewed malaria situation in the WHO South East Asia Region. According to him, in India there was wide variation with respect to malaria among different age groups of both sexes from one state to another. Only 0.5% of total malaria cases were accounted by infants who constituted 2.5% of the country's total population. In the age group of 1- 4 and 5-15 years, there was a marginal difference observed between the population in those age groups and percentages of malaria cases detected in them. This showed that malaria at present was confined to the older age groups probably because of the higher mobility of the adults. Statistical analysis of malaria data of Sri Lanka, Thailand, and Myanmar indicated that malaria incidence was greater among higher age groups than in lower age groups. There was a marked preponderance of malaria among males as compared to females.

Kamal and Das (2001) carried out analysis of age and sex wise data on malaria of tribal village of Darrang district, Assam which experienced persistent transmission of malaria. They found that malaria positive cases were recorded in all age groups including infants in all the months. However maximum number of positive cases were reported in the age groups from 0–1 years (SPR = 32.83%) and 21–30 years (SPR = 2.187%). However the least number of cases were recorded in the age group of 51 years and above. Analysis of the sex wise data revealed very little difference in malaria incidence between the males and females who suffered almost equally with SPR of 18.08 and 16.19 respectively.

Sharma et al. (1985) found that there was low malaria incidence amongst the infants in hutments of Delhi. This was attributed to maternal immunity and also the fact that infants were generally kept well covered. Whereas, maximum incidence was observed in 9-24 years age group. This group was most active and children above 10 years generally accompanied their parents to work.

According to Kumar et al. (2007) who reviewed malaria situation in the entire India found that malaria incidence when distributed according to age and sex specifically showed that the burden is generally higher in men than women in all the age groups. Also children in the states of Assam, Arunachal Pradesh and Rajasthan had a higher incidence of malaria than adults, whereas in the Indo-gangetic plains and in the peninsular India, the situation was reverse i.e. incidence was much higher in the middle and older ages than younger ages .

Kumar et al. (2007) have also shown that in general, malaria mortality across all ages was comparatively higher in males than in females. This mortality gap in both sexes widens after the age of 25 years. Overall, the proportion of deaths in males:females were 1:0.56. Unlike in Africa, where most of the malaria attributed deaths are reported in infants and children, in India, malarial deaths increased up to the age of 44 years in both the sexes and declined thereafter. Although the deaths in infants and children <14 years of age accounted for 20.6%, in older ages (15-54 years), they accounted for 56.1%, and the rest 23.3%, were in those > 55 years of age. Hence, most of the burden of malarial mortality was borne by the economically productive ages. The total computed DALYs lost in India for 1997 because of malaria were 1.86 million years. Among females, DALYs lost were 0.786 million versus

1.074 million in males. The maximum DALYs lost (53.25%) were in the middle productive ages from 15 to 44 years of age, followed by children < 14 years of age (27.68%), and 19% in those > 45 years of age.

Demographic distribution of malaria

Kumar et al. (1991) in their study carried out on malaria related to constructions in Panaji, the capital city of Goa which had experienced a severe outbreak of malaria in 1986 showed that the fever rate in labour camps was comparatively much higher, ranging from 8.3% in December to 33.7% in June as compared to 0.6% noticed in March and April to 4.5% in July observed among the locals. Slide positivity rates (SPR) in the two demographic groups were also compared up to April 1990. In the labour camp, there was a sharp increase from 16.8% in April to 50.5% in May, whereas in the local population SPR increased from 17.2% in April to 25.7% in May i.e. an increase of 8.5% as against 33.7% witnessed in labour camps. The increase in SPR coincided with an abrupt increase in the malaria vector, *An. stephensi* per cent positivity in the construction sites. In the subsequent months, except in the month of November, the SPR remained higher in labour camps as compared to local population. Similarly, slide falciparum rate (SfR) was higher in labour camps ranging from 2.3 to 9.5% as compared to 1.2 to 7.8% in local population. Annual parasite incidence (API) was 528.1 in the labour camps and 37.97 in the local residents in the same year showing a marked difference in the incidence among these demographic groups. According to them, labour camps were very important epidemiological niches of malaria where highly vulnerable population resided.

Stratification based on Malaria endemicity

The stratification of the SEAR was carried out by the WHO based on the distribution of Pf resistance to antimalarials in 1993. The endemic countries were stratified based according to drug to chloroquine (CQ), chloroquinine plus sulphadoxine methamine (SP) and CQ+SP+ Mefloquine. A new strategy was endorsed based on the recognition that malaria varied from country to country, area to area and even within population groups.

Sharma et al. (1996) in their review on Epidemiology of Malaria in India, mention that during early part of this century, the malarious areas of the world were classified on the basis of 'malaria prevalence' in the area. The degree of malaria prevalence was correlated with climatic conditions. Celli and later on Gill (1938) described Equatorial, Tropical, Sub-Tropical and Temperate Zones of malaria. Subsequently as wide variations in malaria prevalence were observed within each zone, Christopher, Pampana, and later on WHO (Kampala Conference, 1950) recommended the classification or stratification of malarious areas during eradication era based on disease prevalence in the population surveyed for spleen enlargement in children in the age group of 2 to 9 years as hypo, meso, hyper and holo-endemic areas. Later on, another dimension was introduced in this classification by adding infant and child parasite rates prevalent in community. Only much later, attempts were made to classify or stratify malarious areas based on 'epidemiological profile' of malaria in the area, as 'stable' and 'unstable' malarious areas. Models of Macdonald and Mostikovsky independently explained malaria 'transmission dynamics' and disease epidemiology, but the control strategies based on these and those adopted in areas like Garki project did not record much success. The atlas of

Kenya and Tanganyika helped in understanding the malaria epidemiology in relation to land relief of the locality but did not lead to successful multi-disciplinary control strategy. The operational stratification was done in El Salvadore, China, Vietnam, Turkey and Iran and recently in many countries of South East Asia. Except for China, the stratification based control programmes have not shown very good results; even in China the programme which had shown good progress till 1990 has recently recorded some setbacks. Therefore, the adoptation of malaria stratification technique for planning a successful, cost-effective and sustainable malaria control programme needed further research and refinement.

Sharma et al. (1996) in their review mention that the zoning of malarious areas of India was carried out in 1986 by the Govt. of India which constituted a malariogenic stratification committee which as a preliminary exercise, took 14 different variables into consideration for stratification and divided the country into seven strata: 1) Non-Refractory Areas with low to moderate epidemic potential of Southern India; 2) Moderately Refractory Areas with high epidemic potential of Central-Western India; 3) Non-Refractory Areas with moderate to high epidemic potential of North-Western India; 4) Non-Refractory Areas with high epidemic potential in North-Western India; 5) Non-Refractory Areas with limited epidemic potential in Northern and Eastern India; 6)Refractory Areas with high - receptivity (malariogenic potential) in Central-Eastern and Eastern India; and 7) Refractory Areas with high receptivity in North-Eastern India. The stratification strategy suggested by this committee was based on 'Refractory' and 'Non-Refractory' nature of malaria. It must be emphasized that malariogenic stratification as suggested by different experts was not an

academic exercise alone but it had an ultimate goal of defining control programme objectives in different malariogenic strata.

The WHO has classified malaria epidemiological types related to human activity viz., (1) Agriculture related malaria including irrigated malaria such as rice field malaria, irrigation canal malaria, tube-well malaria, reservoir/pond related malaria, sugarcane cultivation malaria and non irrigated malaria such as cotton/tapioca/tea garden/coffee plantation malaria, tree plantation malaria including rubber/coconut tree plantation malaria and fruit orchard malaria, animal grazing malaria (2) Forest economy related malaria including gem/gold/ore mining malaria, hunting/food gathering malaria, forest fringed malaria such as settled/shifting cultivation malaria, re-settlement malaria, animal grazing malaria, logging/firewood collection malaria (3) Urban Malaria including urban malaria, peri-urban malaria, slum malaria, industrial malaria and (4) Industry related malaria which included coal/ore mining malaria and developmental project malaria. The above classifications only broadly identified a situation where human population could be exposed to risk of malaria. But to organize a control programme for each situation, detailed investigations on transmission dynamics were required.

The identification of malaria paradigms was carried out by the Directorate of National Malaria Eradication Programme (NMEP) in 1994 as there was a sudden upsurge of malaria in India (Sharma et al. 1996). Epidemics were recorded in the States of Rajasthan, Manipur and Nagaland. The State of Rajasthan recorded about four fold increase in number of deaths due to malaria. To look into the causes of these epidemics and deteriorating malaria situation, the GOI appointed an Expert Committee who reviewed the malaria

NMEP and other agencies and laid down the criteria for identification of 'high risk' areas. Under the Rural areas (1) Recorded deaths due to malaria (on clinical diagnosis or microscopic confirmation of *P. falciparum*) locally acquired infection in an endemic area, during any of the last three years (2) The Slide Positivity Rate (SPR) index is to be used for the identification of the areas as follows: (a) Doubling of SPR during the last three years provided the SPR in second or third year reaches 4% or more (b) Where SPR does not show the doubling trend as above but the average SPR of the last three years is 5% or more. (3) *P. falciparum* proportion is 30% or more provided the SPR is 3% or more during any of the last three years (4) An area having a focus of Chloroquine resistant *P. falciparum* (A Chloroquine resistant PHC will be characterized by detection of more than 25% of R II and R III level cases in a minimum sample of 30 cases), as per WHO recommendations (5) Tropical aggregation of labour in project areas (6) New settlements in endemic/ receptive and vulnerable areas. For the urban areas (1) 15 cities/towns were identified as high risk areas (2) among the remaining cities/towns presently covered under Urban Malaria Scheme, the SPR is 10% and more during the last three years (3) any other urban area with a population of 50,000 or more and SPR more than 5% or the ratio of clinical malaria cases to fever cases more than one third as per hospital/dispensary statistics during the last calendar year. The Committee further broadly classified malaria paradigms into epidemic prone areas, tribal areas and urban areas. They sub-classified these paradigms into: Plain irrigated areas (tube-well irrigation), Plain areas with sandy soil without water logging, Plain desert areas, Plain coastal areas, Undulating hills and foothills areas and malaria in organized sector, etc. The

Committee further divided the epidemic prone areas into different sub-paradigms of malaria, on the basis of the endemic potential of the area, correlating the endemicity levels with the presence of malaria vector. They took into consideration the effect of the vectorial capacity of local vector and other factors related to the transmission dynamics in the area. According to the Committee malaria is an exclusively local phenomenon, the disease prevalence and epidemiological factors vary from area to area and that approach to malaria control in any area should have the following two main activities; firstly disease management, through early diagnosis and prompt treatment (EDPT) and secondly selective suitable intervention measures.

Ceccato et al. (2007) carried out studies on the malaria stratification, climate and epidemic early warning system in Eritrea, a malaria epidemic prone country in the horn of Africa. Eritrea had successful malaria control program but was susceptible to devastating malaria epidemics. Remotely sensed climate and malaria data was averaged over the same 'subzoba' (=districts), geographic administrative units. Relationships between monthly incidence of clinical malaria by 'subzoba' and monthly climate data were investigated. Although correlation was good between malaria anomalies and actual rainfall from ground stations (lagged by 2 months), the stations did not have sufficiently even coverage to be widely useful. Satellite derived rainfall was correlated with malaria incidence anomalies with a lead time of 2–3 months. Their findings revealed that the seasonal forecasting skill from Global circulation Models for the June to August season was low except for the Eastern border and for the coastal October to December season, forecasting was good only during 1997 and 1998 (El Nino period). Thus the monthly malaria data derived from 242

health facilities in 58 'subzobas' of Eritrea from 1996 to 2003 was used in a novel stratification process using principal component analysis and non hierarchical clustering to define five areas with distinct malaria intensity and seasonality patterns to guide future interventions and development of an epidemic early warning system.

Kumar et al. (2007) in a study on burden of malaria in India presented stratification of different states of India based on the annual blood examination rate (ABER), annual parasite incidence (API), and the proportion of *P. vivax* and *P. falciparum* in 2004. It was revealed that against the 10% norm of ABER, the overall ABER in the country was 9%. In 14 out of the total 29 states, it ranged from 1% to 8%, and in the remaining 15 states and union territories, ABER was 10% to 40%. As per the NVBDCP reported incidence data, in most of India, the API was <2, whereas 2-5 API was in scattered regions, and regions with >5 API were scattered in the states of Rajasthan, Gujarat, Karnataka, Goa, Southern Madhya Pradesh, Chhattisgarh, Jharkhand, and Orissa and in northeastern states.

This stratification also showed that the proportion of *P. vivax* and *P. falciparum* varied widely in different parts of India. Although mostly indo-gangatic plains and northern hilly states, northwestern India and southern Tamil Nadu state have <10% *P. falciparum* and remaining *P. vivax* infections; in the forested areas inhabited by ethnic tribes, the situation was reversed, and the *P. falciparum* proportion was 30-90%, and in the remaining areas, it was between 10% and 30%. The stratification also highlighted that in India, malaria is being contributed the most by the Orissa state. Although Orissa has a population of 36.7 million (3.5%), it contributed 25% of a total of 1.5-2 million reported annual

malaria cases, 39.5% of *P. falciparum* malaria, and 30% of the deaths caused by malaria in India (Source NVBDCP, India). Similarly, in the other states inhabited by ethnic tribes mainly in the forest ecosystems, meso to hyperendemic conditions of malaria existed with the preponderance of *P. falciparum* to the extent of 90% or even more.

The stratification of India based on chloroquine resistance in *P. falciparum* based on the results of 28-day in vivo studies until 2001 and therapeutic studies from 2002 onward conducted by the NVBDCP and research institutes including the National Institute of Malaria Research was helpful in revising the National drug policy. The drug policy has been revised in 2007 in 241 primary health centers (PHCs) in 71 districts in 20 states of India.

Malaria Risk Factors and outbreaks

According to World Health Organisation (WHO), malaria in countries of South East Asian Region (SEAR) ie., Thailand, Bangladesh, Nepal, Indonesia, India, Myanmar, Sri Lanka and Bhutan had re-emerged in the mid seventies and reached a peak of 7.2 million cases in 1976. In 1995, however, though 3.4 million cases, the actual number was estimated to be six times higher with increase in the proportion of *P. falciparum* cases. The contributing factors for the increased malaria incidence was the development of drug resistance in the *P. falciparum*, development of new foci of multi drug resistance, insecticide resistance in the mosquitoes, human factors e.g. the expansion of areas under human habitation thus diminishing their immunity and bringing them in close proximity to vector mosquitoes, migrant populations engaged in forest related and other occupation who are important conveyors of drug resistant malaria, effect of climatic changes giving malaria vectors an opportunity to breed in new

geographical areas and cause widespread epidemics, poor political commitment in many countries in respect of adequate allocation of resources leading to institutional deficiencies and weak programme management. Besides these, other factors include radical changes in ecology and land use patterns, highly efficient vectors, multiple vector transmission, and prolonged transmission season due to climatic changes usually resulting in epidemics & lack of commitment for sustainable intersectoral partnership & community involvement in malaria control.

According to the National Vector borne Disease Control Programme, Govt. of India, no state in India was free from malaria and has clusters of villages from where cases were being reported regularly. The problem in these states persisted due to ecological and geographical conditions favourable for spread of malaria in addition to water management deficiencies. About 10% of the total cases of malaria were reported from the urban areas on account of planned and unplanned human activities like proliferation of developmental projects and associated construction activities, population migration, inappropriate water storage and disposal of junk/reused containers, tyres, vessels etc.

Kondrashin (1992) while reviewing the malaria situation in the WHO South East Asia Region analyzed various factors such as levels of malaria endemicity, seasonality of transmission, vector density and bionomics, transmission dynamics. It was observed that forests, developmental projects sites and border areas should be accorded highest priority in all malaria endemic countries of the region. In some countries of South East Asia, the plains, irrigated and urban areas were also identified as malaria priority areas.

Infants, young children and pregnant women were identified as malaria high risk groups followed by mobile population groups particularly those engaged in forest related economy, fishing, industrial and construction work, etc. in all counties of this region. According to him, analysis of the malaria situation state wise in India revealed that there was a correlation between the magnitude of malaria in a state and the proportion of people below the poverty line. The mobility of poor from rural to urban areas also resulted in alteration of malaria pattern, including urban malaria, occupation related malaria and drug resistant malaria.

Sharma (1996) in his studies on Re-emergence of malaria in India opined that the fact that the National Malaria Eradication Program concentrated only on rural areas, ignoring the problem of urban malaria, was one of the factors leading to a resurgence of malaria in the 1970s. Several types of population movement contributed to malaria transmission in India. First, circulation from stable rural malaria areas to unstable urban areas had firmly established malaria transmission in urban areas. Then, after the National Malaria Eradication Program, rural areas became free of endemic malaria but were receptive, so circulation from urban areas back to rural areas reintroduced malaria transmission. Changes in vector behaviour (exophilic and exophagic behavior limiting the effectiveness of spraying), vector resistance to insecticides, and increasing drug resistance, especially in *P. falciparum*, also played a role. Population movement also contributed to drug resistance, with people of different immune status moving from endemic to non endemic disease areas, accelerating transmission of resistant strains.

Prasad et al. (1992) carried out studies to investigate the probable cause of malaria epidemic in Baniyani village of District Farukhabad. Their investigations revealed high incidence of malaria with only *P. falciparum* cases and the occurrence of deaths during the transmission season i.e. July to November along with increase in fever cases, high rate of splenomegaly spelling in children coupled with high infant parasite rate confirmed the ongoing active transmission of the disease in the village. According to them, the cause of the epidemic was breakdown in surveillance, faulty diagnosis of cases, non-spraying of insecticides for the previous ten years and immigration of the people from the village to malarious areas of Madhya Pradesh to bring 'bidi' leaves for making 'bidis' as one of their occupation along with illiteracy and poor socio-economic conditions of the village.

Dev et al. (2003) reviewed the epidemiological situation of seven states of Northeastern India namely Assam, Arunachal Pradesh, Meghalaya, Manipur, Mizoram, Tripura and Nagaland which are malaria endemic and reported deaths associated with focal outbreaks of the disease. The study revealed that this region as a whole constituted only 3.96% of the country's population but accounted for nearly 10% of *P. falciparum* malaria cases and 20% of the total deaths recorded in India. They attributed factors such as drug resistant Pf malaria, delayed diagnosis due to non–availability of health facilities in interior villages/hilly areas and tribal belts, delayed referral from periphery due to difficult communication, late treatment of cases due to non–availability of drugs in interior places and the environment conducive to mosquito proliferation, survival and longevity as reasons for the significantly higher mortality and morbidity in these states. According to the WHO (SEARO), there being poor

health infrastructure at the periphery, many cases go undetected or unreported due to lack of blood examination reports and also because of the fact that 8% to 33% of the ethnic communities were asymptomatic carriers of the parasite.

Martens and Hall (2000) carried out studies on population movement and malaria transmission. According to them, population movement for a number of reasons such as environmental deterioration, economic necessity, conflicts and natural disasters has contributed to the spread of malaria disease. Failure to consider this factor contributed to failure of malaria eradication campaigns in the 1950s and 1960s. The movement of infected people from areas where malaria was still endemic to areas where the disease had been eradicated led to resurgence of the disease. As people move, they increase their risk for acquiring the disease through the ways in which they change the environment and through the technology they introduce, for example, through deforestation and irrigation systems. Such activities create more favorable habitats for Anopheles mosquitoes; at the same time, workers may have increased exposure to the vector. Furthermore, people inadvertently transport infectious mosquitoes to malaria-free areas, reintroducing the disease. Population movement was also increasingly implicated in the spread of drug resistance in malaria. Their findings indicated that identifying and understanding the influence of these population movements would improve prevention measures and malaria control programme.

Poveda et al. (2001) carried out studies on coupling between annual and El Nino/Southern Oscillation (ENSO) time scales in the malaria-climate association in Colombia. Their results presented evidence that El Nino phenomenon intensified the annual cycle of malaria cases for P. vivax and P.

falciparum in endemic areas of Colombia, as a consequence of concomitant anomalies in the normal annual cycle of temperature and precipitation. During El Nino events (Interannual Time Scale) the timing of malaria out breaks did not change with the annual cycle but the number of cases intensified. Such anomalies associated with a consistent pattern of hydrological and climatic anomalies i.e. increase in mean temperature, decrease in precipitation, and increase in dew point and decrease in river discharge favoured malaria transmission. Seasonal statistical correlation according to them was helpful in forecasting outbreaks & for developing health early warning systems of meteorological conditions conducive to malaria outbreak.

Devi & Jauhari (2006) carried out study on climate variables and malaria incidence in Dehradun in Uttaranchal. The study aimed to find out the effect of climatic factors on malaria incidence with particular emphasis to capture the essential events as a result of climatic variability. Their results revealed higher positive correlation of association was found between monthly parasite incidence and climate variables i.e. temperature, rainfall and humidity. However highest significant correlation was found between rainfall and malaria incidence ($r=0.718$, $p<0.0001$) when the data was staggered to allow a lag of one month. In case of maximum temperature, highest correlation was found with two month lag period and for relative humidity was found during zero period lag. This indicated that rainfall seemed to play a more important role in the transmission of the disease then temperature did. Several workers from different places have found similar results (Penget et al. 2003; Greenwood et al. 1993 and Ramasamy et al. 1992). On the basis of correlation analysis, they concluded

that the climatic variables that predicted the presence or absence of malaria were likely to be best suited for forecasting the distribution of malaria disease.

Sensitivity to commonly used antimalarials

Sehgal et al. (1973) reported for the first time chloroquine resistance in *P. falciparum* from Manjha in the Karbi Anglong District in 1973 and from Nowgaon in 1974 in the northeastern state of Assam. More cases were detected in the next 3-4 years in Assam, Arunachal Pradesh, Mizoram, and Nagaland. Although foci of resistance to chloroquine are present in the entire country, the problem is more pronounced in areas with intense *P. falciparum* transmission like the northeastern states and Orissa and in areas where there is intermixing of the population, such as project areas, including construction sites, in big metropolitan areas, and along international borders.

Although the available data on sulfadoxine-pyrimethamine (SP) resistance is limited, it seems that efficacy for this drug is within acceptable limits, except in limited areas such as the Indo-Myanmar border in Arunachal Pradesh and some parts of Assam and West Bengal NVBDCP (2002) and Mohapatra et al. (2003).

Only limited reports of chloroquine resistance in *P. vivax* are available from India. Recently, 16% RI and 6.7%, RII resistance in *P. vivax* was reported in 75 patients in Bihar in a study conducted by Singh R.K. (2000). In addition, multi-drug resistance has also been reported by Kshirsagar et al. (2000). Contrary to this, Nandy et al. (2003) observed in a study in West Bengal and Orissa during 1998-2001, 100% cure rates by Day 7 in 480 P. vivax malaria patients. Incidentally, these areas, where *P. vivax* is still sensitive to chloroquine, have high drug pressure and chloroquine resistance in *P. falciparum*. Similar findings

were confirmed in a therapeutic efficacy study with chloroquine in vivax malaria in Gautam Budh Nagar (Uttar Pradesh) in the north, Navi Mumbai (Maharashtra) in the west, and Chennai (Tamil Nadu) in south India in 287 patients in 2002. The curative efficacy of chloroquine was 100% in these patients with vivax malaria. Rapid parasite and fever clearance was observed in all cases, and the drug was well tolerated Valecha et al. (2006). From the data available thus far, it is evident that the problem of drug resistance in *P. vivax* is not of major concern; however, one needs to be vigilant because *P. vivax* produces a relapsing type of infection and is a predominant species in India.

Malaria Control Strategies

According to the report of WHO study group (1995) the four basic elements of the global malaria control strategy for all endemic countries are (a) to provide early diagnosis and prompt treatment (b) to plan and implement selective and sustainable preventive measures including vector control (c) to detect early, contain or prevent epidemics, (d) and to strengthen local capacities in basic and applied research to permit and prompt the regular assessment of a country's malaria situation in particular the ecological, social and economic determinants of disease.

Earlier in 1992 WHO had outlined malaria control strategy for all endemic countries of the South East Asia Region (SEAR). The objective of this malaria control strategy was to prevent deaths, reduce morbidity and reduction in social & economic loss. It had essentially all the elements of the global strategy of malaria control outlined above.

According to the National Vector Borne Diseases Programme (NVBDCP), Government of India, strategies for malaria control in rural areas of

India are (a) early detection and prompt treatment (EDPT) through village based community volunteers such as Drug Distribution Centres (DDCs), Fever Treatment Depots (FTDs) or Malaria Link Volunteers (MLVs) (b) Integrated vector management by IRS in selected project populations at high risk of malaria, promotion of insecticide treated bed nets (ITBNs) through free or subsidized supply to Blow Poverty Line (BPL) population living in remote, inaccessible areas with high risk of malaria, as well as insecticide treatment of community owned bed nets, use of larviourous fish, environment and minor engineering methods (c) capacity building of the medical and non-medical personnel as well as involvement of inter-sectoral partner organizations, community volunteers for imparting knowledge & strengthening skills in respect of prevention and control initiatives including innovative technologies (d) IEC to enhance awareness among members of the target communities & health care service providers about cause, prevention and treatment of malaria, availability of facilities, (e) Epidemic preparedness and response by having rapid response teams in the event of an outbreak of malaria, (f) Monitoring and evaluation of programme activities including effective utilization of computerized management information system (CMIS).

The current strategy for malaria control in Goa includes early detection and complete treatment (EDCT) of malaria cases, selective mass suppressive treatment (MST) in outbreak areas, intensified anti larval measures with larvicides, Abate (Temephos), Baytex (Fenthion)/MLO (Mosquito larvicidal oil) and introduction of larvivorous fish in mosquito breeding habitats, etc., selective anti-adult measures i.e. thermal fogging with pyrethrum and Ultra Low Volume (ULV) fogging of synthetic pyrethroids in the affected areas aimed at knocking

down infected adult females and finally health education aimed at behavioural change and community participation (Source: NVBDCP, Goa).

Covell, (1928) investigated in to malaria problem in Bombay and recommended various preventive measures to tackle the problem. He recommended that (1) all the permanent breeding places of *An. stephensi* such as wells should be hermetically covered, (2) all cisterns must be of iron or reinforced concrete, (3) corrugated iron sheets should not be permitted as covers for any cisterns, (4) water gauges necessitating an aperture in the roof or side of a cisterns must be prohibited, (5) man hole lids to be well fitting the pattern approved by the Municipality, (6) no inlet pipe to enter a cistern through the man hole, large cisterns to be covered with a double flange secured by bolts through the cover, (7) all unserviceable cisterns to be removed, (8) malaria sub inspectors inspect every cisterns in their area on a specified day of every month, (9) in case of non mosquito proof cisterns, one weeks notice to be given to repair the defect, if no action has been taken within a week, the Municipal Commissioner should permit the work to be carried out immediately and recover the cost from the owner, (10) all garden tanks to be demolished or filled in and converted into flower beds if so desired, (11) no fountains to be permitted, except those which were constructed such that no water remains, when fountain has ceased playing, (12) in case of reinforced concrete buildings, all builders and contractors engaged be required to add a sufficient quantity of saponified cresol (larvicide) to all water used to keep cement concrete wet till the water turned distinctly milky, (13) A register of the number and location of all buildings under construction should be maintained in the office of the Special Malaria Officer of the Municipality so that he can at any

time make a personal inspection of them, (14) all water receptacles including those used for soaking bricks must be inspected daily after use and turned upside down, (15) during the monsoon, the temporary breeding places such as yards containing machinery and scrap iron should be levelled and adequately drained and the machinery, etc., stacked so that it provides no hollow in which rain water collects, (16) unfinished and abandoned buildings should have each floor levelled so that water may no longer collect and any depression beneath the building to be filled in, (17) roof gutters and terraces in case of new buildings to have proper grading so that no water collects and in old buildings to be compulsory swept once a week, (18) the presence of discarded tins, earthenware vessels, etc. on roof or in yards of compounds found to contain mosquito larvae should constitute an offence punished by law, (19) all the open drains to be covered and properly graded, the provision of adequate legal powers to enforce the necessary measures and which will apply to private individuals as well as the Government bodies, (20) the use of larvicidal fish and (21) lastly free distribution of drugs to be administered systematically & under strict supervision.

Sharma et al. (1985) carried out field trials for the control of mosquito breeding in their natural habitats using EPS beads (Expanded Poly Styrene Beads) in the villages of Nadiad taluka of Gujarat. They found that the application of EPS beads in biogas plants, unused wells and septic tanks eliminated culicine mosquito breeding on a semi-permanent to permanent basis.

Rao (1984) and Sharma (1985) have reported that in Delhi, rural areas support profuse breeding of *Cx. quinquefasciatus* along with *An. culcifacies* and

An. stephensi in wells. On the other hand, Seetharaman et al. (1975) and Batra & Reuben (1979) have reported that in Salem and Hyderabad, *An. stephensi* breeds mainly in wells and maintains malaria transmission throughout the year. Since, EPS beads were safe and one application lasted for a very long time, its application in wells could greatly reduce the anopheles mosquitoes breeding in wells and also would reduce or eliminate the disease transmission.

Chakravorthy and Kalyanasundaram (1992) carried out studies to find the speed of selection for resistance to permethrin in the adults of *An. stephensi* and also evaluated the extent of cross resistance to other pyrethroids and DDT and multiple resistances to malathion. They recommended change of insecticides in vector control programmes with different modes of action in situations where the vector mosquitoes developed resistance against pyrethroids or organochlorine insecticides as a high level of resistance to permethrin and cross resistance to other pyrethroids and DDT was observed.

Biswas et al. (1992) carried out a longitudinal study on breeding survey of *An. stephensi* in an area of Calcutta and observed that the water storage practices among the city dwellers were mainly responsible for *An. stephensi* breeding in intra and peridomestic containers which further supported malaria transmission in the city. According to them, an effective solution for the reduction of the breeding sources of the vector species was through the implementation of bye-laws and by generating massive public awareness.

Ansari et al. (1992) carried out studies on Esbiothrin impregnated ropes as mosquito repellent in two villages in Ghaziabad district which had high density of *An. culicifacies.* Their findings revealed that the smouldering Esbiothrin impregnated ropes @ dose of 500ppm prevented entry of more than

95% of the *An. culicifacies* and nearly 96% of total mosquitoes in the open rooms of the houses and in the cattle sheds respectively. The impact of the ropes was more pronounced on the biting rate of mosquitoes. According to the authors, indoor and outdoor human baits made to seat at a distance of about 3 metres from smouldering esbiothrin ropes did not experience many bites from *An. culicifacies*. They recommended that Esobiothrin impregnated ropes could prove to be an effective and cost effective method of personal protection measures in the rural areas under the influence *An. minimus, An. fluviatilis* and *An. culicifacies* as well in labour population in urban slums as compared to the high cost of repellents viz: oils, creams, coils/mats which do not provide adequate protection against mosquitoes. Similar studies were also carried by earlier workers using ropes impregnated with deltamethrin by Sharma et al. (1989) and Ansari et al. (1990).

Singh et al. (1993) undertook studies to observe the mosquito collections by (CDC) light traps in 4 tribal villages of Madhya Pradesh, to assess the feasibility of using impregnated bed nets for controlling malaria in the area. The hamlets were located on hill slopes or at the foot of hills and were scattered with natural barriers of thick forest and rocky streams. The analysis of the all night mosquito collection data in human dwellings (indoors) in each village showed that peak activity for *An. culicifacies*, the predominant vector species were between 19.00 and 21.00 hrs. However, their findings highlighted the fact that as the feeding of *An. culicifacies* started soon after dusk, the use of impregnated bed nets for control of malaria was not feasible in that area against that particular species.

Prasad et al. (1993) carried out studies on the control of mosquito breeding through *Gambusia affinis* in the nursery and paddy fields. They identified six anopheline species, viz; *An. culicifacies*, *An. annularis*, *An. subpictus*, *An. nigerrimus*, *An. barbirostris* and *An. aconitus* along with Culex and Aedes species breeding in the rice fields. Results of their study revealed that, *G. affinis* survived well in submerged rice fields and provided mosquito larval control to the extent of 87.8%. However, moderate larval control was achieved in those rice fields, which exhibited intermittent drying up leading to formation of pools, puddles, etc. They suggested that though this method had limitations, mosquito larval control in the rice fields could be achieved to a good extent through larvivorous fish.

Lopes et al. (1994) undertook a massive campaign for the promotion of bioenvironmental control of malaria in Goa through the Junior Red Cross Counsellors volunteers (a NGO), supported by school authorities, the education department, religious and business institutions. The programme first of its kind was introduced in the school curriculum in Goa to reach the community through the students and teachers so as to involve people in the vector and disease control process. This target oriented health education campaign resulted in creating awareness and motivation in the community to prevent the disease and take various remedial measures

Kumar et al. (1994) carried out studies on community participation and Intersectoral Cooperation in Malaria control in Panaji, Goa. Various government and non governmental agencies actively participated in malaria control activities viz., weekly survey of breeding sites, mosquito proofing of lids of water cisterns, introduction of larvivorous fish in the wells, masonry tanks,

fountains, pit wells, drains, etc., application of biolarvicides in masonry tanks, curing and rain water collections in the construction sites, source reduction measures and health education campaigns through exhibitions, health camps, door to door visits to residential and construction sites, distribution of pamphlets, training programmes to disseminate information in the community about various malaria prevention and control measures. The results showed a marked decline in the overall positivity of intra-domestic breeding sites for all mosquitoes in general including *An. stephensi* in 1991 as compared to 1990. Earlier, in the area of vector borne diseases, the community based programmes have not only been framed but also applied successfully in India at various locations such as Nadiad in Gujarat (Sharma and Sharma 1989), Hardwar (Dua et al. 1988), Mandla (Singh et al. 1989), Shahjahanpur, Madras and Rishikesh (Sharma 1991 b).

In another study, Kumar et al. (1994) had also demonstrated control of malaria utilizing *Bacillus sphaericus* (spherix formulation) against *An. stephensi* in the urbanised area of Panaji. The spherix spraying in the vector habitats showed sharp reduction in habitat positivity and immature densities of *An. stephensi* in the treated areas. The impact was very much pronounced during the monsoon months from May to July which was also the peak Plasmodium transmission period in Panaji. The study proved that *B. sphaericus* strain proved to be a useful bio-control agent for the control of vector mosquito, *An. stephensi* and also on the overall incidence of malaria.

Sharma et al. (1996) carried out studies on impact of Deltamethrin spraying on malaria transmission in Rameshwaram Island in Tamil Nadu. This Island was endemic for malaria since several decades. *An. culicifacies* was the

main vector in the area. The impact of spraying deltamethrin 2.5% w.d.p @ 20mg/m^2 and malathion 25% w.d.p. @ 2gm/m^2 was carried out. The monitoring of entomological and parasitological indices revealed that due to deltamethrin spray, malaria transmission was effectively interrupted and a significant reduction in malaria cases was achieved. *P. falciparum* also showed a significant reduction, whereas in the malathion areas for comparison, reduction in malaria cases or in Pf cases was not recorded. Similar observations were recorded by Ansari et al. (1986) and Sharma (1988). The study thus indicated that the conventional residual spray having failed, the change of insecticides like deltamethrin should be considered for control of malaria in the area like Rameshwaram where malaria has been a major public health problem.

Kumar et al. (1997) in their study on dynamics and control of *An. stephensi* transmitted *P. vivax* and *P. falciparum* malaria in the coastal belt of Goa, since mid eighties revealed that the vector breeds in wells, sumps, overhead tanks, masonry tanks, waterlogged basements, curing waters, rain water pools, ornamental fountains and a variety of intradomestic water containers. Further, *An. stephensi* build-up starts in April with the rise in temperature and peak populations are observed in June or July depending upon the onset of south-west monsoons. A natural decline in vector populations occurs from mid August as the rains subside. Following the spurt in the vector populations, a very active transmission is witnessed and peak malaria incidence is observed from May to October each year. The incidence however, declines from November to February with the lowering of temperature and humidity. Based on malaria transmission dynamics, a time frame intervention model for *An. stephensi*

control was prepared and tested in the Candolim PHC of Goa in 1995. The intervention measures included selective spraying of *Bacillus thuringiensis* var. *israelensis* and introduction of indigenous larvivorous fishes, *Aplocheilus blocki*. As a result, malaria incidence declined to the extent of 81.6% in the PHC areas with the reporting of 263 cases in 1995 as compared to 1431 in 1994. *P. falciparum* cases were not encountered after March 1995. This intervention model for the control of *An. stephensi* transmitted malaria was recommended not only for Goa but for similar situations in India.

Sharma and Srivastava (1997) carried out studies on role of remote sensing (RS) and geographic information system (GIS) in malaria control. One study explained the application of RS on the mosquito production in the Sànjay Lake and surrounding areas in Delhi and its usefulness in assessing relative mosquito abundance in large water bodies. The second study was carried out in the Kheda Village in Nadiad Taluka of Gujarat, provided the application of RS and GIS in analyzing receptivity and vulnerability to malaria. Their results showed that malaria annual parasite incidence (API) indicated a relationship with water table (37%; p=0.05),) followed by soil type (26%; p=0.04) irrigation (24%; p=0.02)) and water quality (21%) contributed significantly to malaria receptivity. Based on GIS analysis, they suggested location specific malaria control strategy to achieve cost effective control of malaria on a sustainable basis.

Kumar et al. (1998) carried out field trials of biolarvicide *Bacillus thuriengiensis* var. *israelensis* strain 164 and the larvivorous fish, *Aplocheilus blocki* against the vector *An. stephensi* for malaria control in Goa. The study was conducted in highly malaria endemic Candolim Primary Health Centre.

Their results demonstrated that the biolarvicide *Bacillus thuringiensis israelensis* 164 (Bacticide formulation) in combination with the indigenous larvivorous fish *A. blocki* proved highly effective. This one year intervention field trial led to the containment of the vector *An. stephensi* and reversed the upward trend of malaria in the malaria affected PHC to the extent of 80.5% when the incidence of 1995 was compared with 1994 as well as the near elimination of *P. falciparum* malaria in 1995, which suggested that the intervention measures had successfully curtailed transmission of malaria in this endemic PHC.

Sumodan and Kumar (1998) carried out studies on the distribution and feeding efficacy of indigenous larvivorous fishes of Goa. Fifteen species of larvivorous fishes from different parts of the state were collected and tested. They studied their natural distribution and density. In laboratory experiments, they found that the daily average consumption of mosquito larvae varied between 62.5 & 736 per fish. On the basis of their larvivoracity and extensive distribution, *Aplocheilus blocki* and *Rasbora daniconius* were recommended for use in malaria control in Goa.

Yapabandara et al. (2001) carried out studies on control of malaria vectors with the insect growth regulator pyriproxyfen in a gem mining area in Sri Lanka. There were many shallow pits dug by gem miners breeding malaria vectors *An. culicifacies* and *An. subpictus*. With the help of local volunteers and on the basis of a year's pre-intervention data, the villages were stratified into four with high levels of malaria transmission and the other four with lower transmission. Within each stratum, two villages selected randomly and all the gem pits and river bed pools were treated with pyriproxyfen @ 0.01 mg a.i./litre. The intervention caused significant reductions in the adult populations of *An.*

culicifacies and *An. subpictus*. Similarly, incidence of malaria was reduced in the intervention villages to about 24% (95% C.I.; 20-29%) of that in the controls. Prevalence of parasitaemia also declined significantly. Their study indicated that with active community participation, the vector control by a highly active and persistent insect growth regulator was a very effective means of malaria control.

Yeya (2001) in his report entitled 'Malaria vector control in Africa: Strategies and Challenges' states that indoor spraying of insecticides in high mortality endemic and drug resistant areas was implemented and yielded good results in Africa. Other vector control strategies adopted were personal protection methods based on Insecticide Treated Nets (ITNs) and curtains which provided 30 to 60% reduction in malaria morbidity. However, according to him, environmental control if used in urban and periurban areas with community participation and intersectoral collaboration were useful in vector control.

Mishra (2003) took up a hospital based study of malaria in Ratnagiri district of Maharashtra. The results revealed the prevalence of both *P. vivax* and *P. falciparum* infections. Adults were found more vulnerable to the disease in the area and the working group (20-40 years) was more affected, due to malaria. Detailed epidemiological studies indicated Pf transmission was high in new talukas of this district. To improve the malaria situation in the district it was recommended that early detection and prompt treatment along with community awareness. Also mosquito control operations were needed especially before the onset of rainy season as malaria prevalence was high during the rainy season in this area.

Dev et al. (2003) have recommended prevention and control measures based on local transmission pattern in the North eastern region of India facing persistent malaria transmission due to the prevalence of malaria vectors, *An. minimus*, *An. fluviatilis* and *An. dirus*. *P. falciparum* is the major malarial infection in most of the North eastern states. Based on local transmission pattern, they proposed integrated approach for vector control through insecticide impregnated mosquito nets backed by health education, inter-sectoral co-operation and biological control coupled with early case detection and complete treatment. These according to them could provide a long lasting solution for malaria control. Similar strategies were also recommended by Jana-Kara et al. (1985) and Kondrashin (1997).

Curtis et al. (2003) in a study on insecticide treated nets carried out trials in Assam and Tanzania and found that if a whole community was provided with treated nets, so many mosquitoes of anthropophilic species were killed by contact with the nets that the density and sporozoite rate of the vector population was reduced. Their data showed that there was less malaria morbidity in both the areas provided with impregnated mosquito bed nets than those without the nets. This was attributed to the mass effects of the nets.

Ansari et al. (2004) carried out laboratory and field trials of pirimiphos-methyl (50% EC) an organophosphorus insecticide against the immatures of Anopheles and Culex species in different breeding habitats in District Ghaziabad (U.P.) and Goa. Presently in India, temephos and fenthion are used as larvicides in fresh and polluted waters respectively. Since use of the same larvicide's precipitated resistance, an alternative chemical primiphos-methyl was evaluated. The results showed that larvicidal formulation of pirimiphos-

methyl was found to be relatively more effective against immatures of Anopheles i.e. *An. stephensi* and *An. culicifacies* than Culex species. However, the study also suggested that doses higher than 0.25 ppm were not safe to non target species, i.e. the larvivorous fish which is a limitation of this compound.

Matta et al. 2004 carried out a hospital based study for assessment of knowledge about malaria among patients reported with fever at Safdarjang Hospital, New Delhi. Data on socio demographic profile, history of fever & health seeking behaviour of 200 fever cases were recorded. The findings revealed that about 83% of fever cases did not approach the doctor even after three days of onset of fever symptoms, 25.5% tried self medication and 20.5% approached chemists for treatment. Their results indicated that knowledge about cases and symptoms of malaria was poor even in persons residing in urban localities and proper health education was required for successful control of malaria. Information, Education and Communication (IEC) activities were suggested to create awareness among the community

Panda and Mohapatra (2004) have highlighted malaria situation in the context of malaria eradication in India. The manmade natural destructions such as concretizations, water storage for future consumption, irrigation etc., sometimes resulted in the emerging of malaria in non endemic areas. The findings revealed the fact that besides other factors it is essential to bring about the changes in the health seeking behaviour among the rural inhabitants and especially among the migrant labourers, who are frequently travelling from one direction to another carrying the malaria parasite with them. According to them, the control strategy will be fruitful only when people understand the problem of disease transmission and its management and also realize the seriousness of

the disease. The health workers have to be oriented to malaria properly along with the community for better malaria control.

Sreehari et al. ((2007) evaluated the bioefficacy of PermaNet® in both the laboratory and field against *Anopheles culicifacies* and *An. stephensi*, major malaria vectors in India. Contact bioassays were carried out after repeated washings and ring net bioassays to determine the median knockdown time of mosquitoes. Three villages were selected for the field trial: in the 1st village PermaNets® were distributed, in the 2nd village untreated nets were distributed, and the 3rd village was kept as a control. Entomological data was collected using standard procedures. The PermaNet® contact bioassays showed high mortality (>80%) even after 20 washes against both the vector species. The median knockdown time of *An. culicifacies* and *An. stephensi* was 392 and 480 sec when exposed to fresh PermaNets® and 472 and 986 sec when exposed to PermaNets® that had been washed 20 times, respectively. Their studies indicated that PermaNets® showed high efficacy in reducing the person-vector contact as evidenced by reduced person-hour density in the PermaNet® village.

Chapter 3: MATERIAL AND METHODS

The present study was undertaken to understand the epidemiological intricacies in the transmission dynamics of malaria and to identify the risk factors responsible for the enhanced receptivity and vulnerability to malaria in Goa during the past about two decades. This is a detailed epidemiological study carried out in both rural and urban areas of Goa from 2002 to 2007.

A comparative analysis particularly of epidemiological data has also been done with the prior period from 1990 to 2001. Prior to the present study, small scale epidemiological studies have been carried out. The inter relationship of the different factors and parameters pertaining to the risk of malaria has been studied during the present investigation. The epidemiological and entomological data have been collated and new data generated so as to identify the key factors responsible for the enhanced receptivity and vulnerability and therefore sustained malaria transmission in the last decade in Goa with the aim to recommend suitable intervention strategies for control malaria. For this study, material used and methodology were as follows.

Literature Search:

The information and literature on malaria in Goa for the last one Century, of other malaria endemic States of India and other affected countries was collected from various sources listed below.

1. Archives of India, Goa.
2. Central Library, Goa.
3. National Vector Borne Disease Control Programme (Government of India & State Government of Goa).

4. National Institute of Malaria Research, Field station – Goa.

5. Xavier Centre of Historical Research, Goa.

6. Goa Research Institute for Development.

7. Goa University.

8. World Health Organisation reports.

9. Books and Journals.

10. Electronic data bases.

11. Print media/Local newspapers, etc.

The publications in Portuguese language were translated in English with the help of expert translators. Besides published work, reports on malaria situation in Goa and other states of India and malaria endemic countries of the world was collected from books, technical reports and other documents related to malaria. The scientific journals accessed were Indian Journal of Malariology, Journal of Communicable Diseases, Bulletin of Indian Society of Malaria and Communicable Diseases, Bulletin of Vector borne Diseases and Journal of Vector borne Diseases available in NIMR library and NVBDCP collection. Large numbers of foreign journals were also accessed from the internet and print outs of the relevant publications in free access journals were taken and used in the study. The published literature in both Indian and International journals were also collected from the National Institute of Malaria Library and collections.

Study area:

1. Physical Features

The vital information on Goa with respect to the physical maps (physiography), terrain features and soil type distribution was collected from the Directorate of Agriculture, Government of Goa. A series of maps of Goa were collected showing following features.

1. Goa Administrative map showing state and 'Taluka' Boundaries, Rail & Railway lines, Rivers and water bodies.
2. The physiographical features of different areas.
3. Geological map of Goa.
4. Rainfall zones in Goa.
5. The different soil types in Goa.
6. Soil suitability for various crops.
7. Present land use pattern with respect to different type of crops, forest, barren areas and built areas.
8. The soil available water capacity from very low to medium type.
9. Soil drainage from poorly drained to excessively drained soils.
10. Surface soil texture ranging from sandy to silt clay.
11. Land irritability in different areas of Goa.

These coloured maps were photocopied and computerised. A correlation between malaria prone areas and the different geographical features, soil types which are conducive for malariogenic conditions created and also due to the various developmental activities was studied.

2. Meteorological data

The Meteorological data for the state of Goa from 1980 to 2007 was collected from the Meteorological Observatory, Government of India, at Panaji.

The month wise data collected was on following meteorological parameters.

1. Temperature: maximum and minimum.
2. The percentage of relative humidity observed at 5.30 and 23.30 hours.
3. Month wise rainfall (mm) pattern for all years and number of rainy days/ month.

This data was computerized month and year wise. The climate data was analysed to study relationship of each weather parameter viz, Rainfall, Humidity and Temperature with epidemiological and entomological data to identify the key climatic factors influencing transmission of malaria.

3. Developmental Activities

A detailed survey of construction projects in the state of Goa, particularly in the capital city, Panaji was carried out. Panaji was chosen for the study being one of the major high risk areas and also because of the fact that it contributes to 50% or more to the malaria problem in Goa and here the transformation from traditional houses to multi storey complexes has completely changed the sky line of the city (Fig. 3.1 to 3.3).

4. Migrant Population

The district and 'taluka' wise distribution of the population of construction workers for North Goa and South Goa was collected from the Census Department at Panaji. The information on the migratory population i.e., persons engaged in construction/developmental activities in Goa was collected through KAP studies carried out in Panaji. The data was analysed according to state of origin and the age and sex of migrant population engaged in construction activities (Fig. 3.4).

Fig. 3.1 Showing traditional houses of Goa in the foreground and newly built multi storey structures in the background.

Fig. 3.2 Showing changed sky line of Panaji where extensive development has taken place since 1980s. Multi Storey buildings have replaced traditional houses.

Fig. 3.3 A typical Construction complex where water stagnations are responsible for breeding of *Anopheles stephensi.*

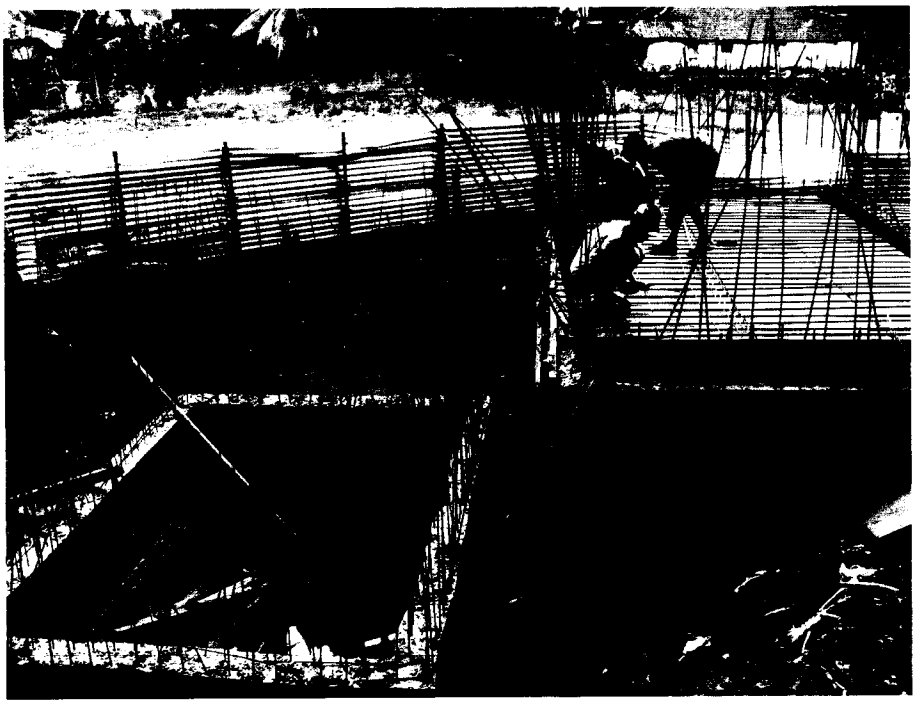


Fig. 3.4 Showing masonry tank under construction. Such water filled tanks are source for vector breeding.

Mosquito Population Surveys:

1. Geographical Reconnaissance of Breeding Habitats

A survey of the potential mosquito breeding habitats was carried out in Panaji area. Panaji has 15 wards. The habitats were surveyed in each ward and the information was recorded.

Various types of potential breeding habitats such as ground tanks, overhead tanks, underground tanks, sumps, wells, swimming pools, curing/ stagnant waters, rain water collections, bottles, tyres, coconut shells, grinding stones, drums, barrels, containers, drains, chambers and other miscellaneous habitats were surveyed in each ward and the information was recorded. The survey of the number of wells present in each ward of Panaji was carried out.

Depending on the nature and type of breeding habitats recorded, the breeding habitats were categorized into permanent and temporary breeding sites. The temporary breeding habitats were further separated into project associated potential breeding habitats and rain associated intra/extradomestic temporary habitats. The preferential breeding places of the vector species were also noted and recorded, on the basis of which the data was segregated into Anophelines, Culicines and Aedine breeding habitats. The information on geographical reconnaissance of the breeding habitats carried out was recorded in designed proforma-3.1.

PROFORMA- 3.1

GEOGRAPHICAL RECONNAISSANCE OF BREEDING HABITATS OF MOSQUITOES

SR. NO.	BUILDING NAME AND ADDRESS	BREEDING SITE	SURFACE AREA / DIA IN SQ. MT / MT	NUMBER ASSIGNED	CURRENT BREEDING STATUS	MEAN DENSITY/DIP	REMARKS

BREEDING SITE CODE: WL=WELL, OHT=OVERHEAD TANK, UGT=UNDER GROUND TANK, CON=CONSTRUCTION SITE, CW=CURING WATER, FT=FOUNTAIN, SUM=SUMP, COC=COCONUT SHELL, BOT=BOTTLE, BRL=BARREL, POT=POT, PON=POND, GT=GROUND TANK, CHM=CHAMBER, SCR=SCRAP, TYR=TYRE, ACP=AC PLANT, SPT=SEPTIC TANK, FBK=FIRE BUCKET, SLC=SLUICE VALVE CHAMBER, DRN=DRAIN, CTM=CONCRETE MIXER, CNT=CONTAINER, TWC=TERRACE WATER, LC=LIFT COLUMN WATER, DRN=DRAIN, SWP=SWIMMING POOL, POL=POLYTHENE SHEET, STW=STAGNANT WATER

2. Larval sampling

Larval sampling was done weekly in Panaji, Margao, Candolim/Calangute, Bicholim, Ponda, Vasco/Cortalim, & Sanguem areas covering various types of breeding habitats in different ecotypes in both urban and rural areas. The breeding habitats surveyed for immature stages of mosquitoes were both permanent and temporary habitats (Fig. 3.4 to 3.12). Under the temporary habitats both rain associated and those not associated with rains were covered. Among permanent sites covered were sumps, cement tanks, plastic/iron/asbestos tanks, overhead tanks, swimming pools, fountains, wells, while the temporary sites covered were, curing waters, stagnant rain waters, iron/plastic barrels, tyres, buckets, bottles, grinding stones, coconut shells, containers and drains. Dippers and plastic containers/bowls of 300 ml capacity, pasteur pipettes, galvanized iron buckets of 5 litre capacity, plastic/enamel trays, netted cloth, cotton, rubber bands, labels, pen were used during larval sampling and for the labelling of containers.

The larval sampling of mosquito population was carried out in overhead tanks, sumps, fountains, masonary tanks etc with the help of 300 ml dippers. Plastic containers/ bowls were used to draw samples from iron/plastic barrels. Pasteur pipettes were used to collect samples of immature from stagnant rain waters and curing water collections, narrow tyres and intradomestic containers. Galvanized iron bucket was used to sample larval stages of mosquitoes from the wells. The method used for collecting the larvae and pupae was as follows. The dipper was gently lowered into the water at an angle of about 45° until one side was just below

Fig. 3.5 Sampling of curing water in progress for mosquito immature stages which are brought to the laboratory and identified after the adults have emerged.

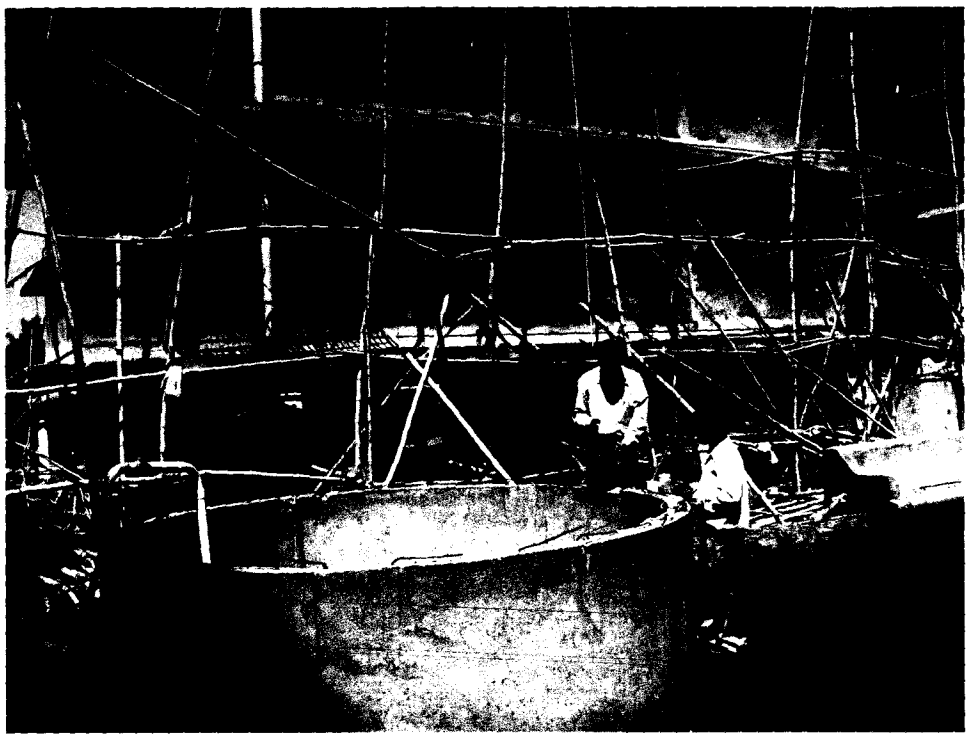


Fig. 3.6 Bore wells are a common site at the construction sites. They support breeding of mosquitoes especially the vector *An stephensi.*

Fig. 3.7 Larval samples are being collected from an Over Head tank.

Fig. 3.8 Wells are perennially suitable for vector breeding if devoid of larvivorous fishes.

Fig. 3.9 Sampling of immature stages in progress in masonry tank retained after construction work has been completed.

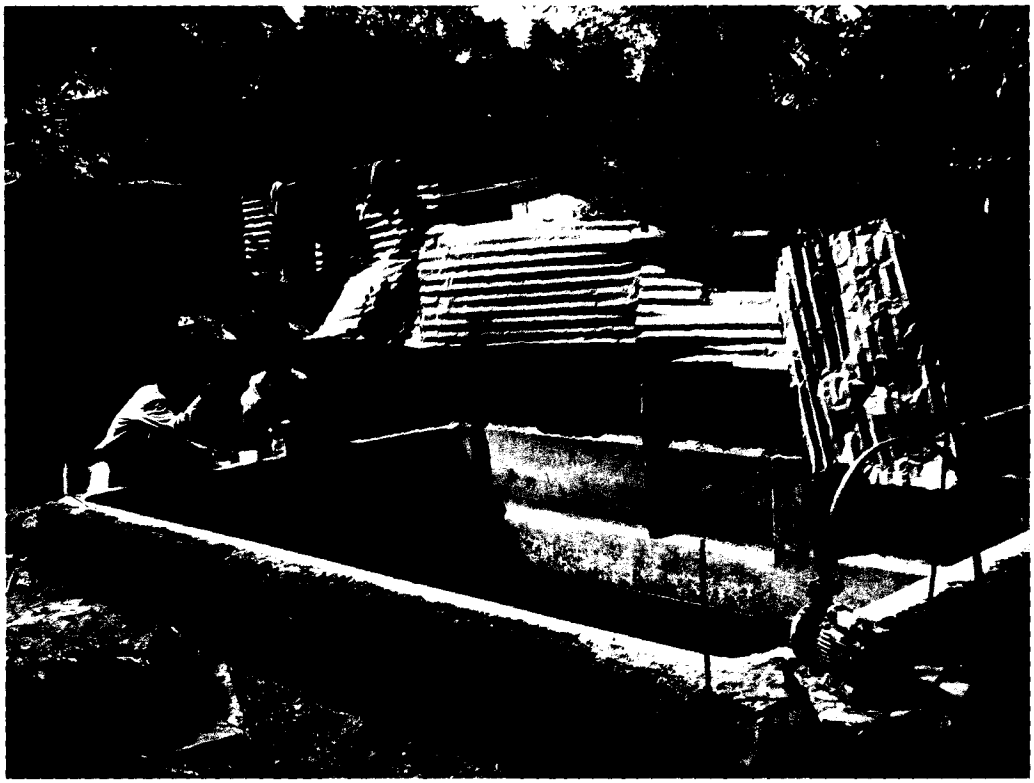


Fig. 3.10 Masonry tank being sampled at an active construction site.

Fig. 3.11 Swimming pool samples being carefully examined for smaller instars of mosquitoes.

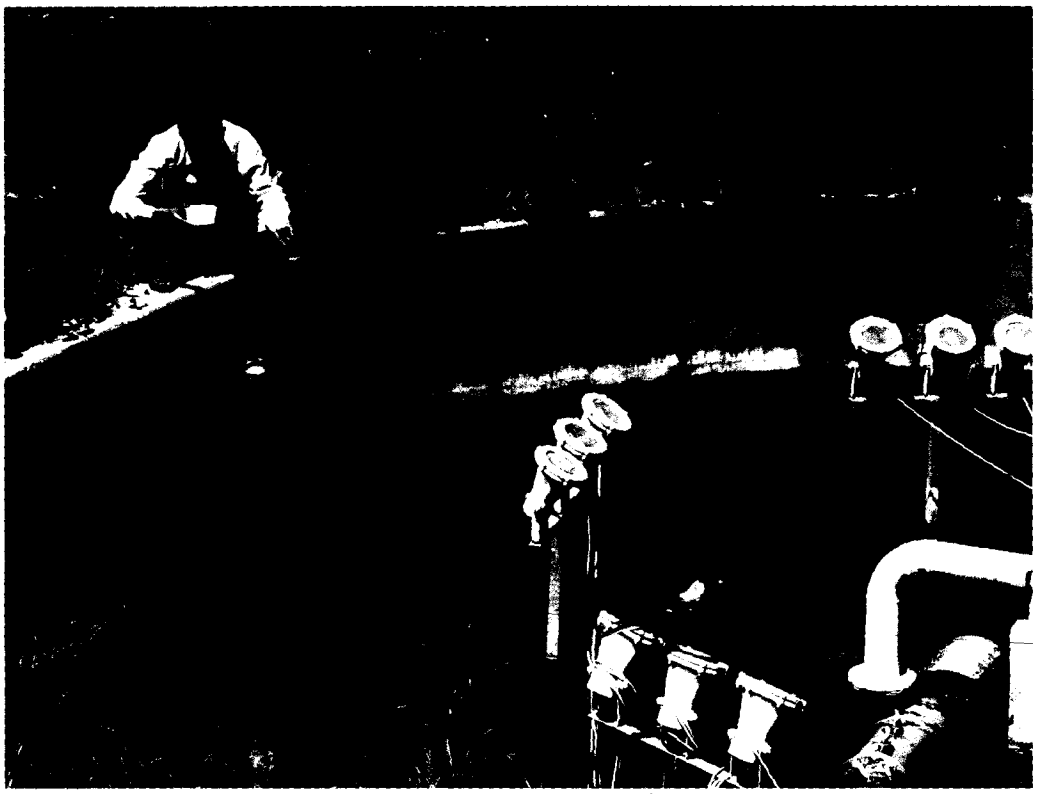


Fig. 3.12 Ornamental tank being sampled for mosquito immatures.

the surface so that water was drawn in along with the larvae and pupae. Care was exercised not to disturb water surface much so that immature stages of mosquitoes were least disturbed during the sampling. In this manner, five samples were drawn from each well, fountains, overhead tanks, masonary tanks, etc. 4 samples were drawn from the corners/sides and one from the centre.

The immature stages of mosquitoes i.e. larvae and pupae found in the various habitats were transferred in the plastic containers along with water. The containers were individually labelled showing date, place and type of breeding habitat. The containers were placed in trays and brought to the laboratory. The mouths of the containers were covered with a netted cloth to provide atmospheric oxygen to the immature stages during transportation. Care was taken to avoid jerks to the water in the containers to prevent injury and mortality to the immatures while transportation especially of the 1st and 2nd instar larvae.

In the laboratory, the mosquito immature stages were transferred in to the enamel or plastic trays of 5" width x 10" Length x 3" height containing tap water. The immatures were reared in the insectary at room temperature (25-30°C). A pinch of food (Cerelac™ powder) was provided to the growing larvae once daily till the development of pupal stage. Dead larvae were pipetted out and discarded on daily basis. Larvae and pupae were shifted to fresh water every 3rd day.

PROFORMA – 3.2

LARVAL SURVEYS OF MOSQUITOES IN GOA

DATE: PHC/UHC: VILLAGE/WARD:

Sr. No.	Breeding site	Dips	Anopheles				Culex				Aedes				Sample No.
			I+II	III+IV	P	T	I+II	III+IV	P	T	I+II	III+IV	P	T	
		D1													
		D2													
		D3													
		D4													
		D5													
		Total													
		D1													
		D2													
		D3													
		D4													
		D5													
		Total													
		D1													
		D2													
		D3													
		D4													
		D5													
		Total													

D1=Dip one, P=Pupa, T=Total number of larvae, I+II (1^{st} & 2^{nd} Instar larvae), III+IV (3^{rd}&4^{th}Instar larvae)

The pupae were transferred into plastic bowls containing tap water and covered with a piece of nylon net having a hole in the centre and plugged with cotton until the emergence of adults. This hole was kept plugged with cotton to prevent the emerged adult mosquitoes from escaping. The adult mosquitoes after emergence were aspirated and identified using the standard keys of Christophers (1933); Barraud (1934) and Puri (1954).

After every collection, the containers, bowls, dippers, pipettes and trays used for larval collections were washed and cleaned thoroughly with soap solution. The results of the emerged adults from various samples were were recorded in a designed proforma 3.2.

3. Adult mosquito collections

1. Adult collection with Mosquito Trap (Mosquito Magnet™)

The collection of adult mosquitoes was carried out in the problematic and non-problematic wards in Panaji city. A Mosquito trapping machine, LPG cylinder (15 kg), Octenol cartridge, collection bag, plastic vials, silica gel, zipper bags, marker pens were used. PRO model of Mosquito Magnet™ trap (MM™-Trap) was used for the sampling of adult mosquitoes. This trap has been developed by the American Biophysics Corporation, North Kingstown, Rhode Island, USA and is commercially available in India under the trade name Mosquito Magnet™ (Fig. 3.13a). The mosquito magnet was run on 15 kg liquefied petroleum gas (LPG) cylinder.

Functionally, the MM™-Trap mimics human breath and uses a counter flow technology, which enables it to emit a plume of carbon dioxide, heat and moisture, while the Octenol cartridge acts as a mosquito attractant. A small fan in the machine blows down the mosquitoes into a collecting bag and traps

them. In each locality, this trap was operated up to 9 times during the period of collection. The device was run round the clock to trap both nocturnal and diurnal adult mosquitoes in a removable bag.

Fig. 3.13a Mosquito Magnet Trap (Pro Model) used for the Mosquito Sampling

The 24 hours collection of adult mosquitoes was carried out in four localities (wards) of Panaji viz., Market area, Boca-de-Vaca, Miramar and Caranzalem. On each day of collection, the insects trapped were removed and put into labelled zipper bags, once at 10:00 hrs and then at 17:00 hrs and transported to the insectary. The mosquitoes were segregated from other insects and identified using the keys of Christopher's (1933); Barraud

(1934) and Puri (1954). The data was recorded locality and species wise in designed proforma 3.3.

PROFORMA-3.3

ADULT MOSQUITO COLLECTION WITH MOSQUITO MAGNET					
Place:		Collection Spot:			
Day/Night Collection		Time:			Date:
S. No.	Species	Male	Female	Total	Remarks
1	*An. stephensi*				
2	*An. subpictus*				
3	*An. vagus*				
4	*An. jamesi*				
5	*An. tesellatus*				
6	*An. peditaeniatus*				
7	*An. pseudojamesi*				
8	*An. subpictus*				
9	*An. barbirostris*				
10	*An. nigerrimus*				
11	*Ae. aegypti*				
12	*Ae. albopictus*				
13	*Ae. vittatus*				
14	*Cx. quinquefaciatus*				
15	*Cx. vishnui*				
16	*Cx. tritaeniorhynchus*				
17	*Cx. bitaeniorhynchus*				
18	*Cx. gelidus*				
19	*Cx. lutzia fuscanus*				
20	*Cx. pseudovishnui*				
21	*Mansonia uniformis*				
22	*Armegeres subalbatus*				

2. Collection of Landing Mosquitoes

Biting rhythm of mosquitoes was studied by capturing landing of mosquitoes on human baits from 18.00 to 06.00 hours. The study was conducted in 3 ecotypes viz., coastal, sub-coastal and hilly terrains covering both urban and rural areas of Goa (Fig. 3.14 to 3.17).

A preliminary survey was conducted to identify and select the villages/construction site areas for all night bait collections in both rural and urban areas of Goa. The inhabitants of the selected houses/ and construction sites were informed about the purpose of mosquito collections.

For the collection of adult landing mosquitoes during all night collections, a canvas handbag, sucking tube or aspirator, test tubes, cotton, pocket stop watch, rubber bands, torch (with spare bulb and batteries), mosquito forceps, test tube stand, plastic vials, silica gel, zipper bags, marker pens, note book, pen, were used.

Aspirator/Sucking tube used for capturing adult mosquitoes consisted of a plastic tube (approximately 15 inches long) attached to a flexible rubber tubing (about 20 inches long) and a small plastic or glass mouth piece (Fig 3.18). A fine wire mesh / gauze separated the plastic and rubber tubes to prevent mosquitoes from entering into the mouth while collecting.

For the sampling of adult mosquitoes, two mosquito collectors and a human volunteer (bait) were involved. The human volunteer participating in the all night collections was explained about his role as bait for capturing landing mosquitoes on his body which was needed to study the biting

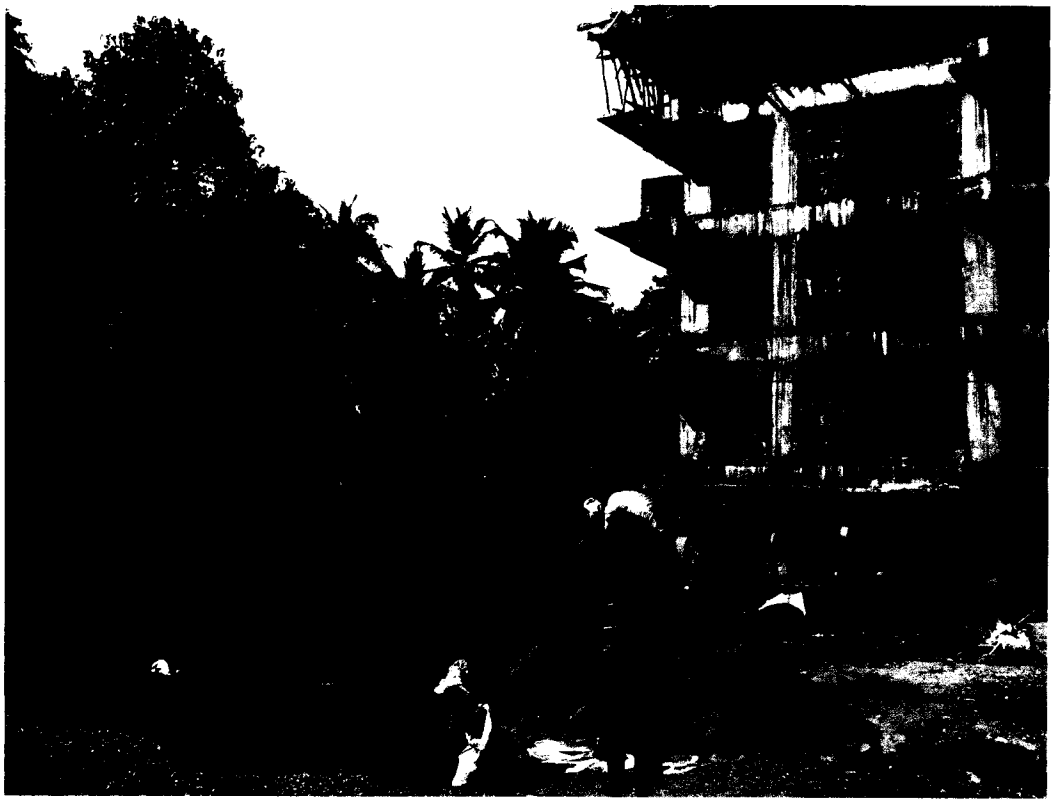


Fig. 3.13 Migrant construction workers live in the vicinity of the construction site where vector breeding takes place.

Fig. 3.14 All Night collections of mosquitoes on bait in progress at a construction site.

Fig. 3.15 All Night collections of mosquitoes on a bait is in progress in a rural area of Goa.

Fig. 3.16 All Night collections of mosquitoes on a bait is in progress in an urban area of Goa.

behaviour of mosquitoes from dusk to dawn. Informed consent was taken from the potential bait/volunteer (Form No. 3.4).

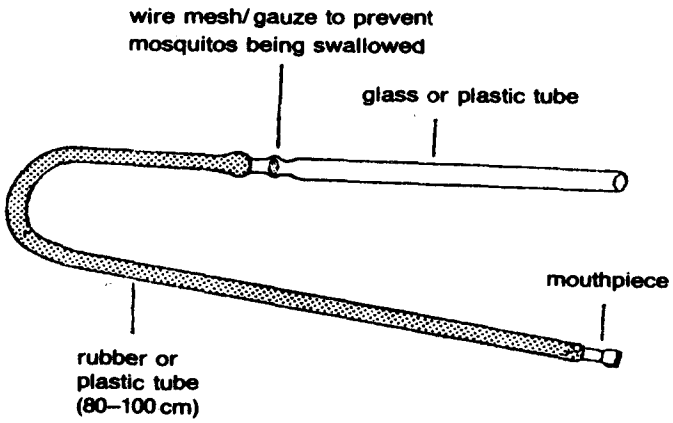


Fig. 3.18 An Aspirator (Suction tube) with the help of which hand catch of mosquitoes was done.

Only after voluntary consent was obtained, the human bait and mosquito collectors were made to participate in the collections. The necessary ethical approval was taken for conducting the adult mosquito collections on human volunteers from the ethics Committee of National Institute of Malaria Research, Delhi. The human volunteers and mosquito collectors were administered prophylactic doses of antimalarial, chloroquine @ 300mg stat (2 tablets of 150 mg ai) weekly until one week after the conclusion of the study. It may be mentioned that none of the volunteers and mosquito collectors suffered from malaria during the course of the study.

The person acting as a bait was made to expose his limbs i.e., hands up to the forearms and legs up to the knees. He was made to lie on a cot. The mosquitoes were collected by hand catch method using aspirator and torch following the standard procedures in the selected areas. With the mouth piece in the mouth, the suction tube was held by the collector with its opening about 1cm away from the mosquito. The open end of the sucking tube was moved closer to the mosquito and at the same time sucked quickly and gently so as to draw the mosquito into the tube. The captured mosquito was prevented from escaping by immediately covering the suction end with the thumb.

The mosquito was transferred into a clean test tube 150 mm long with 16 mm dia, by gently blowing it into the tube. The test tube was then plugged with cotton wool and placed in the test tube stand. Each test tube was labelled individually showing the hour, place and date of collection. Two to three test tubes were used for collecting mosquitoes during each hour of collection. On an average, 4 to 8 all night collections were done in each month.

Next day morning, the mosquitoes were transported to the laboratory. The live mosquitoes in each test tube were anaesthetized to facilitate identification of mosquitoes by putting 1-2 drops of ether on the cotton plug. WILD dissecting binocular microscope was used to magnify and identify the mosquitoes based on morphological features up to species level using the keys of Christopher's (1933), Barraud (1934) and Puri (1954).

Following precautions were taken during the mosquito collections.

1. Care was taken not to suck or blow too hard, as mosquitoes being fragile could easily lose legs or damaged and lose their characters which would hamper their identification.

2. Care was taken to prevent breakage of test tubes during transportation.

3. After every night collection, the test tubes were washed, cleaned and kept dry before re-use. This was essential to keep the test tubes free from dirt.

4. The oil or ointment that may act as mosquito repellent and smoking was strictly prohibited during the all night collections.

5. Same bait was used throughout the collection duration.

6. The data was recorded locality and species wise in designed proforma 3.5.

3. Sporozoite ELISA Test:

The collected Anopheline female mosquitoes with the help of Mosquito Magnet™ and during all night collections and after their identification were dried and stored individually in plastic vials containing dried silica gel under cold conditions (0-4°C). The head and thoraces of *An. stephensi* females were tested by sporozoite ELISA method (Burkot et al., 1984) using antibodies to circumsporozoite proteins of *Plasmodium falciparum*, *Plasmodium vivax*-210 and *P. vivax*-247. End point results were read visually and confirmed at 450 nm using a Vmax kinetic microplate reader manufactured by Molecular Devices Corporation (Sunnyvale, CA, USA).

INFORMED CONSENT (FORM No.3.4)

Project Title: An Epidemiological study on risk factors responsible for the enhanced receptivity and vulnerability to malaria in Goa- Ph.D. research work being pursued in NIMR (ICMR), Field station, Goa.

Information Sheet : Introduction

We are doing a research study on risk factors that help in the increase and spread of malaria in Goa. I am going to give you detailed information about this study and invite you to participate as a volunteer in this study. Before you decide about it, you can talk to any one you feel comfortable with. There may be some words that you may not understand. You may stop me and ask question if you desire as we go through the information and I will explain it to you. If you have questions later, you can ask me whenever you wish to.

You may be aware that Malaria is one of the common and dangerous diseases in Goa. Malaria is spread by a certain variety of mosquitoes. Generally such mosquitoes bite humans at different hours of the night. The purpose of this study is to find out when the mosquitoes that spread malaria in Goa attempt to bite us and in how many numbers. This information will be useful for finding out a solution for prevention of such bites and malaria.

In this study we need some volunteers and insect collectors who are trained in the collection of mosquitoes that may land and attempt to bite.

As a volunteer you will be first provided with a preventive (prophylactic dose) of chloroquine (300mg base) as per the guidelines of the National Vector borne Diseases Control Programme. This will be repeated every week till one week after the end of the study.

As a volunteer you will act as bait for mosquitoes and expose only the limbs i.e. hands and legs up to the knees to attract mosquitoes. Any mosquito that lands on these parts will be promptly sucked in the suction tube by the Insect Collector. This collection will be done from 18.00 to 0.600 hours on each collection night. This may cause some annoyance and irritation to you. However utmost care will be taken to promptly collected mosquitoes to avoid the biting.The collected mosquitoes will be kept separately hour wise in labelled test tubes and brought next morning to the laboratory for identification.

As a volunteer you will not be provided with any incentive to take part in the study. However for the transportation you will be reimbursed with not more than Rs. 120/- per night. During the course of the study we will follow you closely and keep track of any event during the study to prevent the risk of malaria to you.

The knowledge we get from this study will be shared with you at any time you desire. Confidential information will not be shared with any one and your name shall not be disclosed. Afterwards, we will use the results of the study in the Ph.D. thesis and publish them in the scientific journals in order that other people may learn and benefit from our study.

You do not have to take part/to agree to take part in this epidemiological study if you do not wish to do so and may refuse to take part in the study. Even during the course of the study you may withdraw without assigning any reason even if you have consented to take part in the study. This will not affect you in any way.

If you have any questions you may ask them now or later, even after the study has started. If you wish to ask questions later, you may contact any of us.

Mrs. Nandini S. Korgaonkar,NVBDCP Panaji Goa Contact Telephone No:0832-2225837

Dr. Ashwani Kumar, NIMR, FS, Panaji, Goa. Contact Telephone No. 0832-2222444

Certificate of Consent

I have been invited to participate in a research study on risk factors that help in the increase and spread of malaria in Goa. I understand that it will involve me as a volunteer to attract mosquitoes. I have been informed about the risks and the protective dose of chloroquine medicine that will be given to me to prevent malaria at weekly interval and I undertake to consume the same without fail. I am aware that there may be no benefit to either myself and that I will not be compensated beyond travel expenses. I have been provided with the name of investigators who can be easily contacted using the numbers.

I have read the foregoing information, or it has been read to me. I have had the opportunity to ask questions about it and any questions that I have asked have been answered to my satisfaction. I hereby consent voluntarily to participate in this study and understand that I have the right to withdraw from the study at any time without assigning reason for the same.

Name of Participant_____

Signature of Participant/Thumb Impression _____

Date _____
day/month/year

Name of witness_____

Signature of Participant/Thumb Impression _____

Date _____
day/month/year

Name of investigator_____

Signature of investigator _____

Date _____
day/month/year

A copy of this Informed Consent Form has been provided to participant .

PROFORMA-3.5

All night Landing Mosquito Collections on Human baits in Goa

PHC/UHC: VILLAGE/WARD: COLLECTION LOCATION:

Hours▶		18.00-19.00		19.00-20.00		20.00-21.00		21.00-22.00		22.00-23.00		23.00-24.00		24.00-01.00		01.00-02.00		02.00-03.00		03.00-04.00		04.00-05.00		05.00-06.00		Total	
Date	Species	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀

♀-Male mosquito ♂-Female mosquito

Epidemiological Data Collection and Analysis:

Malariometric Indices

The various levels of endemicity of malaria were ascertained with the help of standard malariometric indices, surveillance indices and entomological indices. The following indices were worked out as a measure of malaria endemicity during the course of the present study.

i). Parasitological Indices

1. Annual Blood Examination Rate (ABER): It is expressed as the proportion of blood slides examined for malaria in a human population in a year.

It was calculated as follows.

$$ABER = \frac{\text{No. of blood slides examined in a year}}{\text{Total Population covered}} \times 100$$

2. Annual Parasite Incidence (API): It is expressed as the number of malaria positive cases in a particular year in a particular place per thousand populations and was calculated as follows.

$$API = \frac{\text{Total No. of malaria positive cases in a year}}{\text{Population of the area}} \times 1000$$

3. Monthly Parasite Incidence (MPI): It is expressed as the number of malaria positive cases in a particular month in a particular place per thousand populations.

$$MPI = \frac{\text{No. of malaria positive cases in a month}}{\text{Total population of that area}} \times 1000$$

4. Annual Vivax Incidence (AVI): It was expressed as the number of *Plasmodium vivax* positive cases in a particular year in a particular place per thousand populations and was calculated as follows.

$$AVI = \frac{\text{Total No. of } P.\ vivax \text{ positive cases in a year}}{\text{Population of the area}} \times 1000$$

5. Annual Falciparum Incidence (AFI): It was expressed as the number of *Plasmodium falciparum* positive cases in a particular year in a particular place per thousand population and was calculated as follows.

$$AFI = \frac{\text{Total No. of } P.\ falciparum \text{ positive cases in a year}}{\text{Population of the area}} \times 1000$$

6. Slide Positivity Rate (SPR): It was expressed as the proportion of positive slides out of those examined for malaria.

$$SPR = \frac{\text{No. of slides positive for malaria}}{\text{Total No. of blood slides examined}} \times 100$$

7. Slide Vivax Rate (SVR): It is the proportion of slides showing *Plasmodium vivax* infection out of the total slides examined for malaria.

$$SvR = \frac{\text{No. of slides with } P.\ vivax \text{ infection}}{\text{Total No. of slides examined}} \times 100$$

8. Slide Falciparum Rate (SfR): It is the proportion of slides showing *Plasmodium falciparum* infection out of the total blood slides examined for malaria.

$$SfR = \frac{\text{No. of slides with } P.\ falciparum \text{ infection}}{\text{Total No. of slides examined}} \times 100$$

9. Plasmodium falciparum Proportion (Pf %): It is expressed as the proportion of slides showing *Plasmodium falciparum* infection out of the total positive slides with malaria infection.

$$Pf\% = \frac{\text{Total No. of } P.\ falciparum \text{ cases}}{\text{Total No. of slides positive for malaria}} \times 100$$

ii). Entomological indices

Similar to parasitological indices malariometric indices related to mosquitoes used were the following.

1. Per Night Per Trap Density (PNPTD): It is expressed as the number of mosquitoes collected during the whole night (from sunset to sunrise) with the help of a trap. It can be expressed for the total mosquitoes collected or per species.

$$PNPTD = \frac{\text{Total no. of mosquitoes collected during all the night}}{\text{Total no. of nights of collection}}$$

2. Larval Density: It is expressed as the average number of larvae collected with the help of a dipper per dip.

$$\text{Mean per dip density} = \frac{\text{Total Number of larvae collected in all the dips}}{\text{Number of dips}}$$

Malaria Data of Goa: 1963 to 2007

The malaria incidence data of Goa state was collected from the State National Vector borne Disease Control Programme of the Directorate of Health Services, Government of Goa from the year 1963 till 2007. The year wise data for the above years collected was as follows:

1. Blood slides collected and examined.

2. Total number of blood slides found positive.

3. Total number of blood slides found positive for *P. vivax*.

4. Total number of blood slides found positive for *P. falciparum*.

From the above data, the following malariometric indices were worked out.

1. *Plasmodium falciparum* percentage (Pf %).
2. *Plasmodium vivax* percentage (Pv %)
3. Slide Positivity rate (SPR)
4. Slide *falciparum* rate (SfR)
5. Slide *vivax* rate (SvR)
6. Annual Blood Examination Rate (ABER)
7. Annual *falciparum* Incidence (AFI)
8. Annual *vivax* Incidence (AVI)
9. Annual Parasite Incidence (API)

The year wise population data of the state was collected from the Health Intelligence Bureau (HIB) of the Directorate of Health Services. The mid year population figures were calculated based on Census of India, 1991 and 2001. The population figures were used for calculating ABER and API of different years.

Seasonal Distribution of Malaria

The month wise data of malaria morbidity of the state of Goa was tabulated and analysed from the year 1990 to 2001 and 2002 to 2007 and various malariometric indices mentioned above were worked out. The data for all the above years was further analyzed according to different seasons of the year i.e. pre-monsoons, monsoons and the post monsoons.

Stratification of Goa based on malaria endemicity:

1. Malaria Data of Goa: District and PHC/UHC wise

The data of each district, Primary Health Centre (PHC)/Urban Health Centre (UHC) on malaria morbidity was tabulated from the year 1990 to 2001 and 2002 till 2007. Based on the population data of each PHC, the total blood slides collected and examined and the number of slides positive for *P. vivax* and *P.* falciparum, various maleriometric indices such as SPR, SFR, Pf% and API were worked out for each year for all the PHCs.

2. Stratification of Goa based on Malaria Endemicity

Based on the SPR, ABER and API calculated from 1990 to 2007 for each PHC/UHC and CHC of Goa, a colour scheme for stratification was developed and different colours were assigned to different levels of ABER, SPR and API for visual separation of PHCs according to their malaria endemicity during the above period.

3. Micro Stratification of Panaji based on Malaria endemicity

The area wise data of malaria was tabulated and analyzed from January to December 2004. For each month and all localities of the city, SPR, Pv% and Pf% was worked out. The data was also segregated according to the method of malaria surveillance i.e. Active Case Detection (ACD) and Passive Case Detection case (PCD). A coloured map of Panaji was prepared to denote municipal localities according to different malaria endemicity for prioritising malaria control.

4. Age and Sex Distribution of Malaria Cases in Panaji

Malaria cases were assigned to the following age groups of both sexes to study age and gender distribution of malaria incidence in Panaji in the year 2004. The age groups were < 1 year, 1 – 4 years, 4 – 8 years, 9 – 14 years, 15 – 20 years, 21 – 30 years, 31 – 40 years, 41 – 50 years, and > 50 years and malariometric indices were worked out for each of the above age groups for both the genders.

5. Demographic Distribution of Malaria in Panaji

The malaria incidence of Panaji for the year 2004 was analysed according to three demographic groups viz., local, labour and hotel/restaurant workers and the malariometric indices were worked out separately for each of these groups.

Identification of Malaria Risk Factors:

The malaria risk factors were identified based on relationship between malaria incidence and various parameters i.e. physical features, meteorological factors, developmental activities, migratory population, vector prevalence and the epidemic outbreak potential in the PHC/UHC and CHC responsible for receptivity and vulnerability to malaria transmission.

Malaria Control Strategy for Goa:

Based on the stratification of the PHC/UHC and CHCs into malaria endemic zones, seasonal trends of malaria, demographic distribution of malaria, vector prevalence, breeding ecology, previously conducted and published studies, a simple and specific malaria control strategy has been proposed for the state of Goa.

Chapter 4: RESULTS

1. Physiographical Features of Goa

Goa is located on the Western Coast of India having an area of 3702 km^2 and population of 13.49 Lacs as per 2001 census. The state has two districts viz., North Goa and South Goa with an area of 1736 km^2 and 1966 km^2 and population of 7.58 Lacs and 5.8 Lacs respectively.

The state of Goa is bounded by the Arabian Sea on the west, Terakhol river in the North which separates Goa state from Sindhudurg district of Maharashtra, by Belgaum district of Karnataka state in the East and by Uttar Kannara district of Karnataka in the South. Goa is situated between the latitudinal parallels of 14° 53' and 15° 47' and longitudinal parallels of 73° 40' and 74° 21'. From North to South and from East to west the Goa spans 105 Km and 65 km respectively.

Goa has a hilly terrain especially on its eastern side where lies southern end of the Sahyadri range (Fig. 4.1). The mountains after skirting a considerable portion of the North eastern and South Eastern boundaries branch off Westwards across the territory with many spurs and ridges. The terrain is intersected by 4 major perennial rivers viz., Terakhol, Chapora, Mandovi and Zuari. These are navigable rivers and most important for the economy of the state as inland waterways play an important role in transportation of mineral ores to the Vasco port for exports. Besides there are three rivers in the South Goa viz., Sal, Talpona and Galgibagh, which are relatively smaller. The coast is full of creaks and estuaries formed by these rivers which are used for fisheries. Estuaries are rich in Marine fauna. The coast line of Goa is uneven and consists of inlets and outlets giving rise to

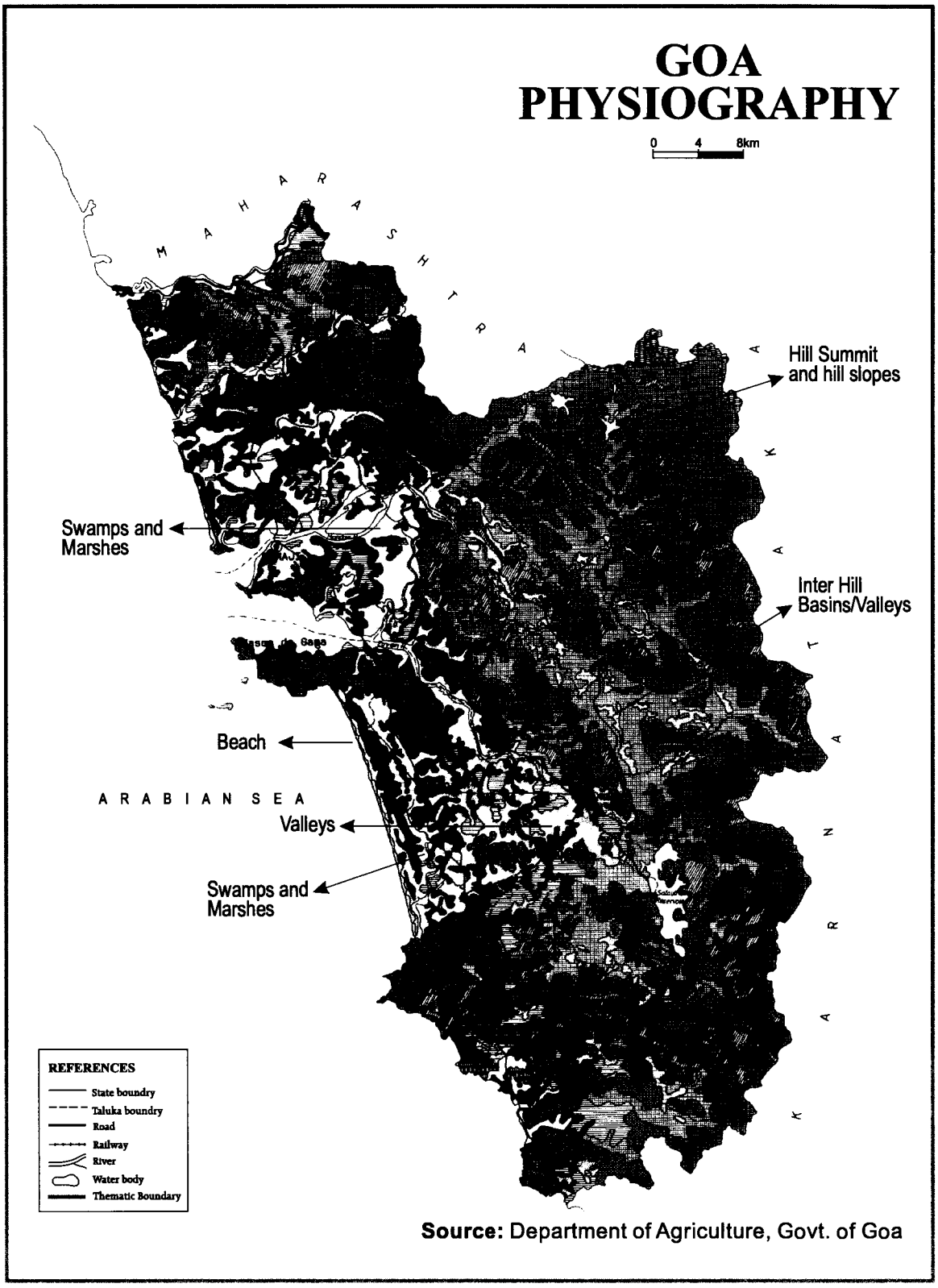


Fig. 4.1 Physiographic Features of Goa

bays and capes. The state has number of islets viz., Chorao, Divar, Kumbarjuwa, Jua and Corjuem, Sao Jocinto, Sao Jorge and Anjadip islands.

The physiographic features are rich and varied consisting of verdant hills, forests, cashew, coconut groves and rich paddy field. In the valleys where perennial springs occur, cultivation of Areca nut is done (Fig. 4.2). Soil of Goa is in general laterite. The agricultural lowlands especially in the coastal tract are alluvial flats formed through sedimentation along the principal rivers and net area sown is about 40% of the total land. About 35% of the total area is covered under forests (Fig. 4.3) and remaining 25% is lateritic and unsuitable for cultivation. The soil is murmur on the slopes. Many commercial tree species thrive in the well aerated soils at the foothills where the murmur is mixed with humus to form a loamy soil supporting high and thick growth of trees. The soils of Goa are excessively drained from Eastern hilly region to westwards towards the sea (Fig. 4.4). However, the flat alluvial soils ('khazan' lands) along the western coast are poorly drained.

2. Meteorological Data

The climate of Goa is warm and humid through out the year (Table 4.1, Fig. 4.5). Rainfall varies from 2500 to 4300mm and there are four distinct rainfall zones in Goa. Whereas, the coastal belt receives less than 3000mm rainfall, the middle sub coastal part receives between 3000 and 3500mm followed by 3500 to 4000mm in the foothill tracts and >4000mm in the high altitude areas along the north eastern belt (Fig. 4.6). The number of rainy days varied from 90 to 137 in the years 1980 to 2007 (Annexure 1). The average maximum temperature ranged from 29°C to 33.6°C and minimum temperature ranged from 20.2°C to 26.5°C in different month in the years 1980 to 2007. The

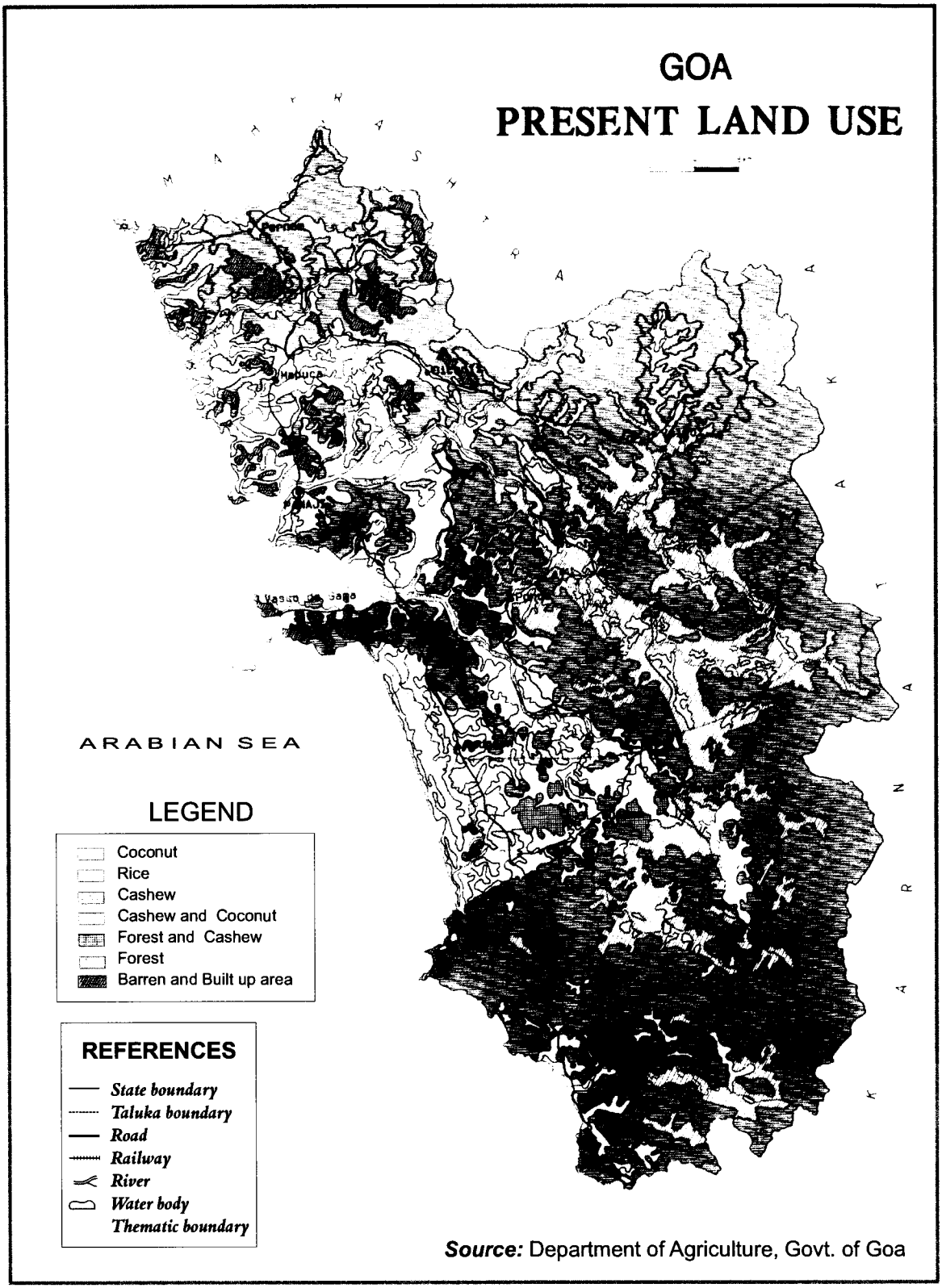


Fig. 4.2 Map of Goa showing soil drainage

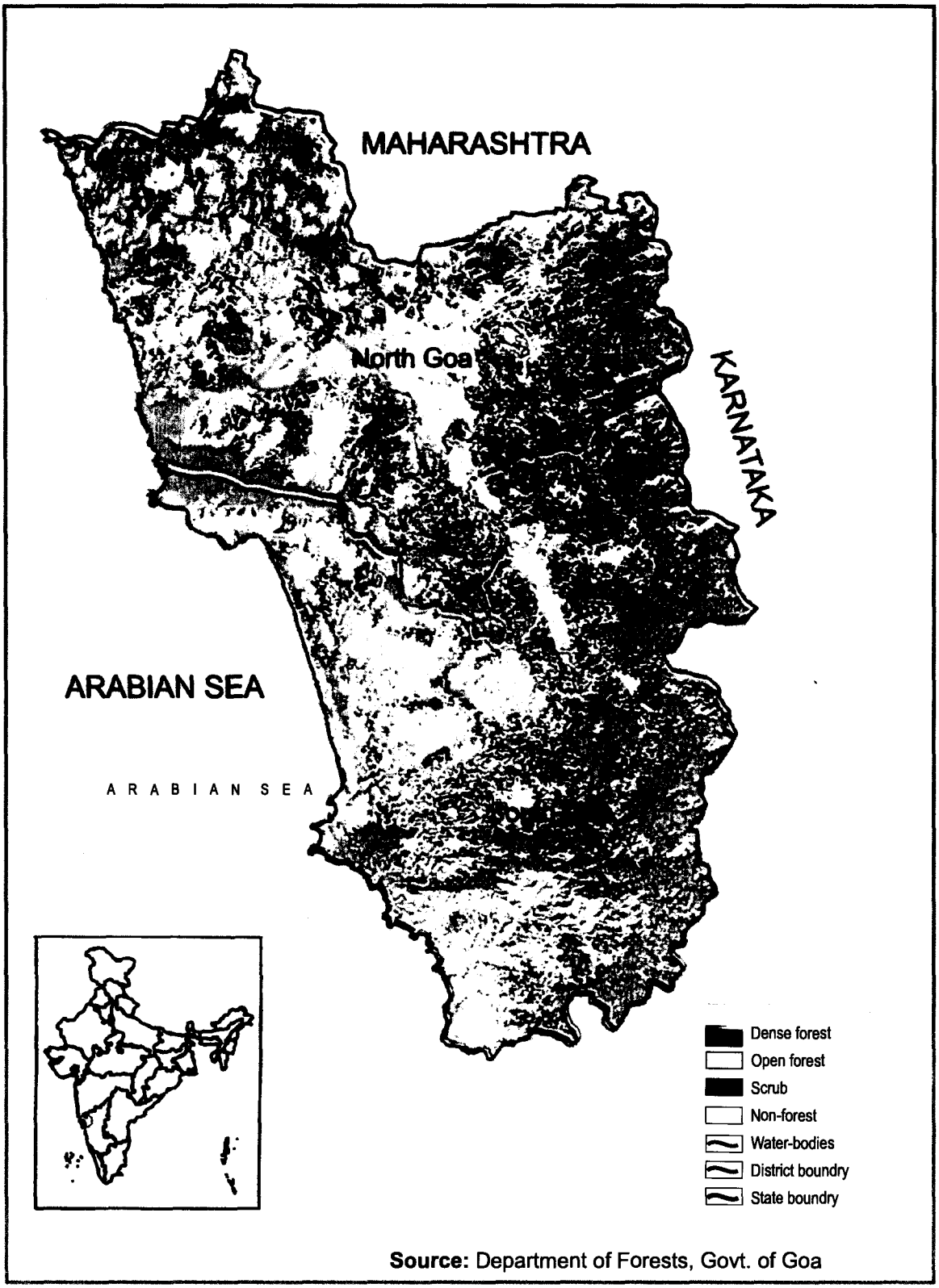


Fig. 4.3 Map of Goa showing forest cover

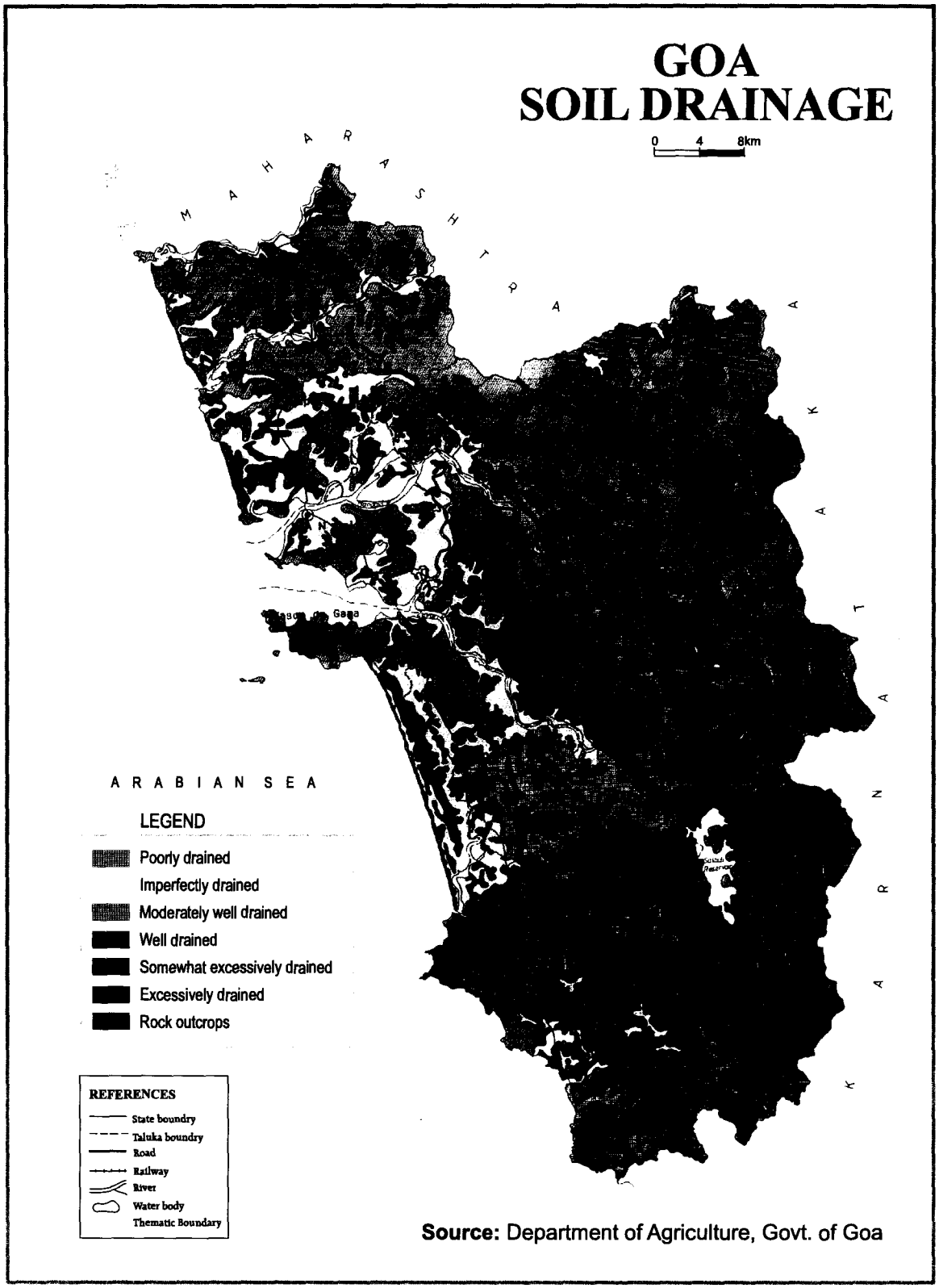


Fig. 4.4 Map of Goa showing soil drainage

Table: 4.1 Average monthly weather parameters: Rainfall (mm), Relative humidity (%), Maximum (°C) and Minimum (°C) temperature from 1980 – 2007.

Month	Rainfall (mm)	Relative humidity (%)	Maximum Temperature °C	Minimum Temperature °C
Jan	1.0	74.8	32.2	20.2
Feb	0.2	75.9	32.2	20.8
Mar	1.6	78.4	32.2	23.3
Apr	4.8	76.8	33.1	25.4
May	84.5	77.5	33.6	26.5
Jun	901.9	87.9	30.5	25.0
Jul	883.8	90.4	29.2	24.5
Aug	604.7	91.0	29.0	24.2
Sep	242.2	89.8	30.0	24.2
Oct	127.8	86.9	31.8	24.0
Nov	19.8	78.1	33.3	22.5
Dec	4.8	73.5	32.8	21.1

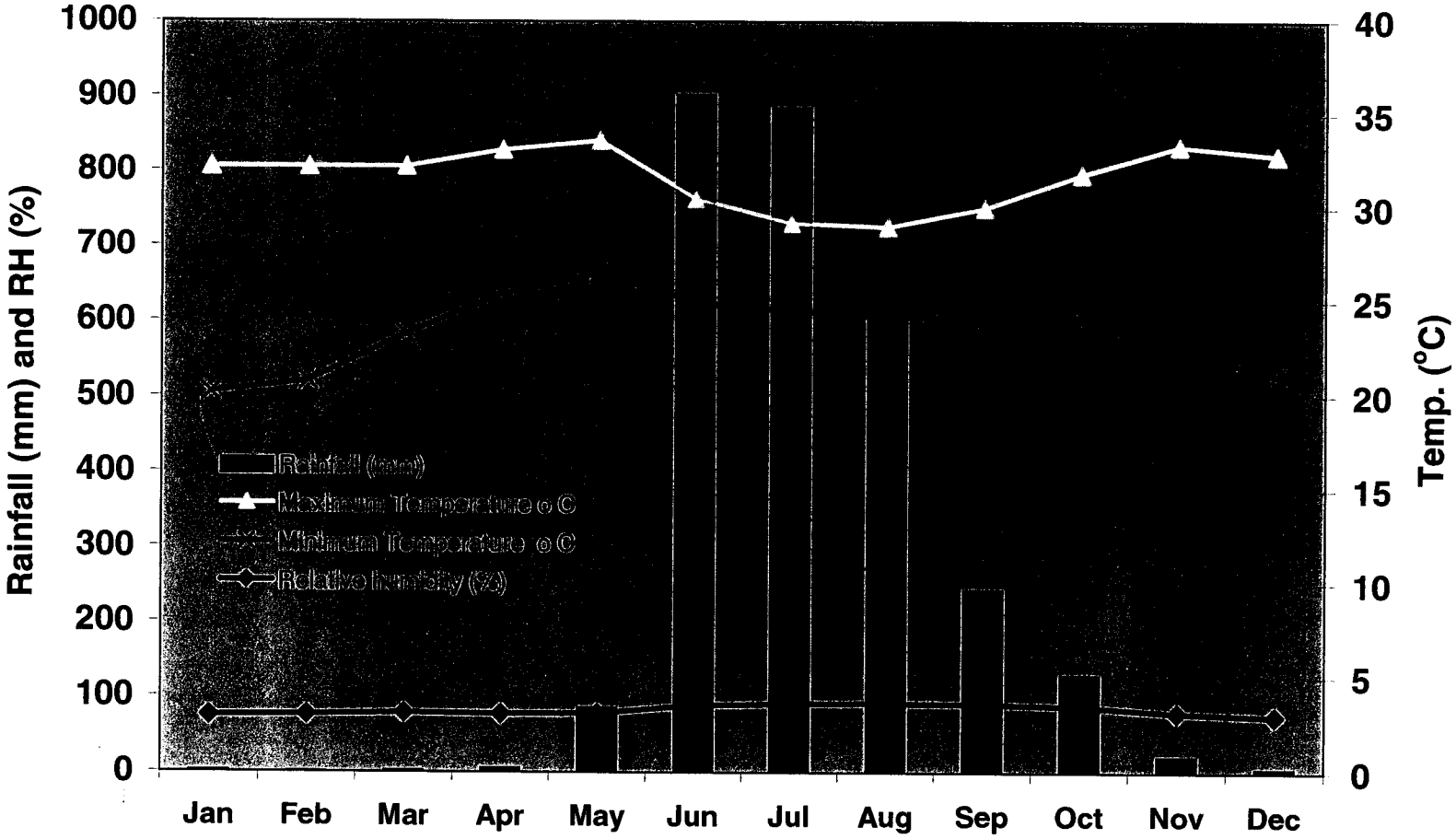


Fig. 4.5 Average monthly rainfall, relative humidity, maximum and miimum temperature from 1980 to 2007

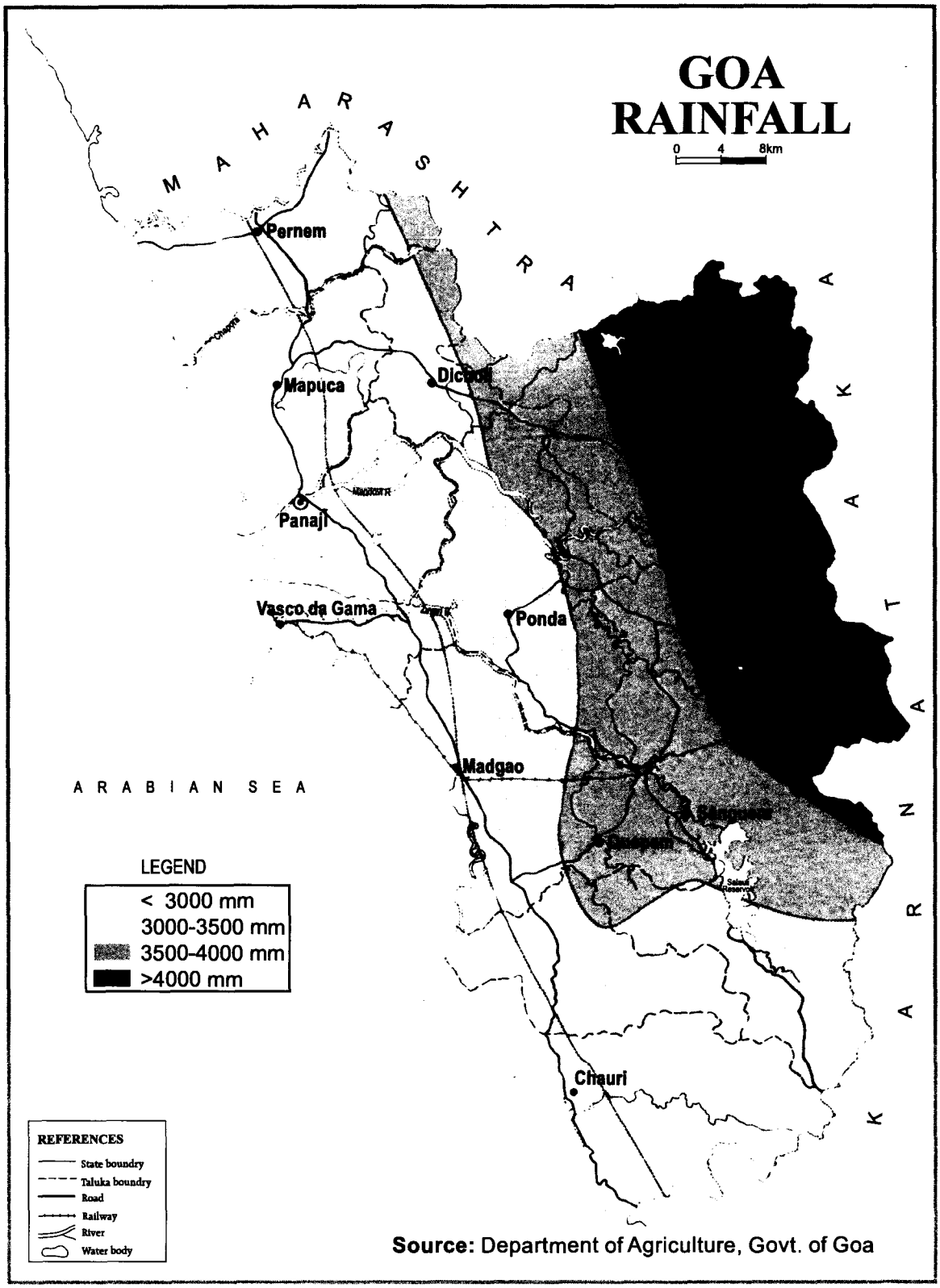


Fig. 4.6 Different rainfall zones of Goa

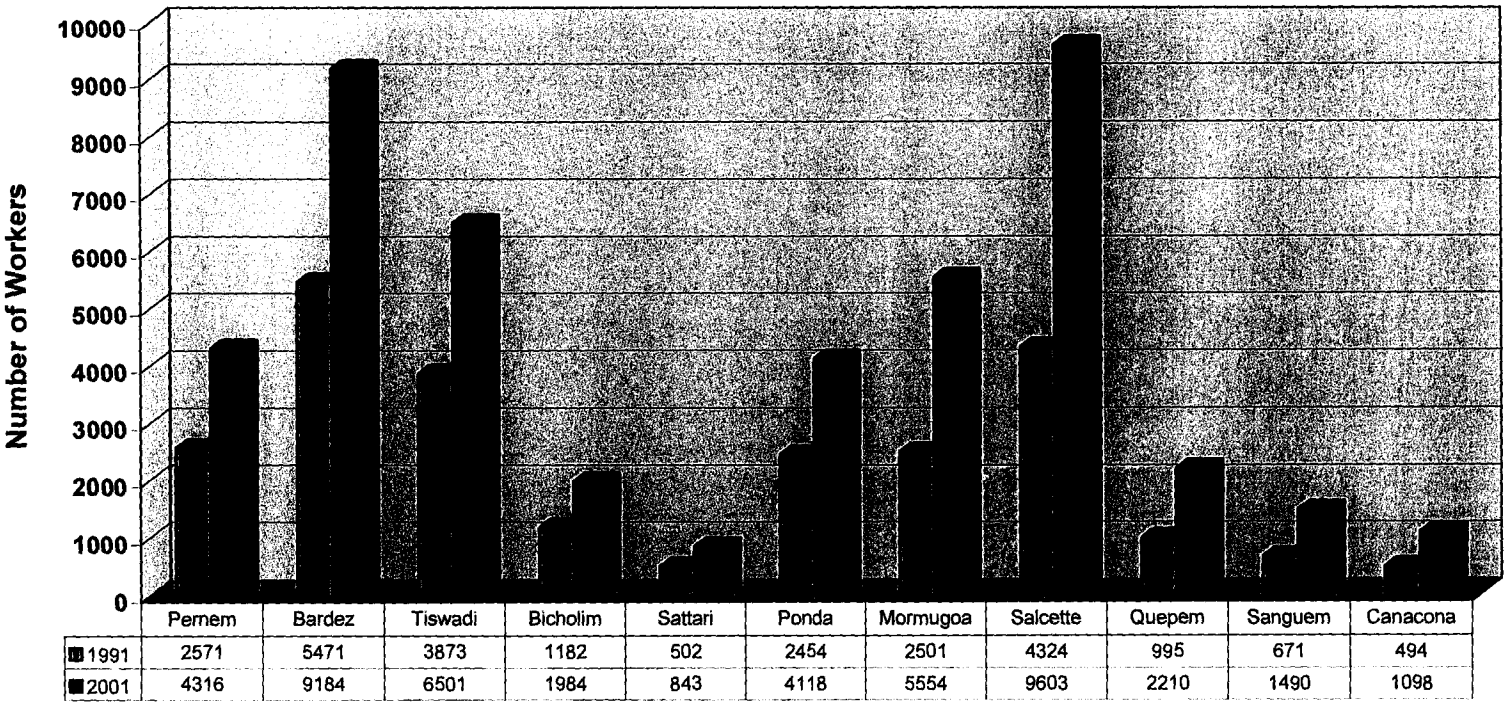
relative humidity during these years ranged from 73 to 91% in different months.

3. Developmental Activities and Human Migration

As per the Directorate of Planning and Statistics, Govt. of Goa there were 1019 construction sites in urban and rural areas of Goa in the year 1997-98 These fell in the categories of residential, industrial, commercial, institutional and religious. Besides, 214 buildings under these different categories were renovated during this period in Goa. As per 1991 and 2001 censuses of India, there were 25037 and 46901 migrant construction workers in the state of Goa respectively (Table 4.2). The 'Taluka' wise distribution of migrant construction workers shows that maximum number of workers were in Bardez, followed by Salcete, Tiswadi, Pernem, Marmugoa, Ponda, Bicholim, Quepem, Sanguem, Sattari and Canacona according to 1991 and 2001 census of India (Fig. 4.7). A representative survey carried out during the course of this study revealed that the number of migrant construction workers in Panaji in the year 2002 were 1168. It was observed that migrant workers had come from 17 states of India and also from the neighbouring country Nepal (Fig 4.8). The bulk of migrant workers were from Karnataka (46.2%) followed by Maharashtra (15.3%), Goa (10.7%), West Bengal (6.5%), Uttar Pradesh (5.7%), Andhra Pradesh (3.3%), Kerala (2%), Orissa and Bihar (1.5%). The remaining 9 states viz., Rajasthan, Tamil Nadu, Jharkhand, Delhi, Madhya Pradesh, Uttaranchal, Chandigarh, Himachal Pradesh and Assam contributed less than 1% each to the total migrant population. There were 39 migrant workers from Nepal i.e. (3.3%).

Table: 4.2 District wise distribution of population of construction workers as per the census of India 1991 & 2001 in Goa state.

Sr. No.	Name of the State / district	Population of no. of construction workers	
		1991	2001
1.	North Goa District	16052	26946
2.	South Goa District	8985	19955
	Total Goa State	25037	46901



	Pernem	Bardez	Tiswadi	Bicholim	Sattari	Ponda	Mormugoa	Salcette	Quepem	Sanguem	Canacona
1991	2571	5471	3873	1182	502	2454	2501	4324	995	671	494
2001	4316	9184	6501	1984	843	4118	5554	9603	2210	1490	1098

Fig. 4.7 Showing number of construction workers in different talukas of Goa during 1991 and 2001 as per the Census of India 2001.

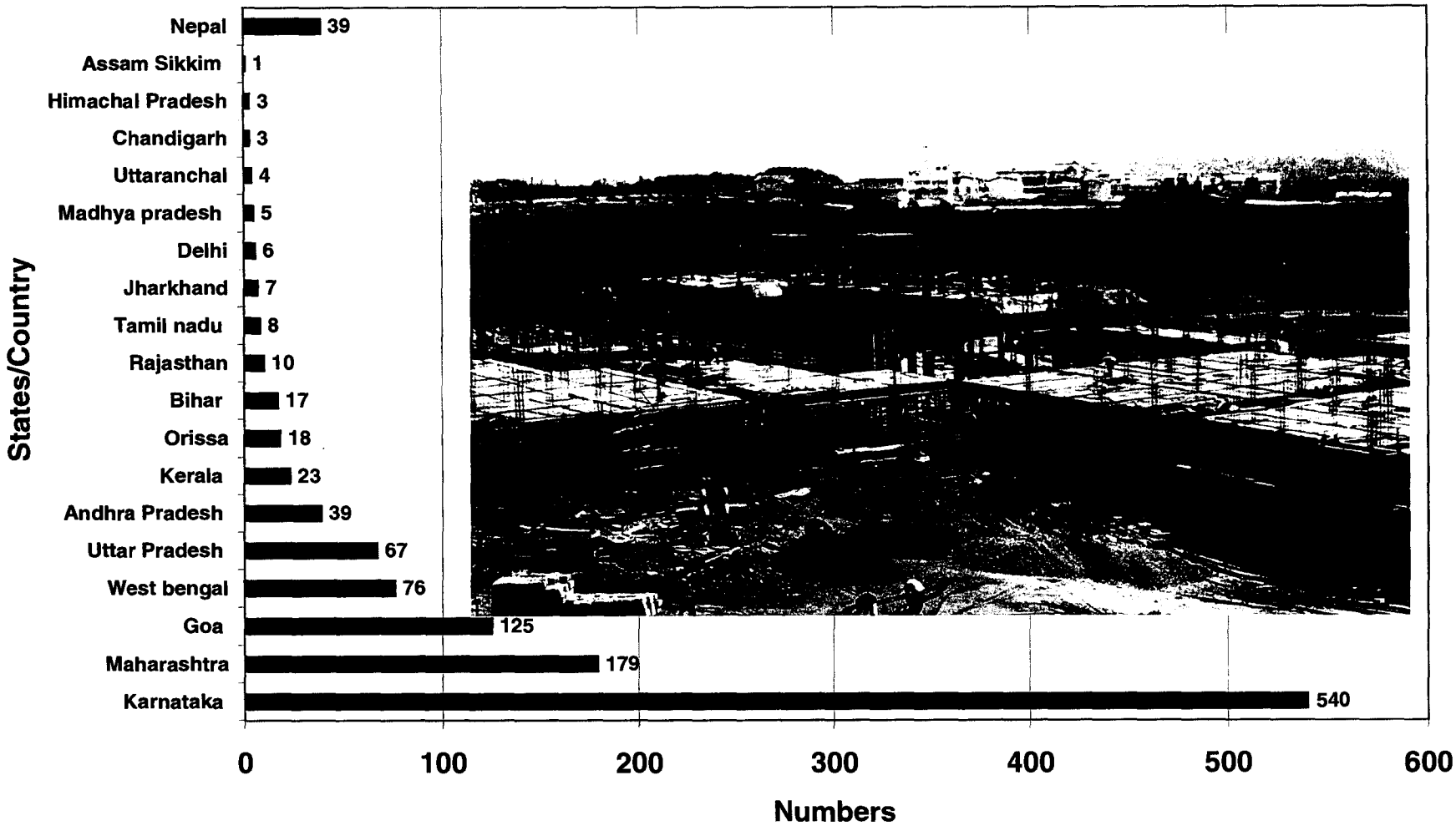


Fig.4.8 Composition of migrant workers in Goa by the states of India and Nepal in 2002

A study carried out to determine the number of migrant workers at the construction sites revealed that average number of migrant workers ranged from 52 to 65 per construction site during different months of 2007. The number during the monsoon months from May to Oct. which received total rainfall of 3531mm did not significantly differ from the other months (Table 4.3 & Fig. 4.9).

4. Entomological Studies

Entomological studies included (1) geographical reconnaissance of breeding habitats in Panaji, which has been the epicentre of malaria in Goa, (2) extensive immature surveys in the breeding habitats of mosquitoes covering permanent and temporary sites in the coastal, middle sub-coastal and interior hilly belts of Goa and (3) adult vector collections including landing collection of adult females in different locations of Goa viz., Panaji, Candolim, Cortalim, Margao, Cansarvarnem, Bicholim, Ponda, Valpoi, Quepem, Canacona and Sanguem. Besides, adult mosquitoes were also collected by deploying Mosquito Magnet™ trap in different localities of Panaji. The results of these studies are presented below.

4.1 Geographical Reconnaissance (GR) of Mosquito Breeding Habitats

The GR survey of breeding habitats was carried out in all the wards of Panaji in the year 2004. A total of 151288 breeding sites were detected. These habitats were broadly categorized into permanent and temporary sites. Further, the temporary sites were categorized in to rain associated and those not associated with rains. Their surface area was also measured and recorded. The permanent breeding sites were 61600 (40.72%), temporary breeding habitats (associated with rains) were 76345 (50.46%) while the

Table: 4.3 Relationship between average numbers of construction workers per construction site and rainfall in Goa during 2007

Month	Mean number of construction workers	Rainfall (mm)
Jan	52	0.0
Feb	54	0.0
Mar	57	0.0
Apr	63	0.0
May	63	113.8
Jun	59	1077.4
Jul	58	688.6
Aug	60	887.0
Sep	65	764.0
Oct	65	81.9
Nov	63	75.6
Dec	64	0.7

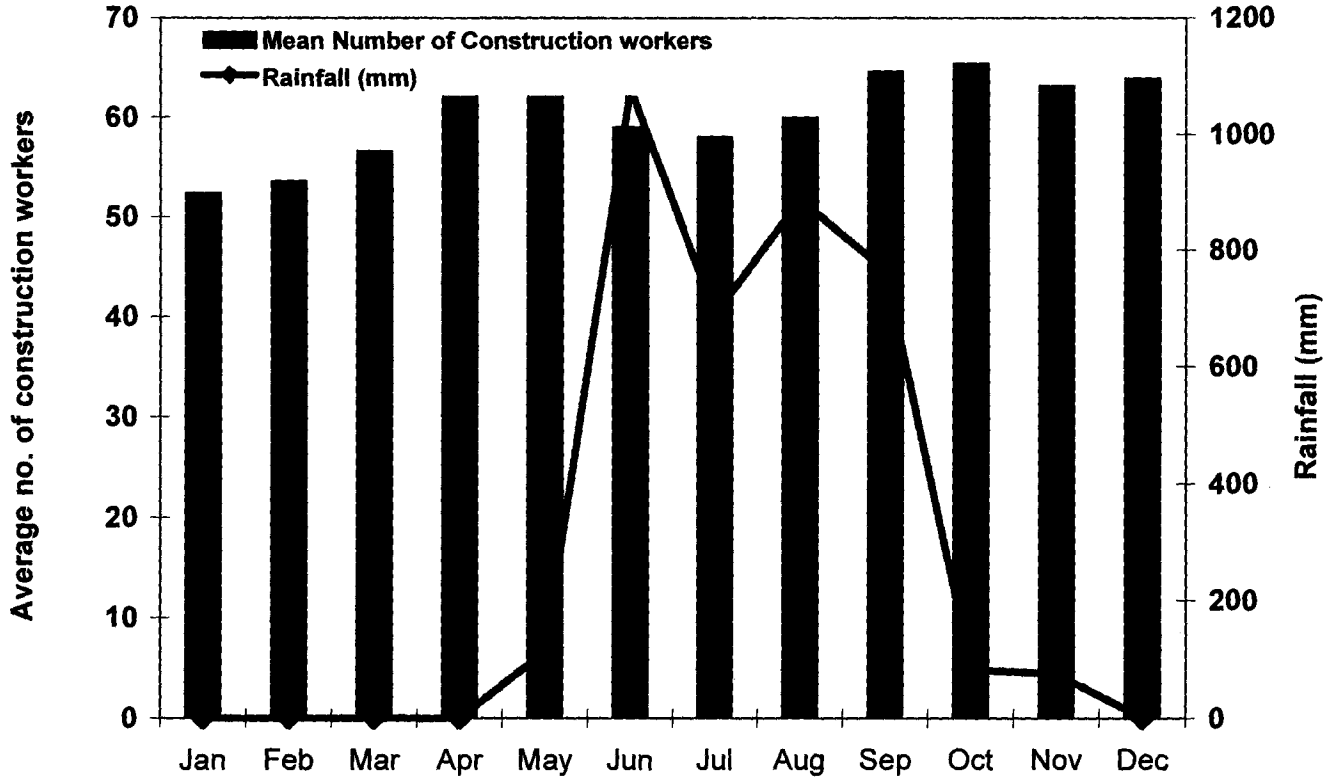


Fig. 4.9 Relationship between average no. of workers per construction site and rainfall in Goa during 2007

remaining temporary habitats which were not associated with rains were 13343 (8.82%). The relative contribution to the water surface area available for breeding by the permanent breeding sites was 144275 sq. m. (56%), temporary breeding sites (associated with rains) 67774 sq. m. (26%) while the total surface area of temporary breeding sites which were not associated with rains was 45264 sq. m. (18%) [Fig. 4.10].

Permanent Breeding Sites: Out of 61600 permanent breeding sites, the contribution of different types of breeding habitats and their percentage contribution to the total surface area was as follows: wells – 877(1.4%), various types of overhead tanks – 11021 (37.1%), different types of ground tanks – 4454 (5.2%), sumps – 2523 (23.3%), swimming pools – 68 (4%), chambers – 39386 (12%), fountains – 126 (0.7%), drains – 1032 (7.4%), septic tanks – 1838 (8.1%). The remaining permanent habitats viz., settling tanks, underground tanks, streams, ponds, cesspits and fire buckets contributed marginally to the total numbers and breeding surface areas (Table 4.4).

Temporary Breeding sites (Rain associated): There were 76345 rain associated temporary breeding sites with the total surface area of 67774.4 sq. m. The major contributors among these were water collections (n=2661; area:58975.8 sq.m.) on different floors of open cast constructions as well as on the terraces. Notable among the other 11 types of rain associated breeding habitats were bottles (n=46531; area:1163.3 sq. m.), coconut shells (n= 6642; area:677.5 sq. m.), buckets (n= 5062; area:1498.4 sq. m.), tins (n= 5890; area:1556.1 sq. m.), tyres (n= 3646; area:1521.1 sq. m.). The remaining habitats such as containers, grinding stones, pots, fish aquarium, scrap, water

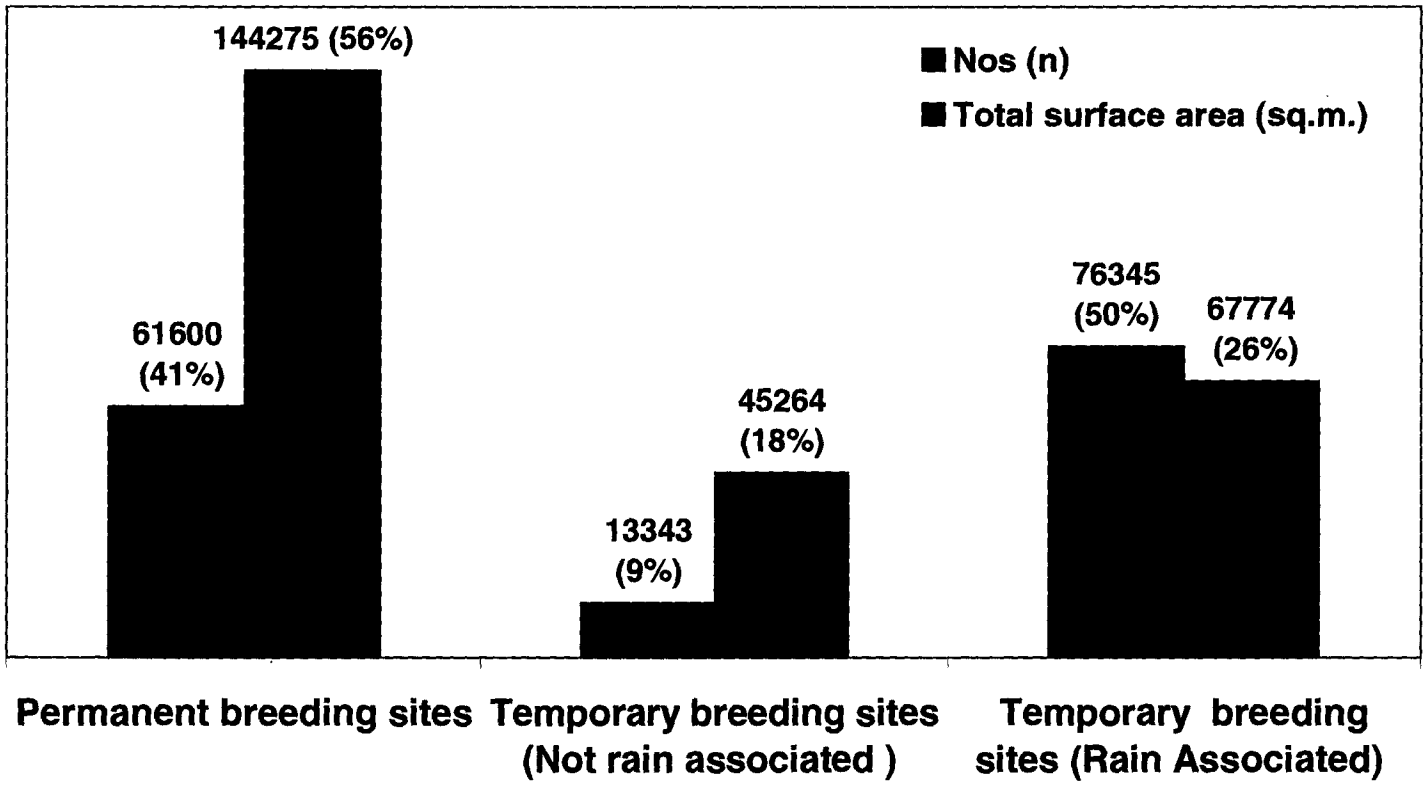


Fig 4.10 Relative contribution to the total surface area to the number of permanent, temporary and rain associated mosquito breeding sites in Panaji in 2004

Table: 4.4 Geographical reconnaissance of the various categories of permanent breeding habitats in Panaji in 2004

I.	PERMANENT BREEDING SITES				
S. No.	Breeding habitats	Nos. found (n)	Average surface area in sq. m. (a)	Total surface area in sq.m. (na)	% to Total
1.	Wells	877	2.38	2087.3	1.4
2.	OverHead Tanks				
2.1	Plastic	6917	1.15	7954.6	5.5
2.2	RCC	892	1.00	892	0.6
2.3	Asbestos	3092	14.43	44618	30.9
2.4	Metal	120	1.00	120	0.1
	TOTAL OHTs	**11021**		**53584.6**	**37.1**
3.	Ground Tanks				
3.1	Plastic	2795	0.95	2663.6	1.8
3.2	Cement	1485	3.17	4701.5	3.3
3.3	Asbestos	112	0.75	84	0.1
3.4	Metal	62	1.25	77.5	0.1
	TOTAL Ground Tanks	**4454**		**7526.6**	**5.2**
4.	Settling Tanks	4	144.00	576	0.4
5.	Under ground Tanks	35	4.20	147	0.1
6.	Sumps	2523	13.34	33657	23.3
7.	Swimming Pools	68	84.00	5712	4.0
8.	Fountains	126	8.25	1039.5	0.7
9.	Drains	1032	10.33	10661	7.4
10.	Streams	6	37.50	225	0.2
11.	Ponds	1	7.00	7	0.0
12.	Septic Tanks	1838	6.34	11653	8.1
13.	Chambers	39386	0.44	17330	12.0
14.	Cess Pits	42	0.50	21	0.0
15.	Fire buckets	187	0.26	47.9	0.0
	TOTAL	**61600**		**144274.9**	**100.0**

puddles contributed marginally to the total rain associated breeding sites. It may be mentioned that 87% of the total surface area of rain associated breeding sites was observed at the construction sites (Table 4.5).

Temporary Breeding Sites (Not Associated with Rains): Nine categories of temporary breeding sites and their per cent contribution to total surface area mentioned in parenthesis were barrels 4146(4.4%), curing water (accumulated at the site for toilet in the construction sites), 3096(29.1%), stagnant water (on the floor of the construction sites) 2576(57.0%), drums 2469(1.7%), foundation pit – 530(2.6%) and terrace water collections due to leakage in the overhead tanks or overflowing– 252(2.5%). The remaining breeding sites viz., lift columns, concrete mixers, basement contributed insignificantly (Table 4.6).

The analysis of data to find out relative contribution of construction sites and the remaining categories of breeding sites showed that there were 12 different types of breeding habitats in the construction sites. The total number of these habitats in all the construction sites surveyed was 17489 (11.6%) having surface area of 108941.2 sq. m. On the other hand, there were 25 categories of breeding habitats in areas other than constructions sites totalling to 133799 (88.4%) with total surface area of 148372.5. It was noteworthy that total surface area of breeding habitats was 42.3% while in other areas it was remaining 57.7% (Table 4.7). Further it was observed that the number of potential breeding habitats of malaria vector in the construction sites was 18728 as compared to 11591 in the residential colonies which meant that while the construction sites had 61.8% habitats preferred by urban vector *Anopheles stephensi* the residential colonies had remaining 38.2% of

Table 4.5 Geographical reconnaissance of the various categories of temporary rain associated breeding habitats in Panaji in 2004

	TEMPORARY BREEDING SITES (Rain Associated)				
S.No.	Breeding Sites	Nos. found (n)	Average surface area in sq. m. (a)	Total surface area in sq. m. (na)	% to Total
1.	Rain water collection & Terrace water collection (in the construction sites)	2661	21.13	58975.8	87.0
2.	Buckets	5062	0.30	1498.4	2.2
3.	Tins	5890	0.26	1556.1	2.3
4.	Bottles	46531	0.03	1163.3	1.7
5.	Tyres	3646	0.42	1521.1	2.2
6.	Containers	974	0.22	215.4	0.3
7.	Grinding Stones	519	0.30	155.7	0.2
8.	Pots	4207	0.23	952.9	1.4
9.	Coconut shells	6642	0.10	677.5	1.0
10.	Fish aquarium	27	0.20	5.4	0.0
11.	Scrap	11	0.25	2.8	0.0
12.	Water puddles	175	6.00	1050	1.5
	TOTAL	76345		67774.4	100.0

Table 4.6 Geographical reconnaissance of the various categories of temporary breeding habitats not associated with rains in Panaji in 2004

	TEMPORARY BREEDING SITES (Not Associated with Rains)				
S. No.	Breeding Sites	Nos. found (n)	Average surface area in sq.m. (a)	Total surface area in sq.m. (na)	% to Total
1.	Curing water(at site for toilet in the construction site)	3096	4.25	13158	29.1
2.	Stagnant water(on the floor of construction sites)	2576	10.02	25811.5	57.0
3.	Foundation Pit	530	2.25	1192.5	2.6
4.	Lift Column	120	4.20	504	1.1
5.	Concrete Mixer	138	0.50	69	0.2
6.	Basement	16	40.00	640	1.4
7.	Terrace water Collection (OHT leakage/overflow)	252	4.42	1113.8	2.5
8.	Drums	2469	0.31	761.9	1.7
9.	Barrels	4146	0.49	2013.7	4.4
	TOTAL	13343		45264.4	100.0

Table : 4.7 Relative contribution of construction sites and the remaining categories of breeding sites to total breeding surface area in Panaji in 2004

	Breeding Sites		
	Construction sites	Other sites	Total
Types	12	25	37
Total Nos.	17489 (11.6%)	133799 (88.4%)	151288
Surface Area	108941.2 (42.3%)	148372.5 (57.7%)	257313.7

the habitats preferred by the vector. Comparatively construction sites had 63.6% vector potential as compared to 36.4% in the residential complexes. (Table 4.8).

When breeding habitats were segregated according to the preferences by Anophelines (Clean water habitats), Culicines (Organically rich water/waste water habitats) and Aedines (Container habitats) in all the areas, it was observed that the habitats preferred by the Anophelines were 34867 (23.1%), by Culicines 73696 (48.8%) and by Aedines 42473 (28.1%). However, the total surface area available for breeding of Anophelines was 207567.7 (81.1%), followed by Aedines 40714.3 (15.9%) and Culicines 7796.5 (3.0%) [Table 4.9].

4.2 Surveys of Mosquito Immature Breeding Habitats

Extensive surveys were carried out at Panaji, Margao, Candolim, Cortalim, Bicholim, Ponda and Sanguem in the year 2004 covering urban, rural and forested areas of Goa. The results are given below.

Immature Surveys in Panaji: A total of 5953 breeding sites were surveyed in Panaji, out of which 108 (1.8%) sites were found positive for the breeding mosquito immature stages. Of these, 71 (1.2%) had anopheline larvae while 37 (0.6%) had culicine immature (Table 4.10). The habitats were of 12 different categories. Of the 308 sumps checked, 18 (5.8%) were found positive for breeding of which upon emergence in the laboratory 10 samples were of *Anopheles stephensi* and the remaining 8 were of Culicines. Out of 2143 curing waters checked, 24 (1.1%) were positive for immatures, most of which (23; 1.1%) contained *An. stephensi* immature. Out of the 13 (0.7%) of 1764 stagnant waters, 8 were positive for anopheles immature. Percentage

Table: 4.8 Relative contribution of construction sites and residential colonies to breeding sites to vector potential in Panaji in 2004

	No. of sites	Vector potential
Construction sites	18728 (61.8%)	63.65%
Residential colonies	11591 (38.2%)	36.35%

Table: 4.9 Relative contribution of Anophelines, Culicines and Aedines mosquito breeding sites to habitat surface area in Panaji in 2004

Breeding Preference	Nos.	(%)	Habitat surface area (sq.m.)	(%)
Anophelines	34867	23.1	207567.7	81.1
Culicines	73696	48.8	7796.5	3.0
Aedines	42473	28.1	40714.3	15.9
Total	151036		256078.5	

positivity of remaining breeding habitats for Anophelines ranged from 0 to 7.4, the maximum being that of fountains (7.4%) followed by disused swimming pools (5.1%) and drains (22.4%) in which clean water had stagnated (Table 4.10).

Immature surveys in Margao: A total of 1758 sites were surveyed out of which 53 (3%) sites were found positive for immature breeding of mosquitoes. Of these, 24 (1.4%) were found containing anopheline breeding, while 29 (1.6%) were positive for culicine breeding. Of these habitats, 17 (3.4%) curing waters contained immature of *An. stephensi* while 7.1% of terrace stagnant waters had this vector species. *An. stephensi* was also found breeding in stagnant waters on the floors (0.2%), barrels and drums (0.7%) and flower pots (2.6%). It may be mentioned that anopheline immatures collected from cement tanks and terrace water collections did not survive long enough in the laboratory for emergence and subsequent identification of adults to species level (Table 4.11).

Immature surveys in Candolim: A total of 2154 breeding sites were surveyed belonging to 18 different types which included both construction sites as well as domestic and peri-domestic breeding habitats. Of these, 74 (3.4%) were positive for mosquito immature including 39 (1.8%) and 35 (1.6%) for anophelines and culicines respectively. Among these habitats, stagnant waters (1.6%), curing waters (4.1%), sumps (17.4%), terrace water collections (15.4%), ground cement tanks (15%), wells (8.1%), swimming pools (9.1%) supported primarily *An. stephensi* breeding. Ground cement tanks also supported breeding of *An. subpictus,* which is a non vector species in this area (Table 4.12).

Table: 4.10 Results of extensive breeding surveys carried out in various habitats of mosquitoes in Panaji, Goa in 2004

S. No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Sump	308	18	5.8	10	3.2	8	2.6	*An. stephensi*
2	Curing Water	2143	24	1.1	23	1.1	1	0.0	*An. stephensi* *Aedes aegypti*
3	Stagnant Water	1764	13	0.7	8	0.5	5	0.3	Immatures died
4	Ground Cement Tank	294	12	4.1	7	2.4	5	1.7	*An. stephensi,* *Ae. aegypti*
5	Ground Polyplast Tank	350	4	1.1	4	1.1	0	0.0	*An. stephensi*
6	Iron Barrel	187	4	2.1	3	1.6	1	0.5	*An. stephens,* Ae. larvae died
7	Plastic Barrel	331	2	0.6	0	0.0	2	0.6	*Ae. aegypti*
8	Swimming Pool	39	2	5.1	2	5.1	0	0.0	*An. stephensi*
9	Fountain	27	2	7.4	2	7.4	0	0.0	*An. stephensi*
10	Well	216	6	2.8	6	2.8	0	0.0	*An. stephensi*
11	Over Head Tank (Concrete)	209	2	1.0	2	1.0	0	0.0	*An. stephensi*
12	Drain	85	19	22.4	4	4.7	15	17.6	*An. stephensi* (drains with clean water) *Cx. quinquefasciatus* (polluted water)
	Total	5953	108	1.8	71	1.2	37	0.6	

Table: 4.11 Results of breeding surveys carried out in various habitats of mosquitoes in Margao in 2004

S.No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Stagnant Water	420	6	1.4	1	0.2	5	1.2	*An. stephensi ,Cx. quinquefasciatus*
2	Curing Water	497	25	5.0	17	3.4	8	1.6	*An. stephensi, Culicine larvae died*
3	Sump	42	0	0	0	0	0	0	*An. stephensi*
4	Terrace Water Collection	14	1	7.1	1	7.1	0	0	Immatures died
5	Polyplast Tanks	67	0	0	0	0	0	0	-
6	Tyres	78	1	1.3	0	0	1	1.3	Immatures died
7	Barrel/Drums	148	5	3.4	1	0.7	4	2.7	*Ae. aegypti, An. stephensi*
8	Concrete Mixer	10	0	0	0	0	0	0	-
9	Cement Tank	13	5	38.5	3	23.1	2	15.4	Immatures died
10	Wells	35	0	0	0	0	0	0	-
11	Coconut Shells	57	0	0	0	0	0	0	-
12	Lift Tank	12	0	0	0	0	0	0	-
13	Flower pots	39	2	5.1	1	2.6	1	2.6	*An. stephensi, Cx. quinquefasciatus*
14	Drain	45	6	13.3	0	0.0	6	13.3	*Ae. aegypti, Cx. quinquefasciatus*
15	Buckets	89	0	0	0	0	0	0	-
16	Containers	34	0	0	0	0	0	0	-
17	Plastic Pots	43	0	0	0	0	0	0	-
18	Bottles	61	0	0	0	0	0	0	-
19	Pits	23	0	0	0	0	0	0	-
20	Ponds	1	0	0	0	0	0	0	-
21	Grinding Stone	17	1	5.9	0	0	1	5.9	*Ae. aegypti*
22	Chambers	13	1	7.7			1	7.7	*Cx. quinquefasciatus*
	Total	1758	53	3.0	24	1.4	29	1.6	

Table 4.12: Results of breeding surveys carried out in various habitats of mosquitoes in Candolim, Goa in 2004.

S.No.	Breeding Habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Stagnant Water	442	12	2.7	7	1.6	5	1.1	*An. stephensi*
2	Curing Water	345	24	7.0	14	4.1	10	2.9	*An. stephensi*, *Cx. Lutzia fuscanus*, *Aedes albopictus*
3	Sump	23	4	17.4	4	17.4	0	0	*An. stephensi*
4	Terrace Water Collection	13	2	15.4	2	15.4	0	0	*An. stephensi*
5	Polyplast Tanks	64	0	0	0	0	0	0	-
6	Tyres	958	16	1.7	0	0	16	1.7	*Ae. vittatus*, *Ae. albopictus*
7	Barrel/Drums	56	1	1.8	1	1.8	0.0	0.0	*An. stephensi*
8	Concrete Mixer	11	0	0	0	0	0	0	-
9	Ground Cement Tank	40	6	15.0	6	15.0	0	0	*An. subpictus*, *An. stephensi*
10	Wells	37	3	8.1	3	8.1	0.0	0.0	*An. stephensi*
11	Septic Tank	11	1	9.1	0	0	1	9.1	*Cx.quinquefasciatus*
12	Water puddles	52	2	3.8	0	0	2	3.8	*Ae. aegypti*
13	Ponds	2	0	0	0	0	0	0	-
14	Chambers	19	0	0	0	0	0	0	-
15	Swimming Pool	11	1	9.1	1	9.1	0.0	0.0	*An. stephensi*
16	Ornamental Tank	18	0	0	0	0	0	0	-
17	Foundation Pits	37	2	5.4	1	2.7	1	2.7	Larvae dead
18	Drain	15	0	0	0	0	0	0	-
	Total	2154	74	3.4	39	1.8	35	1.6	

Immature surveys in Cortalim: Among 1066 breeding habitats falling in 17 categories, 46 (4.3%) were found with mosquito immature. Of which 25 (2.3%) were anophelines and remaining 21 (2.0%) were culicines. *An. stephensi* breeding was detected in stagnant waters (4.5%), curing waters (6.3%), sumps (5.7%) and iron/plastic barrels (1.2%). The anopheline immatures in the ground cement tanks did not survive in the laboratory. The remaining 21 sites were positive for culicines viz., *Culex quinquefasciatus*, *Cx. Lutzia fuscanus, Aedes aegypti* and *Armigeres subalbatus.* These species were confirmed upon emergence (Table 4.13).

Immature surveys in Bicholim: Out of the 832 breeding habitats surveyed, 31 (3.7%) were positive for mosquito immature. Anophelines were breeding in 12 (1.4%) and culicines in 19 (2.8%) habitats. Interestingly the emergence did not show breeding of *An. stephensi* amongst anophelines although *An. culicifacies* was found breeding in the paddy fields (Table 4.14). It may be added that Anopheline immatures from ground plastic tanks, foundation pits and wells did not survive in the laboratory for their identification.

Immature surveys in Ponda: 12 different types of breeding habitats were surveyed and out of the total 379 habitats, 20 (5.3%) were positive for mosquito immature including 7(1.8%) for anophelines and 13(3.4%) for culicines respectively. *An. stephensi* was found breeding in 7(19.4%) out of 36 curing waters searched for mosquito breeding. Hence *An. stephensi* was encountered only in the curing waters during this survey in Ponda town. The culicines emerged were *Culex quinquefasciatus*, *Aedes albopictus, Ae. aegypti* and *Armigeres species* (Table 4.15).

Table: 4.13 Results of breeding surveys carried out in various habitats of mosquitoes in Cortalim, Goa in 2004

S.No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Stagnant Water	110	8	7.3	5	4.5	3	2.7	*An.stephensi, Armigeres subalbatus*
2	Curing Water	175	20	11.4	11	6.3	9	5.1	*An. stephensi*
3	Ground Cement Tank	29	6	20.7	3	10.3	3	10.3	Immatures died
4	Ground Plastic Tank	15	0	0	0	0	0	0	-
5	Overhead Tank	21	0	0	0	0	0	0	-
6	Sump	35	2	5.7	2	5.7		0.0	*An. stephensi*
7	Polyplast Tank	23	3	13.0	2	8.7	1	4.3	*Cx. quinquefasciatus, Cx. Lutzia fuscanus*
8	Containers	82	0	0	0	0	0	0	-
9	Plastic Buckets	61	1	1.6		0.0	1	1.6	*Ae. aegypti*
10	Iron/ Plastic Barrels	170	4	2.4	2	1.2	2	1.2	*Ae. aegypti, An stephensi*
11	Chamber	44	0	0	0	0	0	0	-
12	Drain	16	0	0	0	0	0	0	-
13	Foundation Pit	25	0	0	0	0	0	0	-
14	Septic Tank	11	0	0	0	0	0	0	-
15	Tyres	53	2	3.8		0.0	2	3.8	Immatures died
16	Coconut shells	163	0	0	0	0	0	0	-
17	Bottles	33	0	0	0	0	0	0	-
	Total	1066	46	4.3	25	2.3	21	2.0	

Table: 4.14 Results of breeding surveys carried out in various habitats of mosquitoes in Bicholim, Goa in 2004

.No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Ground Plastic Tank	16	3	18.8	1	33.3	2	66.7	*Anophelines immatures died*
2	Lake	4	0	0	0	0	0	0	-
3	Foundation Pit	36	3	8.3	1	33.3	2	66.7	Immatures died
4	Well	22	3	13.6	2	66.7	1	33.3	Immatures died
5	Paddy Field W.C	17	2	11.8	1	50.0	1	50.0	*An. culicifacies, Cx. sinensis*
6	Ground Cement Tank	21	3	14.3	2	66.7	1	33.3	*Cx. sinensis*
7	Fountain	7	2	28.6	1	50.0	1	50.0	*Cx. whitmori*
8	Pond	5	0	0	0	0	0	0	-
9	Barrels	65	0	0	0	0	0	0	-
10	Buckets	88	0	0	0	0	0	0	-
11	Coconut shells	69	0	0	0	0	0	0	-
12	Plastic/Flower Pots	159	6	3.8	2	33.3	4	66.7	*Ae. albopictus*
13	Container	115	0	0	0	0	0	0	-
14	Bottles	58	0	0	0	0	0	0	-
15	Tyres	115	6	5.2	1	16.7	5	83.3	*Ae. albopictus, Ae. vittatus*
16	Water puddles	22	0	0	0	0	0	0	-
17	Drain	13	3	23.1	1	33.3	2	66.7	*Cx. quinquefasciatus*
	Total	832	31	3.7	12	1.4	19	2.8	

Table: 4.15 Results of breeding surveys carried out in various habitats of mosquitoes in Ponda, Goa in 2004

S.No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Stagnant Water	16	1	6.3			1	6.3	*Cx. quinquefasciatus*
2	Curing Water	36	9	25.0	7	19.4	2	5.6	*An. stephensi*
3	Ground Concrete Tank	16	0	0	0	0	0	0	-
4	Ground Plastic Tank	27	0	0	0	0	0	0	-
5	Sump	16	0	0	0	0	0	0	-
6	Tyres	116	3	2.6	0	0	3	2.6	*Cx .quinquefasciatus*
7	Plastic Bucket	13	1	7.7	0	0	1	7.7	*Ae. albopictus*
8	Iron Barrel	11	1	9.1	0	0	1	9.1	
9	Plastic Barrel	21	2	9.5	0	0	2	9.5	*Ae. aegypti*
10	Well	8	0	0	0	0	0	0	-
11	Bottles	65	1	1.5	0	0	1	1.5	*Ae. aegypti*
12	Plastic Containers	34	2	5.9	0	0	2	5.9	*Armigeres spp.*
	Total	379	20	5.3	7	1.8	13	3.4	

Immature surveys in Sanguem: A total of 187 breeding sites of 8 different types were sampled, of which 39 (20.9%) were positive for mosquito immature. Of these, 12 (6.4%) were positive for anophelines and 27 (14.4%) were positive for culicines. *An. stephensi* was not found breeding in any of the habitats, however *An. fluviatilis* was detected from stone quarries and water puddles. Among the culicines were *Culex quinquefasciatus*, *Ae. albopictus*, and *Toxorhynchites species* (Table 4.16).

4.3 Mosquito Adult Catches

Adult Mosquito Collections with Mosquito Magnet™ Trap: During 24 hours of adult collections using Mosquito Magnet on 34 days, a total of 2329 mosquitoes (mean of 68.5 mosquitoes/day) were trapped, out of which 2120(91%) were females and the remaining 210(9%) were males (Table 4.17). These mosquitoes belonged to 16 species and were identified as *An. stephensi* Liston, *An. subpictus* Grassi, *An. vagus* Doenitz, *An. barbirostris* Van der Wulp, *An. Jamesi* Theo., *An. nigerrimus* Giles, *Cx. quinquefasciatus* Say, *Cx. vishnui* Theo., *Cx. tritaeniorhynchus* Giles, *Cx. gelidus* Theo., *Cx. bitaeniorhynchus* Giles, *Cx. pseudovishnui* Colless, *Ma. uniformis* Theo., *Ae. albopictus* Barraud, *Ae. vittatus* Biggot (only 1 male was trapped) *and Armegeres subalbatus* Coq.

The mosquitoes of public health importance collected included, 59(2.78%) malaria vector *An. stephensi*; 1013 (47.8%) Filaria vector *Cx. quinquefasciatus*; 551 (26.0%) Japanese Encephalitis vectors *Cx. vishnui* group, 216 (10.2%) Filaria vector *Ma. uniformis* and 1 (0.04%) Dengue/Chikungunya vector *Ae. albopictus.* The remaining 13.2% mosquitoes were non-vectors (Table 4.18). Thus of the total 2120 female

Table: 4.16 Results of sample breeding surveys carried out in various habitats of mosquitoes in Sanguem, Goa in 2004

S.No.	Breeding habitat	No. surveyed	+ve for mosquito breeding		Anopheles immature breeding		Culicine immature breeding		Species emerged in the laboratory/ Remarks
			No.	%	No.	%	No.	%	
1	Stone Quarries	6	2	33.3	2	33.3	0	0.0	*An. fluviatilis, An. maculatus*
2	Pit	29	5	17.2	1	3.4	4	0.0	*Cx. quinquefasciatus*
3	Water Puddle	5	1	20.0	1	20.0	0	0.0	*An. fluviatilis*
4	Stream	4	1	25.0	1	25.0	0	0.0	*Immatures died*
5	Tyre	74	21	28.4	4	5.4	17	23.0	*Toxorhynchites sp.*
6	Barrel	11	2	18.2	1	9.1	1	9.1	*Ae. albopictus*
7	Tin	31	4	12.9	2	6.5	2	6.5	*Cx. quinquefasciatus*
8	Pot	27	3	11.1	0	0.0	3	11.1	*Immatures died*
	Total	187	39	20.9	12	6.4	27	14.4	

Table: 4.17 Number of Adult female mosquitoes collected* from four localities using Mosquito Magnet® Pro-Model in Panaji.

Sr. No.	Mosquito species**	No. of females collected	%	Mean ± SD/collected per day
1	*Anopheles stephensi* Liston	59	2.78	1.73±2.43
2	*An. subpictus* Grassi	65	3.06	1.91±2.90
3	*An. vagus* Doenitz	19	0.89	0.56±1.57
4	*An. barbirostris* Van der Wulp	4	0.18	0.12±0.40
5	*An. jamesi* Theobald	5	0.23	0.15±0.43
6	*An. nigerimus* Giles	1	0.04	0.03±0.17
7	*Culex quinquefasciatus* Say	1013	47.78	29.79±53.97
8	*Cx. vishnui* Theobald	180	8.49	5.29±14.39
9	*Cx. tritaeniorhynchus* Giles	365	17.21	10.73±23.52
10	*Cx. bitaeniorhynchus* Giles	51	2.40	1.50±3.75
11	*Cx. gelidus* Theobald	60	2.83	1.76±3.24
12	*Cx. pseudovishnui* Colless	6	0.28	0.18±0.86
13	*Mansonia uniformis* Theobald	216	10.18	6.35±10.89
14	*Ae. albopictus* (Skuse)	1	0.04	0.03±0.17
15	*Armigeres subalbatus* (Coquillett)	75	3.53	2.20±3.04
Total		2120**		

* During 24 hr collections done on 34 days

**Excluding one male *Aedes vittatus* trapped

Table: 4.18 Locality wise vector females collected (Numbers & percentage) using Mosquito Magnet® Pro-Model during 24 hrs each in 34 collections in Panaji, Goa.

Locality	*An. stephensi*	*Cx. quinquefasciatus*	*Cx. vishnui group*	*Ma. uniformis*	Total*
Market area	41(69.4%)	923(91.1%)	100(18.2 %)	12(5.6%)	1076
Miramar	0	59(5.8%)	41(7.4 %)	82(37.9%)	182
Caranzalem	18(30.5%)	24(2.4%)	404(73.3 %)	122(56.5%)	568
Boca-de-Vaca	0	7(0.7%)	6(1.1 %)	0	13
Total	59	1013	551	216	1839*

*In addition, one *Ae. albopictus* was collected from Caranzalem.

mosquitoes, 1840 (86.8%) were the known vectors of different mosquito borne diseases.

Maximum number of *An. stephensi* was trapped from the Market locality (41, 69%) followed by Caranzalem locality (18, 30.5%) of the city. On the other hand, filarial vector *Cx. quinquefasciatus* was the most predominant species in Market locality (923, 91.1%), followed by Miramar (5.8%) and Caranzalem localities (2.4%) but was collected in a few numbers in Boca-de-Vaca locality of Panaji. Japanese encephalitis vectors belonging to *Cx. vishnui* group of mosquitoes were also collected from all the 4 study localities, highest numbers in Caranzalem (404, 73.3%) followed by Market (100, 28.2%), Miramar (41, 7.4%) and least in Boca-de-Vaca (6, 1%). Lastly, *Ma. uniformis*, a vector of Brugian filariasis was present in three out of 4 localities; maximum (122, 56.5%) were in Caranzalem followed by 82 (37.9%) in Miramar and least 12 (5.6%) in Market area and none in Boca-de-Vaca locality. Amongst the vector species trapped, *Culex quinquefasciatus* was the most prevalent species (55%) followed by *Culex vishnui* group (30%), *Mansonia annulifera* (12%) and the least were *An. stephensi* (3%) [Fig. 4.11].

Landing Collections of Adult Mosquito Females: A total of 4191 mosquitoes were collected during 85 all night collections from fourteen different localities with mean mosquito landing rate of 49.3 mosquitoes per bait per night. These mosquitoes belonged to 23 species and included vectors of malaria viz., *An. stephensi* Liston 55(1.31%), *An. fluviatilis* James 75(1.79%), *An. culicifacies* Giles 32(0.76%); Filaria vectors *Cx. quinquefasciatus* Say 1710(40.80%), *Ma. uniformis* Theobald 76 (1.81%); Japanese encephalitis vectors, *Cx. vishnui* Theobald group 1057 (25.47%)

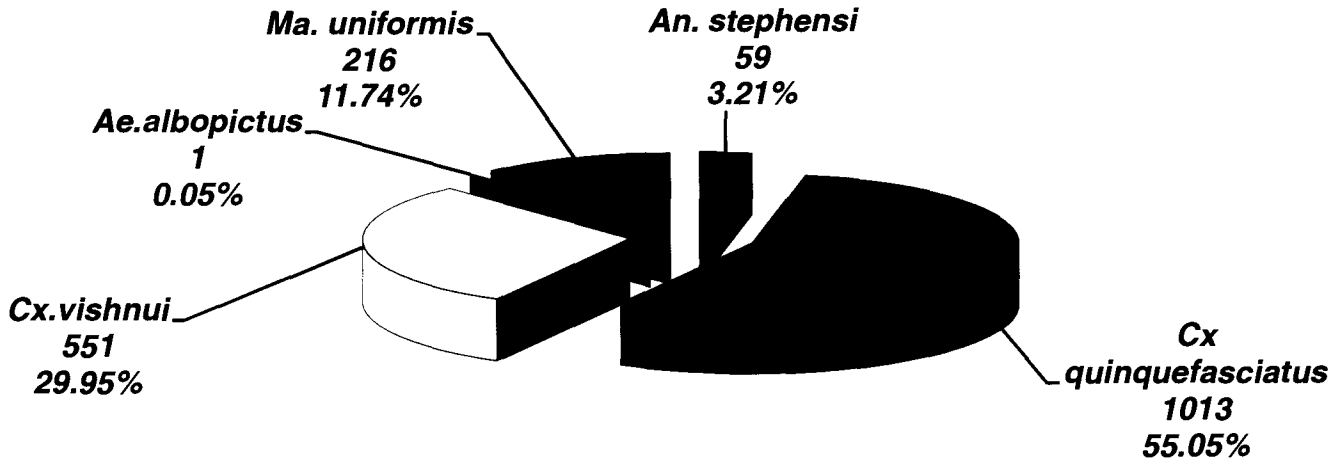


Fig. 4.11: Relative contribution of vector mosquito species collected with Mosquito Magnet Trap in 34 collections done in Panaji, Goa

and Dengue/Chikungunya vectors *Aedes albopictus* (Skuse) and *Aedes aegypti* (Linnaeus) 63(1.50%) and remaining 1123(26.79%) were non vectors. Of the total 4191 female mosquitoes, 3068 (73.20%) were the known vectors of different mosquito borne diseases (Table 4.19.) The number of mosquitoes of all species collected on human bait was maximum in the post-monsoon season (2156; 51.4%), followed by pre-monsoons (1586; 37.8%) and least during the monsoons (449; 10.7%). *An. stephensi* was maximum in the post-monsoon months (23; 41.8%)) followed by Monsoons (17; 30.9%) and pre-monsoons (15; 27.3%). The foothill vector *An. fluviatilis* was however, collected in maximum number in the pre-monsoon months (54; 72%) followed by post-monsoons (16; 21.3%) and lest during the monsoons (5; 6.7%). The rural malaria vector *An. culicifacies* was also collected and its maximum collection during the post-monsoon months (25.0; 78.1%) followed by pre-monsoons (5; 15.6%) and least during the monsoons (2; 6.3%).The other anophelines were maximum during pre-monsoon months (356; 53.2%) followed by post-monsoons (243; 36.3%) and least during the monsoons (70; 10.5%). The culicines were found maximum during the post monsoons (1849; 55%) followed by pre-monsoons (1156; 34.4%) and least during monsoons (355; 10.6%) [Table 4.20].

Anopheles stephensi which is the primary malaria vector was found in the urban coastal localities of Panaji, Candolim, Margao and Cortalim. It was found actively pursuing host throughout the night (Table 4.21). Out of total 55 *An. stephensi* caught, 15 (27.3%) were captured during early hours i.e. 18.00 to 21.00hrs. From 21.00-24.00hrs 11 (20%) *An. stephensi* were caught while

Table: 4.19 Landing mosquito females collected during 85 all night (18:00 - 06:00 hrs) in 14 different localities of Goa.

Sr. No.	Species	No. collected	% to Total mosquitoes collected	% to Total of the respective Genera
	Anopheline spp.			
1	*An. stephensi* Liston	55	1.31	6.02
2	*An. fluviatilis* James	75	1.79	9.03
3	*An. culicifacies* Giles	32	0.76	3.85
4	*An. barbirostris* Van der Wulp	17	0.41	2.05
5	*An. nigerrimus* Giles	81	1.93	9.75
6	*An. jamesi* Theobald	224	5.34	26.96
7	*An. tesselatus* Theobald	58	1.38	6.98
8	*An. vagus* Doenitz	45	1.07	5.42
9	*An. subpictus* Grassi	157	3.75	18.89
10	*An. karwari* (James)	87	2.08	10.47
	Total Anophelines	831	19.83%	
	Culex spp.			
11	*Cx. quinquefasciatus* Say	1710	40.80	55.35
12	*Cx. tritaeniorhynchus* Giles	729	17.39	23.59
13	*Cx. vishnui* Theobald	324	7.73	10.48
14	*Cx. pseudovishnui* Colless	4	0.10	0.12
15	*Cx. nilgiricus* Edwards	11	0.26	0.35
16	*Cx. bitaeniorhynchus* Giles	4	0.10	0.12
17	*Cx. gelidus* Theobald	205	4.89	6.63
18	*Cx. whitmori* (Giles)	102	2.43	3.30
	Total Culex spp	3089	73.71%	
	Aedes spp.			
19	*Ae. aegypti* (Linnaeus)	26	0.62	34.21
20	*Ae. albopictus* (Skuse)	37	0.88	48.68
21	*Ae. vittatus* (Biggot)	13	0.31	17.10
	Total Aedes	76	1.81%	
	Other spp.			
22	*Mansonia uniformis* Theobald	76	1.81	38.97
23	*Armigeres subalbatus* (Coquillett)	119	2.84	61.03
	Total Others	195	4.65%	
	Total	4191		

Table: 4.20 No. of mosquitoes collected on bait during different seasons.

Sr. No.	Species	Pre-Monsoons (Jan-May)	Monsoons (June-Sept.)	Post Monsoons (Oct-Dec.)	Total
1.	*An. stephensi*	15 (27.3 %)	17 (30.9 %)	23 (41.8 %)	55
2.	*An. culicifacies*	5 (15.6 %)	2 (6.3 %)	25 (78.1%)	32
3.	*An. fluviatilis*	54 (72 %)	5 (6.7%)	16 (21.3 %)	75
4.	Other Anophelines	356 (53.2 %)	70 (10.5 %)	243 (36.3 %)	669
5.	All Culicines	1156 (34.4 %)	355 (10.6 %)	1849 (55 %)	3360
	Total Mosquitoes	**1586 (37.8 %)**	**449 (10.7 %)**	**2156 (51.4 %)**	**4191**

Table: 4.21 Total number of mosquitoes collected on bait during different phases of night

Sr. No.	Species	18:00 - 21.00 hrs	21:00 - 24:00 hrs.	24:00 - 03:00 hrs	03:00 - 06:00 hrs.	Total
1	*An. stephensi*	15 (27.3%)	11 (20 %)	6 (10.9 %)	23 (41.8 %)	55
2	*An. culicifacies*	11 (34.2%)	5 (15.6 %)	9 (28.1%)	7 (21.9 %)	32
3	*An. fluviatilis*	18 (24%)	17 (22.7 %)	10 (13.3 %)	30 (40%)	75
4	Other Anophelines	173 (25.9%)	132 (19.7 %)	120 (17.9 %)	244 (36.5 %)	669
5	All Culicines	842 (25.1%)	665 (19.8 %)	535 (15.9 %)	1318 (39.2 %)	3360
	Total Mosquitoes	**1059 (25.3%)**	**830 (19.8%)**	**680 (16.2%)**	**1622 (38.7%)**	**4191**

from 24.00-03.00hrs 6 (10.9%) and maximum 23 (41.8%) were found biting during early morning hours between 03.00-06.00hrs.

An. culicifacies, which is a known rural vector of malaria in India, was found biting through out the night at variable frequency. The feeding activity of *An. culicifacies* was found more pronounced during early hours between 18.00 and 21.00hrs (11; 34.2%) followed by 24.00 to 03.00hrs (9; 28.1%), 03.00-06.00hrs (7, 21.9%) and least during 21.00-24.00hrs (5;15.6%).

The feeding pattern of this foothill species *An. fluviatilis,* was almost similar to *An. stephensi.* The maximum numbers of this species were caught from 03.00-06.00hrs (30; 40%) followed by 18.00-21.00hrs (18; 24%), 21.00-24.00hrs (17; 22.7%) and the least during 24.00-03.00hrs (10, 13.3%).

The other anophelines were captured 173 from 18.00-21.00hrs. (25.9%), 132 (19.7%) from 21.00-24.00 hrs., 120(17.9%) from 24.00-03.00hrs and 244 (36.5%) from 03.00-06.00hrs. The culicines caught from 18.00-21.00hrs were 842(25.1%), 665(19.8%) from 21.00-24.00 hrs, 535(5.9%) from 24.00-03.00hrs and 1318(39.2%) from 03.00-06.00hrs.

Based on entomological studies carried out in different parts of Goa, a map was prepared showing distribution of the three malaria vectors viz., *Anopheles stephensi*, *An. fluviatilis* and *An. culicifacies* (Fig. 4.12). While the *An. stephensi* was distributed mostly in the coastal belt, the other two vectors were distributed in the sub-coastal regions in the valleys and foothills.

4.4 Vector Incrimination with Sporozoite ELISA

Out of the 984 female Anophelines belonging to 10 species viz., *An. stephensi* (114), *An. fluviatilis* (75), *An. culicifacies* (32), *An. barbirostris* (21), *An. nigerrimus* (82), *An. jamesi* (229), *An. tessellates* (58), *An. vagus* (64),

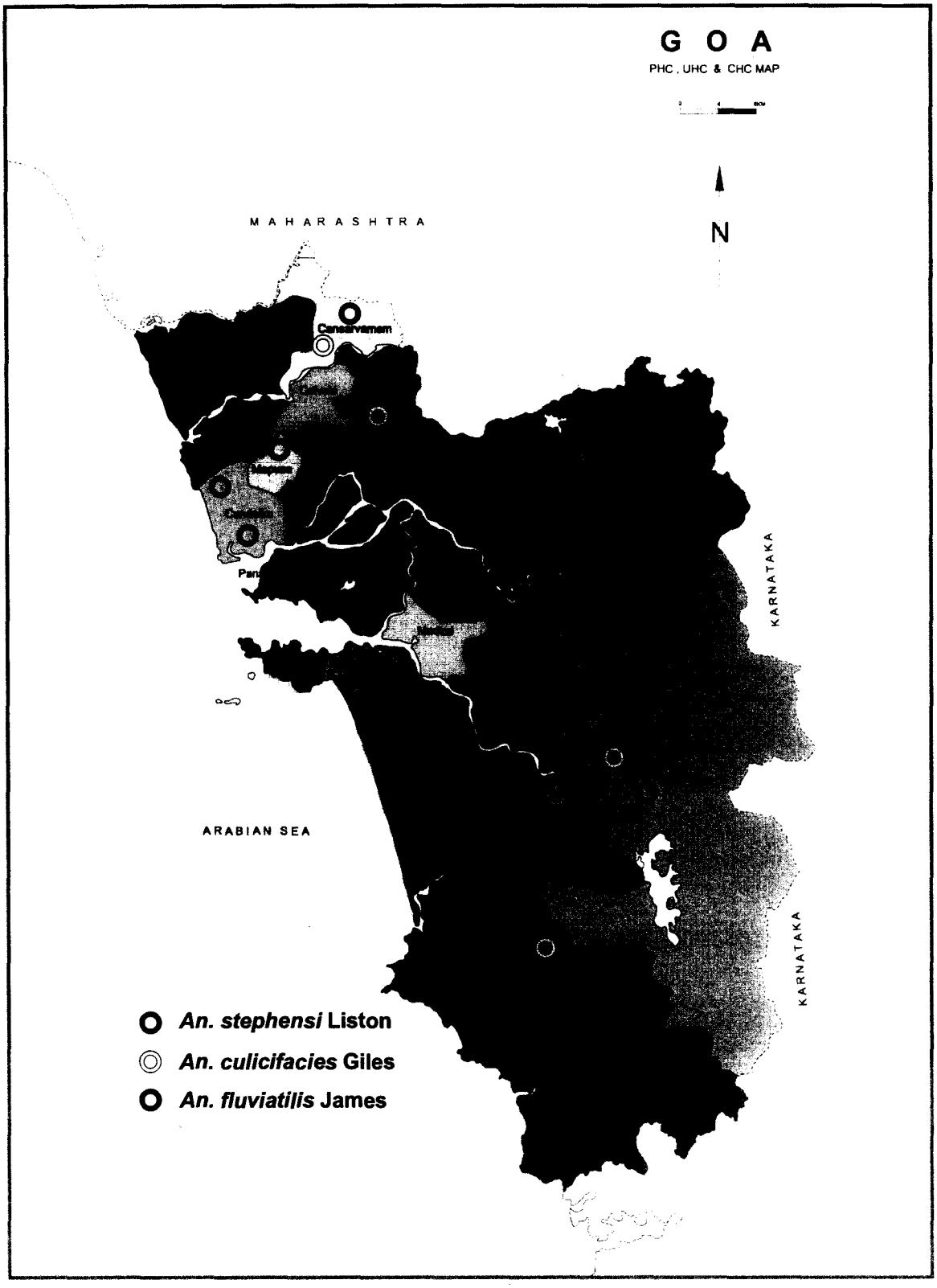


Fig: 4.12 Map of Goa State showing distribution of malaria vectors ***An. stephensi*** in red dots, ***An. culicifacies*** in yellow dots and ***An. fluviatilis*** in green dots.

An. subpictus (222) and *An. karwari* (87) collected during all night collections and mosquito magnet™ trap collections and evaluated for CSP by ELISA technique, 3 (2.6%) specimens out of 114 *An. stephensi* collected from Panaji were found to contain *Plasmodium falciparum,* while all the samples of other Anophelines did not show infection of Plasmodium species (Table 4.22). For the first time the Entomological Inoculation Rate (EIR) of *P. falciparum* was worked out as 18.1 and 2.35 for Panaji and Goa respectively based on biting rates of *An. stephensi* and infection rates in the vector.

5. Malaria Incidence in Goa

Parasitological data of malaria in the state of Goa from 1963 to 2007 is presented in Table 4.23. This data is mentioned below separately for the years from 1963 to 1985, 1986 to 2001 and 2002 to 2007. The reason being, that soon after the liberation of Goa from the Portuguese rule in the year 1961, the National Malaria Eradication Programme of India was extended to the state of Goa in the year 1963 and the parasitological data became available from that year onwards. Till the year 1985, the problem of malaria was restricted to the rural areas in the hinterlands of Goa. However, from 1986 to 2001, many outbreaks of malaria occurred in many urban towns and urbanized villages mainly along the coastal belt. For the sake of comparison with earlier years, the data from 2002 to 2007 during the study period has been presented separately.

1963-1985: It was observed that from the years 1963-74, total malaria cases varied from 3 to 201, mostly of *P. vivax,* whereas *P. falciparum* cases were negligible (0 to 3 cases). The SPR was less than 1 during this period. However, compared with 165 cases of malaria in 1974, in the year 1975, a sudden increase in malaria cases to 634 (SPR:0.9%) including 16 *P. falciparum* cases occurred. Malaria incidence further increased to 2012 cases including 148 *P. falciparum.*

Table : 4.22 Results of circumsporozoite protein (CSP) ELISA for *P. falciparum* & *P. vivax* infection in female Anophelines collected from different parts of Goa*

S.No.	Species	Collection Method						Total		
		Mosquito Magnet PRO-Model			Human Landing Collection					
		No. Tested	No. +ve	Percent +ve	No. Tested	No. +ve	Percent +ve	No.Tested	No. +ve	Per cent +ve
1	*An. stephensi*	59	1	1.7	55	2	3.6	114	3	2.6
2	*An. fluviatilis*	-	-	-	75	0	0.0	75	0	0.0
3	*An. culicifacies*	-	-	-	32	0	00	32	0	0.0
4	*An. barbirostris*	4	0	0.0	17	0	0.0	21	0	0.0
5	*An. nigerrimus*	1	0	0.0	81	0	0.0	82	0	0.0
6	*An. jamesi*	5	0	0.0	224	0	0.0	229	0	0.0
7	*An. tessalatus*	-	-	-	58	0	0.0	58	0	0.0
8	*An. vagus*	19	0	0.0	45	0	0.0	64	0	0.0
9	*An. subpictus*	65	0	0.0	157	0	0.0	222	0	0.0
10	*An. karwari*	-	-	-	87	0	0.0	87	0	0.0
	TOTAL	**153**	**1**	**0.6**	**831**	**2**	**0.2**	**984**	**3**	**0.3**

***(Burkot et al. 1984)** ** **All *An. stephensi* +ve for *P. falciparum* CSP**

Table: 4.23 Malaria Incidence in the state of Goa from 1963-2007

YEAR	POP	BSC/E	PV	PF	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	AVI	AFI	API	DEATHS
1963	522934	17863	115	0	115	3.4	0.6	0.6	0.0	100.0	0.0	0.2	0.0	0.2	0
1964	549869	33027	174	1	175	6.0	0.5	0.5	0.0	99.4	0.6	0.3	0.0	0.3	0
1965	576804	42487	35	0	35	7.4	0.1	0.1	0.0	100.0	0.0	0.1	0.0	0.1	0
1966	603739	51963	3	0	3	8.6	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
1967	630674	64534	11	0	11	10.2	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
1968	657609	62736	9	0	9	9.5	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
1969	684544	23433	6	0	6	3.4	0.0	0.0	0.0	100.0	0.0	0.0	0.0	0.0	0
1970	711479	16644	12	0	12	2.3	0.1	0.1	0.0	100.0	0.0	0.0	0.0	0.0	0
1971	738414	23075	30	0	30	3.1	0.1	0.1	0.0	100.0	0.0	0.0	0.0	0.0	0
1972	765349	39879	200	1	201	5.2	0.5	0.5	0.0	99.5	0.5	0.3	0.0	0.3	0
1973	792284	42233	153	2	155	5.3	0.4	0.4	0.0	98.7	1.3	0.2	0.0	0.2	0
1974	819219	47574	162	3	165	5.8	0.3	0.3	0.0	98.2	1.8	0.2	0.0	0.2	0
1975	846154	70199	618	16	634	8.3	0.9	0.9	0.0	97.5	2.5	0.7	0.0	0.7	0
1976	873089	98000	1864	148	2012	11.2	2.1	1.9	0.2	92.6	7.4	2.1	0.2	2.3	0
1977	900024	67000	1255	44	1299	7.4	1.9	1.9	0.1	96.6	3.4	1.4	0.0	1.4	0
1978	926959	67462	440	10	450	7.3	0.7	0.7	0.0	97.8	2.2	0.5	0.0	0.5	0
1979	953894	68230	269	1	270	7.2	0.4	0.4	0.0	99.6	0.4	0.3	0.0	0.3	0
1980	980829	74374	181	7	188	7.6	0.3	0.2	0.0	96.3	3.7	0.2	0.0	0.2	0
1981	1007749	63330	146	5	151	6.3	0.2	0.2	0.0	96.7	3.3	0.1	0.0	0.1	0
1982	1012787	71745	102	3	105	7.1	0.1	0.1	0.0	97.1	2.9	0.1	0.0	0.1	0
1983	1017851	79573	105	2	107	7.8	0.1	0.1	0.0	98.1	1.9	0.1	0.0	0.1	0
1984	1022940	80168	110	2	112	7.8	0.1	0.1	0.0	98.2	1.8	0.1	0.0	0.1	0
1985	1028055	82320	77	3	80	8.0	0.1	0.1	0.0	96.3	3.8	0.1	0.0	0.1	0
1986	1033195	73275	430	3	433	7.1	0.6	0.6	0.0	99.3	0.7	0.4	0.0	0.4	0
1987	1038361	108001	4794	16	4810	10.4	4.5	4.4	0.0	99.7	0.3	4.6	0.0	4.6	0
1988	1043553	128955	6445	287	6732	12.4	5.2	5.0	0.2	95.7	4.3	6.2	0.3	6.5	0
1989	1048771	98582	3632	565	4197	9.4	4.3	3.7	0.6	86.5	13.5	3.5	0.5	4.0	0
1990	1054010	99687	4019	871	4890	9.5	4.9	4.0	0.9	82.2	17.8	3.8	0.8	4.6	0
1991	1060279	85953	2380	499	2879	8.1	3.3	2.8	0.6	82.7	17.3	2.2	0.5	2.7	0
1992	1076838	79193	648	203	851	7.4	1.1	0.8	0.3	76.1	23.9	0.6	0.2	0.8	0
1993	1093449	92038	1894	333	2227	8.4	2.4	2.1	0.4	85.0	15.0	1.7	0.3	2.0	0
1994	1111094	105585	3182	288	3470	9.5	3.3	3.0	0.3	91.7	8.3	2.9	0.3	3.1	0
1995	1129121	93378	3630	256	3886	8.3	4.2	3.9	0.3	93.4	6.6	3.2	0.2	3.4	2
1996	1147525	151145	10093	1539	11632	13.2	7.7	6.7	1.0	86.8	13.2	8.8	1.3	10.1	10
1997	1187106	243910	15198	5827	21025	20.5	8.6	6.2	2.4	72.3	27.7	12.8	4.9	17.7	57
1998	1239092	295375	17281	8694	25975	23.8	8.8	5.9	2.9	66.5	33.5	13.9	7.0	21.0	19
1999	1259032	298611	9832	5548	15380	23.7	5.2	3.3	1.9	63.9	36.1	7.8	4.4	12.2	17
2000	1342009	281242	6664	2500	9164	21.0	3.3	2.4	0.9	72.7	27.3	5.0	1.9	6.8	11
2001	1347731	277311	9021	3310	12331	20.6	4.4	3.3	1.2	73.2	26.8	6.7	2.5	9.1	12
2002	1355595	273434	13470	3348	16818	20.2	6.2	4.9	1.2	80.1	19.9	9.9	2.5	12.4	15
2003	1363817	278647	9867	1503	11370	20.4	4.1	3.5	0.5	86.8	13.2	7.2	1.1	8.3	1
2004	1372418	239043	6452	1387	7839	17.4	3.3	2.7	0.6	82.3	17.7	4.7	1.0	5.7	7
2005	1390981	264170	3317	430	3747	19.0	1.4	1.3	0.2	88.5	11.5	2.4	0.3	2.7	1
2006	1409643	277989	3814	1196	5010	19.7	1.8	1.4	0.4	76.1	23.9	2.7	0.8	3.6	7
2007	1428305	337200	8113	3848	11961	23.6	3.5	2.4	1.1	67.8	32.2	5.7	2.7	8.4	11

cases in the year 1976 with SPR of 2.1% and annual parasite index (API) equal to 2.3 [Data Source: NVBDCP] (Table 4.23 & Fig. 4.13). But in the following years, a gradual reduction in the malaria cases was observed till the year 1985 when only 80 malaria cases including 3 *P. falciparum* were reported in the entire Goa (SPR: 0.1% and API: 0.1). No death due to malaria was reported due to malaria from 1963 to 1985.

1986-2001: In the year 1986, a serious malaria outbreak erupted in Campal area of the capital city Panaji. A total of 433 malaria cases including 3 *P. falciparum* cases were recorded in Goa and majority of these cases were contributed by Panaji i.e. 352 (81.3%) malaria cases with 1 *P. falciparum* case. In 1987 malaria took an epidemic proportion and spread like wild fire in the entire Panaji city with cases increasing to 4416 (SPR: 20.3%; API: 103.6) out of the total 4810 (SPR: 4.5%; API: 4.6) cases reported in the entire Goa (Tables 4.23). Significantly high incidence of malaria cases was observed till the year 1991 (2879 cases) followed by a fall in the incidence in the year 1992 with the reporting of 851 malaria cases. From 1993 onwards, multiple foci of malaria developed in the coastal belt of Goa and a gradual upward trend of malaria cases was observed in the following years with disease reaching its peak in the year 1998 as record number of malaria cases i.e. 25975 with 8674 *P. falciparum* cases, and the highest SPR of 8.8% and API of 21.0 were recorded in Goa (Fig. 4.13). Two and 10 deaths attributable to malaria were reported in the years 1995 and 1996 respectively followed by peak no. of 57 deaths due to malaria in 1997 in the state of Goa (Table 4.23). In the years 1999 and 2000, however, there was a declining trend of malaria during which 15380 (SPR: 5.2%, API: 12.2 and SfR: 1.9) and 9164 (SPR: 3.3% and API:

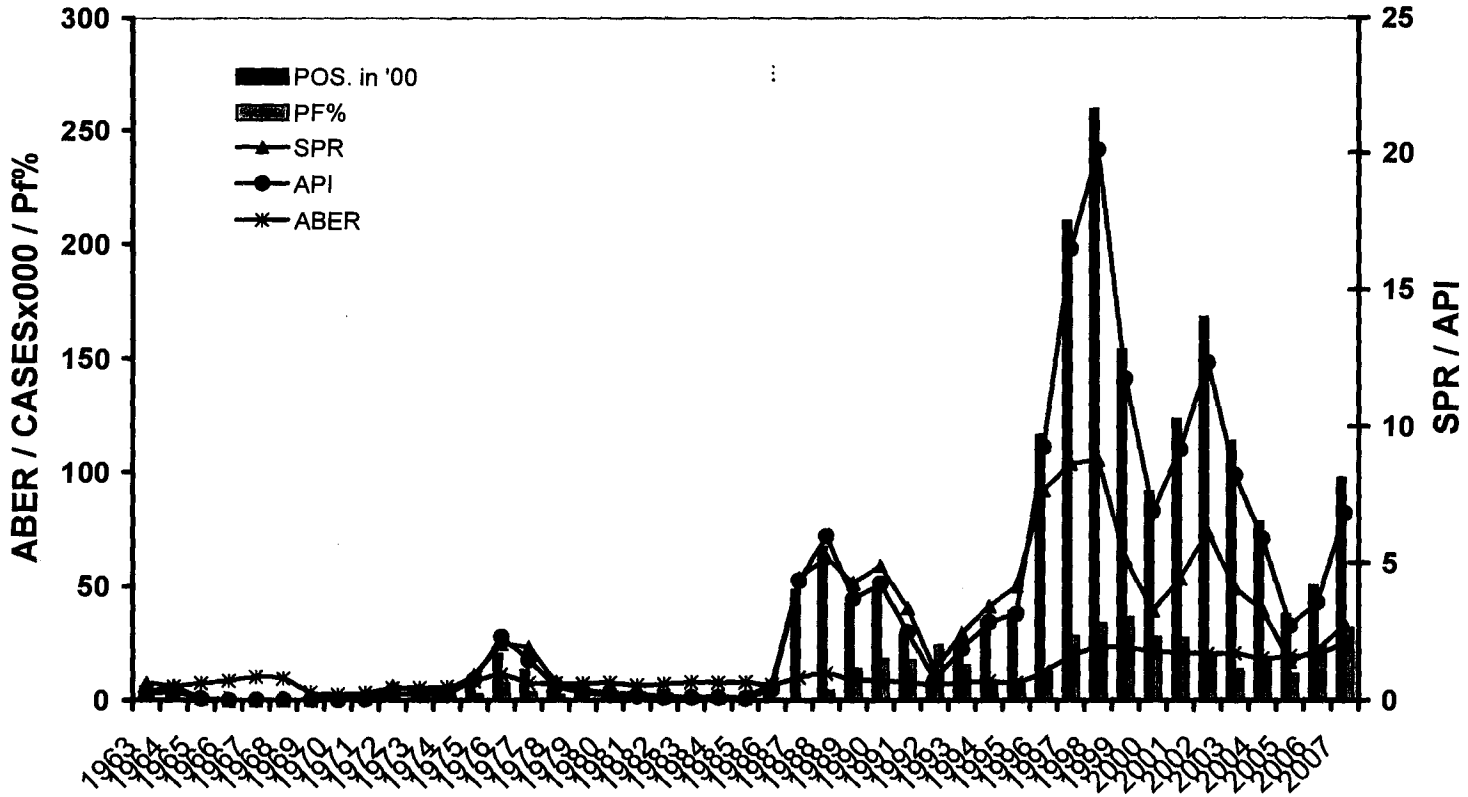


Fig. 4.13 Malaria incidence in the state of Goa from 1963 to 2007

6.8) cases respectively were reported. However, a rise in the malaria trend was again observed in 2001 with 12331 cases with a SPR of 4.4% and API of 9.1. As far as deaths due to malaria are concerned, there were 19, 17, 11 and 12 deaths reported during the years 1998, 1999, 2000 and 2001 respectively. A total of 128 deaths due to malaria were reported from 1995 to 2001.

2002-2007: The rising trend of malaria continued in the year 2002 as a total of 16818 malaria cases including 3348 *P. falciparum* cases in the year 2002 (SPR: 6.2% and API of 12.4) and 15 deaths. Though, a reduction of malaria cases was observed till the year 2005 with 3747 malaria cases including 430 *P. falciparum* cases and 9 deaths (2003-2005), once again in 2006 and 2007, the incidence increased with the reporting of 5010 (SPR: 1.8%; API: 3.6) and 11961 cases (SPR:3.5%; API: 8.4) respectively (Table 4.23). A total of 7 and 11 numbers of deaths were also reported during 2006 and 2007 respectively (Fig. 4.13). A total of 42 deaths attributable to malaria were reported from 2002 to 2007.

Overall, malaria showed a fluctuating trend from 1985 to 2007 with peaks during 1988, 1998, 2002 and 2007 and unlike in the years from 1963 to 1984 with the exception of 1975 and 1976, it showed rather stabilizing tendency from 1985 onwards (Fig. 4.13).

It is well known fact that *P. falciparum* is responsible for mortality due to multi-organ involvement and failure. Fig. 4.14 shows *P. falciparum* and deaths attributable to malaria in Goa from 1993 to 2007. During this period it was observed that out of total 1,61,835 malaria cases reported, *P. falciparum* contributed 24.7% i.e. 40007 cases and the total deaths attributable to malaria were 170 (0.4%) [Table 4.23]. It is worth noticing that *P. falciparum* cases

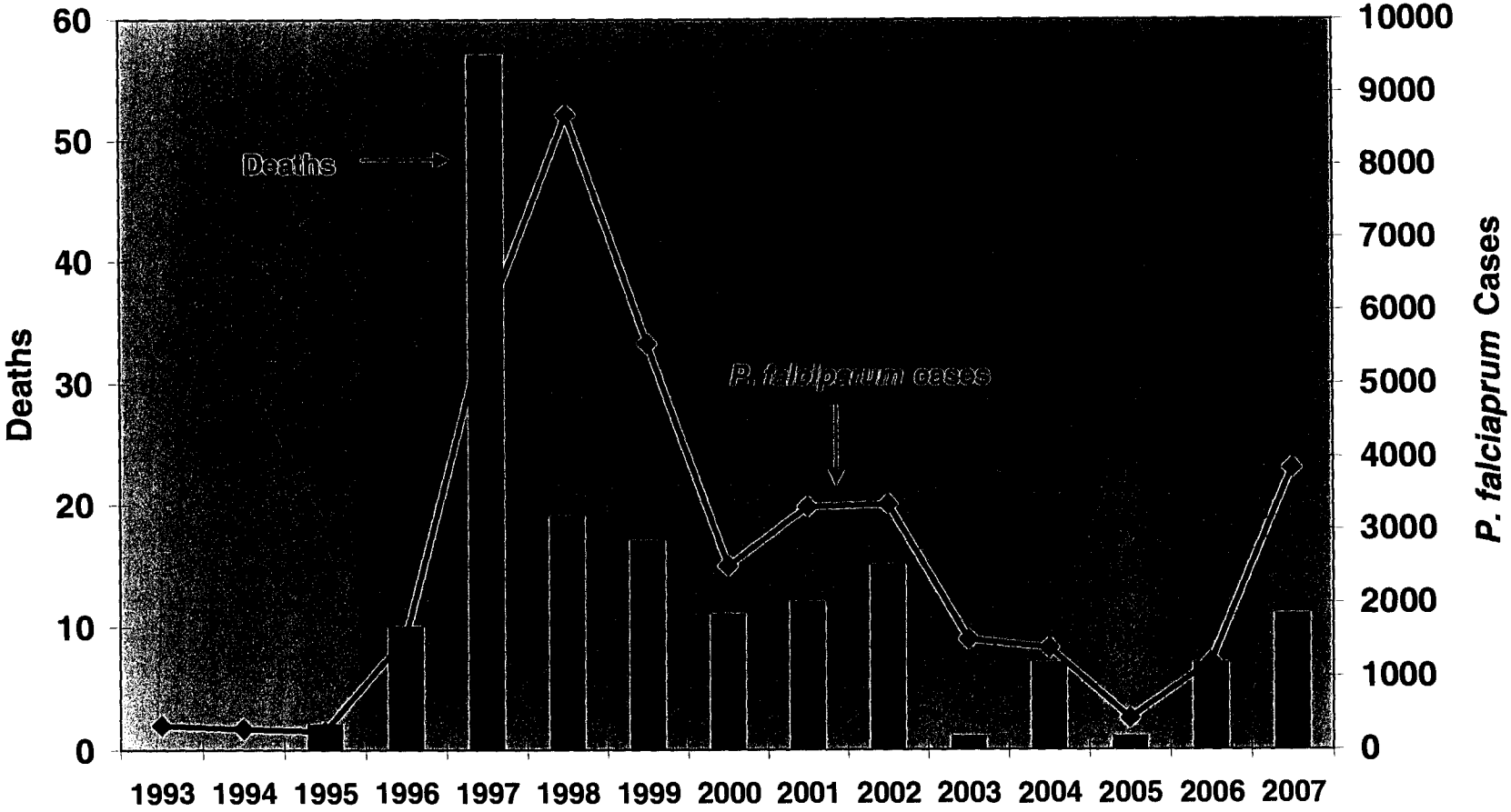


Fig. 4.14 *P. falciparum* cases and deaths attributable to malaria in Goa from 1993 to 2007.

which were only 333 in 1993 increased gradually to 1539 cases in 1996, further to 5827 cases in 1997 and peaked at 8694 cases in 1998 followed by a reduction of 36.1% in 1999 (5548 cases), 39.6% in 2002 (3348 cases) but once again increased to 3848 cases in 2007. No deaths due to malaria were reported in the years 1993 and 1994.

The month wise epidemiological data of malaria reported in Goa are presented in Annexure 2. The monthly trends of malaria incidence were studied for the years from 1990 to 2001 and 2002 to 2007 in Goa and compared (Table 4.24 & 4.25). During these periods, the least number of malaria cases were detected during February and March followed by a steady increase in the cases from the month of April. The peak of cases was observed in the month of July (Fig. 4.15). A declining trend was observed in the month of August. However, during 1990-2001, the fall in cases was steady till the month of December. However, during 2002 to 2007, the cases though less yet remained constant from September to November followed by a sudden reduction in the month of December. During the above two periods the mean number of cases in different months of 1991-2001 and 2002 to 2007 and monthly trends of malaria were found quite similar ($R^2 = 0.96$).

The mean slide vivax rate and slide falciparum rate in Goa were compared between 1990-2001 and 2002-2007 (Fig. 4.16 & 4.17). It was observed that *Plasmodium vivax* rate was significantly higher than *Plasmodium falciparum* rate in all the months of the years from 1991 to 2001 ($z= 40.4$, $p<0.001$, CI>95%) and 2002 to 2007 ($z= 19.9$, $p<0.01$, CI>95%). There were two distinct peaks of *P. vivax* rate, one in May and second in December while *P. falciparum* rate gradually increased and peaked in the

Table 4.24: Monthly & Seasonal contribution to malaria cases in Goa from 1990 to 2001

SEASONS	MONTH	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Mean ± SD
	Jan	234	262	70	37	232	148	549	1243	2019	1149	599	579	593.4 ± 596.7
	Feb	133	225	30	48	156	134	387	911	1464	884	516	351	436.6 ± 439.1
	Mar	167	297	48	42	119	142	406	712	1354	1006	488	394	431.3 ± 408.2
	Apr	155	466	103	62	164	87	616	1135	1422	1046	362	287	492.1 ± 465.3
Pre-	May	344	386	97	113	212	178	814	1126	1692	1121	578	499	596.7 ± 497.9
monsoons	**Total**	**1033**	**1636**	**348**	**302**	**883**	**689**	**2772**	**5127**	**7951**	**5206**	**2543**	**2110**	
	Jun	696	287	99	222	505	370	1038	1496	2065	1591	1067	1332	897.3 ± 630.9
	Jul	1010	251	63	320	538	437	1120	1930	3620	2217	1353	1756	1217.9 ± 1035.0
	Aug	692	193	65	337	540	548	1586	2623	2894	1517	1042	1610	1137.3 ± 927.1
	Sep	418	122	63	274	332	576	1199	2630	3410	1351	714	1913	1083.5 ± 1070.3
Monsoons	**Total**	**2816**	**853**	**290**	**1153**	**1915**	**1931**	**4943**	**8679**	**11989**	**6676**	**4176**	**6611**	
	Oct	371	158	77	310	277	426	1349	2391	2826	1354	879	1471	990.8 ± 906.4
	Nov	366	134	76	193	218	408	1286	2429	1811	1315	915	1196	862.3 ± 757.8
	Dec	304	98	60	269	177	432	1282	2399	1398	829	651	943	736.8 ± 689.8
Post monsoons	**Total**	**1041**	**390**	**213**	**772**	**672**	**1266**	**3917**	**7219**	**6035**	**3498**	**2445**	**3610**	9475.8 ± 8046.2
Year Total	**G.TOTAL**	**4890**	**2879**	**851**	**2227**	**3470**	**3886**	**11632**	**21025**	**25975**	**15380**	**9164**	**12331**	

Total cases from 1990 – 2001: Pre monsoon = 30600 (26.91%); Monsoons = 52032 (45.78%); Post monsoons = 31078 (27.33%)

Table 4.25: Monthly & Seasonal contribution to malaria cases in Goa from 1990 to 2001

SEASONS	MONTH	2002	2003	2004	2005	2006	2007	Mean ± SD
Pre-monsoons	Jan	836	952	542	329	267	457	563.8 ± 275.6
	Feb	690	870	415	226	194	416	468.5 ± 264.6
	Mar	654	850	488	123	181	361	442.8 ± 279.3
	Apr	925	934	554	88	148	487	522.7 ± 364.0
	May	1158	698	653	197	268	788	627.0 ± 354.2
	Total	**4263**	**4304**	**2652**	**963**	**1058**	**2509**	
Monsoons	Jun	1512	832	1051	318	494	1140	891.2 ± 438.8
	Jul	2868	1166	929	413	623	1547	1257.7 ± 884.3
	Aug	1921	1383	792	449	570	1635	1125.0 ± 606.0
	Sep	1497	1074	729	431	600	1340	945.2 ± 426.0
	Total	**7798**	**4455**	**3501**	**1611**	**2287**	**5662**	960.5 ± 507.7
Post monsoons	Oct	1690	969	586	453	615	1450	943.2 ± 553.0
	Nov	1813	895	597	394	564	1396	710.0 ± 344.3
	Dec	1254	747	503	326	486	944	9457.5 ± 4880.8
	Total	**4757**	**2611**	**1686**	**1173**	**1665**	**3790**	
Year Total	G.TOTAL	16818	11370	7839	3747	5010	11961	

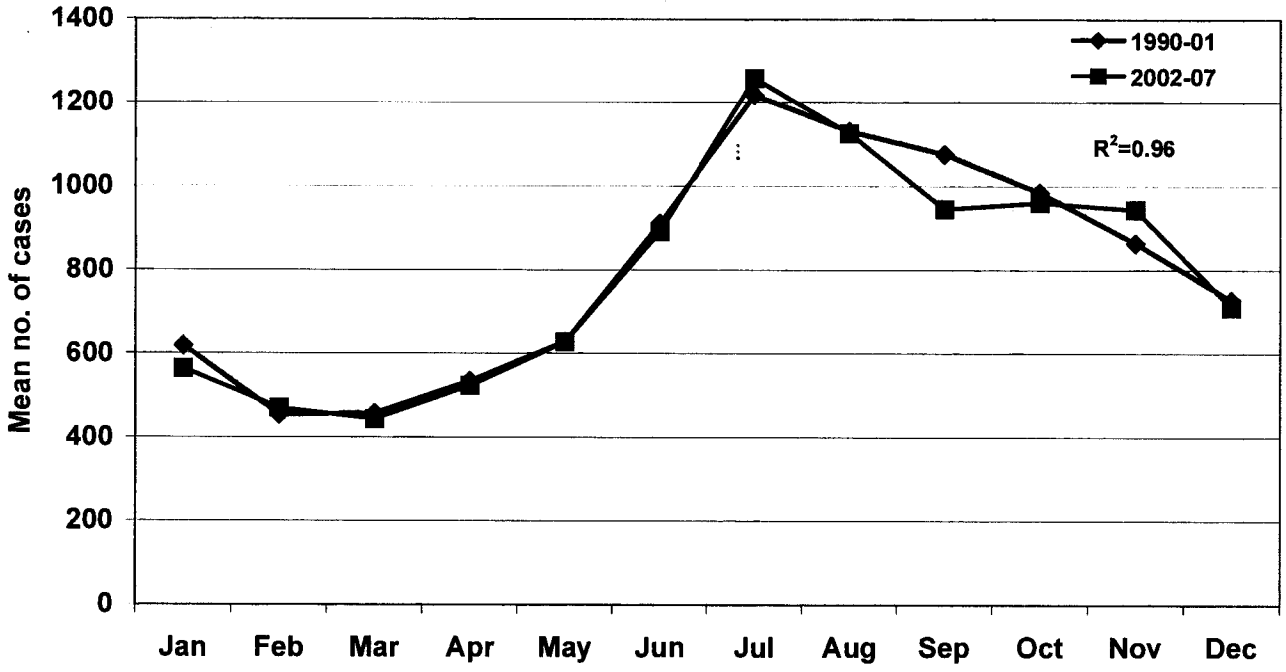


Fig. 4.15 Comparison of monthly malaria trends from 1990-2001 and 2002-2007in Goa

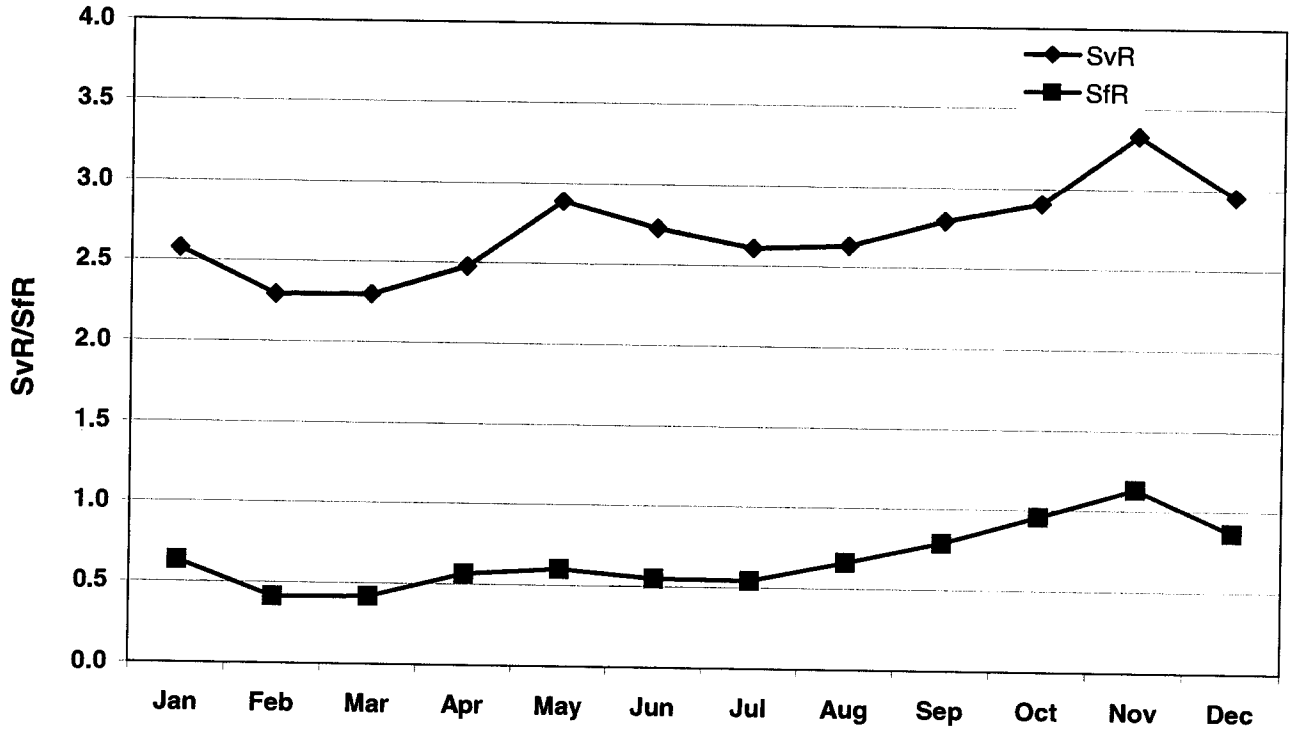


Fig. 4.16 Comparison of mean Slide Vivax Rate & Slide Falciparum Rate in Goa from 2002 to 2007

Fig 6.17

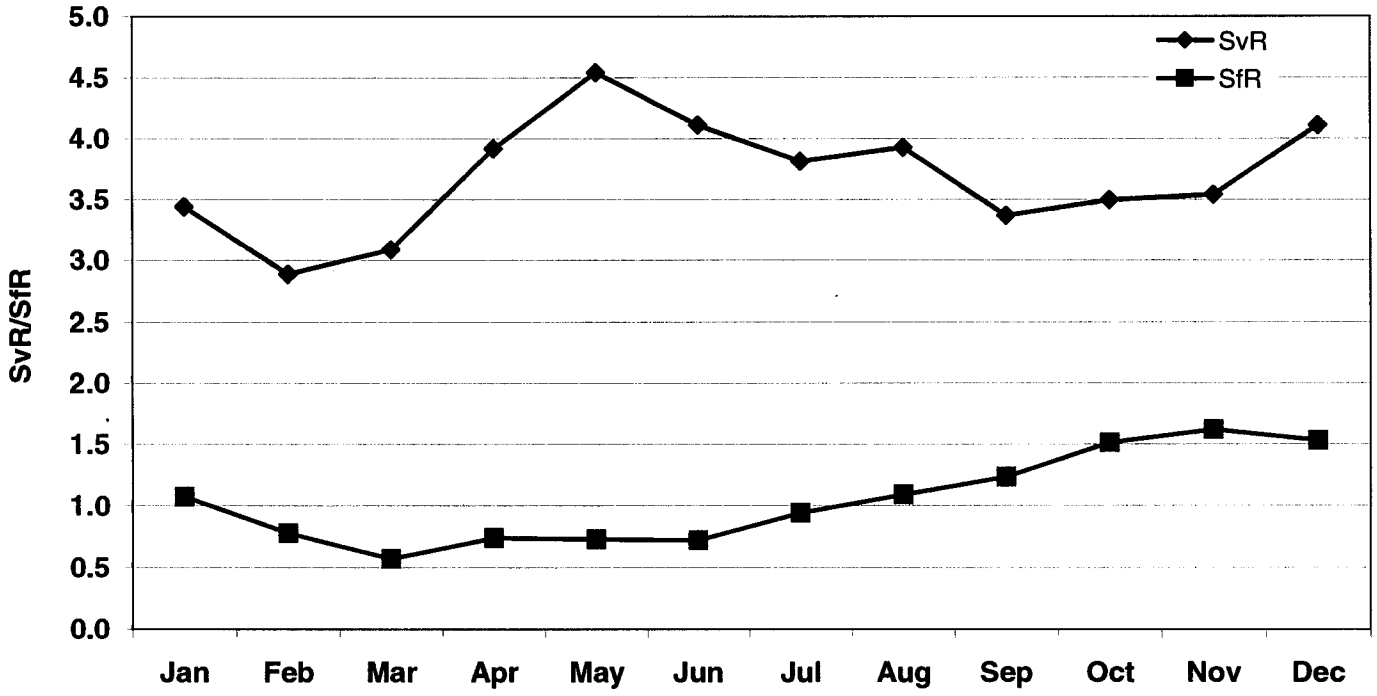


Fig. 4.17 Comparison of Slide Vivax Rate & Slide Falciparum Rate in Goa from 1990- 2001

Fig 4.16

month of November. However, in the period from 2002 to 2007 there were two peaks of *P. vivax*, one in May and second in November while there was one peak of *P. falciparum* in November quite similar in the period from 1990-2001 after which it declined in December.

6. Seasonal distribution of malaria

Seasonal distribution of malaria cases in Goa from 1990 to 2001 and 2002 to 2007 are presented in Table 4.24 & 4.25. Although malaria cases were detected throughout the year, the incidence cases of malaria pooled from 1990 to 2001 in the monsoon months from June to September (n= 52032, 46%,) were significantly more than in the pre-monsoon months from January to May (n= 30600, 27%, z=93.4, $p < 0.001$, CI>95%) and post monsoon months from October to December (n = 31078, 27%, z=91.2, $p < 0.001$, CI> 95%) [Fig. 4.18]. Similarly from 2002 to 2007, cases in the monsoon months (n = 25314, 44.6%) were significantly more than pre monsoon months (n = 15749, 28%, z=59.09, $p < 0.001$, CI>95%) and post monsoon months (n = 15682, 28% z=59.5, $p < 0.001$, CI>95%) [Fig. 4.19].

Relationship between Malariometric Indices: The analysis of data on various malariometric indices from 1963 to 2007 revealed that both Annual Parasite Incidence (API:Cases per 1000 population) and Slide Positivity Rates (SPR) among fever cases showed positive correlation with Annual Blood Examination Rate (ABER and API:R^2=0.638, ABER and SPR: R^2=0.40). However, although the slide positive rates showed positive correlation with ABER but it did not appear to depend much upon quantum of blood examination for malaria. Whereas, the incidence cases had better correlation

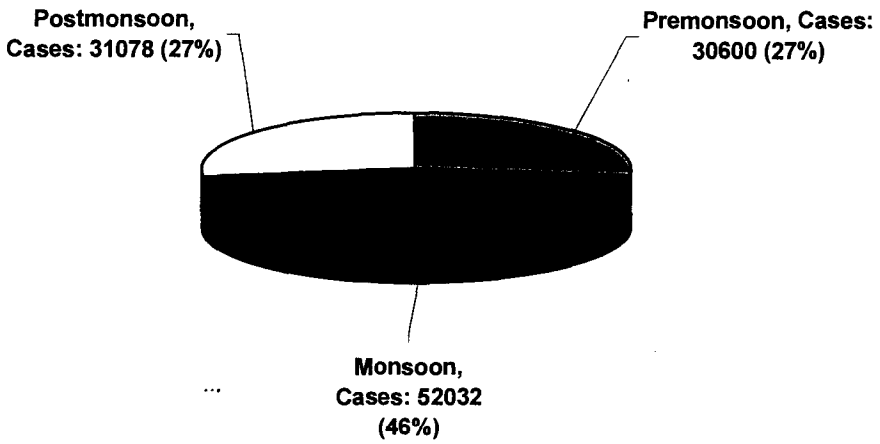


Fig. 4.18 Seasonal distribution of malaria in Goa from 1990 to 2001

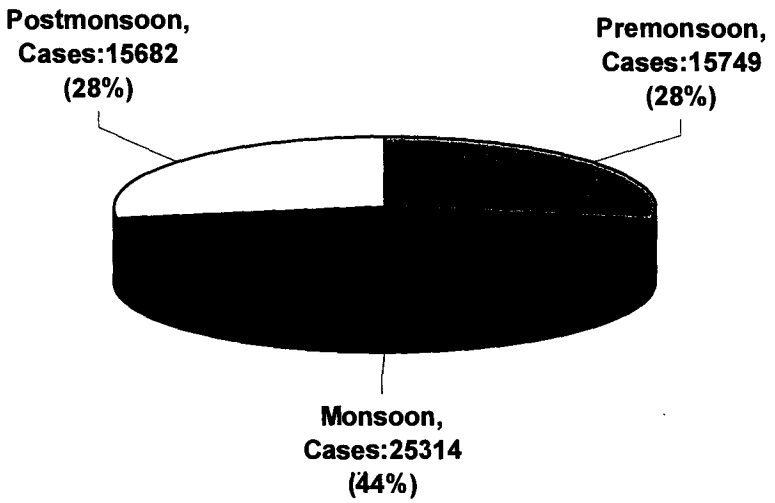


Fig. 4.19 Seasonal distribution of malaria cases in Goa from 2002 to 2007

with blood examination rate which indicated that API depended more upon rate at which blood of fever cases was examined (Figs. 4.20 and 4.21).

The relationship between Slide Postivity Rates and Slide Vivax Rates for different years showed that both were highly correlated (R^2=0.969) and comparatively better than Slide Falciparum Rate (R^2=0.728). This indicated that overall slide positivity rate was a better reflection of *Plasmodium vivax* malaria than *P. falciparum* malaria in Goa (Fig. 4.22 and 4.23). Similar trend was also seen when correlation between Annual Parasite Incidence and Annual Vivax Incidence (R^2=0.979) as well as Annual Falciparum Incidence (R^2=0.881) was studied [Figs. 4.24 and 4.25]. Further Annual Falciparum Incidence and Annual Vivax Incidence were found to be well correlated (R^2=0.774) indicating that in most of the years, both *P. vivax* and *P. falciparum* were being transmitted simultaneously although at different rates [Figs. 4.26].

Identification of Malaria High Risk Areas: Goa has 28 Primary Health Centre (PHC)/Urban Health Centre (UHC)/Community Health Centre (CHC) The year wise epidemiological data of all the PHCs/UHCs/CHCs from the year 1990 to 2007 has been presented in Annexure 3. A detailed analysis of malaria data of Goa was done at PHC/UHC/CHC level from 1990 to 2001 and 2002 to 2007. The analysis of data revealed that there were five high risk areas viz., Panaji, Margao, Candolim, Aldona and Corlim PHCs. The annual malaria incidence data of these PHCs from 1990-2001 is presented in Annexure 5. The pooled up data of malaria for the years 1990 to 2001 and 2002 to 2007 showed that Panaji alone contributed to the highest proportion of cases of malaria in Goa i.e. 38.4% and 44.2% respectively followed by

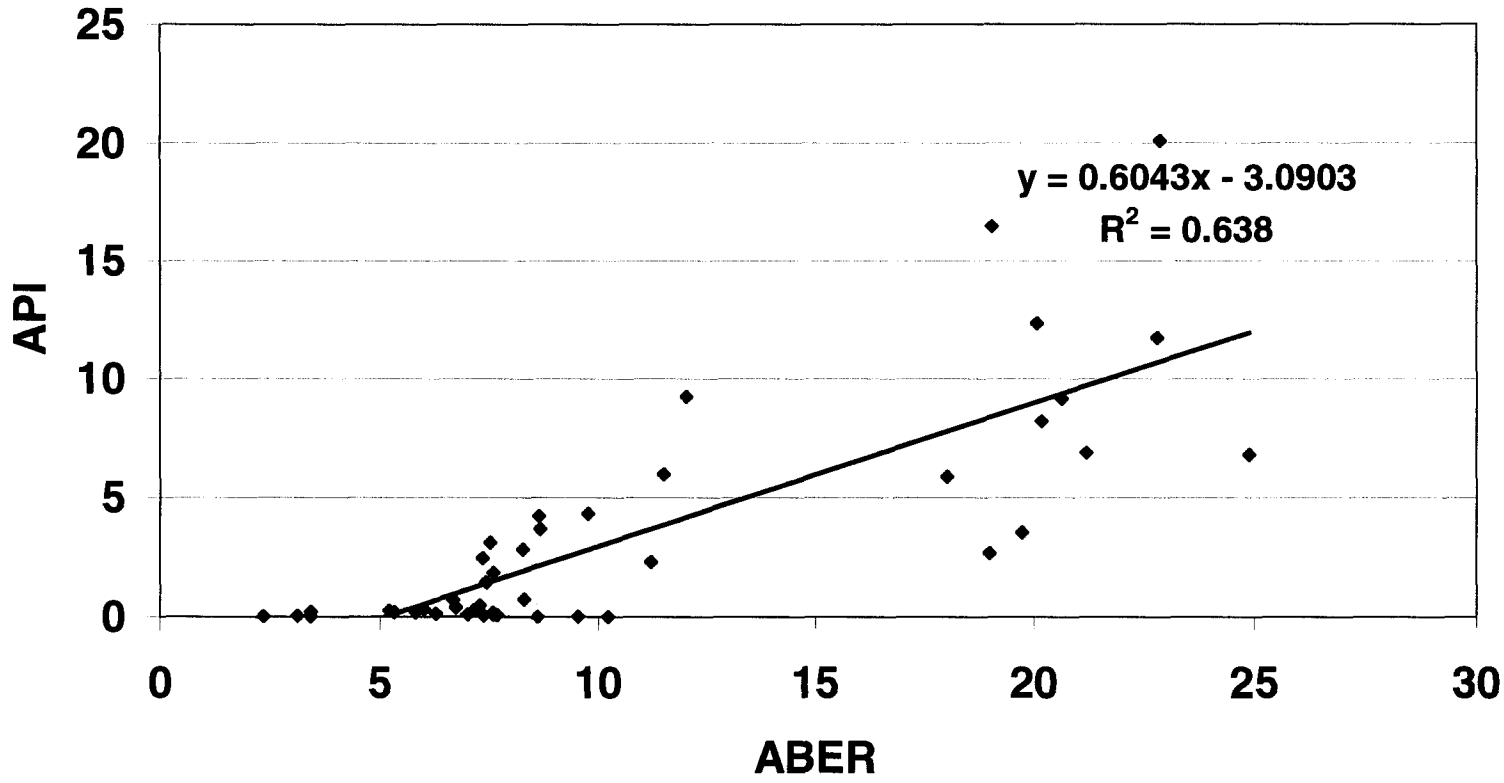


Fig. 4.20 Relationship between Annual Blood Examination Rate and Annual Parasite Incidence for malaria in Goa from 1963 to 2007

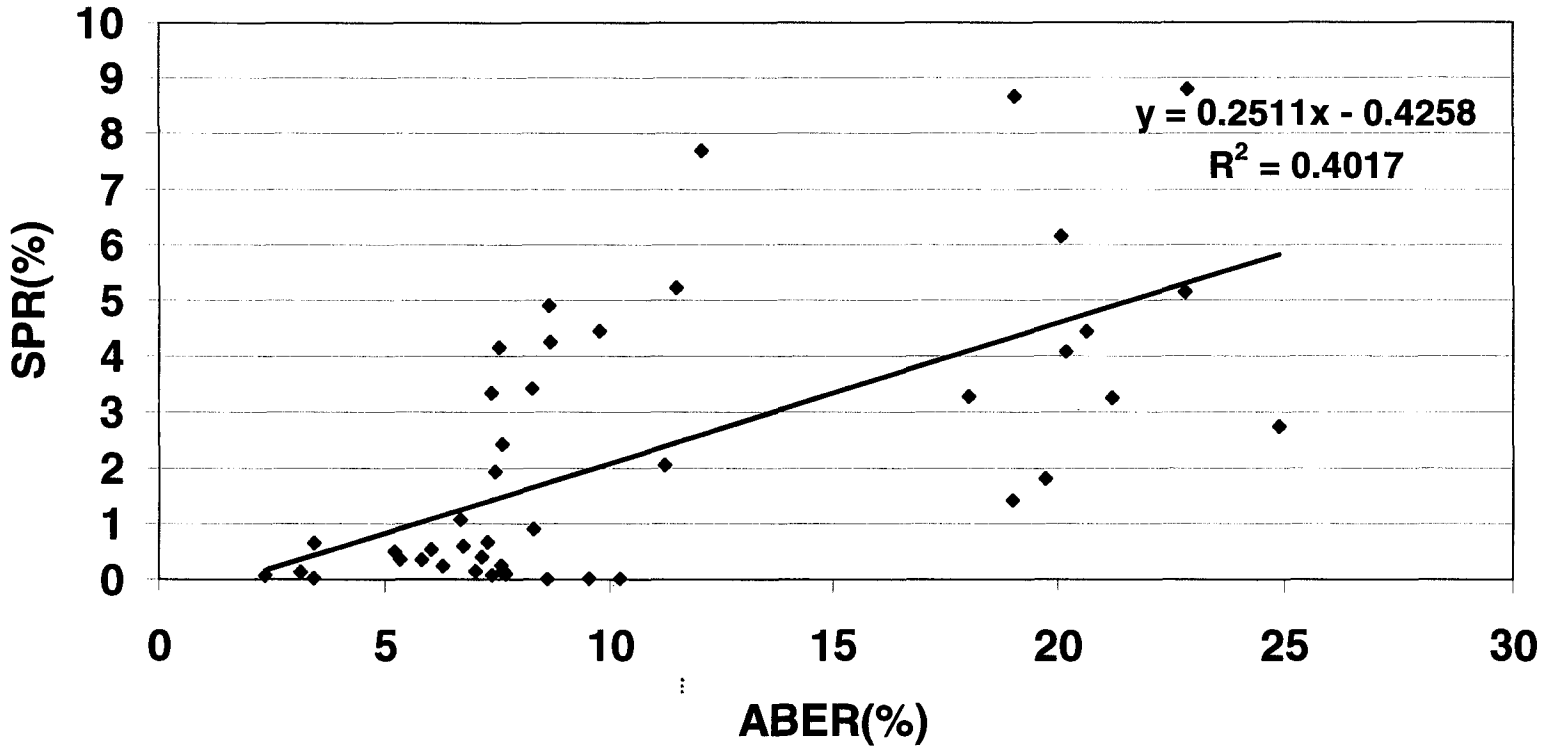


Fig. 4.21 Relationship between Annual Blood Examination Rate and Slide Poitivity Rate for malaria in Goa from 1963-2007.

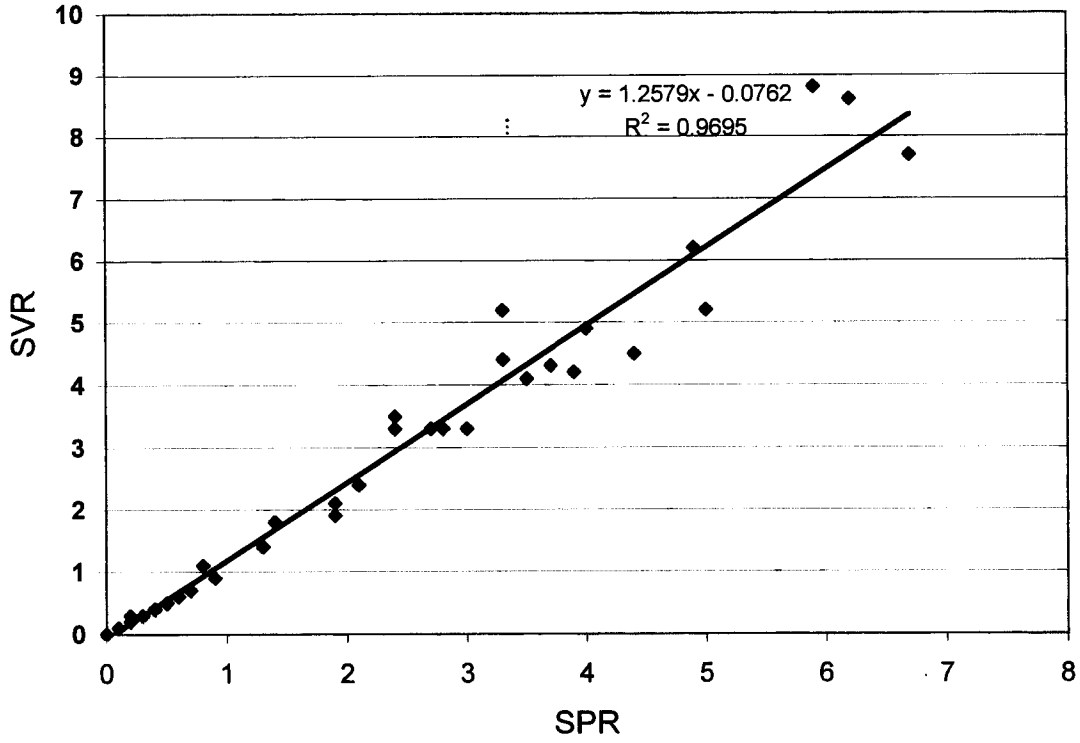


Fig. 4.22: Relationship between Slide Positivity Rate and Slide Vivax Rate for Malaria in Goa from 1963 to 2007

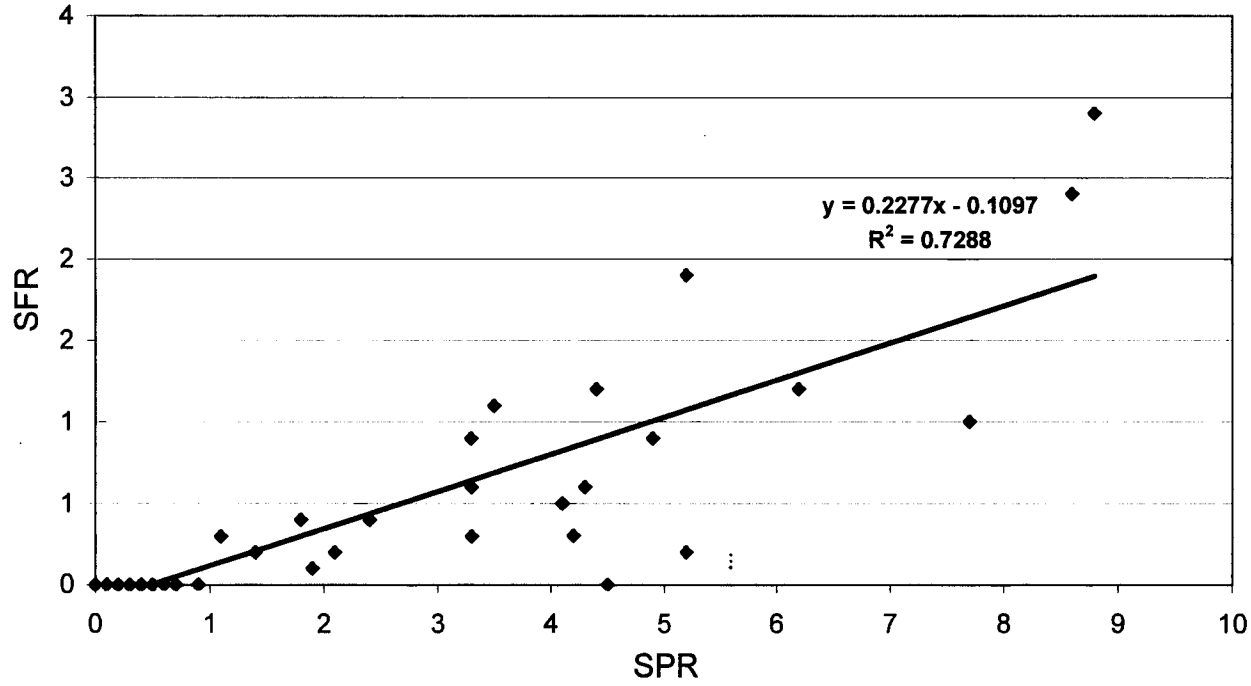


Fig. 4.23: Relationship between Slide Positivity Rate and Slide Falciparum Rate for Malaria in Goa from 1963 to 2007

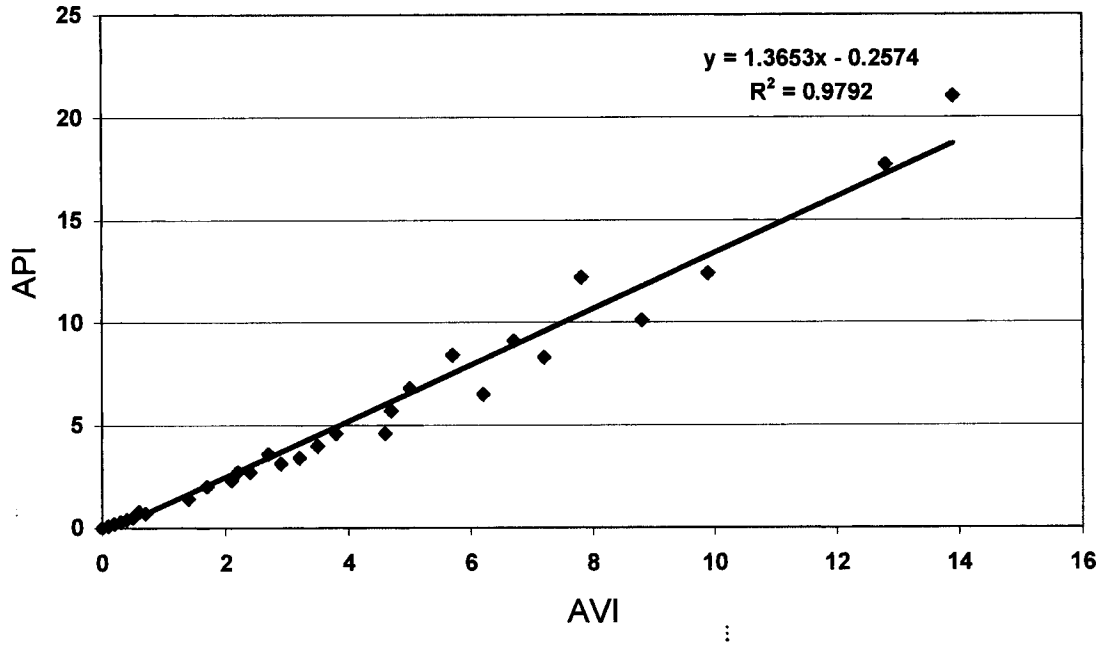


Fig. 4.24: Relationship between Annual Parasite Incidenc and Annual Vivax Incidence in Goa from 1963 to 2007.

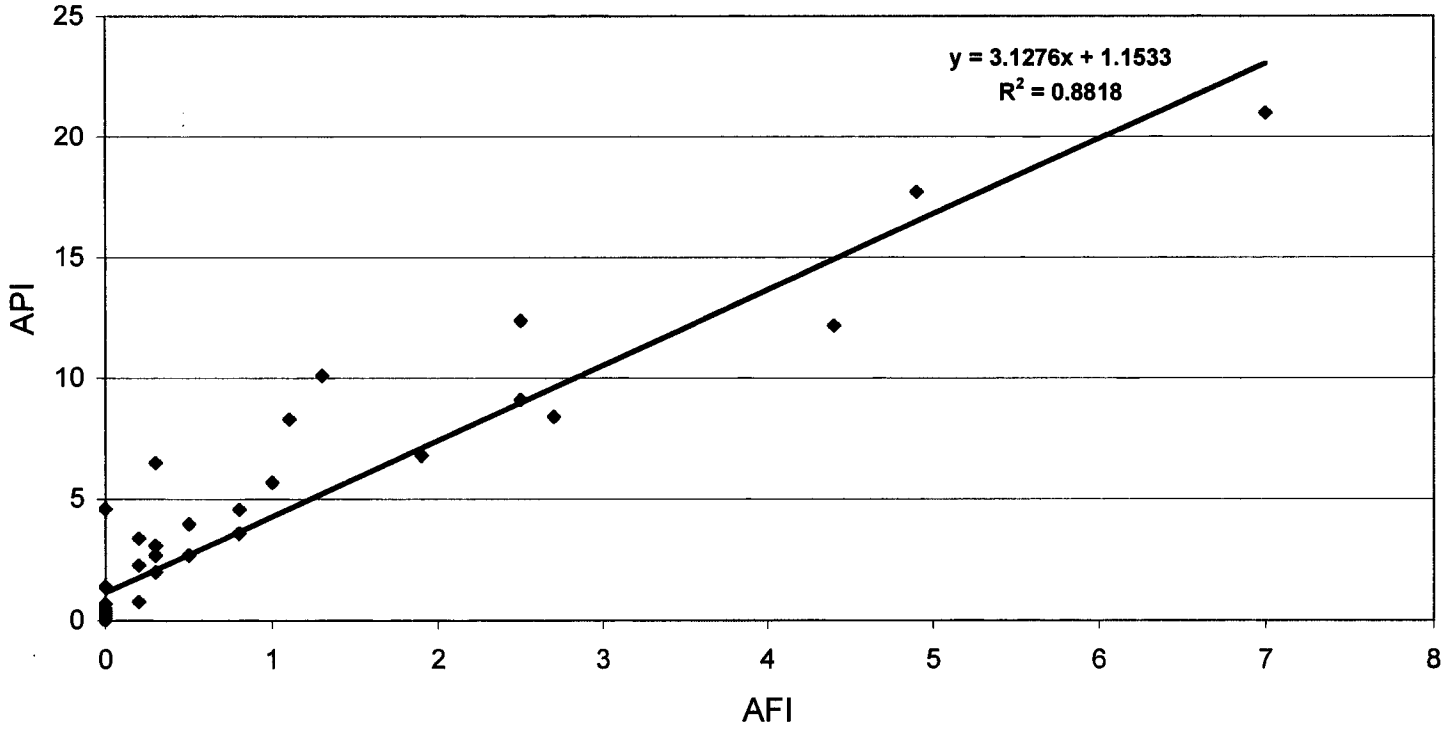


Fig. 4.25: Relationship between Annual Parasite Incidence and Annual Falciparum Incidence of Malaria in Goa from 1963 to 2007

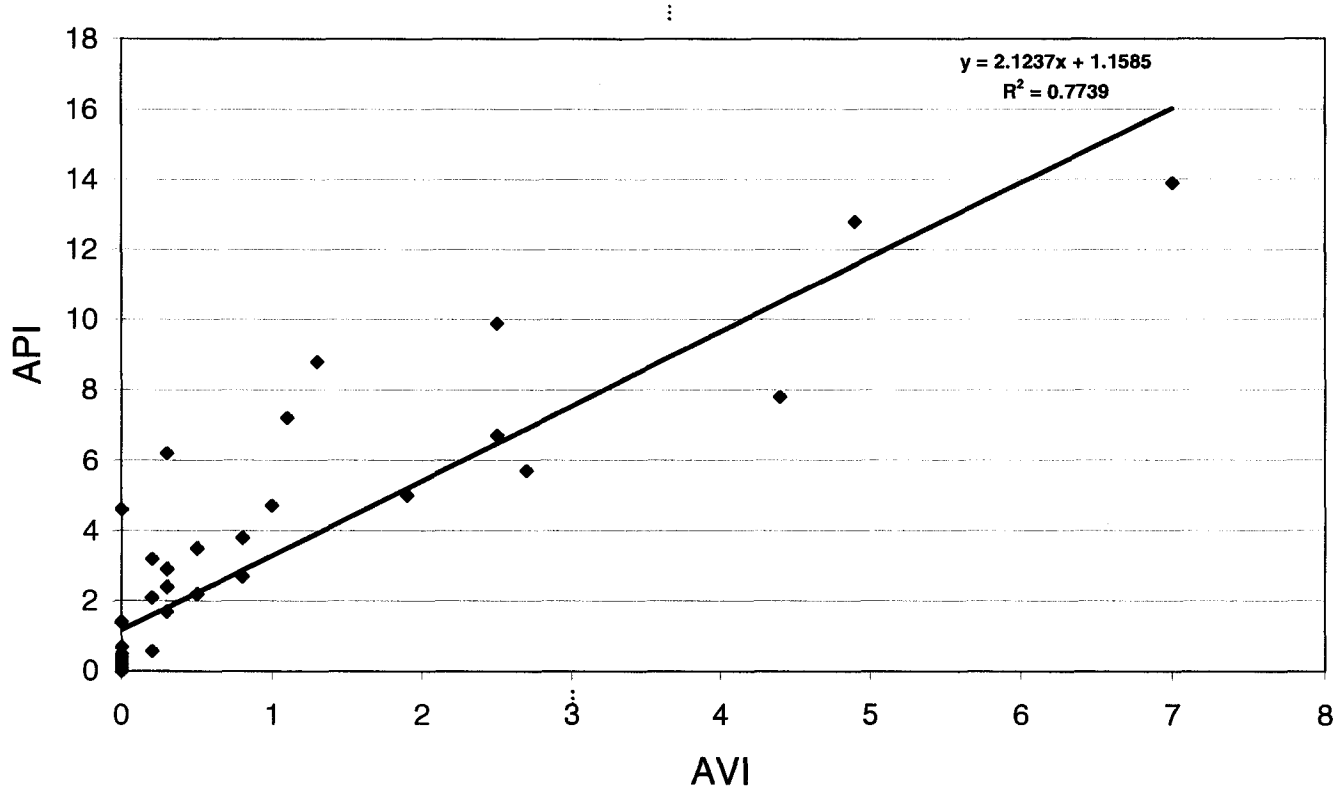


Fig.4.26: Relationship between Annual Falciparum Incidence and Annual Vivax Incidence of Malria in Goa from 1963 to 2007

Candolim, 18.1% & 14.8%, Margao, 11.7% and 14.1%, Aldona, 10.9% and 10.0% and Corlim 6.5% and 3.0%. The rest of the 23 PHCs contributed the remaining 14.4% and 13.8% of malaria cases respectively to the total incidence of malaria in Goa (Figs. 4.27 & 4.28). The more detailed information of malaria in these high risk PHCs/UHCs is presented below.

1. Panaji Urban Health Centre: The analysis of morbidity data showed that 84.6% (range: 81.7% to 91.8%) of malaria cases to total reported from Goa, were contributed by Panaji alone from 1986 to 1990 (Table 4.26). From 1991 to 2001 & 2002 to 2007 the city contributed 40.7% (Range: 21.4-60%) and 42.0% (Range: 27.0-63.6%) of malaria cases to the total cases reported in the state respectively. Since the city of Panaji was the epicentre of malaria in the last about 2 decades in Goa, a thorough analysis of malaria data of Panaji was undertaken during the course of this study.

The monthly malaria cases in Panaji were studied separately for the years from 1984 to 1989, 1990 to 2001 and 2002 to 2007 (Fig. 4.29 and Annexure 4). There were only 12 and 5 malaria cases in 1984 and 1985 respectively in the city. But in 1986 a severe malaria outbreak occurred and 352 malaria cases including 1 *P. falciparum* case were registered. Rest of the cases were of *P. vivax*. Out of the total cases, 315 (89.5%) malaria cases were detected during the months of June to September (Annexure 4:Table 3). In 1987, the outbreak assumed epidemic proportion in Panaji and a total of 4416 malaria cases were detected accounting for 92.1% of the 4810 total malaria cases reported in Goa. It is noteworthy that in the month of January, only 4 cases were reported but in contrast, 2710 cases were detected in the months from June to September, 1987 (Annexure 4.Table 4). In 1988, the

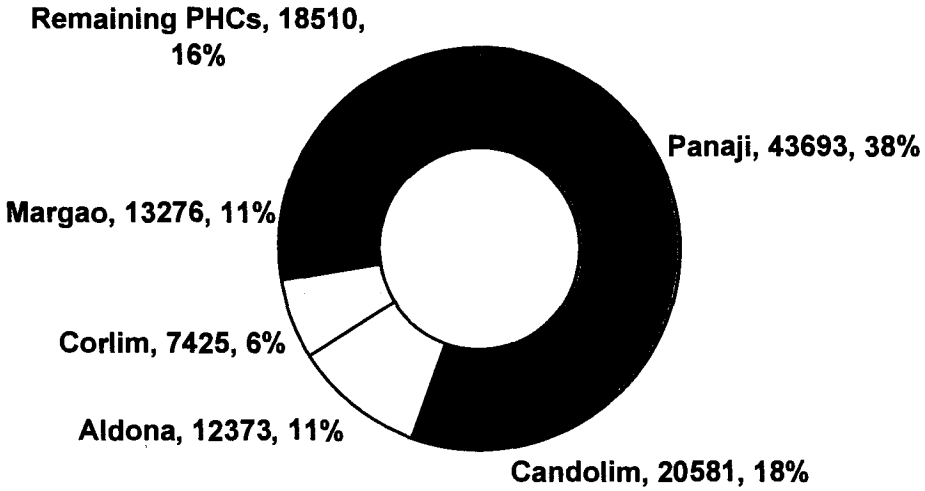


Fig. 4.27 Contribution of 5 high risk areas to malaria incidence compared with remaining PHCs from 1990 to 2001

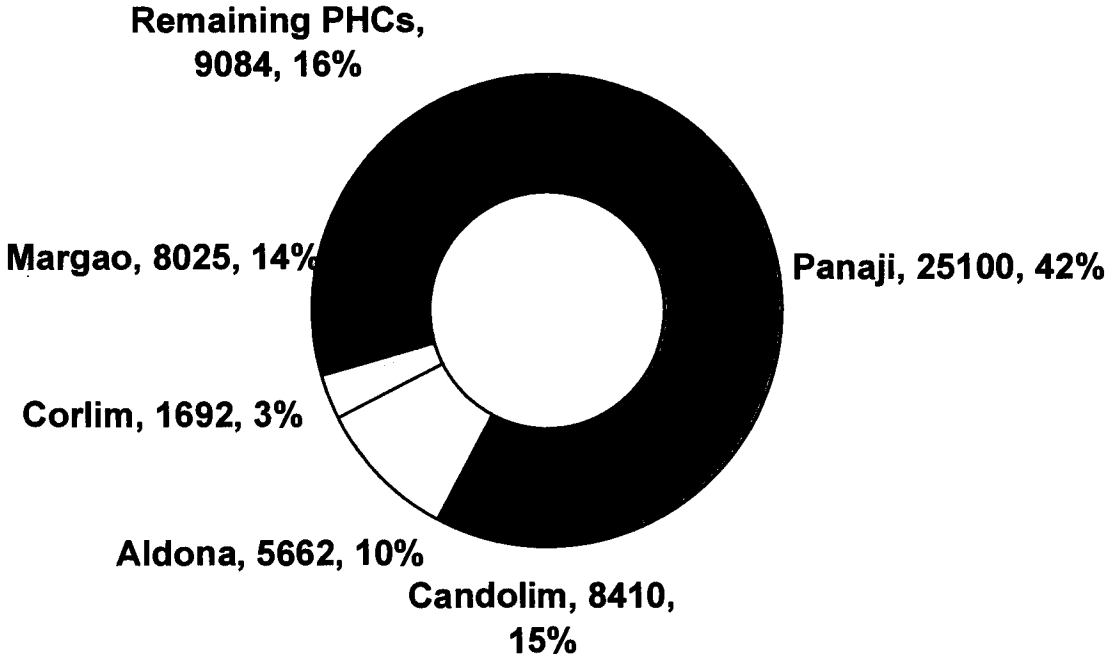


Fig. 4.28 Contribution of 5 high risk areas to malaria incidence compared with remaining PHCs from 2002 to 2007

Table 4.26: Percentage contribution of malaria cases of Panaji from 1986 to 2007

YEAR	GOA malaria cases	PANAJI malaria cases	% Panaji's contribution of malaria cases
1986	433	352	81.3
1987	4810	4416	91.8
1988	6732	5677	84.3
1989	4197	3523	83.9
1990	4890	3995	81.7
1991	2879	1556	54.0
1992	851	452	53.1
1993	2227	1336	60.0
1994	3470	741	21.4
1995	3886	1543	39.7
1996	11632	4323	37.2
1997	21025	7590	36.1
1998	25975	8693	33.5
1999	15380	4518	29.4
2000	9164	3824	41.7
2001	12331	5124	41.6
2002	16818	7893	46.9
2003	11370	5563	48.9
2004	7839	4988	63.6
2005	3747	1012	27.0
2006	5010	1588	31.7
2007	11961	4056	33.9

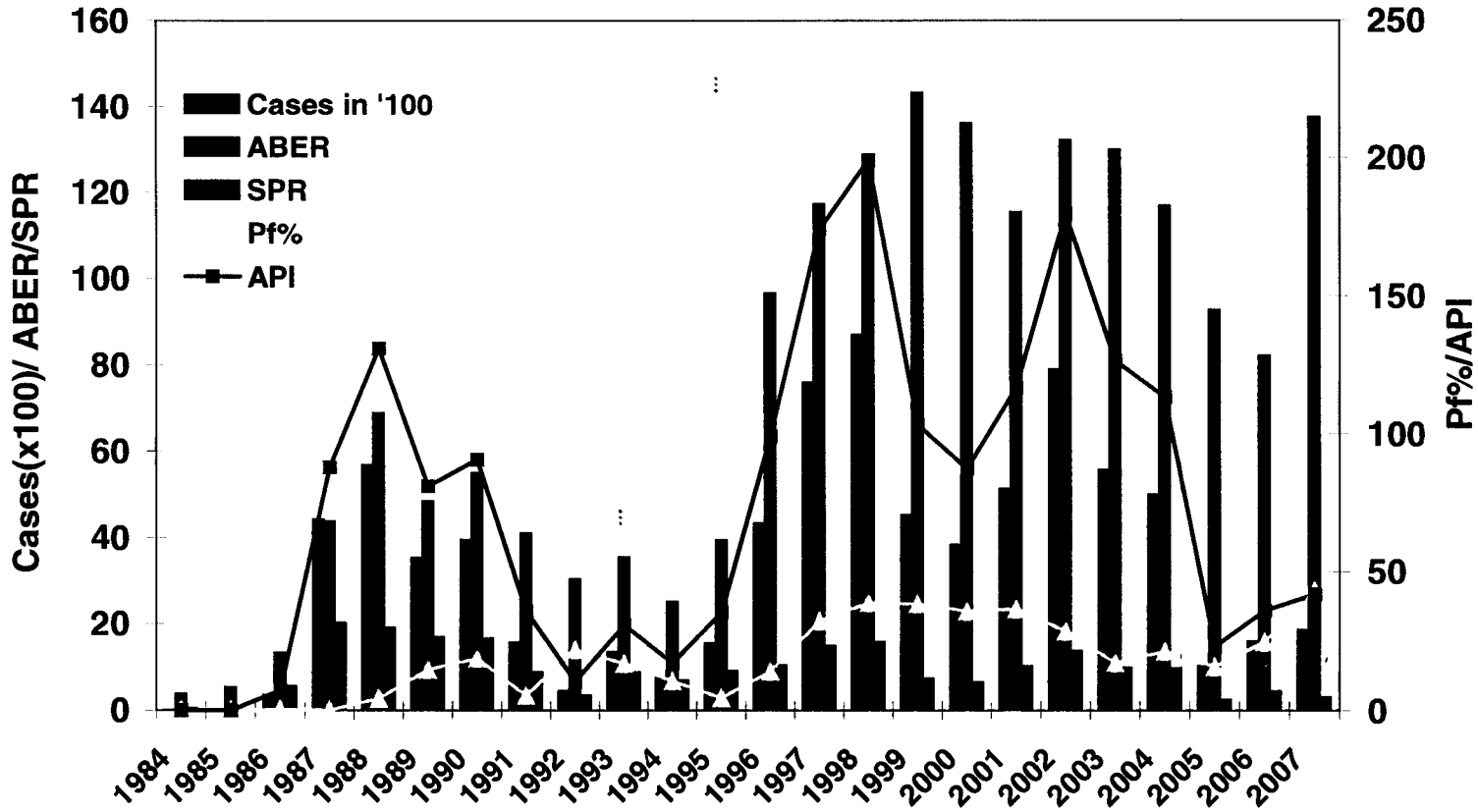


Fig. 4.29 Malaria incidence in Panaji from 1984 to 2007

The Pf % which was highest at 37.3% in 1991 reduced to 5.5% in 1995. However, the trend reversed in 1998 as Pf% once again increased to 28.3%. Subsequently, a gradual reduction in the Pf% was observed in 2001 (20.1%). From 2002 to 2007, the Pf% ranged from 5.7% to 28.1%. The annual parasite incidence ranged from 2.4 to 19.7 from 1990 to 2001 except in 1993 (1.4) and from 1.4 to 7.3 from 2002 to 2007 (Annexure 5: Table5).

Based on the incidence of malaria in the last 2 decades, the high risk and moderate risk areas of Goa have been shown in figure 4.35.

7. Stratification of Goa based on key epidemiological Indices

Stratification according to Annual Blood Examination Rate (ABER): ABER is based on fever rate in the community and ABER at a minimum rate of 10% is prescribed by the National Vector Borne Diseases Control Programme (NVBDCP). The National programme also recommends that all fever cases should be suspected and tested for malaria. If done so, an accurate estimate of malaria incidence can be made in the community. Hence, Annual Blood Examination Rates of malaria of different PHC/CHC/UHC's of Goa from 1990 to 2001 and 2002 to 2007 were worked out to ascertain the quality of malaria surveillance. From 1990 to 1996 it was observed that except in 13 PHCs/UHCs viz., Panaji, Mapusa, Pernem, Candolim, Aldona, Ponda, Betki, Margao, Bali, Canacona, Curchorem, Sanguem and Quepem, the ABER was less than 10%. ABER was even less than 2% in Loutolim and Chinchnim in 1990 (Table 4.28). In North Goa district, during 1997 to 2001, ABER was >100% in Panaji while in the remaining PHCs, the ABER ranged from 2 to 50%. Only the newly created PHC Sankhali had an ABER of 0.6% in the year 2000. However, from 1997 to

cases by 30% as also API declined to 126.6. This situation further improved in 2004 and 2005 as compared to 2003 with the reduction of malaria incidence by 10% and 82% and API to 113.4 and 23.0 respectively. In 2006, however a reverse trend of increase in malaria cases was observed with the API increasing to 36.0 and in 2007 to 91.9.

A comparison of the monthly malaria trends in Panaji from 1990 to 2001 and 2002 to 2007 showed that the least number of malaria cases were detected during February from 1990-2001 and in March during 2002- 2007 whereas the highest number of cases were found in July during both the periods (Fig. 4.30). However, during 1990 to 2001, from August to December, the incidence decreased gradually, but during the years 2002 to 2007, a fall in the malaria cases in September with an increase in incidence during October and November which was followed by decline in December was observed. Overall the trends of malaria cases and mean number of cases from 1990-2001 and 2002 to 2007 were found quite similar and well correlated (R^2= 0.92).

The seasonal pattern of malaria in Panaji observed from 1984 to 1989, 1990 to 2001 and 2002 to 2007 showed that malaria incidence was highest in the monsoons ranging from 42% to 50% of total annual cases followed by cases in the pre-monsoons (29% to 31%) and post monsoons (20% and 27%) [Table 4.27].

2. Candolim PHC: The malaria data of Candolim PHC, under North Goa District was analysed for the malaria incidence from 1990 to 2001 and 2002 to 2007 (Fig. 4.31). It was observed that ABER ranged from 8.2 to 49.9% from 1990 to 2001 and 30.5 to 56.7% from 2002 to 2007. The malaria cases which

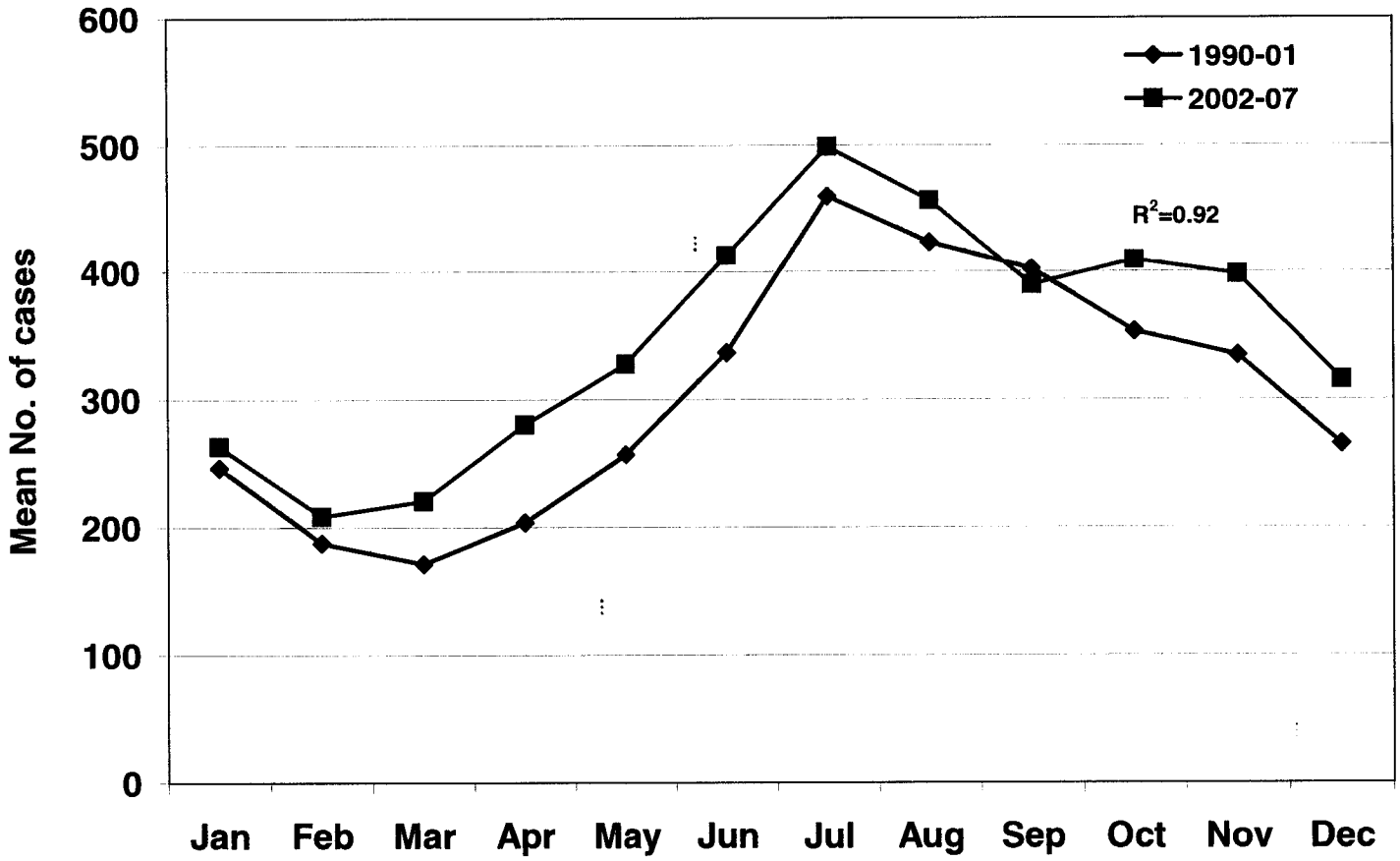


Fig. 4.30 Comparison of monthly malaria trends from 1990-2001 and 2002 to 2007 in Panaji, Goa

Table 4.27: Seasonal contribution to malaria cases in Panaji from 1984-1989, 1990-2001 & 2002 to 2007

Season	1984-1989	1990-2001	2002-2007
Pre monsoons (Jan-May)	4132(30.0%)	12796 (29.0%)	7808 (31%)
Monsoons June –Sept)	7053 (50.0%)	19463 (45.0%)	10553 (42%)
Post monsoons (Oct-Dec)	2800 (20%)	11436 (26.0%)	6739 (27%)
Total	13985	43695	25100

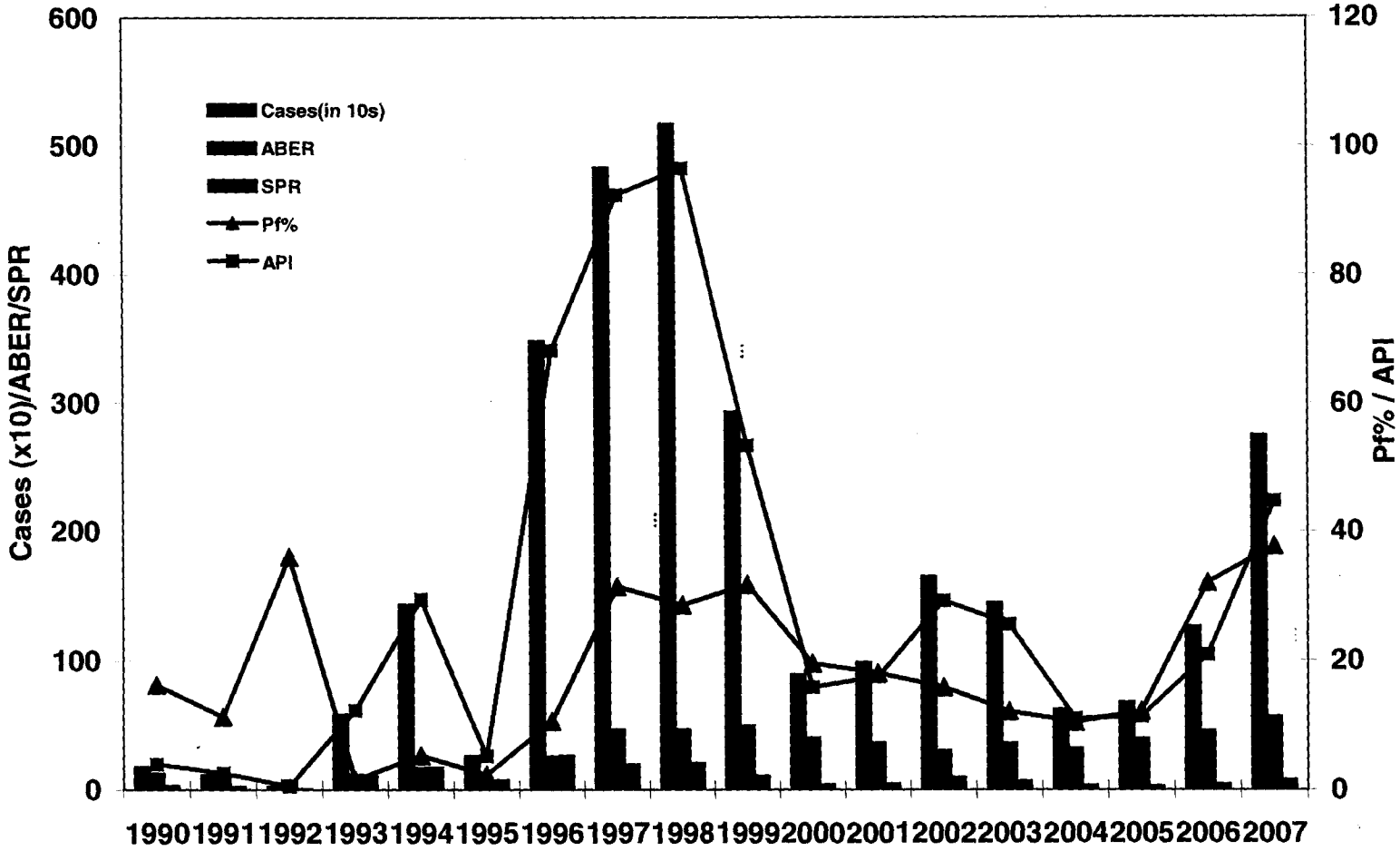


Fig. 4.31 Malaria Incidence in Candolim PHC from 1990-2007

were only 174 in 1990 increased to 1433 cases in 1994 and a further rise in 1998 to 5172 cases was observed. Though there was a sharp decline in 2000, a reverse trend was once again observed in 2002 and 2007. The SPR which was only 3.1% in 1990 increased to 20.6% in 1998 and ranged from 2.9% to 9.6% from 2002 to 2007. The notable feature was that *P. falciparum* proportion which was 16.9% in 1990 more than doubled and increased to 37.7% by the year 2007 and the API ranged from 3.8 in 1990 to 29.4 in 1994 and further increased to 96.5 in 1998. From 2002 to 2007 the API ranged from 11.1 to 44.7 (Annexure 5: Table 4).

3. Aldona PHC: The epidemiological data of Aldona PHC, situated in the North Goa District, is shown in Fig. 4.32. Malaria had been a problem in this PHC too. The ABER was below 10% from 1990 to 1995 but increased to 16.2% in 1996 and was 28.7% in 2001. The ABER ranged from 19.2 to 31.0% from 2002 to 2007. During 1990 to 2001, it was observed that malaria cases ranged from 9 to 4237. The incidence was very low till the year 1993 after which it increased significantly over the years and peaked in 1998 with 4237 Cases and then declined till 2001. The SPR which was 0.6% in 1990 increased to 8.6% in 1993 and showed a three fold increase of 24.2% in 1995. The proportion of *P. falciparum* ranged from 10.5% to 49.6% from 1990 to 2001. From 2002 to 2007, malaria cases ranged from 487 to 1400. Though there was a reduction in the SPR from 9.2% in 2002 to 4.2% in 2005, an increase in SPR to 5.5% was observed in 2007. The proportion of *P. falciparum* ranged from 6.6% to 19.4% from 2002 to 2007. In Aldona PHC from negligible API of 0.4 which was observed in 1990, it increased to 76.7 in 1998 and ranged from 8.0 to 24.2 from 2002 to 2007 (Annexure 5: Table 3).

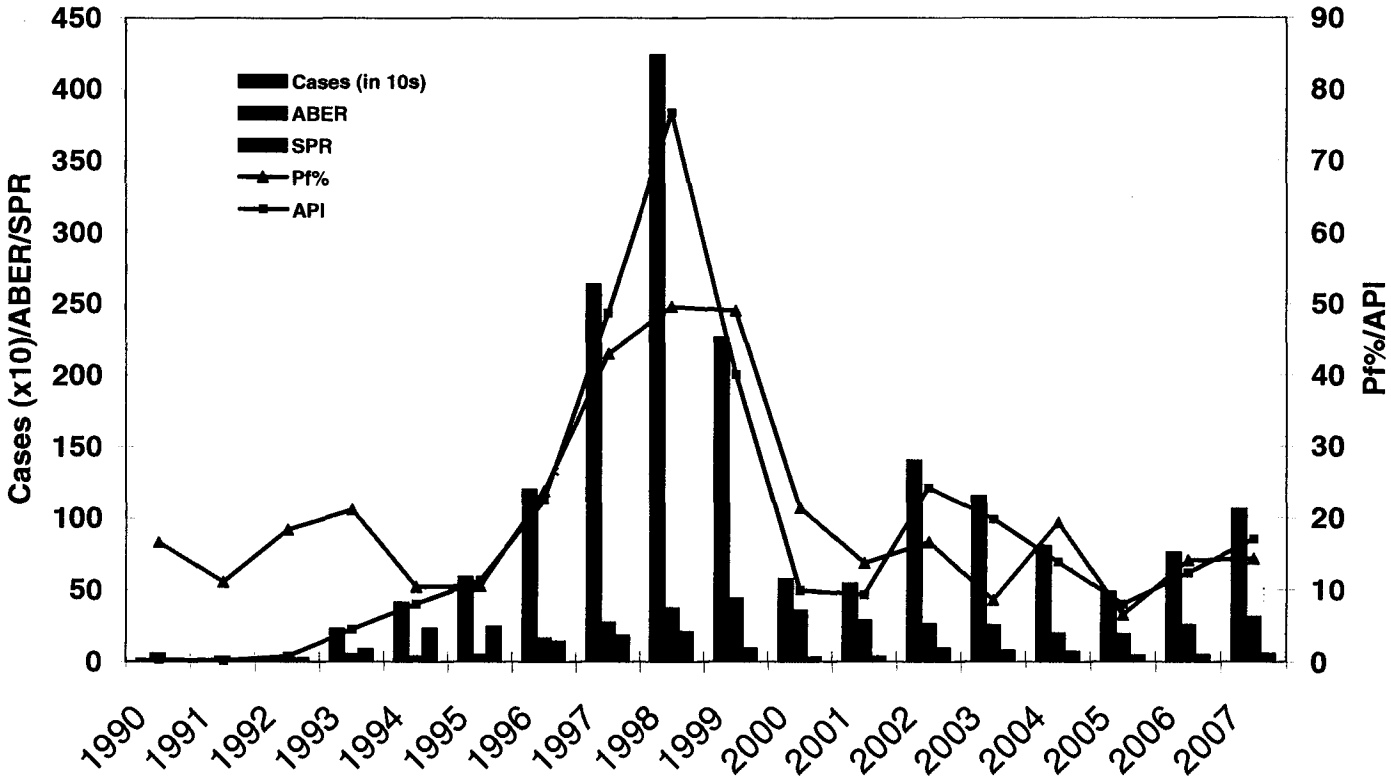


Fig. 4.32 Malaria incidence in Aldona PHC from 1990 to 2007

4. Margao UHC: The malaria incidence of Margao UHC which is situated in the South Goa District was analysed from 1990 to 2001 and 2002 to 2007. The ABER which was below 10% from 1990 to 1993 was on average 11.0% from 1994 to 1996 and 41.0% from 1997 to 2007 respectively (Fig. 4.33). The reported malaria cases which were only 10 to 16 from 1990 to 1993 increased sharply to 3002 cases in 1998. Though there was a decline in 2000 (1764 cases), a reverse trend was observed in 2002 (2577 cases). The malaria incidence ranged from 693 to 2577 cases from 2002 to 2007. Slide positivity rate which was below 1% from 1990 to 1993 which increased to 11.5% in 1998. Subsequently, in the year 2001 the SPR declined to 5.4% and further to 3.2 % in the year 2007. The Pf % also showed a four fold increase from 10% to 40.8% from 1992 to 1999 but decreased sharply to 7.4% in 2001. The Pf% however showed an increasing trend once again from 2005 to 2007 and ranged from 11.4% to 22.6%. The API ranged from 0.16 to 40.6 from 1990 to 2001 and 8.76 to 32.8 from 2002 to 2007 (Annexure 5: Table 2).

5. Corlim PHC: Epidemiological data of malaria for Corlim PHC, situated in the North Goa District is presented in (Fig. 4.34). It may be mentioned that some parts of this PHC such as Taleigao and Donapaula are adjacent to Panaji. From 1990 to 1995 the ABER ranged from 3.2 to 6.8% and from 1996 to 2001 it ranged from 9.8 to 17.7%. From 2002 to 2007, the ABER ranged from 9.9 to 24.2%. Though malaria cases were persistent throughout the years from 1990 to 2001 and 2002 to 2007, a significant increase in incidence was observed in 1991, 1997, 1998 and 2007. The SPR was 21% in 1991, decreased to 3.7% in 1993, however it was 10.1% and 12.1% in 1997 and 1998 respectively. The SPR from 2002 to 2007 ranged from 2.9% to 3.0%.

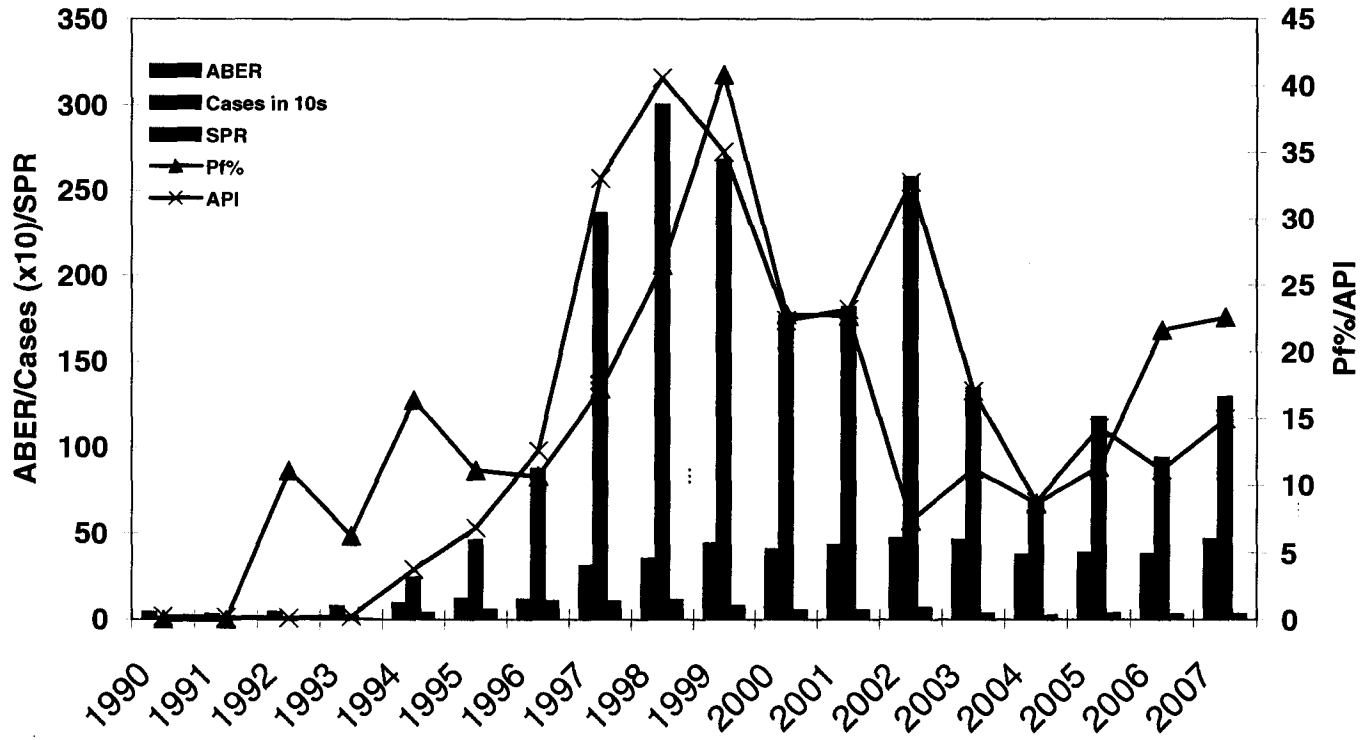


Fig. 4.33 Malaria Incidence in Margao from 1990 to 2007

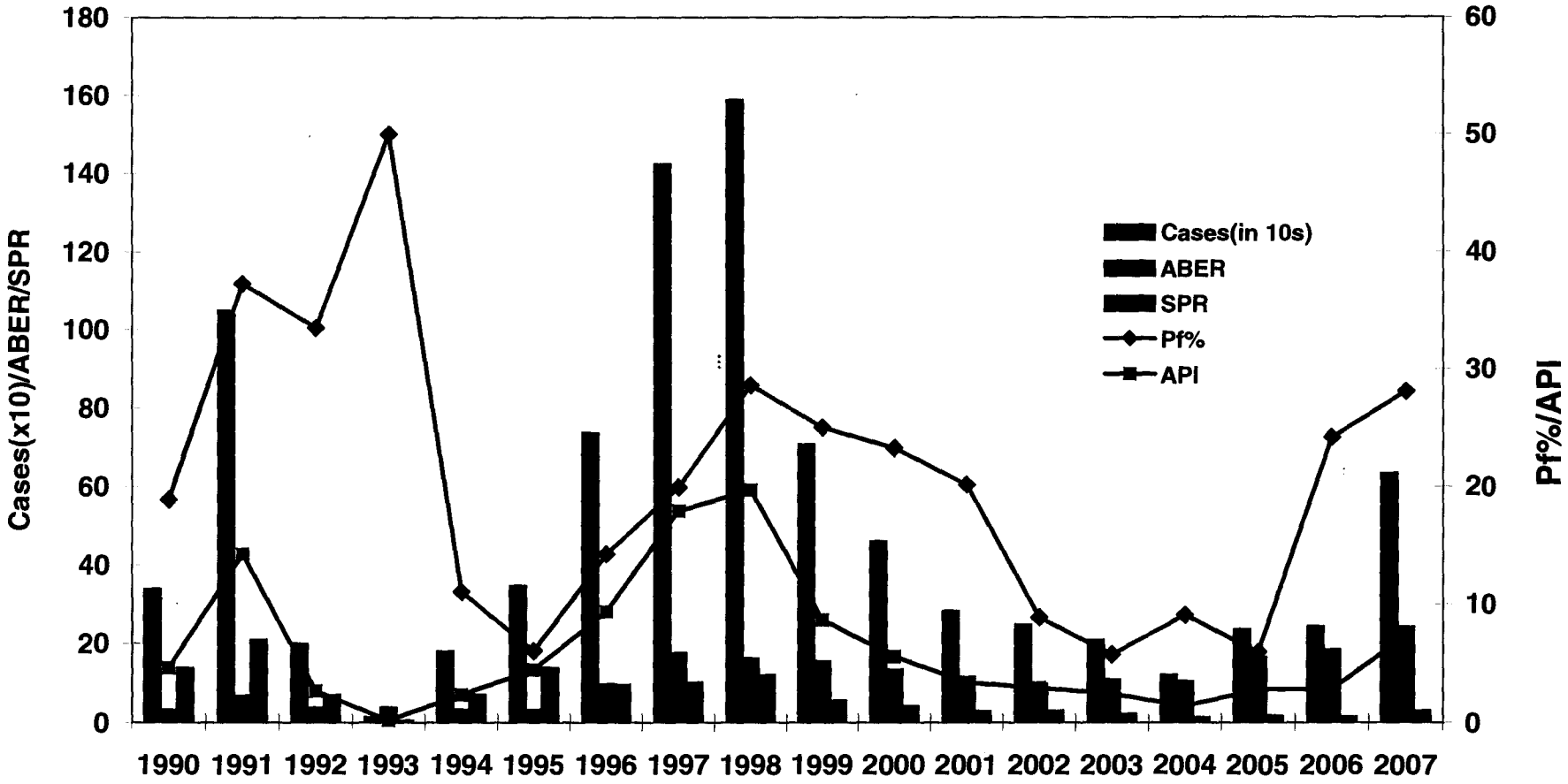


Fig. 4.34 Malaria incidence in Corlim PHC from 1990-2007

The Pf % which was highest at 37.3% in 1991 reduced to 5.5% in 1995. However, the trend reversed in 1998 as Pf% once again increased to 28.3%. Subsequently, a gradual reduction in the Pf% was observed in 2001 (20.1%). From 2002 to 2007, the Pf% ranged from 5.7% to 28.1%. The annual parasite incidence ranged from 2.4 to 19.7 from 1990 to 2001 except in 1993 (1.4) and from 1.4 to 7.3 from 2002 to 2007 (Annexure 5: Table5).

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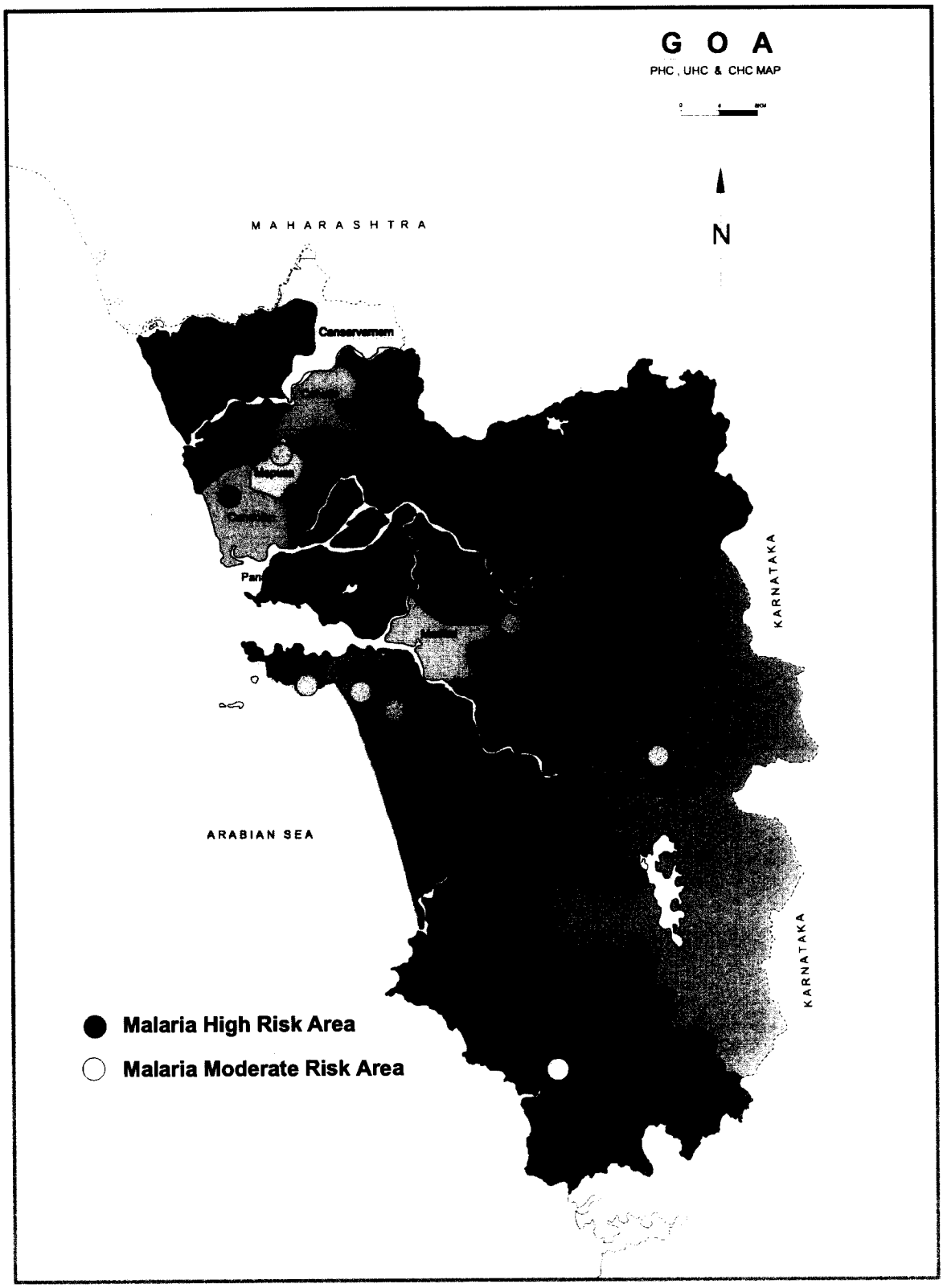

Fig : 4.35 Map of Goa State showing malaria high risk areas in red dots and moderate risk areas shown in yellow dots and rest low risk areas as per the API of 2007

Table 4.28 Number of Primary Health Centres in Goa with different levels of Annual Blood Examination Rate (ABER) for malaria in 1990, 1995, 1998, 2001, 2004 & 2007

	Number of PHCs with ABER							
Year	Total PHCs	>2%	2-5%	5-10%	10-20%	20-30%	30%	PHCs with >10% ABER
1990	24	2	8	8	5	0	1	6 (25%)
1995	24	0	9	9	5	0	1	6 (25%)
1998	26	0	0	4	13	3	6	22 (84.6%)
2001	28	0	0	5	16	3	4	23 (82.1%)
2004	28	0	0	12	11	0	5	16 (57.1%)
2007	28	0	0	2	14	6	5	25 (89.2%)

2001 in the South Goa district, Margao, Canacona, Curchorem, Sanguem and Cortalim PHCs, the ABER ranged between 20 and 50% and from 2 to 20% in the remaining PHCs. During 2002 to 2007, in all the PHCs, the ABER ranged from 2 to 50% with the exception of Panaji where it was > 100% till 2004 and ranged from 82.2 to 95.0% from 2005 to 2007. The summary of ABER can be seen in Table 4.29. Against the prescribed National norm of minimum 10% ABER, only 6 PHC (25%) out of total 24 had more than >10% ABER in the years 1990 and 1995. In 1998 and 2001 there was remarkable improvement in blood examination rate for malaria with 84.6% and 82.1% PHCs respectively having >10% ABER. However in 2004, there was once again deficiency in blood examination with only 16 (57.1%) out of 28 PHCs meeting the target. In the year 2007, 89.2% PHCs had >10% ABER marking significant improvement.

Stratification based on Slide Positivity Rate: The slide positivity rate (SPR) denotes the proportion of slides of fever cases in which malaria parasites are detected. It is sensitive indicator of malaria prevalence in the community. It was observed that the SPR for malaria was the highest (24.2%) in Aldona PHC in the year 1995 followed by 21% in Candolim in 1996. It was 21% in Corlim in 1991. The SPR was highest at 20.6% and 20.7% in Candolim and Aldona PHCs respectively in 1998.

It was observed that the SPR was highly variable in Panaji (range: 3.4 to 16.2%), Candolim (0.7 to 21.2%), Aldona (0.6 to 24.2%) and Corlim (2.9 to 21%). In rest of the PHCs, it was either negligible or less than 5% from 2002 to 2007. During this period, it was observed that the SPR in general declined as compared to previous years. From 2002 to 2007 in Panaji, SPR ranged

TABLE 4.29: Annual Blood Examination Rates (ABER) for Malaria of different PHCs/CHCs/UHCs in Goa from 1990 to 2007

PHC/CHC/UHC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panaji																		
Mapusa																		
Pernem																		
Candolim																		
Aldona																		
Bicholim																		
Valpoi																		
Ponda																		
Betki																		
Cansarvarnem																		
Siolim																		
Colvale																		
Corlim																		
Marcaim																		
Shiroda																		
Sankhali											0.6							
Margao																		
Vasco																		
Cansaulim																		
Curtorim																		
Bali																		
Canacona																		
Curchorem																		
Sanguem																		
Cortalim																		
Loutolim	1.7																	
Chinchinim	1.8																	
Quepem																		
TOTAL																		
ABER		<2																

from 2.5 to 13.6%, in Candolim 2.9 to 9.6%, in Aldona 4.2 to 9.2%, whereas in Corlim it ranged from 1.3 to 3% (Table 4.30).

In the South Goa district, similar variable trend was observed in Margao, Vasco, Cansaulim, Canacona, Sanguem and Cortalim PHCs (Table 4. 30). In Margao UHC it ranged from 0.3 to 11.5% from 1990 to 2001 and 2.3 to 7% from 2002 to 2007. In Vasco-da- Gama it ranged from 0.3 to 5.6% from 1990 to 2001 and thereafter from 0.5 to 1.5% from 2002 to 2007. In Cansaulim, it was below 4.9% up to 2001 and ranged from negligible to 5.3% from 2002 to 2007. In Canacona except for the years 2001 (5%), 2002 (8.3%) and 2003 (2.8%), the SPR was negligible from 1990 to 2007. In Sanguem PHC, the SPR was 3.4% in 1998, 2.6% in 1999 and 6.9% in 2001. In the remaining years, it was less than 2%, except in 2002 (3.7%) and it was negligible from 2003 to 2007. In Cortalim, SPR was negligible up to the year 1997 and thereafter ranged from 1.9% to 8.9% and subsequently it was below 3.9% from 2002 to 2007.

Stratification based on Annual Parasite Incidence: The Annual Parasite Incidence denotes the annual incidence of malaria cases per 1000 population and is an important indicator to determine malaria endmicity in an area. The API for malaria of different PHC's in Goa from 1990 to 2001 and 2002 to 2007 are presented in the Table 4.31. Of all the PHCs in Goa, Panaji had the highest API ranging from 10.4 to 199.1 from 1990 to 2001 and thereafter 23 to 179.7 in 2002 to 2007. This was followed by Candolim PHC in which API ranged from 0.6 to 96.5 from 1990 to 2001 and 11.4 to 44.7 from 2002 to 2007. In Aldona PHC, the API ranged from 0.2 to 76.7 while from 2002 to 2007, it was between 8.0 and 24.2 (Table 4.31). In Corlim PHC, API ranged

TABLE 4.30: Slide Positivity Rates for Malaria of different PHCs/CHCs/UHCs in Goa from 1990 to 2007

PHC/CHC/UHC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panaji																		
Mapusa	0.7	1.3	0.5	1.6						1.5	1.1	0.4	0.5	0.6	0.3	0.2	0.3	
Pernem	0.2	0.0	0.0	0.3	0.3	0.3	0.6	0.5	0.4	0.5	0.4	0.4	0.6	0.6	0.0	0.0	0.0	0.2
Candolim			0.7															
Aldona	0.6	0.6	2.0															
Bicholim	0.6	0.3	0.5	1.0	1.6	0.7	1.6		1.6	1.4	0.6	0.6	1.1	0.4	0.0	0.0	0.0	0.0
Valpoi	0.1	0.1	0.2	0.3	0.0	0.2	0.9	1.7	1.3	0.9	0.7	0.8	1.3	0.9	0.0	0.0	0.0	0.1
Ponda	0.0	0.2	0.3	0.1	0.1	0.2	1.1	1.1		1.0	0.5	0.3	1.3	0.2	0.2	0.2	0.2	0.3
Betki		1.6	0.7		1.1	0.6		1.9	0.6	1.0	0.8	1.3	1.4	0.8	0.2	0.1	0.4	0.9
Cansarvarnem	0.0	0.0	0.4	0.0	0.4	0.5	0.5	0.3	0.5	0.7	1.2	1.0	1.1	0.4	0.0	0.0	0.0	0.3
Siolim	0.0	0.1	0.4	0.2	0.2	0.3	0.7			1.5	1.1	1.1	1.1	1.0	0.0	0.1	0.1	1.1
Colvale	0.0	0.3	0.5	0.7	1.7	0.5	1.4			1.8	0.5	1.4	1.3	0.3	0.2	0.0	0.0	0.6
Corlim						13.9									1.3	1.7	1.5	
Marcaim								1.3	0.6	0.3	0.3	0.2	0.7	0.1	0.0	0.0	0.1	0.2
Shiroda											0.6	0.1	0.6	0.8	0.0	0.0	0.0	0.1
Sankhali											0.4	0.7	0.4	0.3	0.1	0.0	0.1	0.4
Margao	0.6	0.6	0.4	0.3														
Vasco	0.3	0.9	0.3	0.5	1.2						1.1	1.6	1.5	1.3	0.8	0.5	0.5	1.2
Cansaulim	0.0	0.0	0.1	0.3	0.8										0.5	0.0	0.1	
Curtorim	0.1	0.1	0.2	1.6	0.4	1.1	0.9		1.2	1.7				0.5	0.5	0.2	0.1	0.4
Bali	0.1	0.0	0.2	0.3	1.1	1.4	1.2			0.8	0.7	0.5	1.1		0.8	0.2	0.0	0.3
Canacona	0.2	0.0	0.1	0.2	0.8	0.6	0.9	1.6	0.7	0.9	1.0				0.7	0.1	0.1	0.4
Curchorem	0.0	0.0	0.0	0.1	0.3	0.1	0.8	2.0	1.7		1.0		1.2	0.7	0.3	0.0	0.1	0.4
Sanguem	0.8	0.1	0.1	0.1	0.1	0.1	0.4	1.9			0.8			0.7	0.2	0.0	0.1	0.1
Cortalim	0.0	0.0	0.2	0.1	0.4	0.2	0.4	1.0		1.9						0.1	0.2	
Loutolim	0.0	0.0	0.0	0.5	0.9			1.9						1.3	0.1	0.1	0.1	
Chinchinim	0.0	0.0	0.3	0.9		0.2	0.4			1.1	1.1	1.2	1.8	0.7	0.0	0.0	0.0	0.1
Quepem										1.1	0.5	0.5	1.1	0.4	0.1	0.1	0.0	0.1
TOTAL			1.1													1.4	1.8	

SPR = <2%

PHC did not exist

ABLE 4.31: Annual Parasite Incidence (API) for Malaria of different PHCs/CHCs/UHCs in Goa from 1990 to 2007

PHC/CHC/UHC	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Panaji																		
Mapusa	0.6	0.7	0.2	1.1	1.5							1.8	1.7	2.0	0.9	0.7	0.9	
Pernem	0.2	0.0	0.0	0.3	0.2	0.2	0.4	0.3	0.4	0.4	0.5	0.4	0.6	0.7	0.0	0.0	0.0	0.4
Candolim			0.6															
Aldona	0.4	0.2	0.8															
Bicholim	0.3	0.1	0.3	0.6	1.3	0.4	1.4				1.5	0.9	1.5	0.5	0.0	0.0	0.0	0.0
Valpoi	0.0	0.0	0.1	0.2	0.0	0.1	0.4	1.2	1.2	0.7	0.9	0.6	0.7	0.9	0.0	0.0	0.0	0.1
Ponda	0.0	0.1	0.1	0.1	0.3	0.2	1.6			1.0	0.5	0.2	1.3	0.2	0.2	0.2	0.2	0.3
Betki		1.2	0.5	1.4	0.5	0.3	1.0		1.4		1.6		2.0	1.2	0.2	0.2	0.5	1.1
Cansarvarnem	0.0	0.0	0.3	0.0	0.4	0.5	0.3	0.3	0.4	0.4	1.2	1.2	1.5	0.4	0.0	0.0	0.0	0.3
Siolim	0.0	0.0	0.2	0.1	0.1	0.1	0.3	1.8		1.4	1.2	1.1	0.8	1.0	0.0	0.1	0.3	
Colvale	0.0	0.2	0.3	0.4	1.2	0.3	0.5	1.2		0.9	0.2	0.8	0.8	0.3	0.1	0.0	0.0	0.9
Corlim				1.4											1.4			
Marcaim								0.9	0.8	0.4	0.4	0.4	1.1	0.1	0.0	0.0	0.3	0.5
Shiroda											0.2	0.0	0.3	0.6	0.0	0.0	0.0	0.2
Sankhali											0.0	1.2	0.3	0.3	0.1	0.0	0.2	0.9
Margao	0.3	0.2	0.2	0.3	4.0													
Vasco	0.1	0.3	0.1	0.2	0.4	1.5					1.6		2.0	1.4	0.6	0.4	0.5	1.4
Cansaulim	0.0	0.0	0.0	0.1	0.4	1.8		1.4							0.4	0.0	0.1	
Curtorim	0.1	0.0	0.1	0.4	0.2	0.3	0.4		1.3	1.3				0.6	0.5	0.2	0.2	0.6
Bali	0.2	0.0	0.2	0.3	1.2	1.3	1.0			0.9	0.8	0.6	1.3	3.4	0.9	0.2	0.0	0.6
Canacona	0.2	0.0	0.1	0.3	1.4	0.7	1.7		1.7	1.8	1.6				0.6	0.2	0.1	0.6
Curchorem	0.0	0.0	0.0	0.2	0.7	0.1	1.1				1.3		1.6	0.8	0.3	0.0	0.2	0.7
Sanguem	1.1	0.2	0.2	0.1	0.2	0.1	0.4				1.0			1.1	0.3	0.0	0.2	0.2
Cortalim	0.0	0.0	0.1	0.1	0.2	0.1	0.2									0.3	0.3	
Loutolim	0.0	0.0	0.0	0.2	0.3	0.6	2.0	1.3							0.1	0.1	0.2	
Chinchinim	0.0	0.0	0.1	0.4	0.6	0.1	0.2			1.2	1.1	1.3	1.6	1.0	0.0	0.0	0.0	0.3
Quepem										1.1	0.4	0.5	1.0	0.4	0.1	0.1	0.0	0.1
TOTAL			0.8	2.0														
	API =	<2																

from 1.4 to 19.7 from 1990 to 2001 and from 1.4 to 7.3 from 2002 to 2007. In the rest of the PHCs, API mostly remained less than 2 from 1990 to 2007 in North Goa district.

In South Goa district however, API was comparatively less as a whole. In Margao UHC, API ranged from 0.2 to 40.6 from 1990 to 2001 and 8.8 to 32.8 from 2002 to 2007. In Cansaulim PHC, API ranged from negligible to 6.9 from 1990 to 2001 and thereafter 0 to 13.2 from 2002 to 2007. In Canacona PHC area, it ranged from negligible to 9.0 from 1990 to 2001 and thereafter 0.1 to 15.6 from 2002 to 2007. In Sanguem PHC and Cortalim PHC, peak API was observed in the year 2001 when it was 19.2 and 19.6 respectively. In the subsequent years however, API ranged from nil to 8.1 in Sanguem and 0.3 to 11 in Cortalim from 2002 to 2007 (Table 4.31).

The pictorial stratification of Goa based on Slide Positivity Rate and Annual Blood Examination Rates for 4 representative years viz., 1986 (malaria outbreak year), 1994 (foci expansion year), 1998 (peak incidence year) and 2007 (recent year) revealed that malaria expanded from Panaji to surrounding areas by the year 1994 and then further consolidated and expanded to interior areas in 1998. However, in 2007 malaria retracted to Panaji and surrounding areas along the coast primarily in PHCs in Bardez, Tiswadi and Salcete 'talukas'. The areas affected in the declining order of endemicity among the high risk PHCs were Panaji followed by Candolim, Aldona, Margao and Corlim in 2007. The other affected areas were Mapusa, Siolim, Cansaulim, Cortalim and Lutolim (Figs. 4.36 and 4.37).

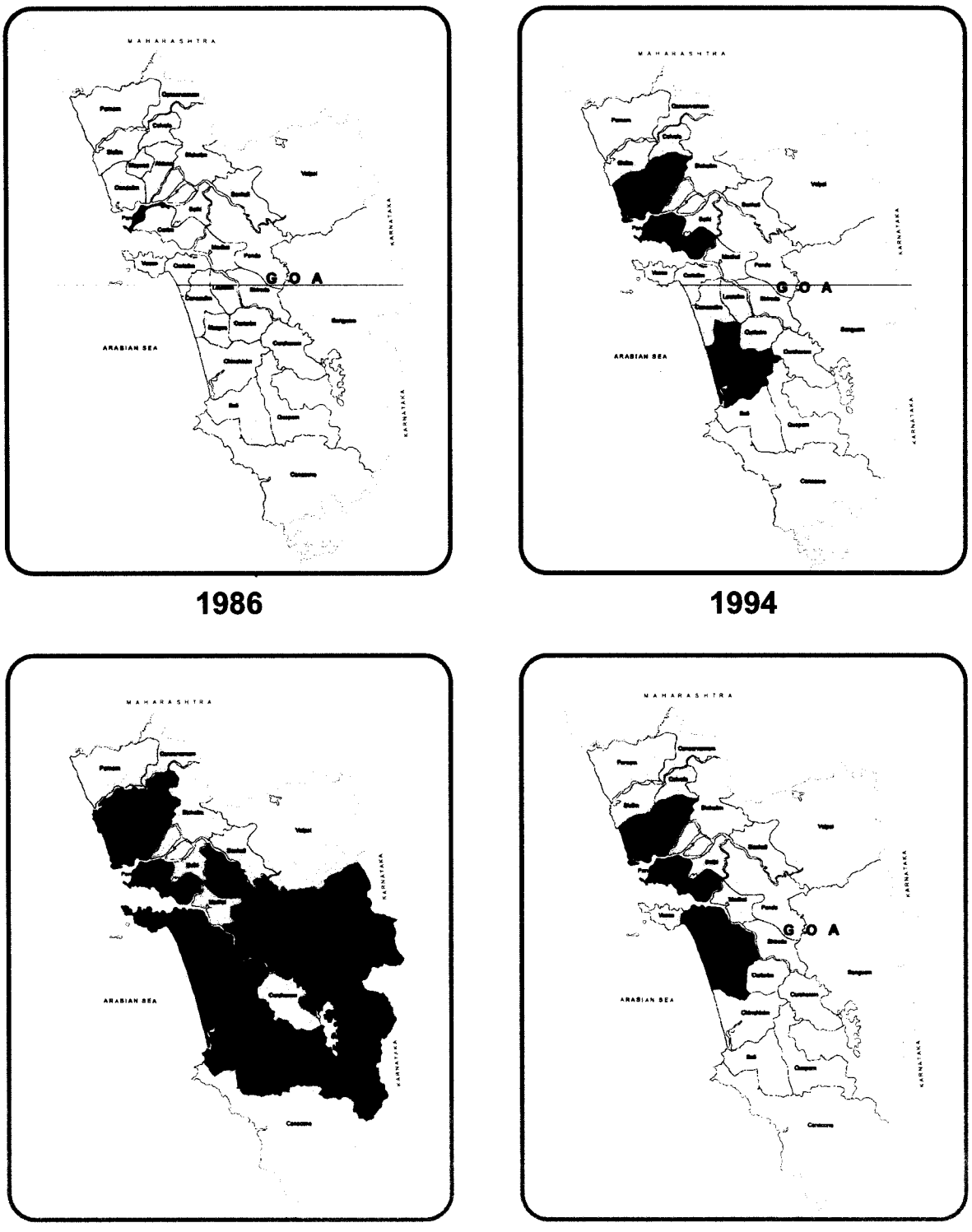

Fig : 4.36 Stratification of Goa based on Malaria Slide Positivity Rate (SPR) in various PHCs / UHCs in 1986 (out break year), 1994 (foci expansion year), 1998 (peak incidence year) and 2007 (latest situation)

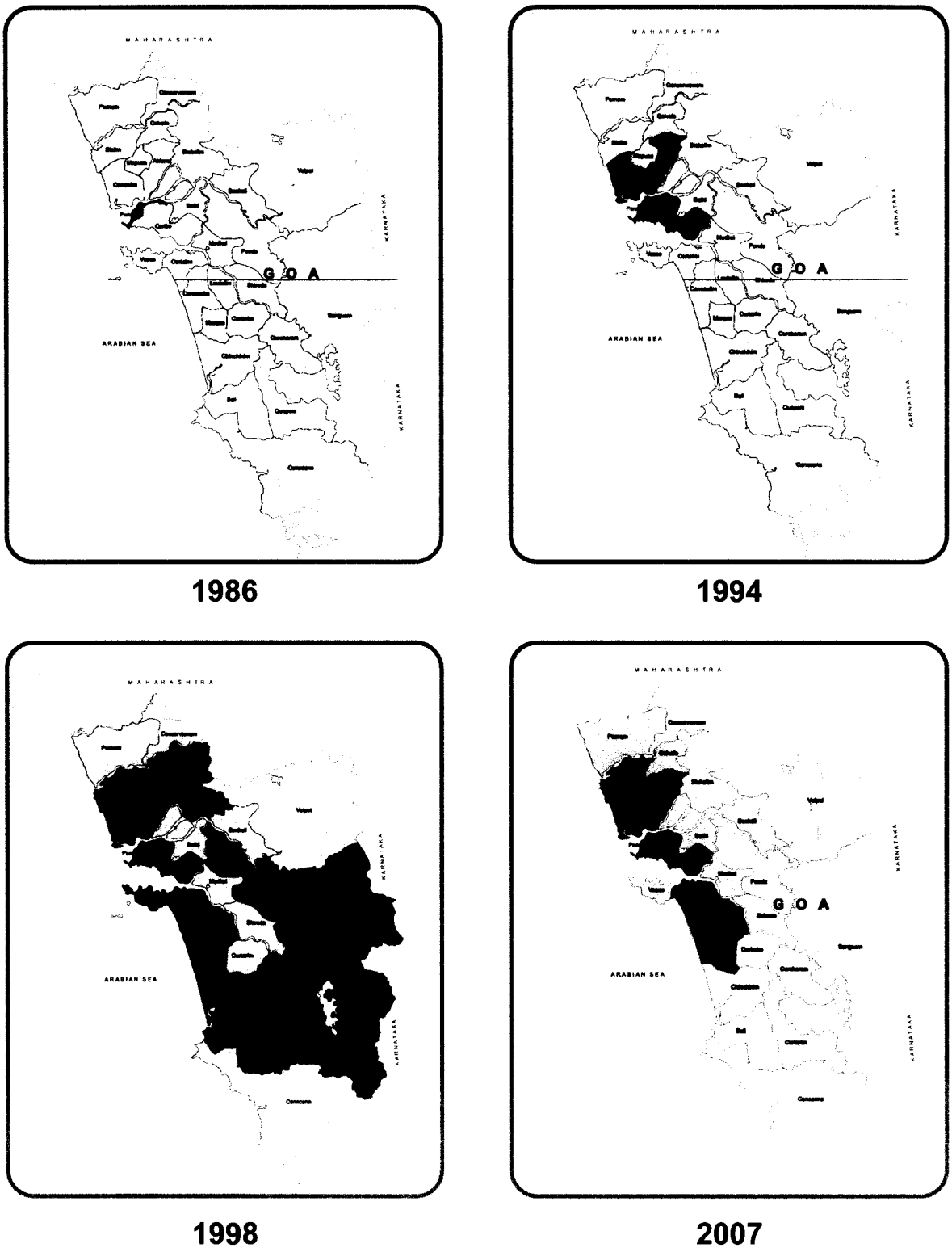

Fig : 4.37 Stratification of Goa based on Malaria incidence per 1000 population (API) in various PHCs / UHCs in 1986 (out break year), 1994 (foci expansion year), 1998 (peak incidence year) and 2007 (latest situation)

9. Microstratification of Panaji according to Malaria Risk

The capital city of Panaji is divided into 15 major localities and malaria data of 2004 was analysed locality wise (Table 4.32 & Fig. 4.38). It was observed that out of 4813 total cases, Caranzalem had the highest number of malaria cases (982; SPR; 14.2%) followed by Market area (769 cases; SPR: 8.8%), Campal (708 cases; SPR: 12.3%), St. Inez (573 cases; SPR: 8.3%), Panaji Main (373 cases; SPR: 8.4%), Taleigao (279 cases; SPR: 11.75), Mala (243 cases; 11.4%), Miramar (208 cases; SPR: 6.6%) and Donapaula (200 cases; SPR: 11.7%). Other localities namely Tonca (122 cases; SPR: 6.5%), Boc- de-Vaca (107cases; SPR: 5.4%), Altinho (91cases; SPR: 5.4%), Bhatlem, (72 cases; SPR: 8.2%), Patto (59 cases; SPR: 6.2%) and Ribandar (29 cases; SPR: 7%) contributed lesser incidence of malaria. The Pf percentage ranged from 6.5% in Boc-de-Vaca to 35% in Campal area (Table 4.32 & Fig. 4.38).

The SPR based stratification of Panaji in the year 2004 showed that Caranzalem and Campal areas had the highest SPR for malaria among fever cases, ranging from 12-15% whereas, Mala, Donapaula and adjacent Taleigao area had SPR ranging from 10-12% followed by Panaji Main and Panaji Market, St. Inez and Bhatlem had the SPR ranging from 8-10% while the remaining areas viz., Ribandar, Patto, Boca-de-Vaca, Miramar and Tonca had the least SPR of 5-8% (Fig. 4.39).

10. Malaria in Relation to Climatic Risk Factors

In order to ascertain relationship between malaria incidence and four different climatic factors viz., rainfall, relative humidity, maximum and minimum temperature, malaria incidence of Goa from 1990 to 2001 & 2002 to 2007 was analyzed and monthly average incidence during this period was worked out.

Table 4.32: Area/Locality wise distribution of malaria cases in Panaji in 2004

S.No.	AREA	BSC	PV	PF	TOTAL	SPR	PF%
1	**RIBANDER**	417	24	5	29	7.0	17.2
2	**PATTO**	948	47	12	59	6.2	20.3
3	**PANAJI MAIN**	4419	285	88	373	8.4	23.6
4	**PANAJI MARKET**	8788	658	111	769	8.8	14.4
5	**BOC DE VACA**	1964	100	7	107	5.4	6.5
6	**ST. INEZ**	6904	510	63	573	8.3	11.0
7	**CAMPAL**	5747	460	248	708	12.3	35.0
8	**MIRAMAR**	3135	160	48	208	6.6	23.1
9	**TONCA**	1890	103	19	122	6.5	15.6
10	**CARANZALEM**	6933	672	310	982	14.2	31.6
11	**DONAPAULA**	1711	150	50	200	11.7	25.0
12	**TALEIGAO**	2389	247	32	279	11.7	11.5
13	**BHATLEM**	877	63	9	72	8.2	12.5
14	**MALA**	2134	204	39	243	11.4	16.0
15	**ALTINHO**	1684	79	12	91	5.4	13.2
	TOTAL	49947	3762	1051	4813	9.6	21.8

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
Pf% = Proportion of P. *falciparum*

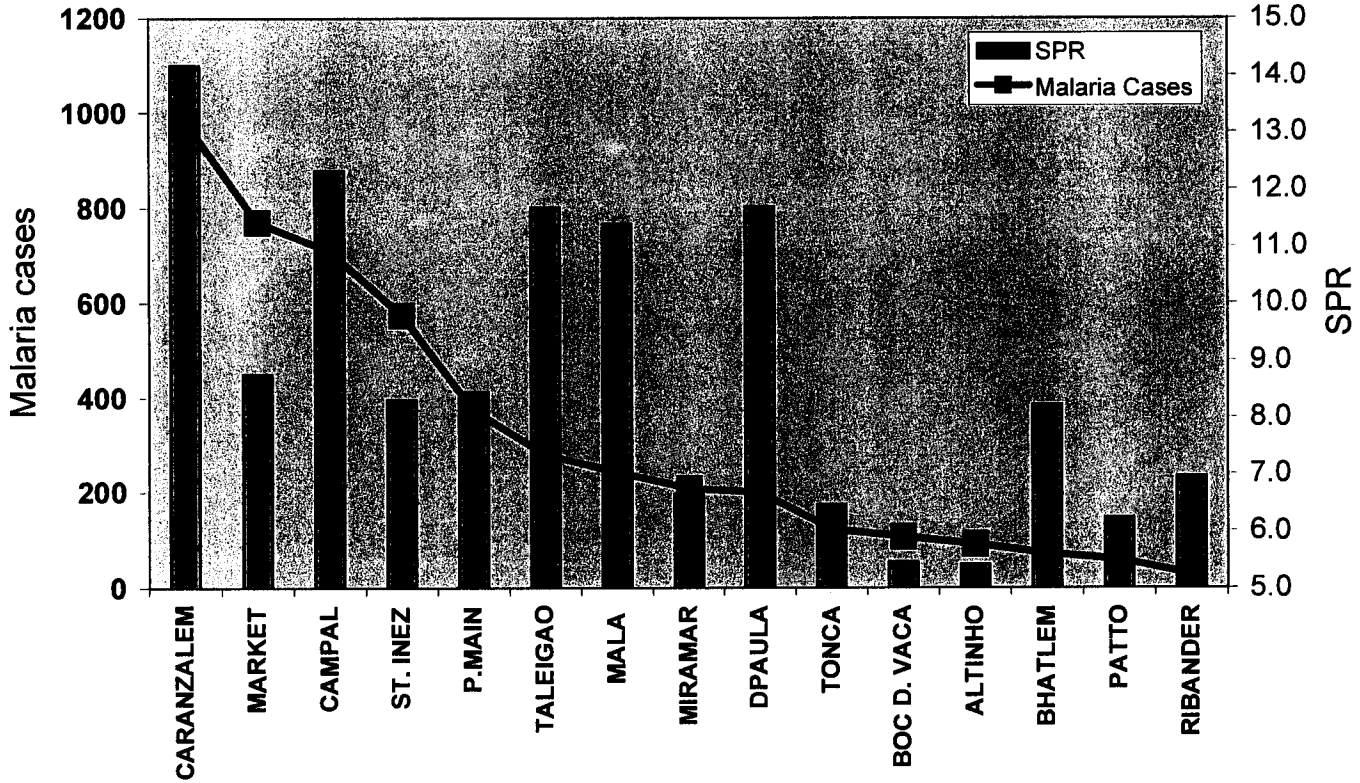

Fig. 4.38 Malaria incidence & Slide Positivity Rate(SPR) in 15 different areas of Panaji in 2004

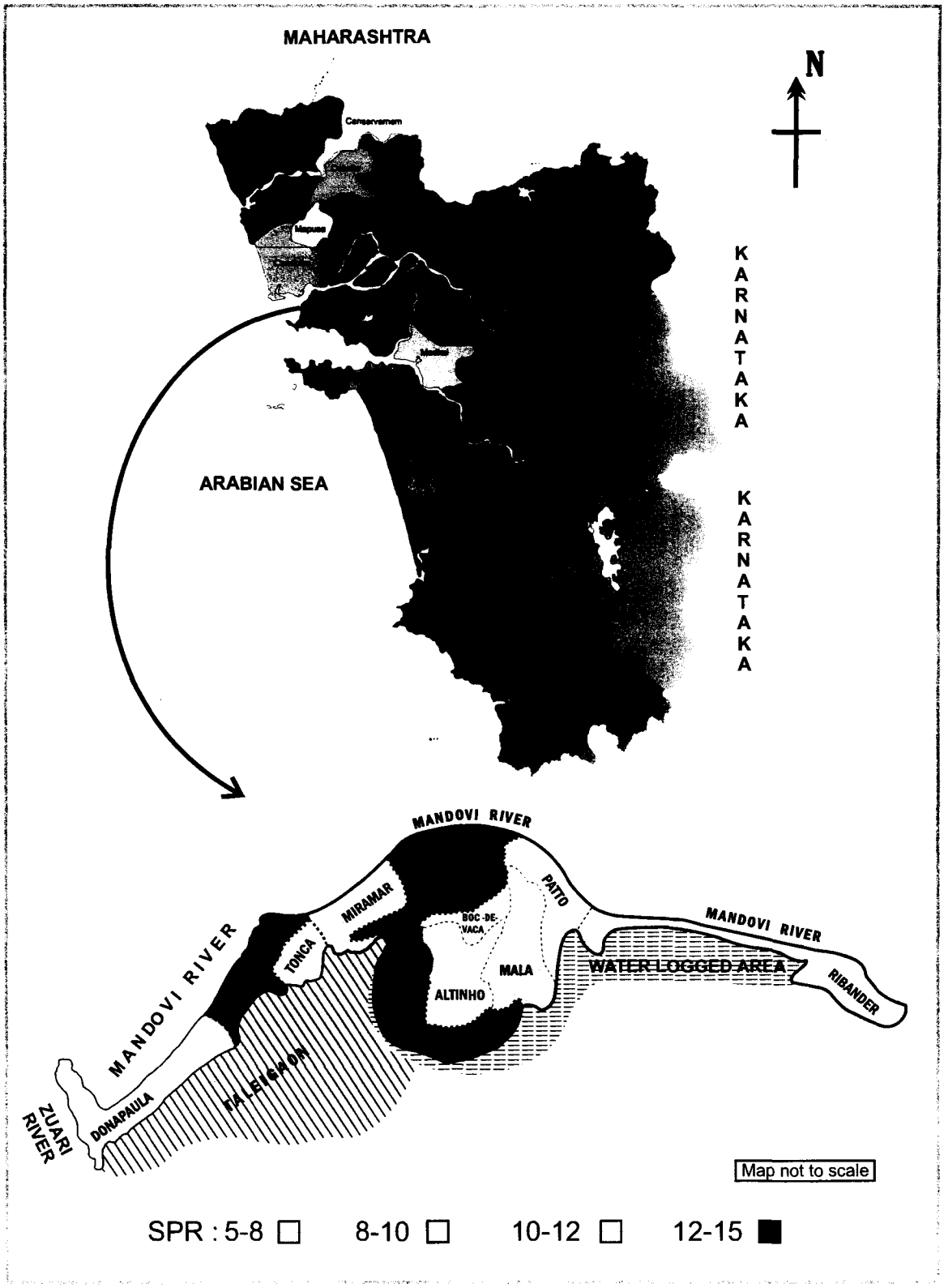

Fig. 4.39 Map of Panaji City showing varying endemicity of Malaria in different areas in the year 2004

Similarly, monthly averages of the four mentioned climatic factors i.e. rainfall, relative humidity, maximum and minimum temperatures were worked out for the period from 1990 to 2001 and 2002 to 2007.

Relationship between Malaria Incidence and Rainfall

Period 1990 to 2001: The monthly incidence of malaria in Goa shows that the average number of cases ranged from 431 to 597 from the month of January to April during 1990 to 2001 (Fig. 4.40). During this period there was no rainfall recorded. However, in the month of May, on an average 120 mm of rainfall was observed and average incidence of malaria increased to 897 cases. There was sharp increase in the rainfall in the month of June to 892 mm and consequently malaria incidence also showed an increase to about 1218 cases. However, further increase in the rainfall did not result in the increase in the incidence in the month of July. Thereafter from August to December the rainfall reduced significantly whereas the incidence of malaria reduced gradually. Overall, there was good relationship between average rainfall and average incidence of malaria in Goa (R^2 = 0.643) [Fig. 4.41].

Period 2002 to 2007: Quite similar to the period from 1990 to 2001, during this study period, it was found that although the rainfall was negligible from the month of January to April, malaria incidence ranged from 443 to 627 cases (Fig. 4.42). With the increase of rainfall to about 133.5 mm, sudden increase in the incidence to about 891 cases was observed in May. This incidence further increased to about 1258 cases as the rainfall increased to about 893.9 mm in June. In the subsequent months, the rainfall declined and became negligible by November. However, the incidence of malaria after declining marginally in the month of July remained static from August to

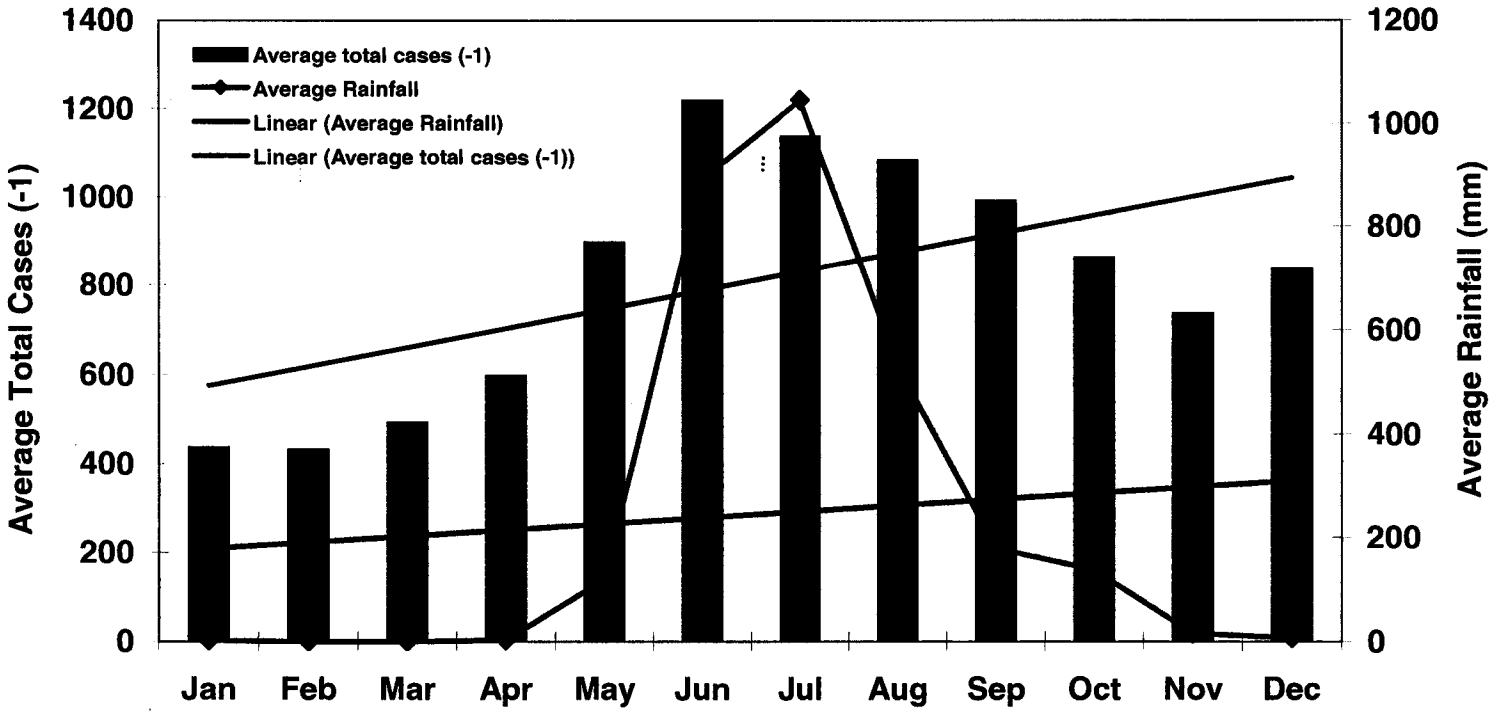

Fig. 4.40 Correlation between average malaria cases and average rainfall in Goa from 1990 to 2001

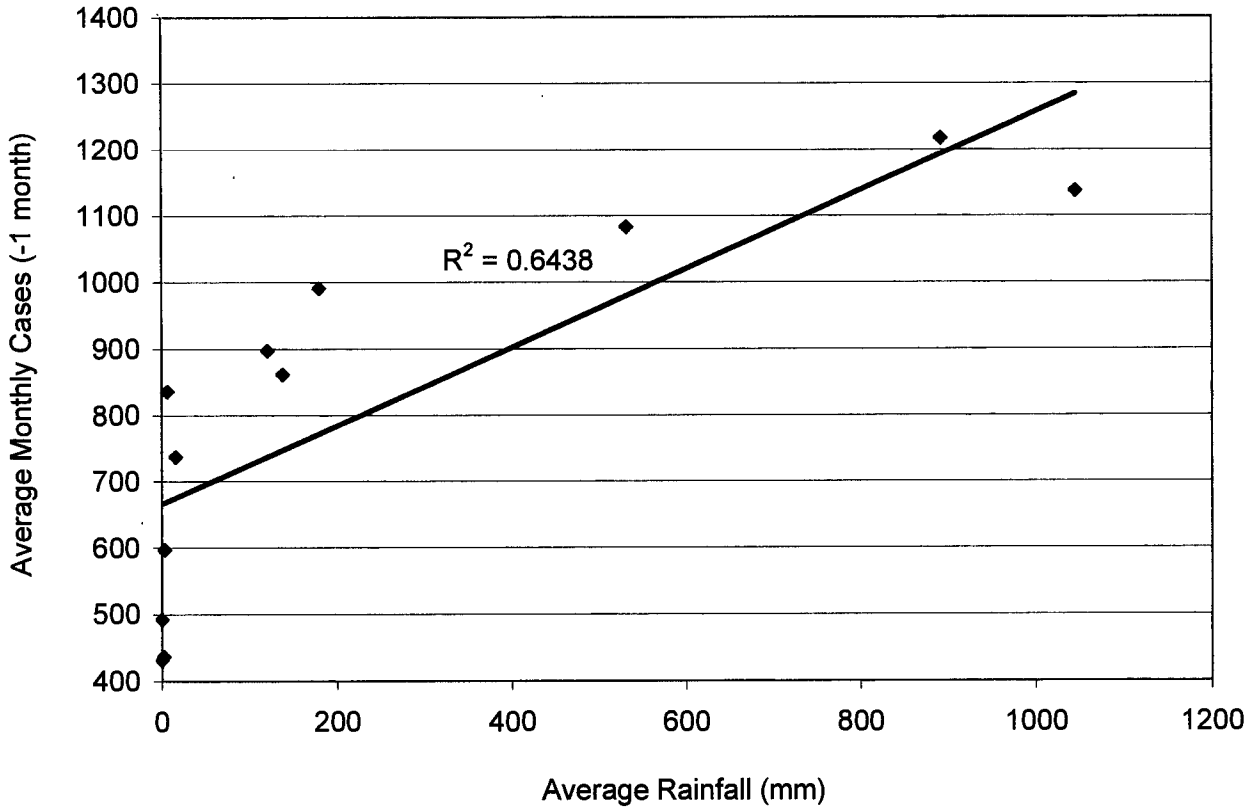

Fig. 4.41 Correlation between average monthly malaria cases & average rainfall in Goa from 1990 to 2001

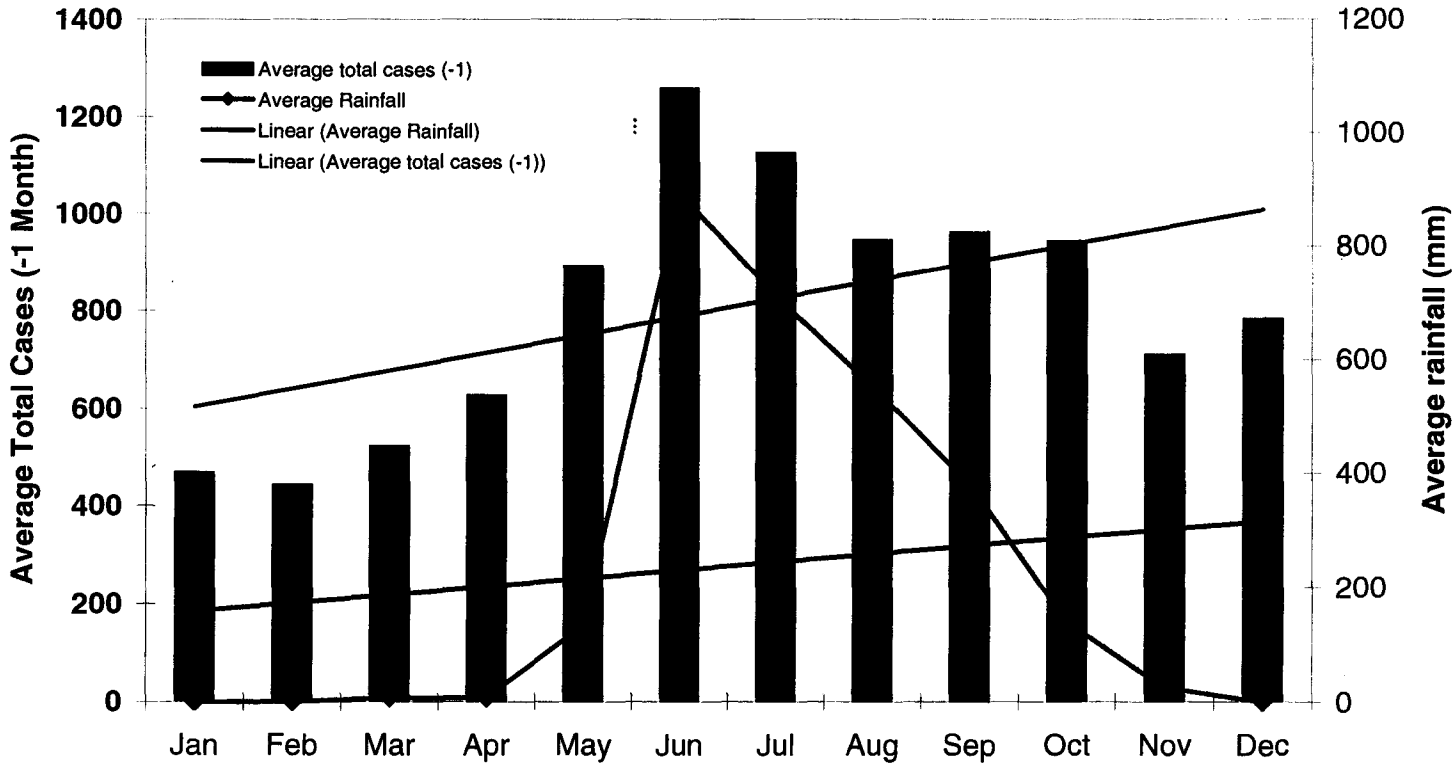

Fig. 4.42 Correlation between average malaria cases and average rainfall in Goa from 2002 to 2007

October to about 950 cases per month and thereafter appreciably declined in the month of November and December (Fig. 4.42). The correlation between the rainfall and incidence of malaria during this period was significant (R^2 = 0.752) [Fig. 4.43].

Relationship between Malaria Incidence and Relative Humidity

The relative humidity is known to influence transmission of malaria and when high, it affects the feeding behaviour and prolongs longevity of the vectors. The relative humidity not only depends upon the number of water bodies but also the rainfall.

Period 1900 to 2001: The relative humidity ranged from 73.3 to 77.4% from January to May. Similarly during this period, the incidence of malaria increased from 431 to 597 cases (Fig. 4.44). In the month of June, the RH increased to 86.7%, during which the malaria cases increased to about 897 cases. Further, RH in the month of July increased to 91.2% and malaria incidence increased to about 1218 cases. From August to December, RH gradually declined to 71.3%. During this period the incidence of malaria also declined from 1137 to 737 cases (Fig. 4.44). The average monthly cases and average relative humidity were found to be significantly correlated (R^2 = 0.741) [Fig. 4.45].

Period 2002 to 2007: Relative humidity ranged from 69.6 to 73.8% from January to May during which the incidence of malaria also ranged from 443 to 627 cases (Fig. 4.46). In the month of June sharp increase in RH to 86.7% was observed. Similarly, the increase of malaria cases to 891 was observed. Relative humidity further increased to 88.9% in the month of July during which month, 1258 cases of malaria were reported. Relative humidity marginally

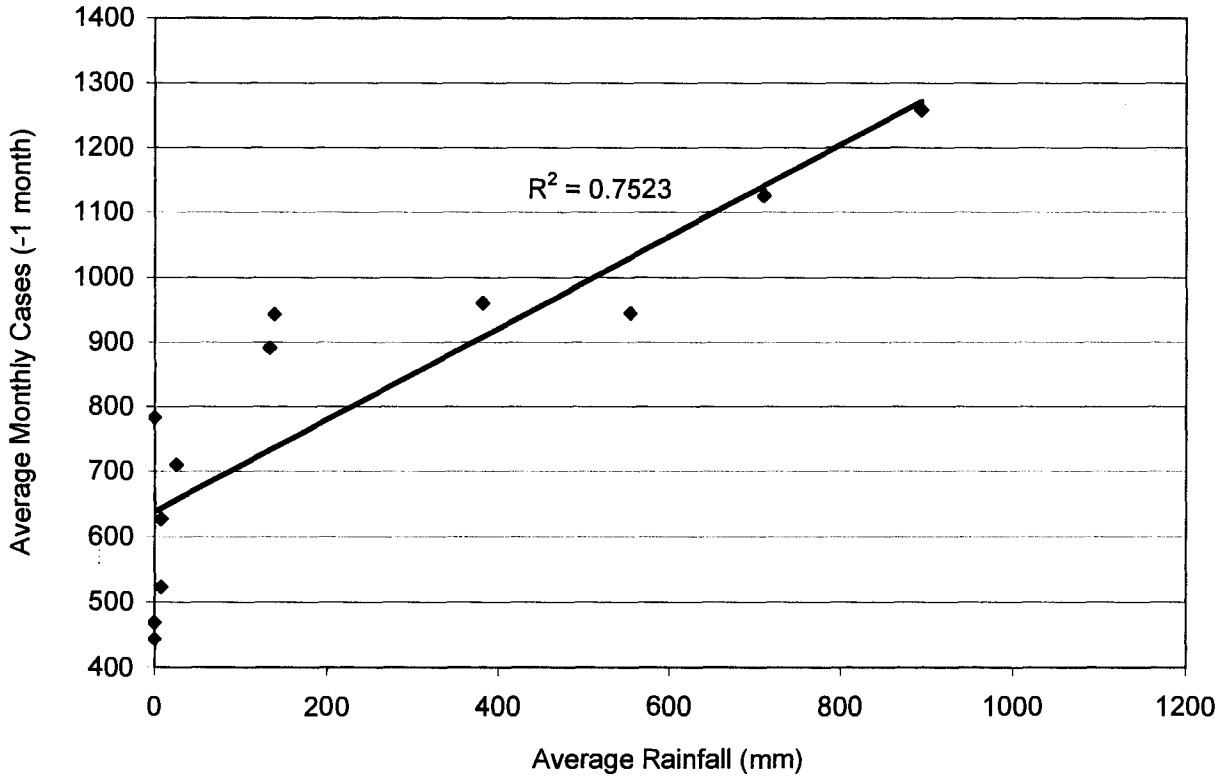

Fig. 4.43 Correlation between average monthly malaria cases & average rainfall in Goa from 2002 to 2007

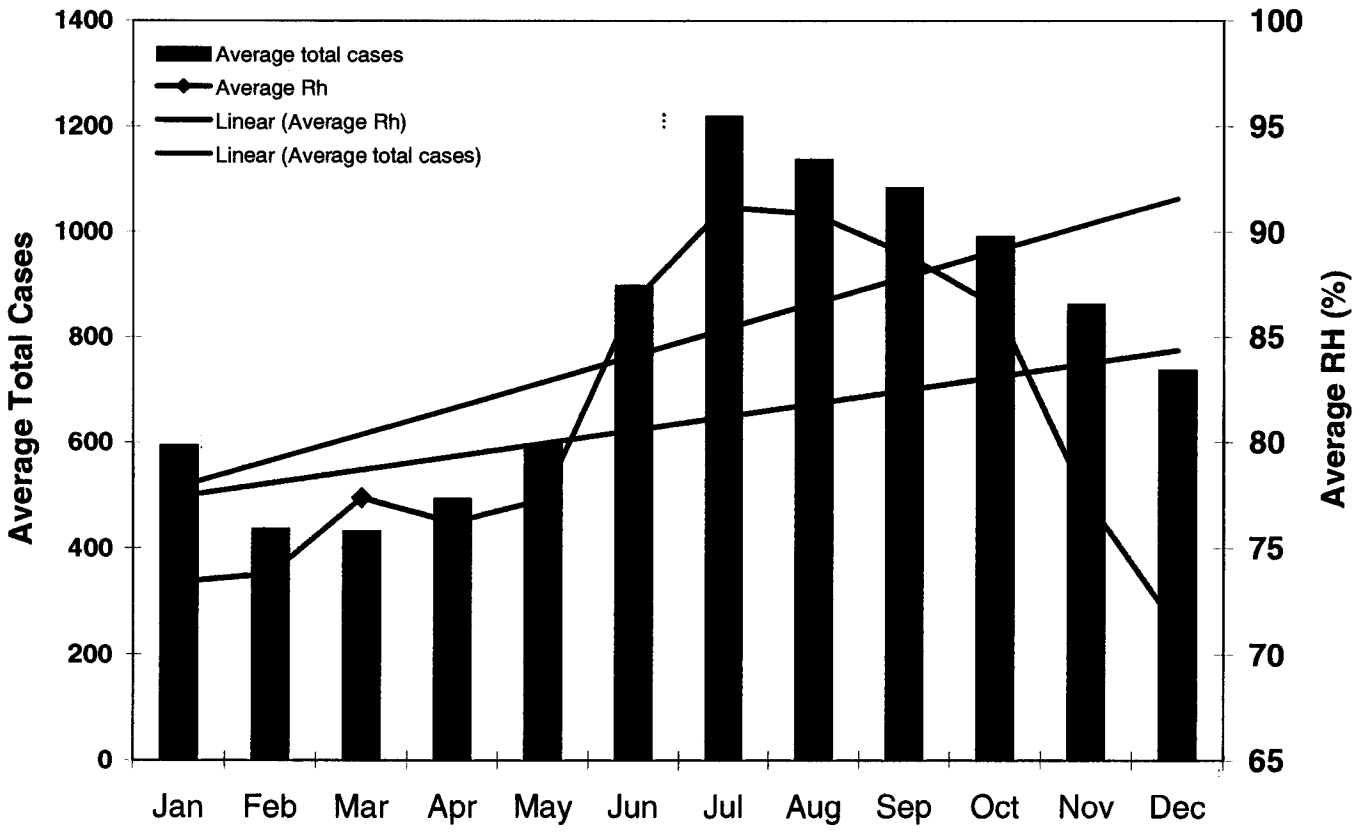

Fig. 4.44 Correlation between average malaria cases and average relative humidity in Goa from 1990 to 2001

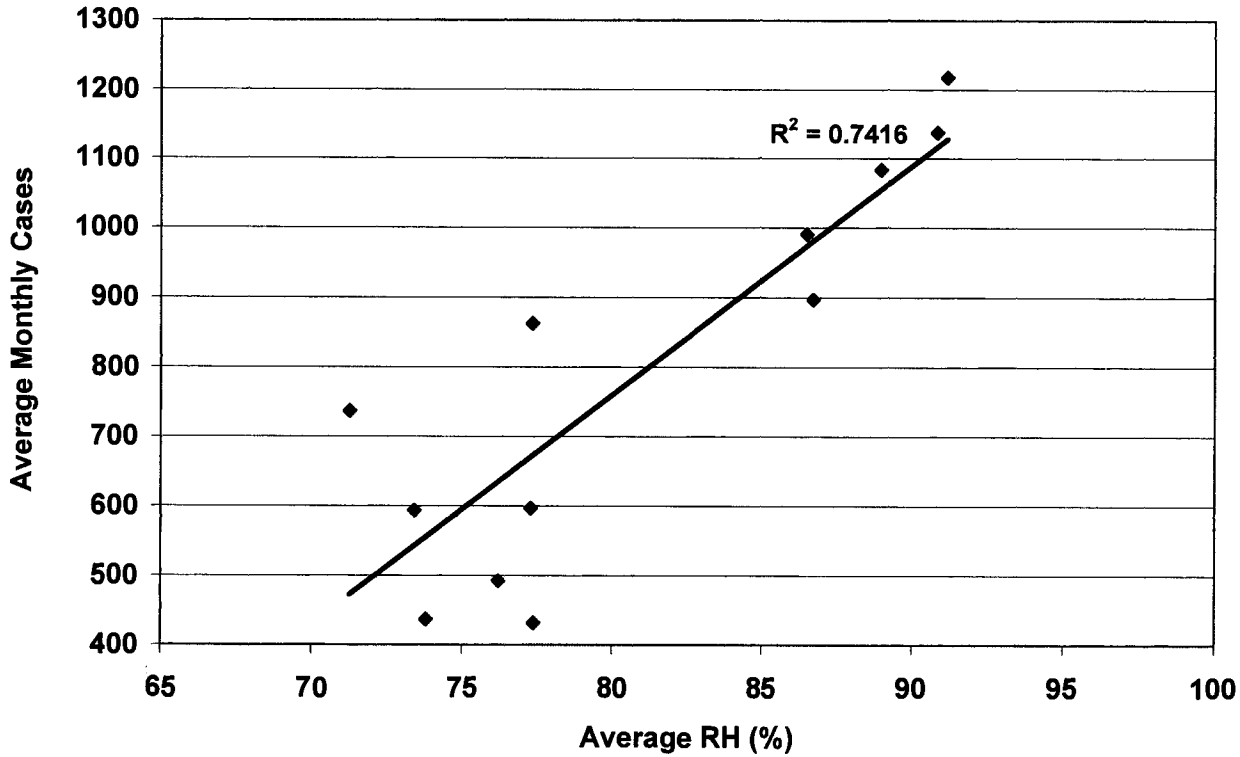

Fig. 4.45 Correlation between average monthly malaria cases & average relative humidity in Goa from 1990 to 2001

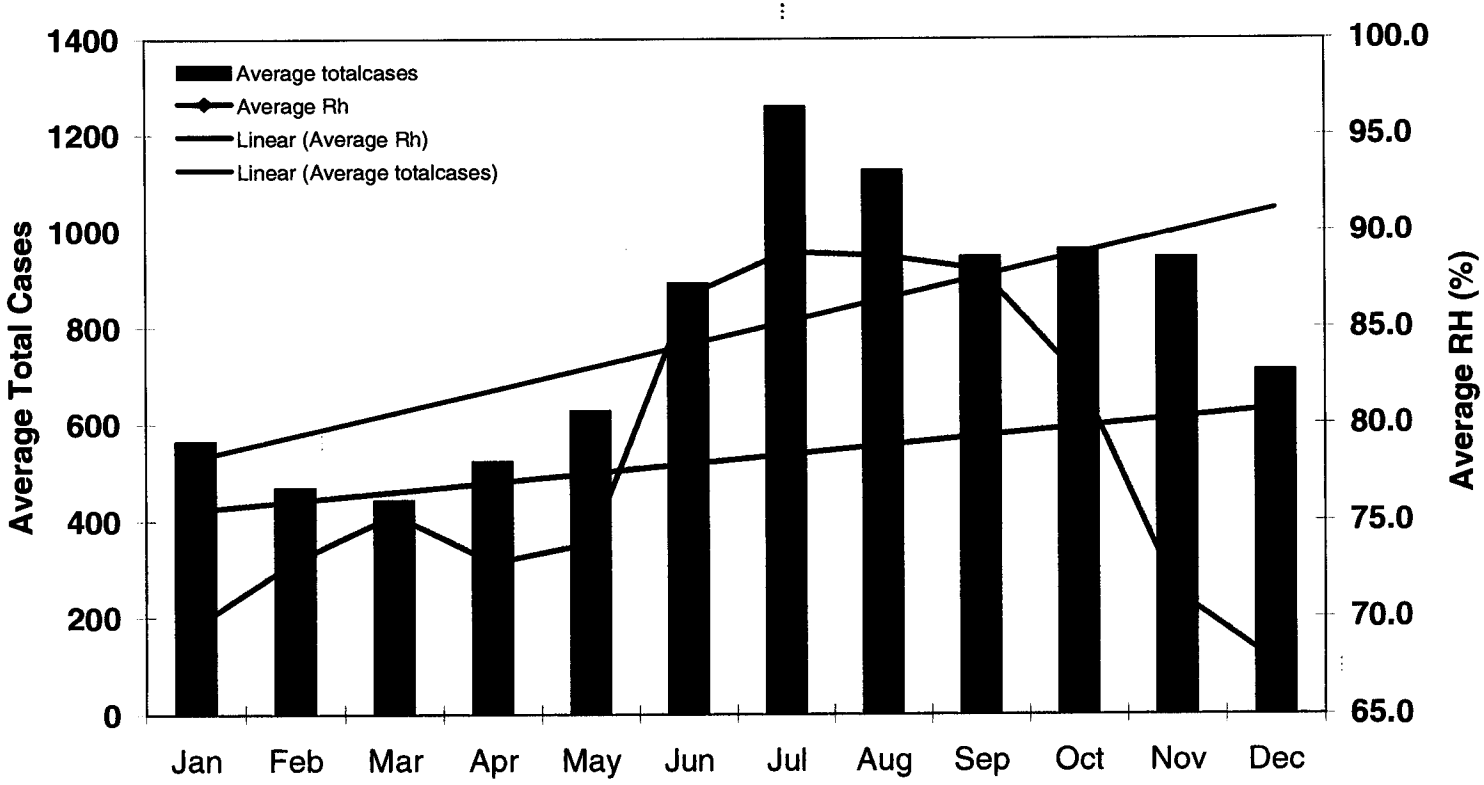

Fig. 4.46 Correlation between average malaria cases and average relative humidity in Goa from 2002 to 2007

declined to 88.7% in August and 88% in September before appreciably declining to 82.4%, 71.3% and 67.7% in the month of October, November & December respectively. During these months, malaria decreased to 1125 cases in August further to about 950 cases from September to November and about 710 cases in the month of December (Fig. 4.46). The relationship between average monthly malaria cases and average relative humidity was found to be positive $R^2 = 0.57$ (Fig. 4.47).

Relationship between malaria and maximum temperature

Period 1990 to 2001: The maximum temperature is more or less static and ranged from 32°C to 32.2°C from January to March and showed increase to 33°C in the month of April and then further to 33.3°C in the month of May (Fig. 4.48). Thereafter, in the month of June and July there was reduction to 30.5°C and 28.8°C followed by gradual rise in the month of August to November, and back to 33.1°C. In the month of December, there is marginal decrease to 32.6°C. In general, the maximum temperature and malaria incidence appeared to show rising trends from March to May. However, in the subsequent months, there does not seem to be correlation between malaria incidence and maximum temperature (Fig. 4.48). This is quite apparent from not very strong relationship between the two factors ($R^2 = 0.44$) [Fig. 4.49].

Period 2002 to 2007: Similar trend in malaria cases in relation to temperature was observed except that the maximum temperature dropped to lowest 29.1°C in the month of August and rose to about 33.9°C in the month of November during this period (Fig. 4.50). Also the temperature in December was higher during this period at 33.5°C as compared to the period from 1990 to 2001. There was similarity in the rising trends of maximum temperature and

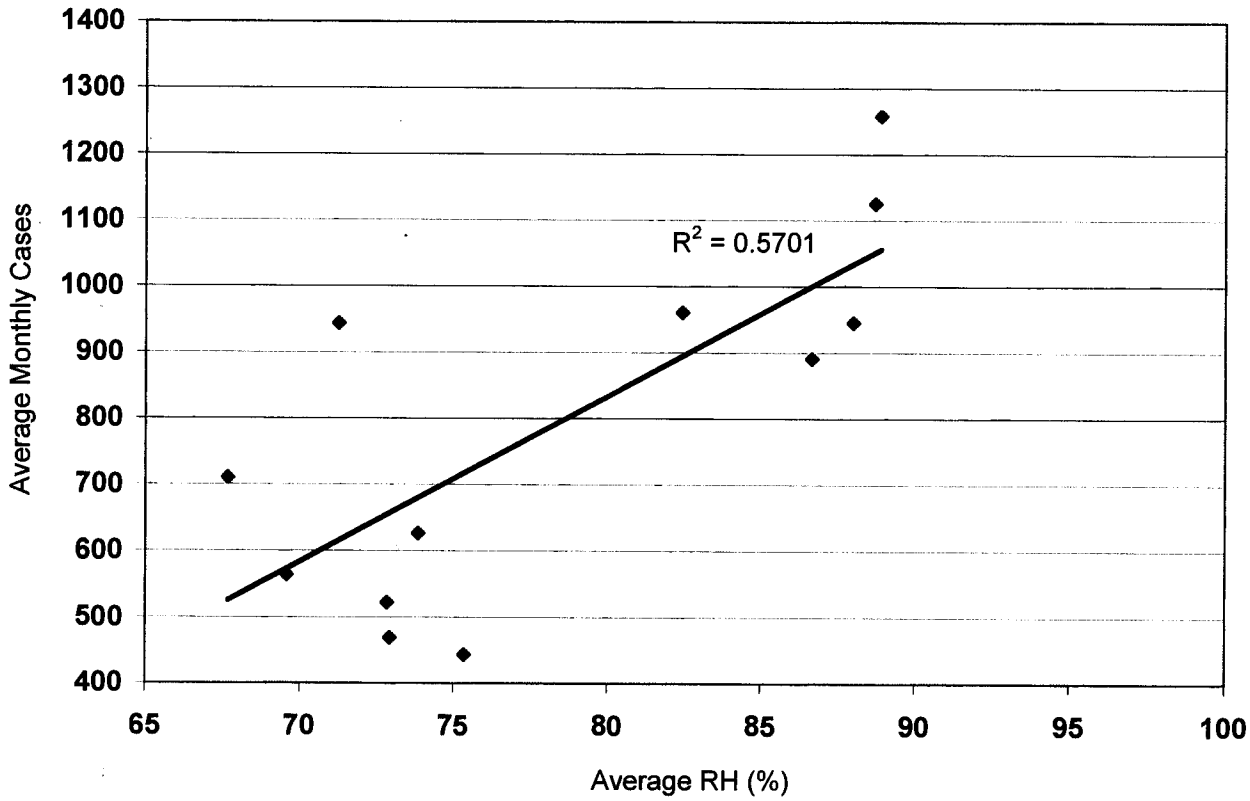

Fig. 4.47 Correlation between average monthly malaria cases & average relative humidity in Goa from 2002 to 2007

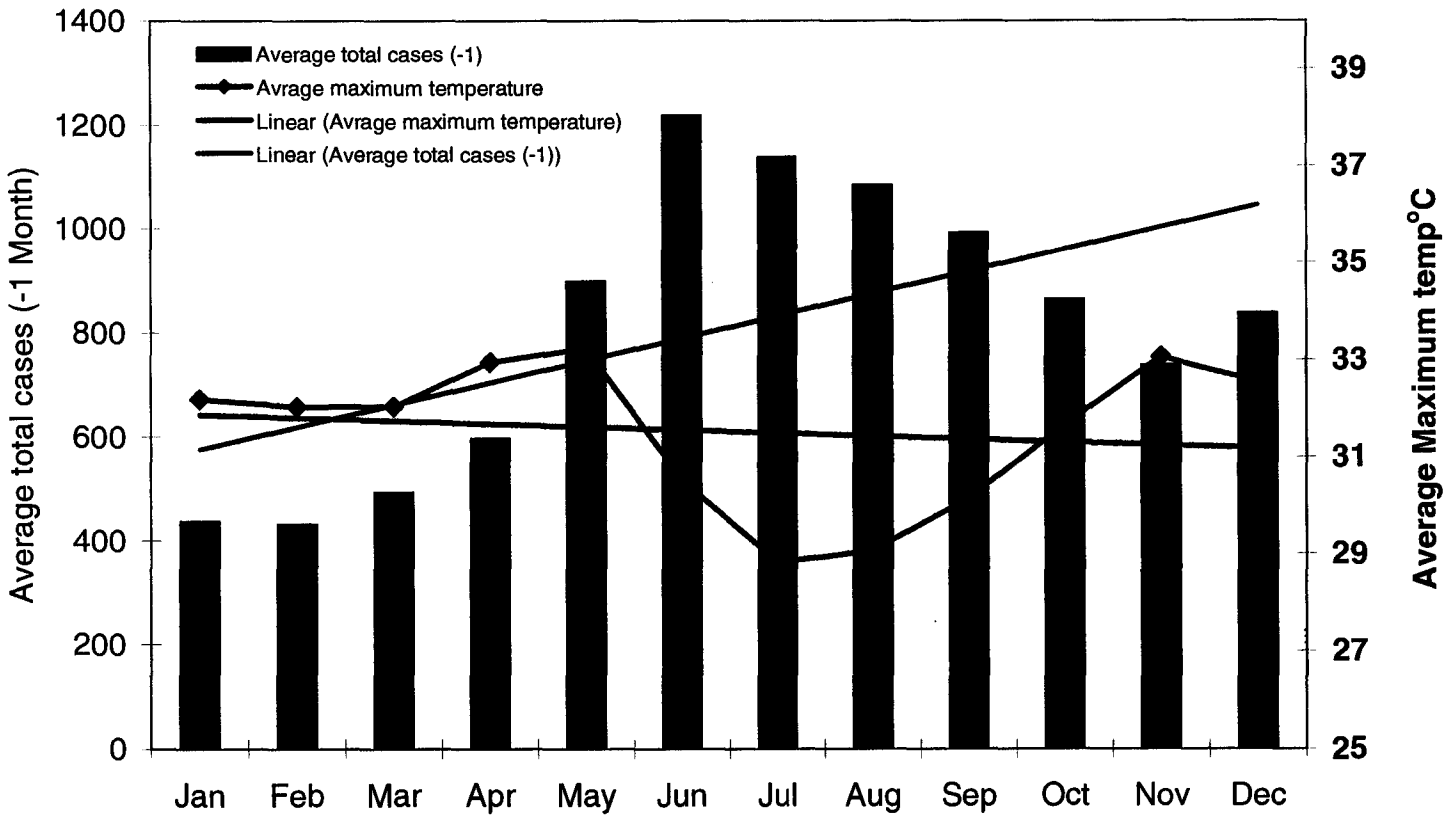

Fig. 4.48 Correlation between average malaria cases and average maximum temperature in Goa from 1990 to 2001

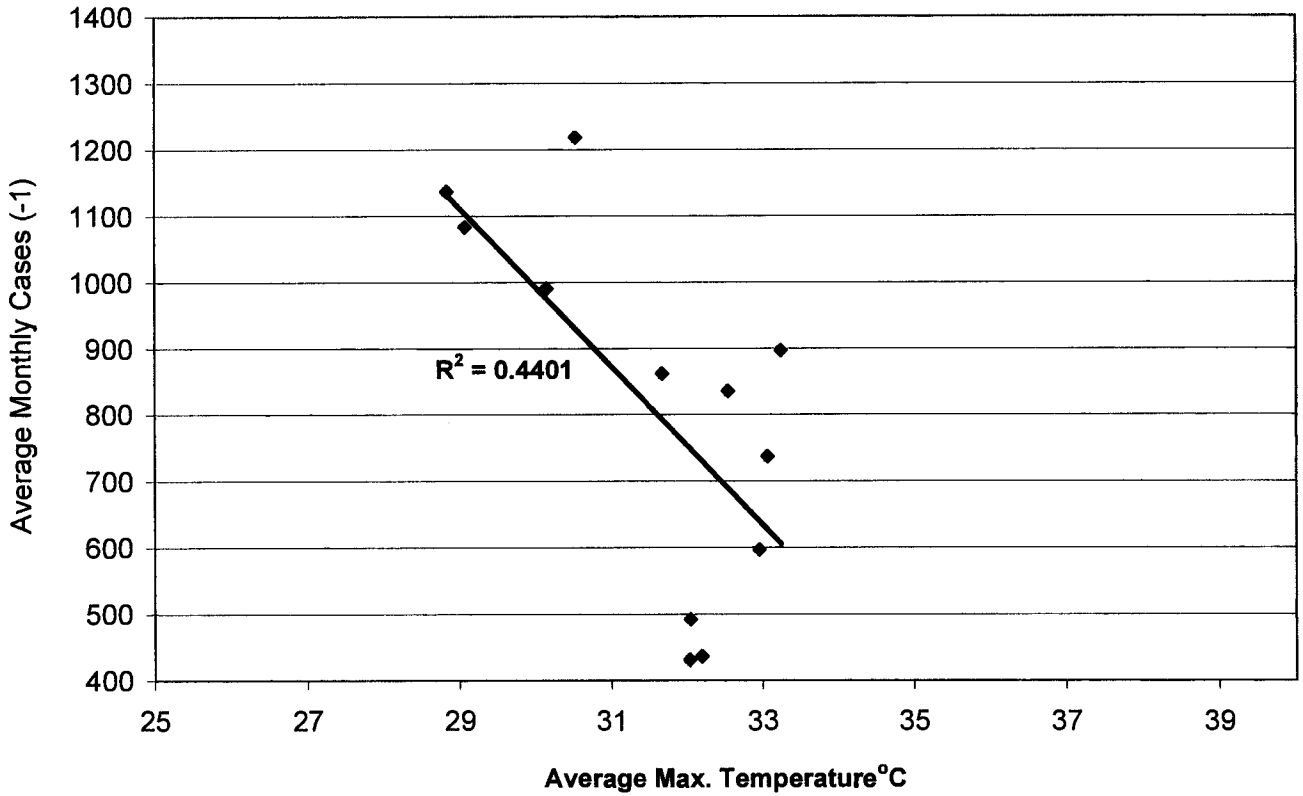

Fig. 4.49 Correlation between average monthly malaria cases & average maximum temperature in Goa from 1990 to 2001

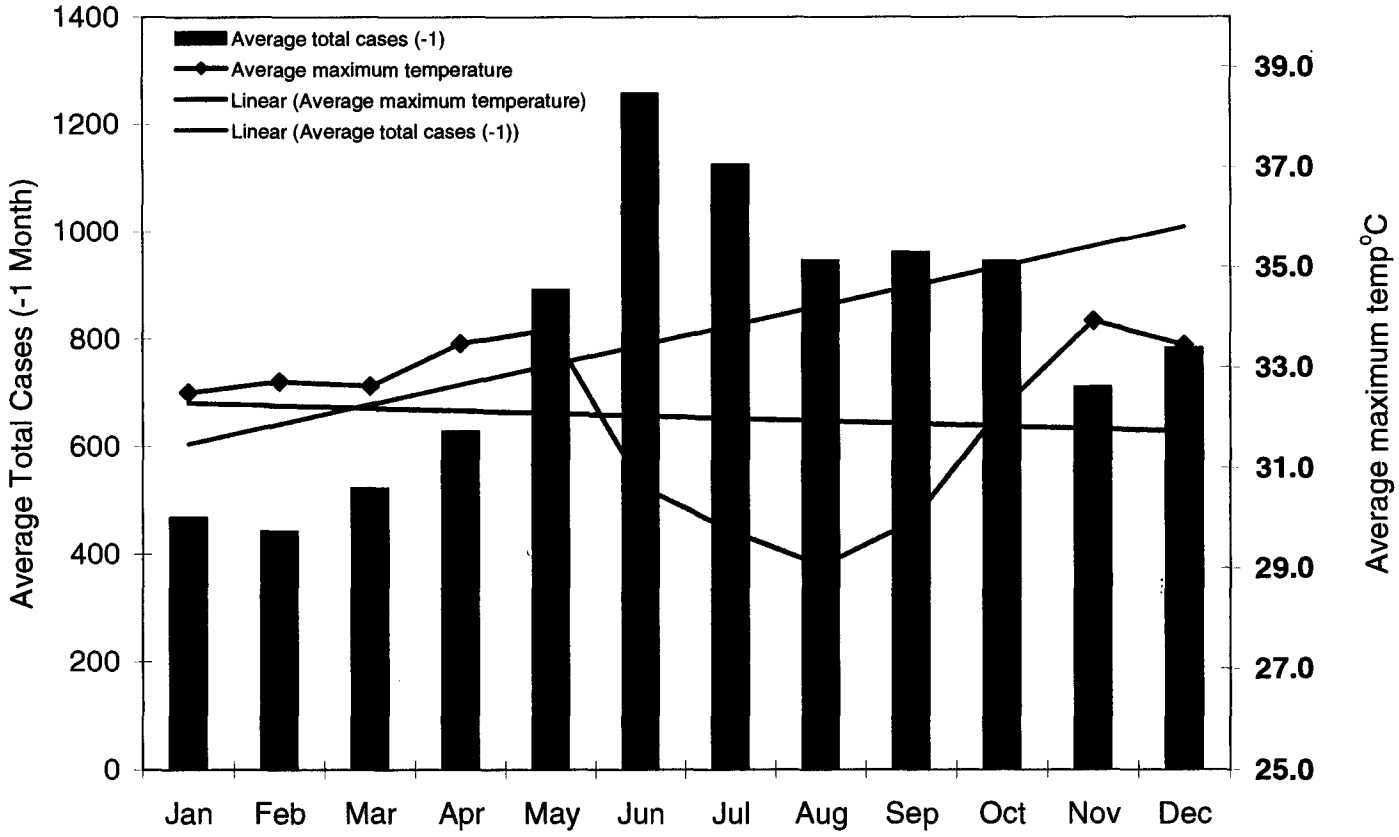

Fig. 4.50 Correlation between average malaria cases and average maximum temperature in Goa from 2002 to 2007

malaria cases from March to May during the years under study which was quite similar to the earlier period from 1990 to 2001. Subsequently, although the temperature decreased significantly, yet there was increase in malaria incidence in the month of June (Fig. 4.50). Overall there was poor correlation between the malaria incidence and maximum temperature during this phase (R^2 = 0.369) [Fig. 4.51].

Relationship between the Malaria Incidence and Minimum Temperature:

Period 1990 to 2001: Minimum temperature ranged from 20.2°C to 26.3°C between January and May. Correspondingly malaria cases also showed a rising trend and ranged between 431 to 897 cases, during these months (Fig. 4.52). Minimum temperature showed a decline in the month of June and July after which it became steady up to October (24.5°C approx.) and thereafter declined sharply at 22.9°C and 21.5°C in the months of November and December respectively. On the other hand, malaria cases peaked in the month of June and showed a steady decline till the month of November and then showed a marginal increase till the month of December (Fig. 4.52). Overall relationship between malaria and minimum temperature was not strong (R^2 = 0.40) [Fig. 4.53].

Period 2002 to 2007: Similar to the period from 1990 to 2001, the minimum temperature increased from 20.2°C to 26.4°C, during the month from January to May. Correspondingly, there was an increase in the incidence of malaria during these months (Fig. 4.54). However, the temperature declined in the month of June to 25°C and remained steady thereafter from July to October to 24.2°C and declined in the month of November to 22.4°C and 20.2°C in the

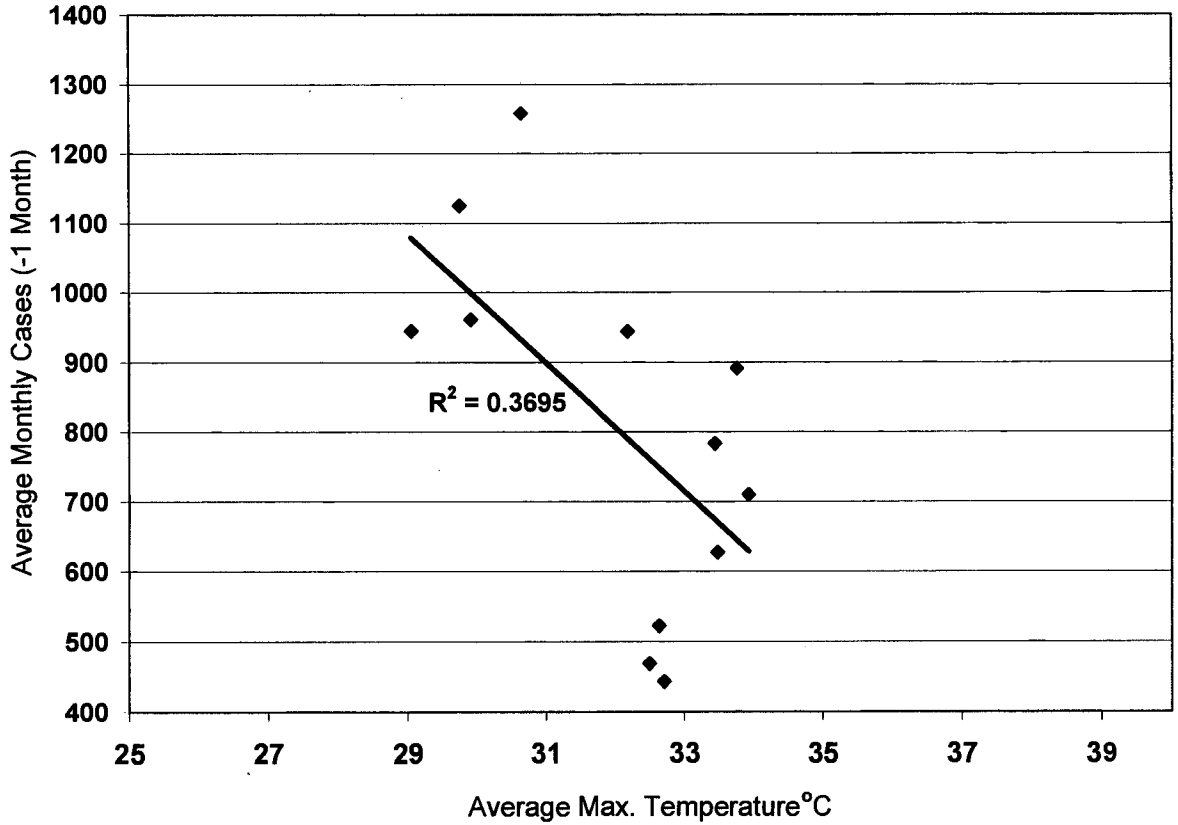

Fig. 4.51 Correlation between average monthly malaria cases & average maximum temperature in Goa from 2002 to 2007

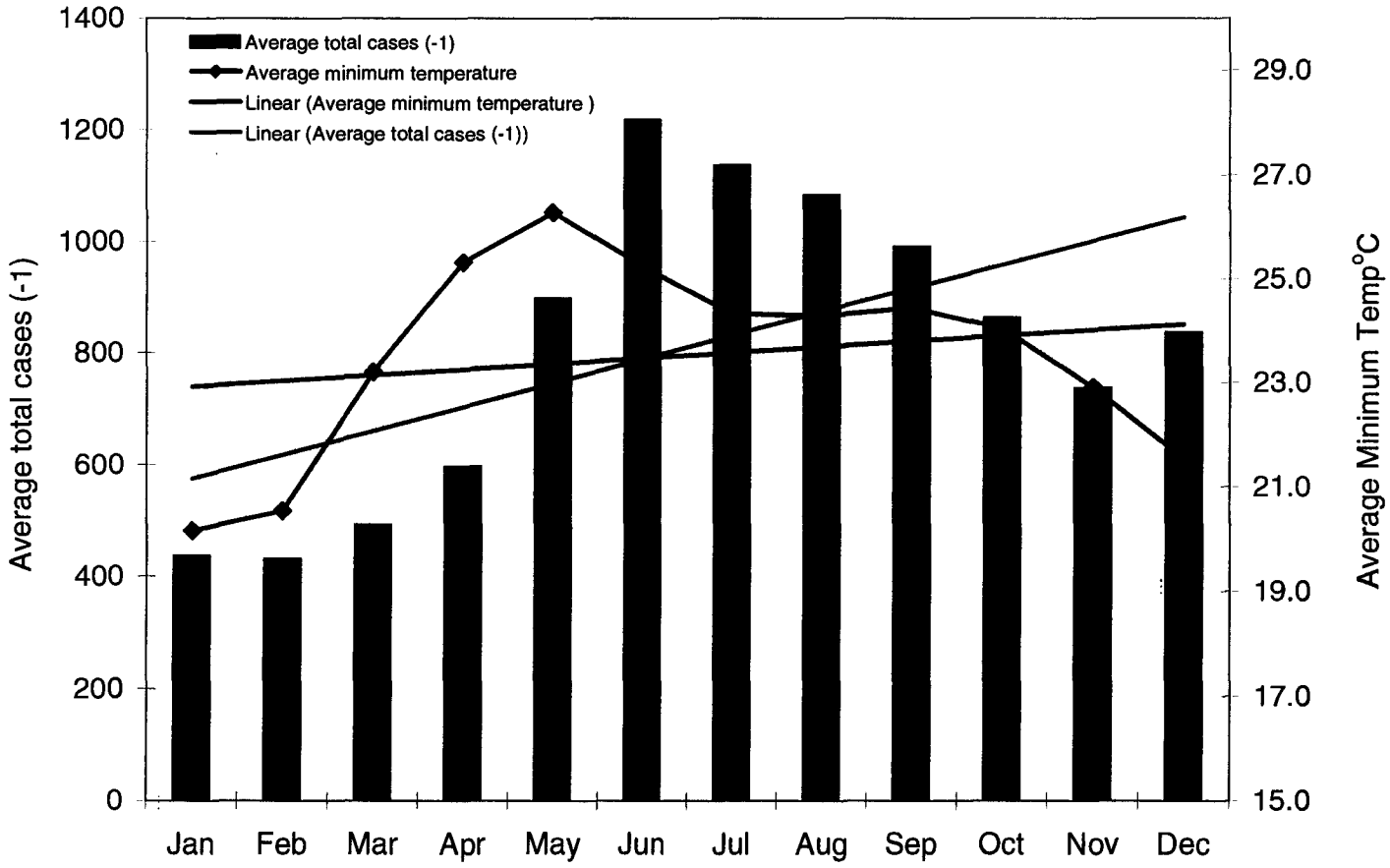

Fig. 4.52 Correlation between average malaria cases and average minimum temperature in Goa from 1990 to 2001

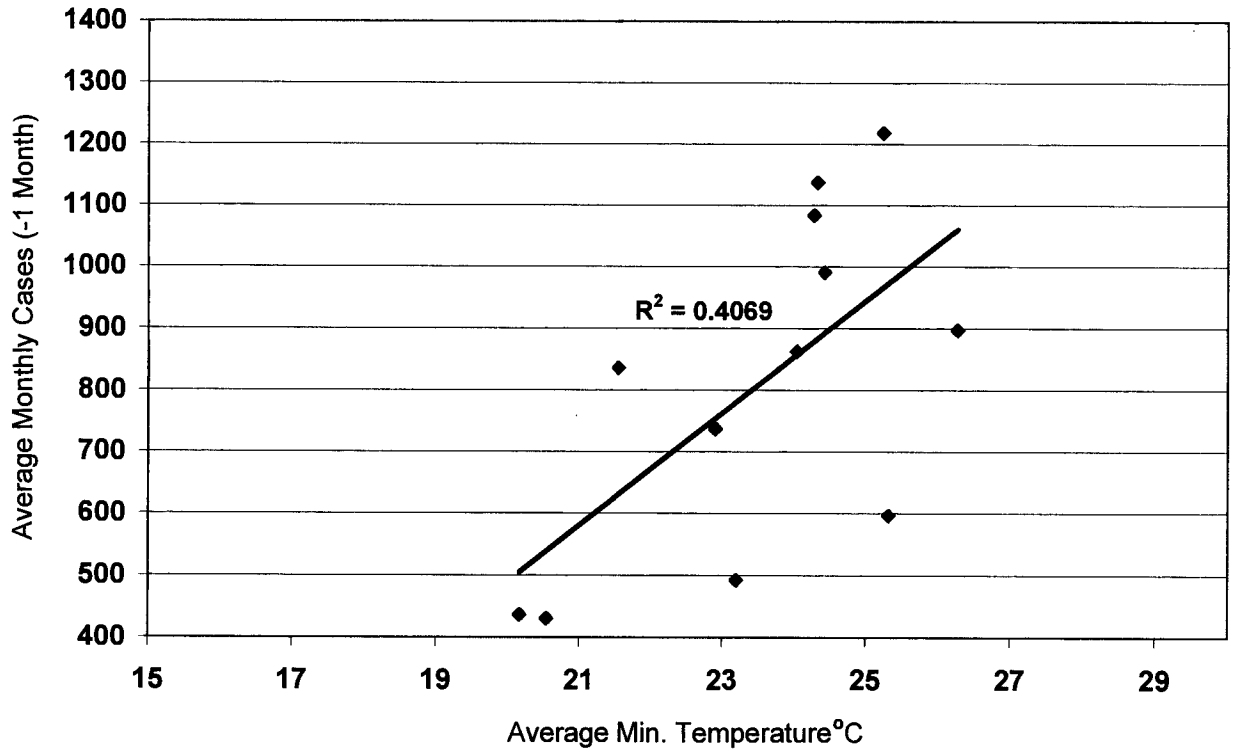

Fig. 4.53 Correlation between average monthly malaria cases & average minimum temperature in Goa from 1990 to 2001

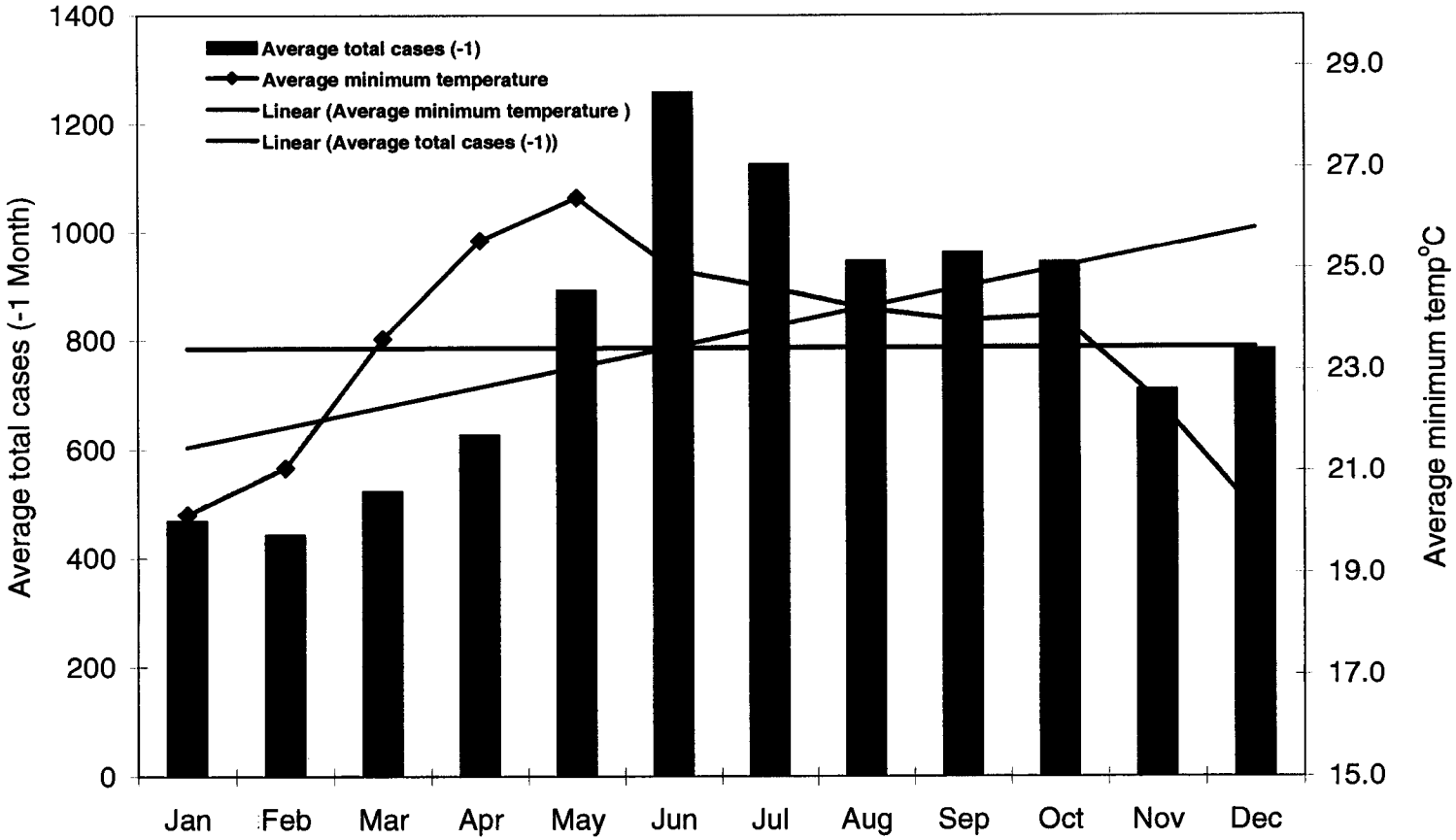

Fig. 4.54 Correlation between average malaria cases and average minimum temperature in Goa from 2002 to 2007

month of December. Overall relationship between malaria incidence and minimum temperature was once again poor (R^2 = 0.319) [Fig. 4.55].

When the correlation between different weather parameters and malaria incidence was compared for 1990-2001 and 2002 to 2007, it was observed that malaria incidence and rainfall were well correlated followed by relative humidity, maximum temperature and minimum temperature thus showing their influence on malaria transmission in that order (Table 4.33).

Factors Responsible for Receptivity and Vulnerability to Malaria

Vector Receptivity: The geographical reconnaissance data of the breeding sites was analyzed according to the breeding preferences by Anophelines, Culicines and Aedines. It revealed that although habitats preferred by Anophelines were 23.1%, their contribution to the total breeding surface area was 81.1%. On the other hand, breeding sites preferred by Culicines and Aedines contributed 48.8% and 28.1% to the total breeding habitats, but their contribution to the surface area was only 3% and 15.9% respectively (Fig 4.56).

Analysis of entomological data to identify key locations contributing to mosquito receptivity revealed that although the construction sites contributed only 11.6% to the total 1,51,288 breeding sites, yet their contribution to the total surface area for breeding was 42.3%, while the remaining 88.4% breeding sites contributed 57.7% to the total breeding surface area available to the mosquitoes (Fig. 4.57). Further, the data also showed that construction sites contributed 61.8% to the breeding habitats preferred by anophelines and 63.6% malaria vector potential. On the other hand, residential colonies

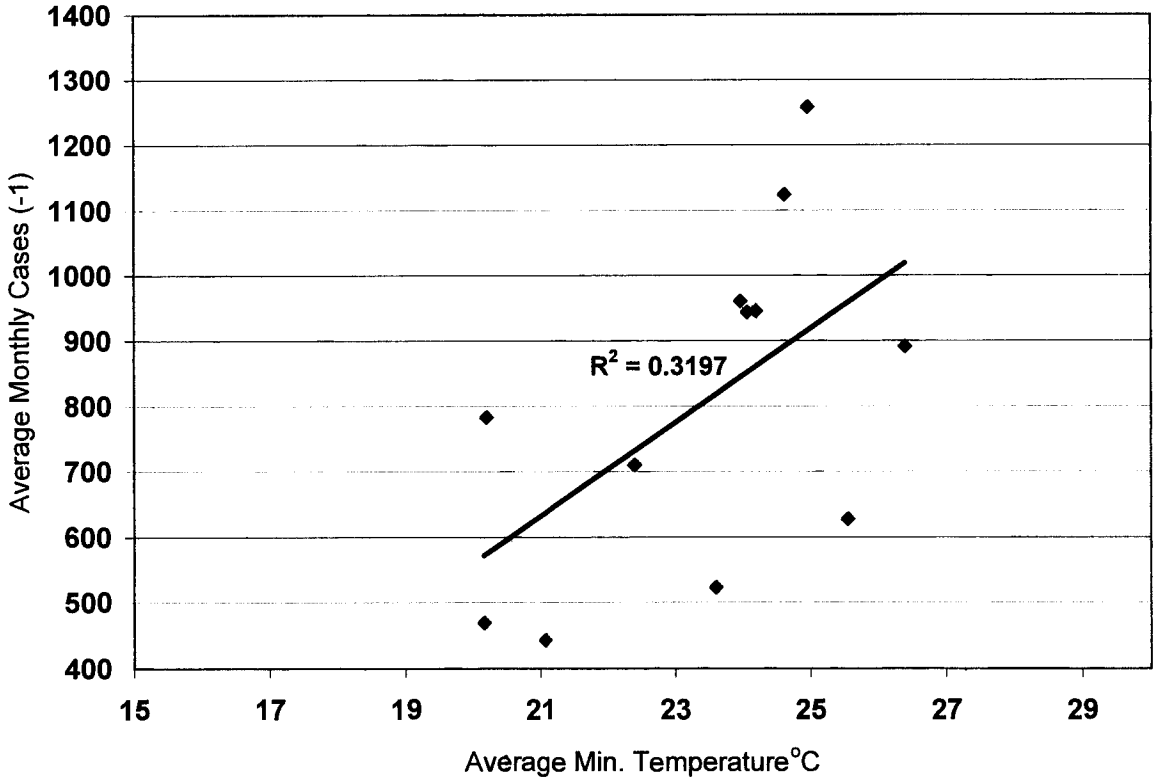

Fig. 4.55 Correlation between average monthly malaria cases & average minimum temperature in Goa from 2002 to 2007

Table 4.33: Correlation between malaria incidence cases and various weather parameters: Rainfall (mm), Relative humidity (%), Maximum (° C) and Minimum (° C) temperature during 1990 - 2001 and 2002 - 2007

Period	R^2 (Goodness of fit)			
	Rainfall (mm)	Relative humidity (%),	Maximum temperature (° C)	Minimum temperature (° C)
1990-2001	0.643	0.741	0.440	0.406
2002-2007	0.752	0.570	0.369	0.319

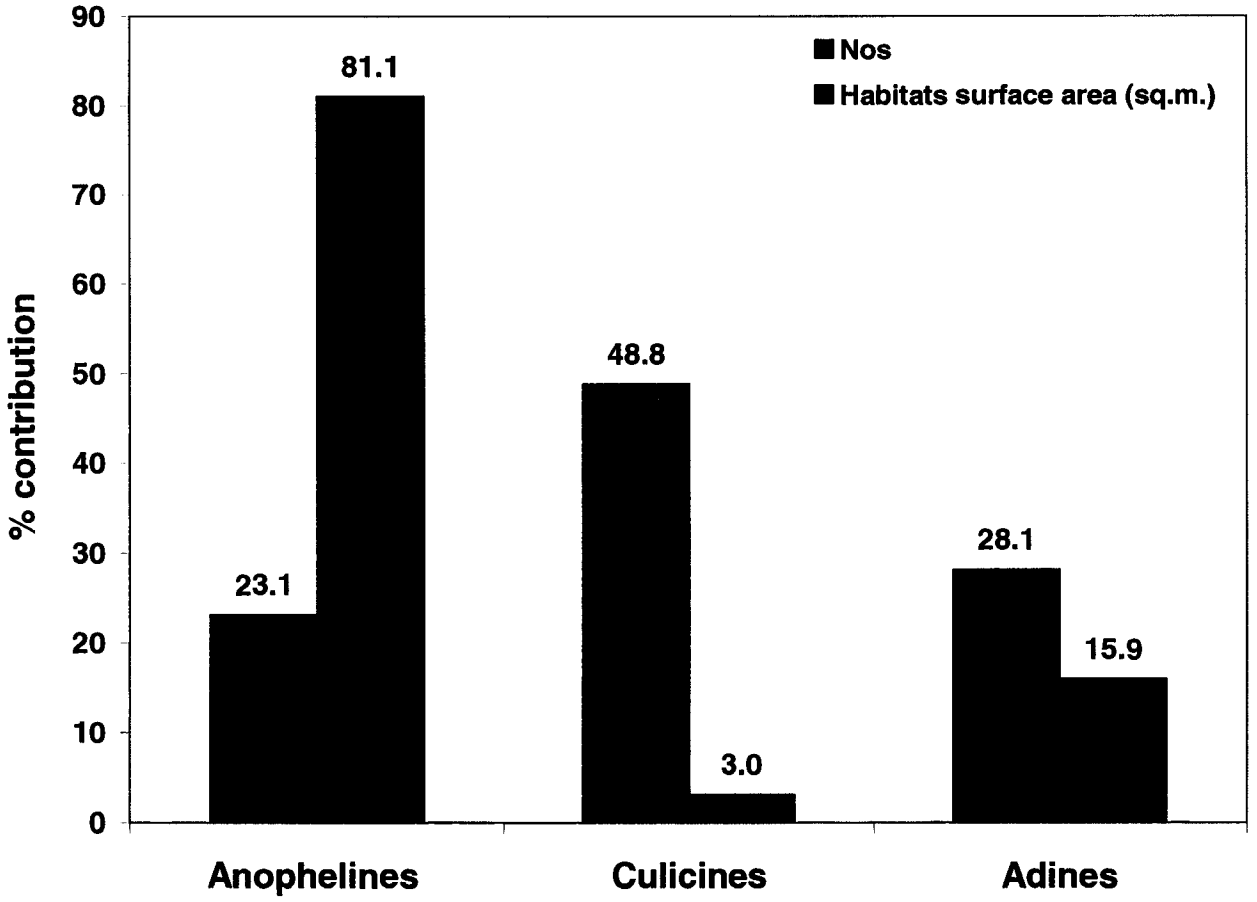

Fig 4.56. Relative contribution of Anophelines, Culicines and Adines mosquito breeding sites to habitat surface area in Panaji in 2004

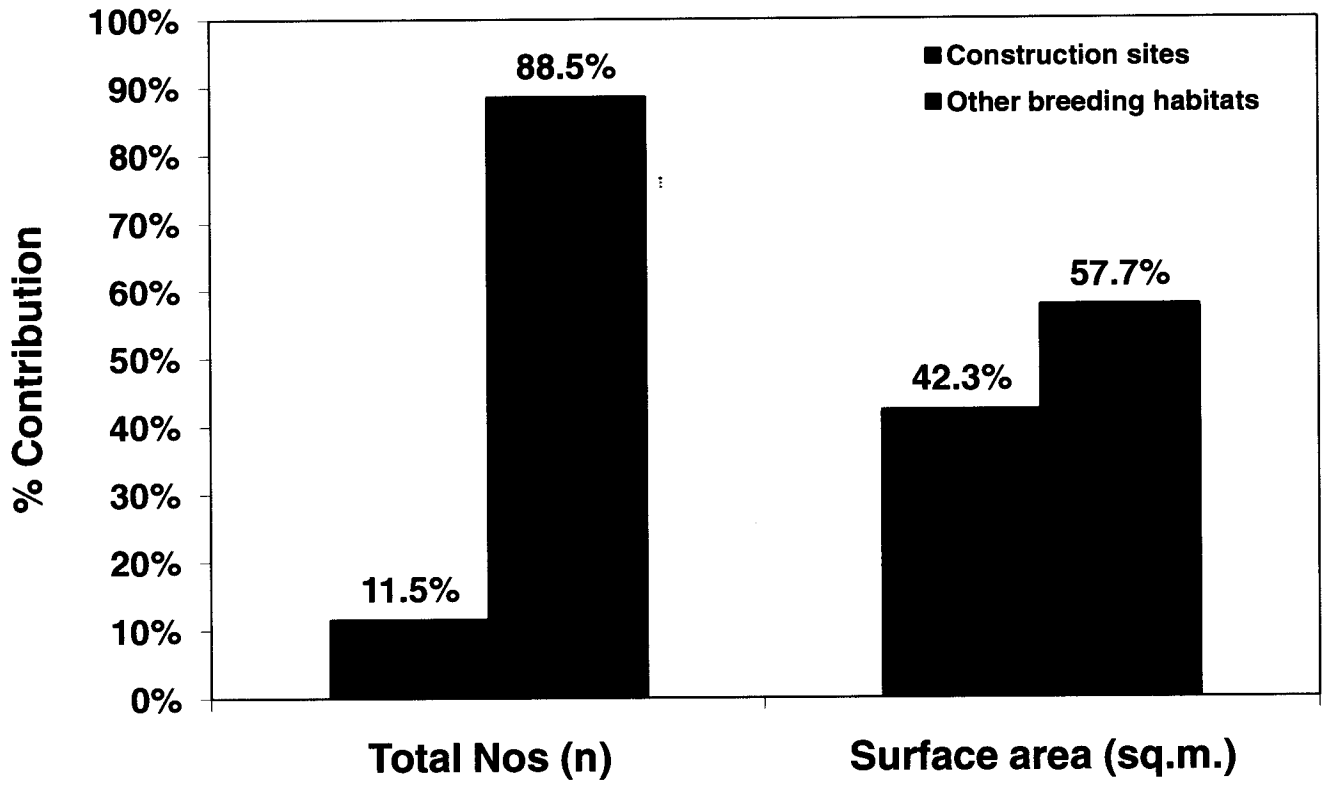

Fig. 4.57 Relative contribution of construction sites and the remaining categories of breeding sites to total available breeding surface area in Panaji in 2004

contributed 38.2% to the total anopheline breeding sites and 36.5% to the total vector potential (Fig. 4.58).

The data when analyzed for correlation between number of different types of breeding sites and their surface area, it was observed that the correlation was poor i.e. R^2 = 0.1469 (Fig. 4.59). However, when a similar relationship was studied separately for permanent breeding sites preferred only by anophelines, it was observed that there was good correlation (R^2 = 0.7683) [Fig. 4.60]. Similarly, there was good correlation between surface area and total number of temporary breeding sites i.e. (R^2 = 0.7589) [Fig. 4.61]. Such a relationship was however, poor (R^2=0.013) in case of rain associated temporary breeding sites (Fig. 4.62). On the other hand, relationship between number of breeding sites and their percentage contribution to total vector potential was also found to be poor (R^2 = 0.1622) [Fig. 4.63].

When malaria vector potential of breeding sites was studied individually, it was observed that overhead tanks had the highest vector potential (28.64%) followed by curing waters (22.91%), masonry tank (16.32%), rain water collections (9.89%), stagnant waters (8.03%), drums (5.35%), barrels (3.63%) and sumps (3.43%). The remaining sites viz., wells, fountains, foundation pits and under ground tanks together had 2% vector potential (Fig. 4.64).

Malaria risk in different demographic groups: The data of Panaji of the year 2004 was analyzed and incidence was separately worked out for the local population, hotel/restaurant workers and construction workers. It was observed that out of 4813 total cases, construction workers contributed about

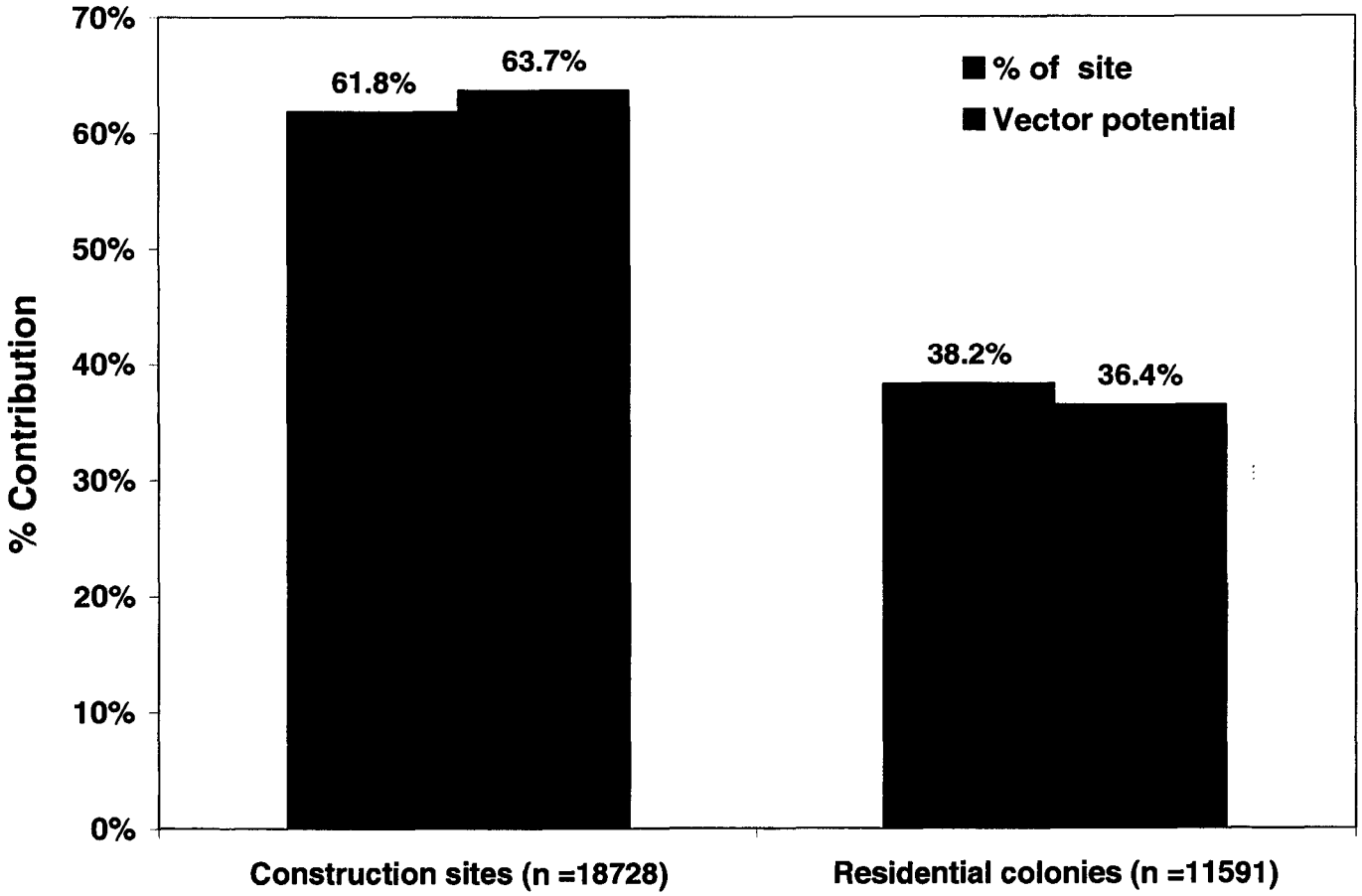

Fig 4.58. Relative contribution of the construction sites and residential colonies to the anopheline breeding sites and malaria vector potential in Panaji in 2004

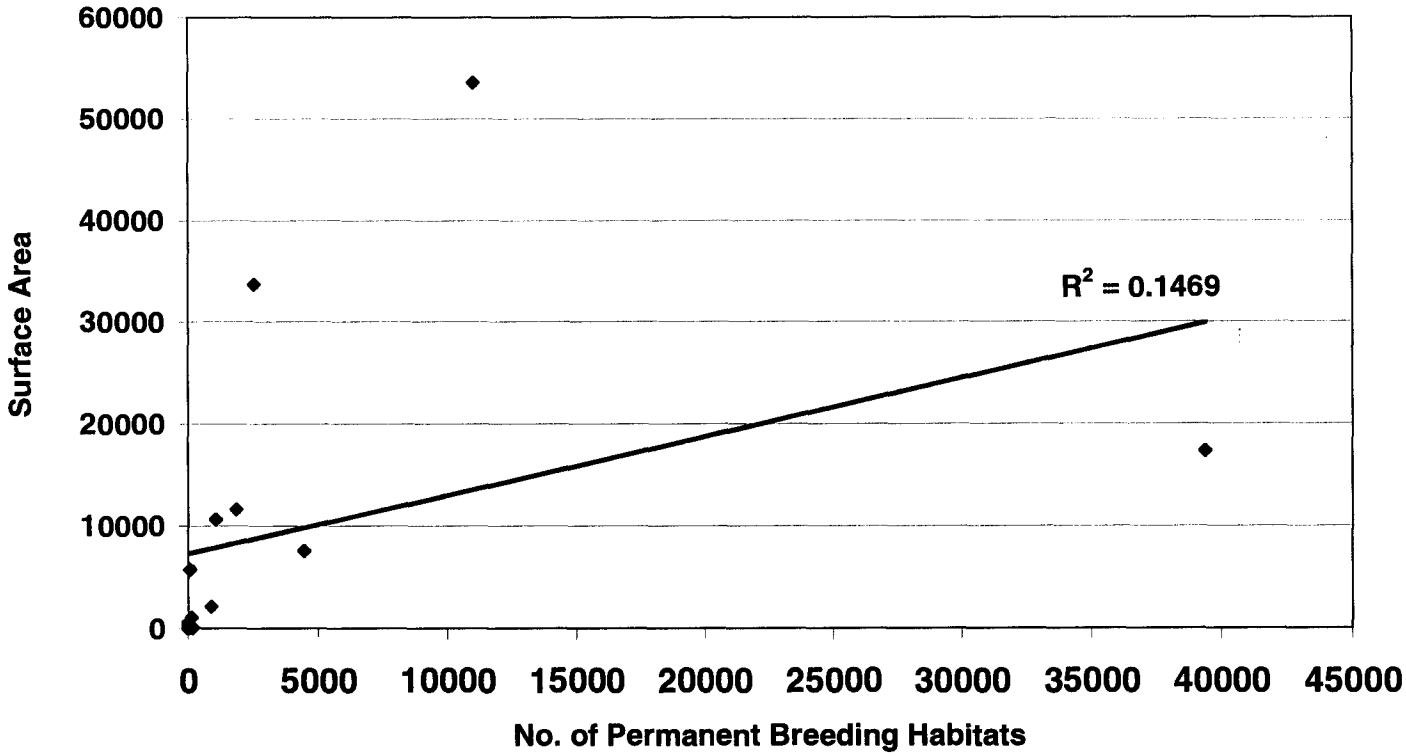

Fig. 4.59 Relationship between number of total permanent breeding sites and total surface area of these habitats in Panaji in 2004.

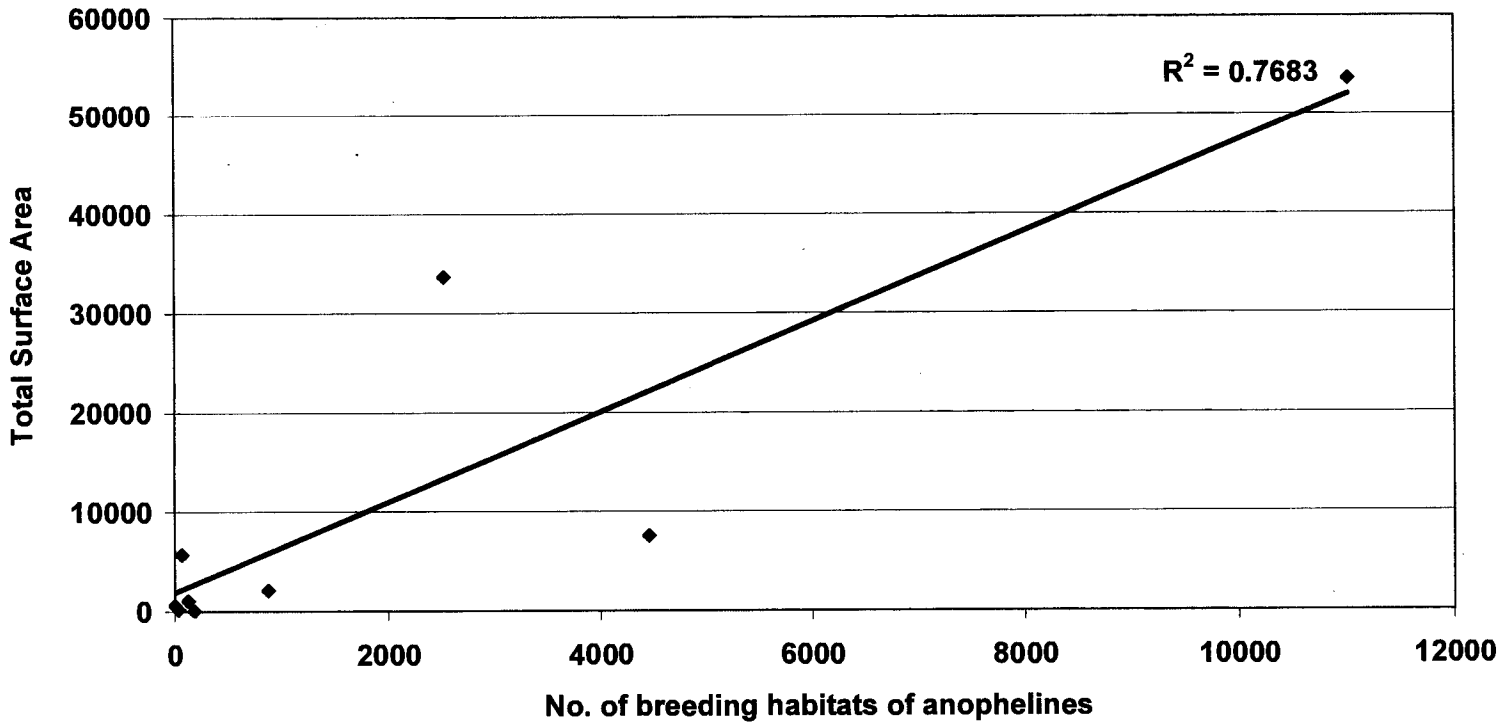

Fig. 4.60 Relationship between number of permanent anopheline breeding habitats and their surface area in sq. metre in Panaji in 2004.

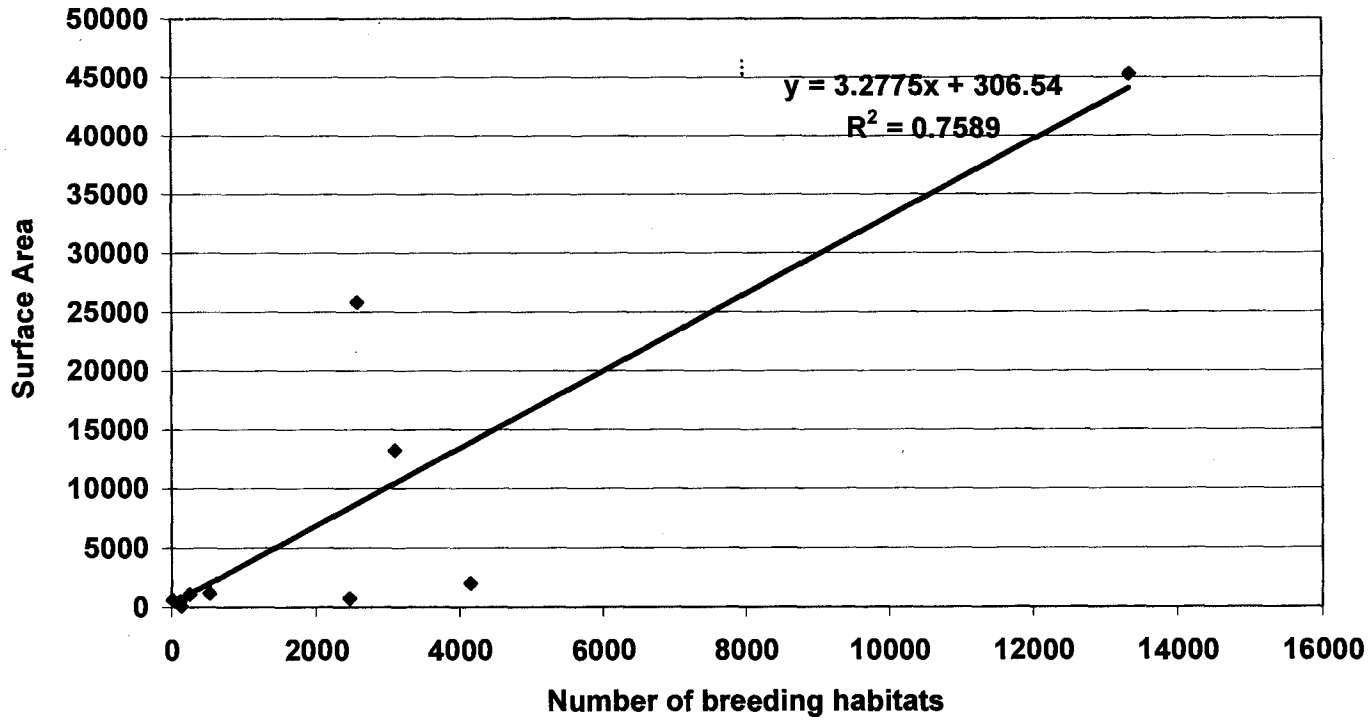

Fig 4.61 Relationship between number of total temporary breeding habitats not associated with rain and their surface area in sq. met. in Panaji in 2004

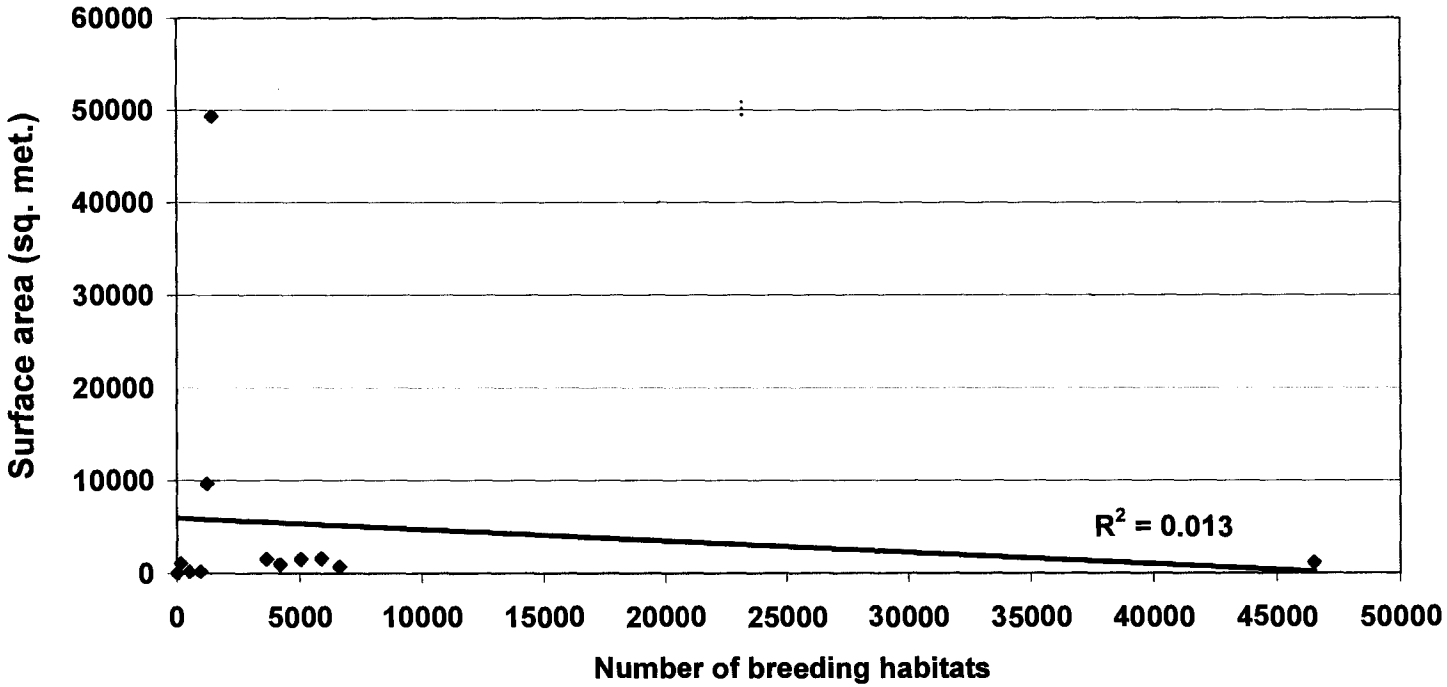

Fig 4.62 Relationship between the number of total rain associated temporary breeding sites with their surface area in Panaji in 2004

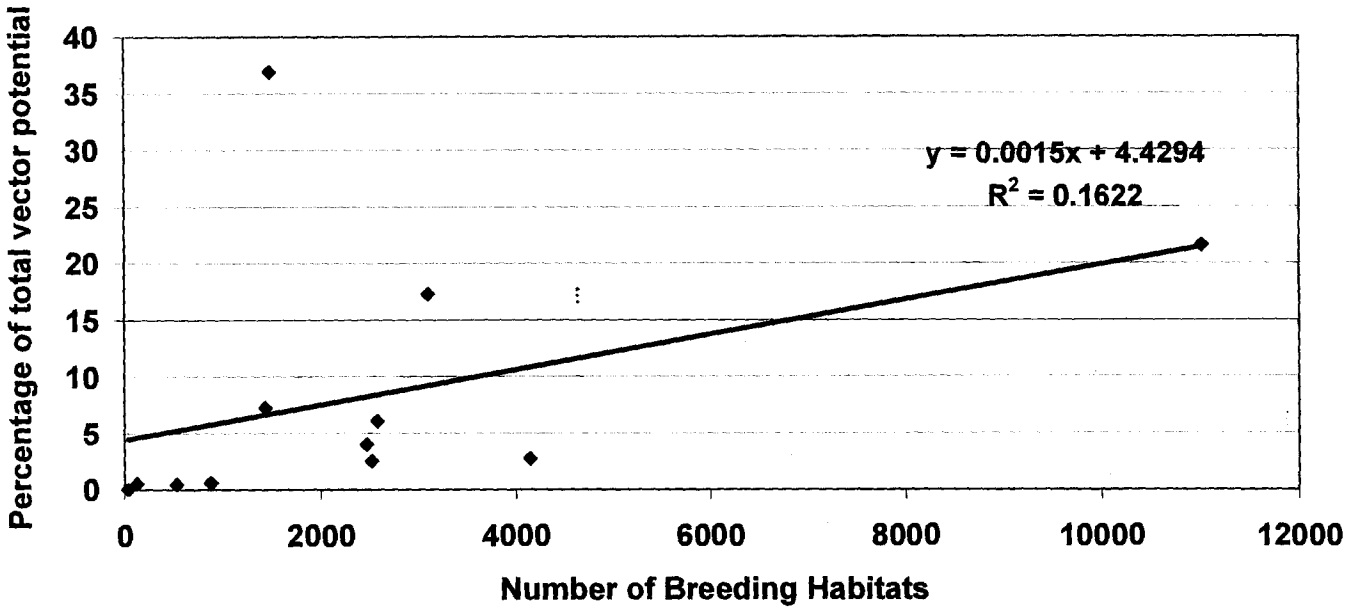

Fig. 4.63 Corelation between number of breeding sites and their vector potential in Panaji in 2004

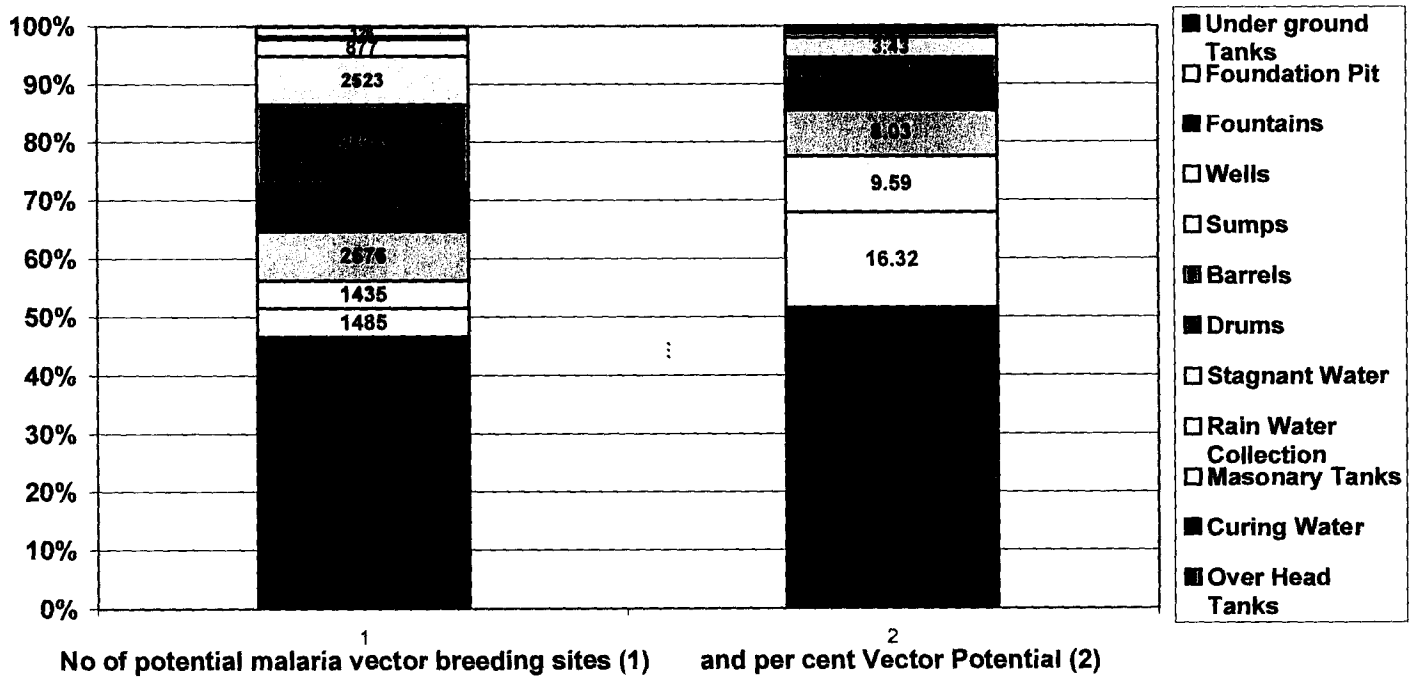

Fig. 4.64 Contribution of different types of habitats to total vector breeding sites and their relative contribution (in %) to the vector potential.

3910 cases (81%) followed by locals 540 cases (11%) and hotel/restaurant workers the least 363 cases (7%). The Slide Positivity Rate (SPR) for malaria was highest 10.8% among the construction workers followed by 7.4% among the local residents and 5.7% among the hotel/restaurant workers. When the proportions of malaria cases were compared statistically between construction workers and locals, the difference was found highly significant ($z = 68.6$, CI>95%, $p<0.001$). Similar difference in the proportion of cases between the construction workers and Hotel and restaurant workers was found to be significant being more in construction workers ($z = 72.7$, CI>95%, $p<0.001$). The difference in the proportion of malaria cases among the locals and restaurant worker was also found significant ($z = 6.2$, CI>95%, $p<0.05$). The proportion of *P. falciparum* cases was also the highest at 23.4% in construction workers followed by 19% in hotel/restaurant workers and least 12.8% in the locals (Table 4.34, Fig. 4.65) The Pf incidence was also significantly more in Construction workers than locals and hotel and restaurant workers ($z = 36.9$, CI>95%, $p<0.001$).

When further categorization of cases was done according to method of detection i.e. during Active case detection and Passive case detection of cases, it was observed that out of total 4813 cases detected 3208 (66.6%) cases were detected during Passive case detection and remaining 1605 (33.4%) were detected during Active case detection (Fig. 4.66) and the difference was found to be highly significant (CI>95%, $p<0.001$).

Malaria risk according to Age and Sex

Malaria in different Age classes: It was observed that out of 4813 cases of malaria, highest number of cases 1621 cases (33.7%) were observed in the

Table 4.34: Distribution of reported malaria cases according to different demographic groups in Panaji during 2004

	ACTIVE CASE DETECTION(ACD)					
CATEGORY	BSC/E	PV	PF	TOTAL CASES	SPR	PF%
LOCAL	3374	80	20	100	3.0	20.0
CONSTRUCTION WORKERS	22468	1040	370	1410	6.3	26.2
HOTEL/RESTAURANT WORKERS	2742	81	14	95	3.5	14.7
TOTAL	28584	1201	404	1605	5.6	25.2
	PASSIVE CASE DETECTION(PCD)					
CATEGORY	BSC/E	PV	PF	TOTAL CASES	SPR	PF%
LOCAL	3911	391	49	440	11.3	11.1
CONSTRUCTION WORKERS	13874	1957	543	2500	18.0	21.7
HOTEL/RESTAURANT WORKERS	3578	213	55	268	7.5	20.5
TOTAL	21363	2561	647	3208	15.0	20.2
	ACD+PCD					
CATEGORY	BSC/E	PV	PF	TOTAL CASES	SPR	PF%
LOCAL	7285	471	69	540	7.4	12.8
CONSTRUCTION WORKERS	36342	2997	913	3910	10.8	23.4
HOTEL/RESTAURANT WORKERS	6320	294	69	363	5.7	19.0
TOTAL	49947	3762	1051	4813	9.6	21.8

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
Pf% = Proportion of P. *falciparum*

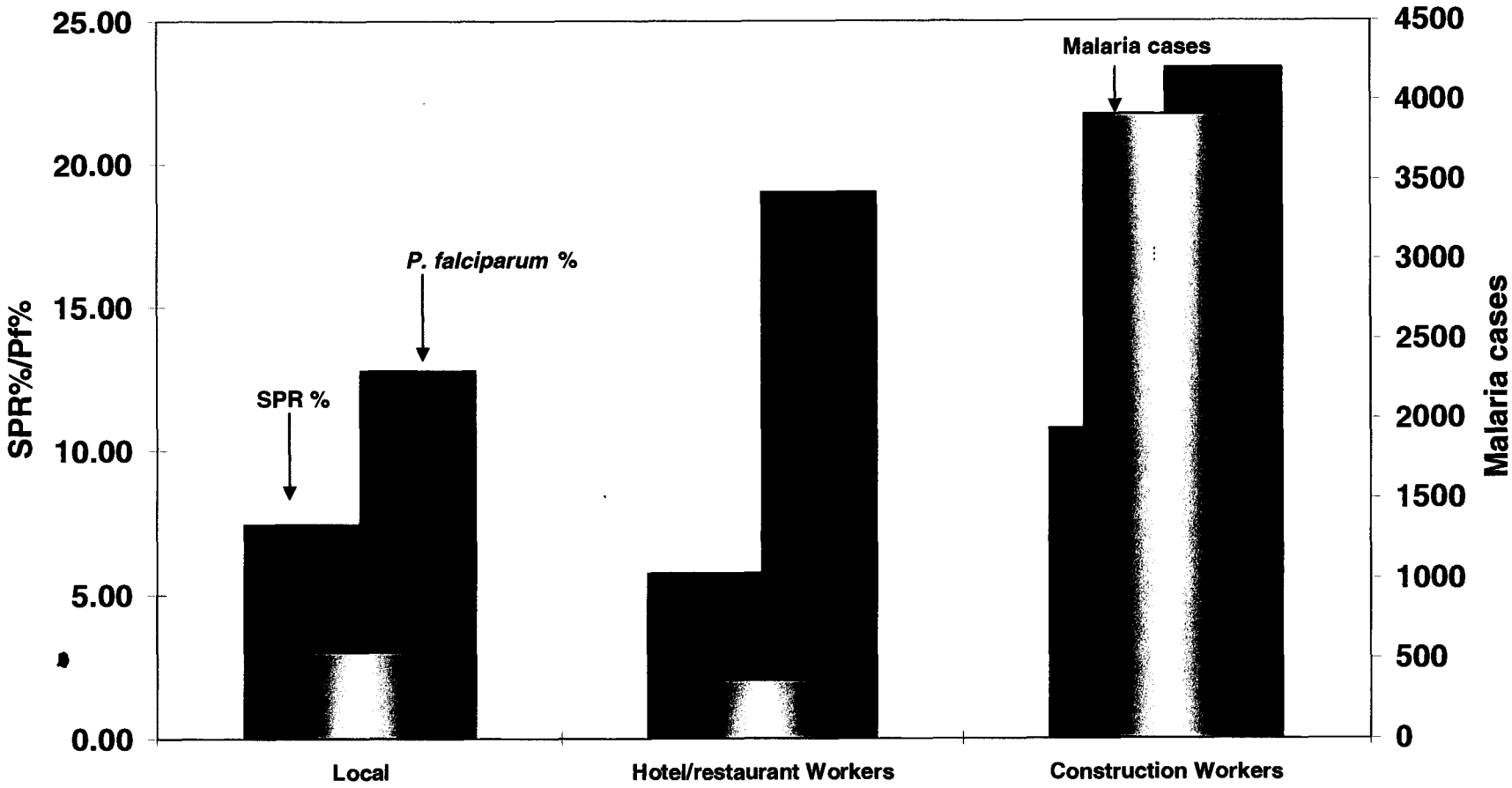

Fig. 4.65 Malaria cases, SPR and Pf% in different demographic categories in Panaji City in 2004

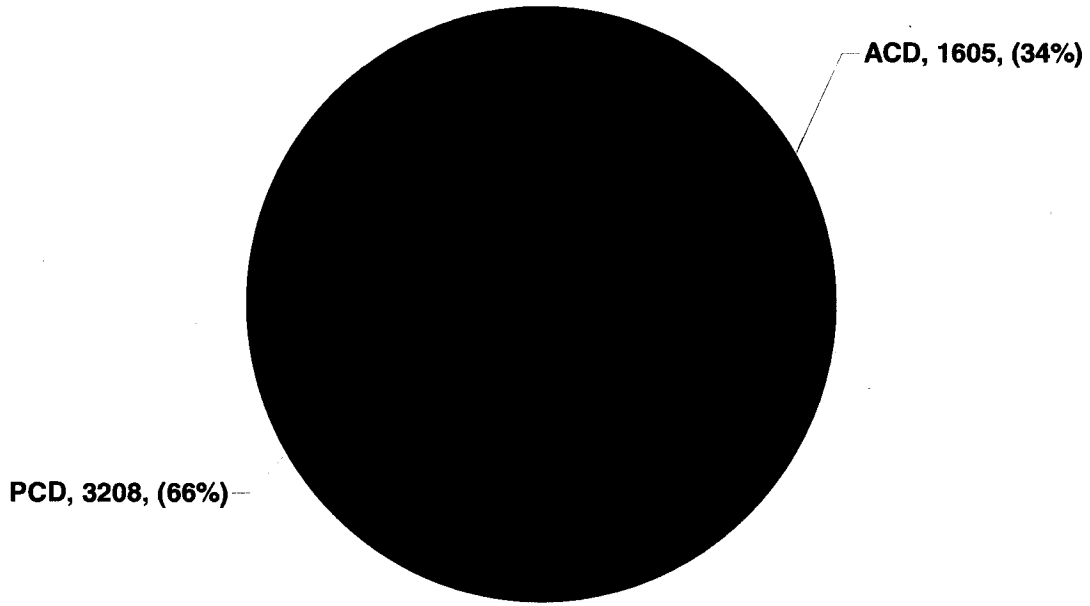

Fig. 4.66 Malaria cases detected in Active (ACD) and Passive Case Detection (PCD) in Panaji in 2004

age group of 21 to 30 years, followed by 978 cases (20.3%) in 31 to 40 years and 778 cases (16.1%) found in 15 to 20 years. Other age groups contributed below 400 cases in the whole year. It may be mentioned that 17 infants (< 1 year of age) suffered from malaria. However, when the Slide Positivity Rate (SPR) in different age groups was observed, the age group between 9 to 14 years was found to be at the highest risk (SPR= 13.6%) followed by 31 to 40 year old (SPR= 12.4%) and above 50 years of age (11.7%) [Table 4.35 and Fig. 4.67].

Gender Wise Malaria Risk: Overall out of 4813 cases, males suffered much more from 4028 malaria cases (80.7%; SPR=10.1%) as compared to females 930 cases (19. 3%; SPR= 8%). Slide *falciparum* Rate (SfR), Slide *vivax* Rate (SvR) and *Plasmodium vivax* proportions were higher in males at 2.2%, 8% and 78.6% respectively as compared to 1.9%, 6.1% and 76.5% in females respectively. When compared the SPR of malaria in different age groups was significantly more in males for all the age groups except for 15 to 20 years and 41 to 50 years age group where it was almost similar.

Strategies for Malaria Control in Goa:

The broad approach recommended for malaria control in urban and suburban paradigms in Goa based on previous studies is as follows:

1. Vector Control

1. Mosquito proofing of Over Head and Ground water tanks (Sumps)

2. Stocking of wells, fountains, masonry tanks, water logged basements and disused swimming pools with larvivorous fishes such as indigenous fish *Aplocheilus blocki* or *Lebistes reticulates* @5 fish per sq. met surface area.

Chapter No. 5: Discussion

Table 4.35: Age & Sex wise Distribution of Malaria cases in Panaji during 2004

	MALE								
AGE GROUP	BSC	Pv	Pf	TOTAL	SPR	SFR	SVR	PF%	PV%
0-1	138	11	1	12	8.7	0.7	8.0	8.3	91.7
1-4	952	78	24	102	10.7	2.5	8.2	23.5	76.5
5-8	1369	128	36	164	12.0	2.6	9.3	22.0	78.0
9-14	1701	203	64	267	15.7	3.8	11.9	24.0	76.0
15-20	8531	490	140	630	7.4	1.6	5.7	22.2	77.8
21-30	15553	1128	280	1408	9.1	1.8	7.3	19.9	80.1
31-40	6068	614	195	809	13.3	3.2	10.1	24.1	75.9
41-50	2492	229	55	284	11.4	2.2	9.2	19.4	80.6
50>	1514	170	37	207	13.7	2.4	11.2	17.9	82.1
TOTAL	38318	3051	832	3883	10.1	2.2	8.0	21.4	78.6

	FEMALE								
AGE GROUP	BSC	Pv	Pf	TOTAL	SPR	SFR	SVR	PF%	PV%
0-1	103	5	0	5	4.9	0.0	4.9	0.0	100.0
1-4	648	31	8	39	6.0	1.2	4.8	20.5	79.5
5-8	1233	68	29	97	7.9	2.4	5.5	29.9	70.1
9-14	1020	83	19	102	10.0	1.9	8.1	18.6	81.4
15-20	1860	106	42	148	8.0	2.3	5.7	28.4	71.6
21-30	3238	146	67	213	6.6	2.1	4.5	31.5	68.5
31-40	1850	137	32	169	9.1	1.7	7.4	18.9	81.1
41-50	952	90	13	103	10.8	1.4	9.5	12.6	87.4
50>	725	45	9	54	7.4	1.2	6.2	16.7	83.3
TOTAL	11629	711	219	930	8.0	1.9	6.1	23.5	76.5

	MALE & FEMALE								
AGE GROUP	BSC	Pv	Pf	TOTAL	SPR	SFR	SVR	PF%	PV%
0-1	241	16	1	17	7.1	0.4	6.6	5.9	94.1
1-4	1600	109	32	141	8.8	2.0	6.8	22.7	77.3
5-8	2602	196	65	261	10.0	2.5	7.5	24.9	75.1
9-14	2721	286	83	369	13.6	3.1	10.5	22.5	77.5
15-20	10391	596	182	778	7.5	1.8	5.7	23.4	76.6
21-30	18791	1274	347	1621	8.6	1.8	6.8	21.4	78.6
31-40	7918	751	227	978	12.4	2.9	9.5	23.2	76.8
41-50	3444	319	68	387	11.2	2.0	9.3	17.6	82.4
50>	2239	215	46	261	11.7	2.1	9.6	17.6	82.4
TOTAL	49947	3762	1051	4813	9.6	2.1	7.5	21.8	78.2

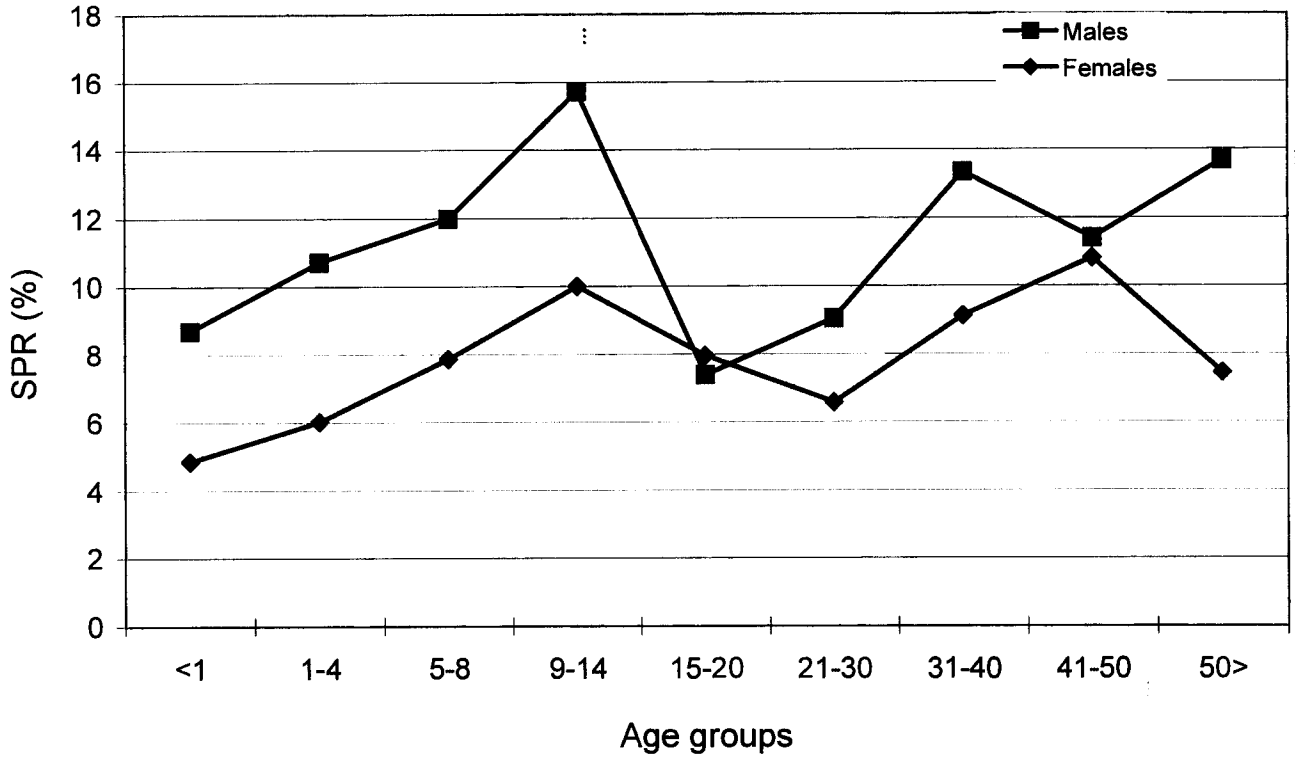

Fig.4.67 Slide positivity rates of malaria according to ages and sexes in Panaji in 2004

3. Spraying of Insect Growth regulators in the curing water and rain water pools at fortnightly frequency.

4. Distribution of Insecticide Treated Nets to the migrant construction workers to prevent vector-host contact during the sleep.

5. Limited and need based Ultra Low Volume (ULV) fogging with synthetic pyrethroids as per the technical guidelines and specifications in the out break situations only.

6. Invoking anti-mosquito legislative measures.

The implementation of above control methods is to be preceded by situational analysis e.g. study of local ecology, geographical reconnaissance of breeding habitats preferred by malaria vectors, their enumeration, categorization, mapping, assessment of intervention needs, drawing up of plan of action, material requisition and management, organization and training of man power and their effective utilization in such a way that the all malaria affected areas are well covered. Since malaria is highly rampant at the construction sites, there must be strong advocacy for the involvement of construction site management and their contribution in vector control should be requisitioned in the form of insecticides and spray men for spraying at regular intervals at the construction site. For this, training and supervision must be provided by the technically qualified trainers and Supervisory staff of the National Vector Borne Disease Control Programme.

Priority areas for vector control: Construction complexes

Critical Period for Vector Control: January to May

Frequency of Anti Larval Treatment: Depending upon residual efficacy of the chosen insecticide and observations in the field.

Entomological Impact Assessment: Concurrent with control measures

Anti-parasitic surveillance:

For this there could be three approaches which may be used individually or concurrently.

1. Active Case Detection at least at weekly interval

2. Passive Case Detection by opening malaria clinic in an outbreak area or at existing facility.

3. Mobile clinics with microscopy facility covering the sensitive area where malaria.

As per the findings of the present study, the bulk of malaria cases were reported from the construction workers. Hence malaria surveillance should be instituted on priority in this highly vulnerable demographic group. The active surveillance should be regular preferably at weekly interval.

For on the spot treatment in an outbreak situation, Rapid diagnostic tests (RDTs) may be deployed. These are easy to perform and treatment can be started immediately after a case has been confirmed with this diagnostic tool. A vigil should be kept on the movement of migrant population and immediately after arrival of new labour, mass screening would mop up malaria cases both febrile and asymptomatic and block further transmission after an effective treatment has been provided.

Health Education and community participation:

For the sustained control of malaria, involvement of the community is essential. Health Education on malaria among students and general public leads to self action. Health education campaign should be designed suiting the target population. The language used should be simple and easily

understood by a lay person. Intersectoral cooperation and involvement of various agencies and sectors that may be inadvertently creating malariogenic conditions is necessary. For this advocacy meetings could be held and specific doable recommendations should be made. Care must be taken not to over depend upon such sectors and main malaria control activities should remain in the hands of the technically qualified personnel of the State Health Services. The malaria control strategy recommended for the state of Goa has been summarized in Table 4.36.

Table 4.36 Proposed malaria control strategy based on risk factors observed during the study

Urban and Suburban Paradigms				
Sr. No.	**Strategy Components**	**Target vector/parasite species /Human population**	**Target Sites (Habitats)/Location & Control options**	**Research Evidence from the present study**
1.	**Vector control**	***An. stephensi***	**Breeding Habitats Observed** 1. OHTs & Sumps-Mosquito proofing. 2. Larvivorous fishes @ 5 fish/m^2 -Wells, Ornamental fountains, Tanks, disused swimming pools, waterlogged basements, etc. 3. Insect growth regulators sparying once in a month/ Fortnightly Temephos spraying in Curing water, Transient Rain water on the terraces and Ground **2) Adult vector control** 1. Personal Protection of High risk population: Insectide treated nets (ITNs) or Long lasting Nets (LLINs)-Migrant labour population. ULV fogging in peak transmission season i.e. from June to Sept.	Larval Surveys in breeding habitats and lab emergences of vector species High risk population with biting of vectors in labour camps. Entomological Inoculation rate of 18.2. based on biting rates and parasite infection rate in the *An stephensi* The Peak malaria season is monsoon When double the number of malaria cases was observed compared to pre and post monsoons. Also rainfall and malaria incidence was well correlated.
2.	**Diagnosis and Treatment of Malaria**	***Plasmodium vivax* and *P. falciparum***	**Surveillance** Active Case Detection through surveillance workers and Mobile squads (ACD) -Migrant population and local population in the residing in the vicinity of Labour camps Passive Case Detection (PCD) in Malaria Clinics – Diagnosis and Treatment	Study showed that Migrants had much higher incidence than local population hence constitute a high risk group suffering from malaria. Active detection and treatment of cases can reduce transmission due to early detection and prompt treatment surveillance
3.	**Community Participation**	**Migrant Labour Community and affected local population surrounding construction sites.**	Health Education for Source reduction, prevention and treatment of water stagnations and regular use of Insecticide Treated Nets or LLINs Training and Supervisory Role Mobilization of the community for Self help vector control in the household	For imparting knowledge by behavioural change communication in the malaria high risk groups for effectiveness of malaria control interventions.
4.	**Inter Sectoral Co-operation**	Builders & Contactors, Engineers.	1. LLINs procurements and distribution among their work force as Corporate Social Responsibility. 2. Source Reduction or modifications - Mosquito Proof Designing of buildings	Protection of High Risk group from malaria i.e. morbidity and mortality reduction.

Chapter No. 5: Discussion

Goa has a complex and rich physiography. The high slopes of the hilly terrain in the East as well as in the intermediate region together with its branches spanning towards the Western coast in the South Goa district, most of which are covered under dense forests and are also very thinly populated, are not receptive to any of the three malaria vector species namely, *An. stephensi*, *An. culicifacies* and *An. fluviatilis,* as these high mountains and their slopes do not permit water stagnations being excessively drained (Fig. 4.1). The inter hill basins and valleys which receive the drained off water from the hill slopes through streams and channels and where cashew, coconut and paddy are cultivated, were receptive to both *Anopheles fluiviatilis* and *Anopheles culicifacies* as these two species were captured from many of these areas during the course of this study (Fig. 4.2). In the earlier studies both *An. fluviatilis* and *An. cuclicfacies* were also reported from the Sanguem, Sattari, Quepem and Canacona 'talukas' of Goa (d'Sa 1919, Garcia 1958, Borcar et al. 1967 and Roy et al. 1980). However, currently these areas are not showing high incidence of malaria except that there have been some occasional small outbreaks e.g. in Sanguem in the year 2001 in mining areas and in Canacona in the year 2002 (Annexure 3: Table13). This indicates that this belt continues to have malaria outbreak potential considering the presence of vectors.

In the sub-coastal region, where the back waters of river system form swamps, estuaries and marshes which are though poorly drained, none of the malaria vector species was found. *Anopheles stephensi,* both in its immature and adult forms were collected in multiple locations along the coast in many urban and sub-urban areas of Goa. The vector was found breeding primarily in the man made situations such as wells, masonry tanks, curing waters,

fountains, swimming pools, over head tanks, sumps, different types of ground tanks, barrels and other intradomestic habitats. Incidentally during this study, the species was also found breeding in the drains having clean water stagnations.

Borcar et al (1967) had found *An. fluviatilis* only above 500 feet mean sea level. However, they had also recorded the presence of *An. stephensi* between 1000 to 2000 feet above M.S.L. along with other anophelines and not below 1000 feet M.S.L. However, they did not find *An. stephensi* in the coastal Goa. Prior to that, *An. stephensi* was collected only from the coastal town of Panaji (d'Sa, 1919). In the more recent times, Narasimham & Khamre (1987); Kumar et al. (1991, 1992, 1994, 1995 and 1998) had also found *An. stephensi* breeding in many coastal cities and suburban areas of Goa. In the present study besides the coastal belt, *An. stephensi* was found breeding in Ponda city in the interior and coastal Canacona.

All the major meteorological parameters namely rainfall, relative humidity, maximum and minimum temperatures are epidemiologically important for the transmission of malaria, may it be vector breeding opportunities, vector longevity, development of malaria parasites in the vector and feeding proficiency of vector in the hot and humid climate especially along the coast. The importance of the above climatic parameters has also been emphasized amply in the earlier studies [Fontaine et al. (1959); Pampana (1969); Loban & Polozok (1985); Singh et al. (1988); Oaks et al. (1991); Kumar et al. (1992); Singh et al. (1995); Marten et al. (1995); Tandon et al. (1995); Kumar et al.(1995); Sharma et al. (1998); Das et al. (1998); Kamal & Das (2001); Dev et al. (2003); Pascaul et al. (2006) and Munga et al. (2006)].

However, it appears that zones in the extreme eastern belt of Goa with excessive rainfall i.e. >4000mm, which are also efficiently drained may not provide foothold to any vectors and this conjuncture is supported by the fact that in such areas, a very low incidence of malaria is reported in Goa now a days (Annexure 3: Tables 15-18; Valpoi and Sanguem PHCs). On the contrary, the areas receiving 3500 to 4000 mm rainfall especially in the foothills and valleys were historically replete with malaria, so much so that, there was depopulation of some of the villages. Even the villages such as Chincegal, Motto Patin, Caranzal, Oxel, Sirxarem, Sonaulim and Talauli disappeared from the map in Sanguem Taluka due to malaria, cholera and small pox as suggested by previous studies (de' Mello, 1933, Gracias, 1994). In these areas, splenic indices varied from 3.5 to 53% with an overall average of 15% and deaths due to malaria were 22/1000 population (Garcia, 1958). Garcia also reported that more than 60000 people in Portuguese Goa fell ill yearly of malaria prior to the year 1950 in the eastern 'talukas'. Although historically, literature reveals that Goa had a serious problem of malaria in the previous centuries along its eastern belt, the disease has also been implicated in the destruction of old Goa city which was famous for trade with many countries as far as Europe, America, China and other Eastern countries (Garcia 1958; Gracias 1994).

During consolidation phase of Malaria Eradication Era, a successful campaign was launched in Goa and malaria control brigades were organized. With the residual spraying and case detection, malaria was drastically reduced in these areas as elsewhere in India (Borcar et al. 1967). The analysis of malaria data during the present study also revealed that malaria was practically negligible in Goa till the mid 1980s except for resurgence in 1975 and 1976 in Quepem

area (Table 4.23). Subsequently, up to the year 1985, malaria declined drastically. Hence by and large malaria eradication program was successful for 2 decades after liberation in Goa. Till this time, the coastal areas of Goa were practically free from malaria (Table 4.23). Incidentally, in all these years no deaths due to malaria occurred in Goa (Source: NVBDCP Goa). Ever since the outbreak of malaria which occurred in Panaji in 1986, not only Panaji, many other small towns and villages wherever the construction activity took place, malaria outbreaks followed. So much so that malaria took epidemic proportions in the coming two decades and was responsible for many deaths (Fig 4.14). The notable feature was that *Plasmodium falciparum* which was negligible in its proportion earlier increased to 30% by the year 2007. This out break situation continues even today. Similar to the Goa situation, many urban areas of the country have witnessed accelerated malaria transmission as shown by various studies (Dhir, 1969; Pattanayak et al. 1977; Choudhary, 1984; Pattanayak et al. 1985; Adak et al. 1994; Sharma 1996a). It was interesting to observe that out of 28 Primary Health Centres of Goa, Panaji, contributed to about 40% of malaria and four other coastal PHC's contributed the remaining 45% of malaria and the rest 23 PHCs contributed to the remaining 14% of malaria (Fig. 4.27 & 4.28) indicating thereby that malaria was highly focal in its distribution in the coastal belt of the state. Seasonally, malaria started building up just before the monsoons and peaked in the month of July, although appreciably high number of cases was reported throughout the year suggesting thereby perennial pattern of malaria transmission in Goa (Fig 4.15). The *Plasmodium vivax* has remained a predominant species which had two peaks as compared to *P. falciparum* which had only one peak. Panaji town has remained the epicenter of malaria in the last

about two decades. In this town of about 45,000 populations, the ABER, SPR and API have remained high since 1986 except from 1991 to 1994 (Fig. 4.29).

After the liberation in 1961, Goa has seen tremendous all round development. Besides the natural mineral wealth and export of iron ore, domestic and international tourism is the mainstay of Goa's economy. As a result, the coastal belt of Goa more particularly the towns and villages situated in Bardez, Tiswadi, Mormugao and Salcete 'talukas' have under gone significant development. This can be gauged from the fact that, there were more than 1000 construction sites in both rural and urban areas in 1997 and 1998 in Goa. To cater to these developments, large number of skilled and unskilled construction workers migrated in the State, as has been shown in the Census of India data. As per the 2001 census, 46,901 migrant construction workers were enumerated constituting 3.5% of the total population of the State (13.44 million) [Table 4.2]. The taluka wise breakup of workers indicated that 66% of the construction workers were enumerated in 4 'talukas' namely Bardez, Tiswadi, Mormugao & Salcete which incidentally also had maximum malaria in the last two decades (Fig. 4.7, 4.29, 4.31-4.34).

During the course of this study undertaken in Panaji, it was found that construction workers had migrated from 17 States of India and also from neighboring country Nepal. Migrant workers from the endemic and non endemic states being a high risk group for malaria thereby enhanced the vulnerability of the State to malaria (Fig. 4.8). The coming in contact of immune and non immune populations has sparked many fulminent epidemics of malaria in the history (Garcia 1958, Pampana, 1969, Kondrachine 1992, Sharma et al. 1996). Earlier studies have emphasized the role of migrant workers in the outbreaks and

epidemics of malaria, both in India and in other South East Asian countries (Sharma et al. 1985; Sethi et al. 1990; Kumar et al. 1991; Kondrashin, 1992; Sharma 1993; Adak et al. 1994; Sharma 1996a; Kondrachine and Trigg 1997; Kumar et al. 1997, Kumar, 1997; Martens and Hall 2001).

Subsequent to the outbreak of malaria and its spread from 1986 to 1989 in Panaji, parts of adjacent Corlim PHC also witnessed accelerated transmission of malaria in the year 1990 and 1991. Unlike Panaji and Corlim PHC, the incidence of malaria in other three endemic PHCs namely Candolim, Aldona and Margao, picked up in the year 1993 and not in the earlier years. However, all the PHCs witnessed epidemic situation in 1998 (Fig. 4.37). During these years, many research studies were undertaken to control malaria in Panaji & Candolim which proved that malaria could be tackled with innovative non-insecticidal approaches (Kumar et al. 1994; Kumar et al. 1995; Kumar et al. 1998).

During the course of present study, the geographical reconnaissance of potential breeding habits of mosquitoes in Panaji provided interesting information. The categorization of these breeding habitats revealed that both permanent as well as temporary habitats of mosquitoes existed in large numbers. The comparative analysis of the results revealed that permanent habitats were although lesser in number, they had more surface area available for mosquito breeding. The temporary habitats which were not associated with rains were only 9% of the total breeding sites but had 18% of the total surface area for breeding. On the other hand, the rain associated habitat, which were of transient nature constituted about 50% of the total habitats in numbers (n=76,345, 50%). Their contribution to the total surface area was only 26% (Fig.4.10). Earlier studies showed that, various categories of both permanent and temporary breeding

habitat supported vector breeding in different months of the year in the urban as well as rural settings in Goa and elsewhere (Uprety et al. 1983; Kumar et al 1991; Mariappan et al. 1992; Gupta et al. 1992; Biswas et al. 1992; Mukhopadhyay et al. 1997; Sharma and Hamzakoya 2001).

The mosquito larval surveys carried out in the coastal, sub coastal and hilly belts confirmed that *An. stephensi* was breeding in different types of habits in Panaji, Margao, Candolim and Cortalim in the coastal belt and Ponda in the interior region. The *An. culicifacies* on the other hand, was found breeding in Bicholim and *An. fluviatilis* in Sanguem taluka where the existence of this species has been well known in the past. Similarly during the adult collection in 14 different localities, *An. stephensi* was captured from Panaji, Candolim, Margao and Cortalim while *An. culicifacies* was collected from Bicholim, Valpoi, Cansarvarnem, Sanguem and Quepem. *An. fluviatilis* was collected from Sanguem, Valpoi, Bicholim, Cansarvarnem, Ponda, Quepem and Canacona which showed that all the 3 vectors species are well distributed in Goa (Fig. 4.12). However these vectors were found in lesser numbers as compared to the non vector Anopheline and Culicine species.

An. stephensi were collected in all the seasons, while *An. culicifacies* was predominantly collected during the post monsoon season, whereas *An. fluviatilis* was predominant in the pre-monsoon months which suggests that *An. stephensi* is well entrenched in man made habitats available throughout the years, whereas *An. culicifacies* peaks in the post monsoon months in paddy fields, ponds and stone quarries, while *An. fluviatilis* breeds in slow streams and stone quarries during the premonsoon months. These observations are in conformity with earlier studies (Garcia 1958; Roy et al. 1980; Kumar 1991; 1992; 1997). It was however,

interesting that *An. culicifacies* was not detected in the periurban situations in Goa which is common elsewhere in India, therefore this species does not seem to play any role in the transmission of malaria in the peripheral area of the towns in Goa (Narsimham and Khamre 1987; Kumar et al. 1991, 1992, 1994, 1995, 1997, 1998 and Sumodhan et al. 2004). It was also interesting to observe that all these three vector species were found feeding throughout the night. However, the feeding patterns of *An. stephensi* and *An. fluviatilis* were quite identical with maximum feeding taking place in the early hour of the morning. In contrast, in case of *An. culicifacies,* peak biting occurred in the early hours of the night (18.00 to 21.00 hrs). The earlier study carried out on biting rhythm of mosquitoes in Goa showed that *An. stephensi* biting peaked before midnight (21.00 to 24.00 hrs) which is contrary to the present observation (Kumar et al. 1995). The feeding pattern of *An. culicifacies* and *An. fluviatilis* was found highly variable and depended on the local ecology particularly climatic factors (Nursing et al. 1934; Rao 1946; Vishwanathan et al. 1943, 1944, 1955; Deburca and Jacob 1947; BrookeWorth 1953; Bhombore et al. 1956; Bhatia et al. 1958; Mukhopadhay and Hati 1978; Reisen and Aslamkhan 1978,1979; Manouchahri et al. 1976; Mukhopadhay 1980; Subbarao et al. 1984; Sharma et al. 1993; Bhatt et al. 1994; Chatterjee and Hati 1995; Dev et al. 2003; Devi and Jauhari 2006).

The collection of adult mosquitoes with the help of Mosquito Magnet™ trap confirmed the presence of only *An. stephensi* in Panaji. Neither *An. culicifacies* nor *An. fluviatilis* were collected in the city. However, it was interesting to note that the vectors of all the mosquito borne diseases were collected in good numbers and together constituted 86.7% of the total mosquitoes captured when this trap was run throughout the day for 34 days (Table 4.17, Fig 4.11). When run

in different localities of the city, this trap proved to be a good sampling device of mosquitoes (Table 4.18). The earlier studies have also shown that mosquito magnet is a useful sampling device (Burkot et al 1984; Kline 2002).

The results of incrimination of all the anophelines captured showed that three female *An. stephensi* were harbouring *Plasmodium falciparum* infection as shown by the gland positivity by Circumsporozoite protein ELISA. This shows that *An. stephensi* is currently the primary vector of malaria in the State of Goa. Incidentally, all the three positive specimens were collected from Panaji which has the highest endemicity of malaria. Earlier, Sumodan et al. (2004) had also incriminated *An. stephensi* from Panaji and Candolim areas. However, never before EIR, which denotes intensity of infection by the vectors, was determined as has been done during this study.

The Annual Blood Examination Rate is an important indicator of quality of surveillance for detection of malaria. When we tried to analyze about the status of various PHCs of Goa in six representative years, it was observed that in 1990 and 1995 only 6 PHCs out of 24 met the National norm of 10% ABER. In 1998 however, there was marked improvement and 22 PHCs out of 26 had desirable ABER. This situation was more or less similar in the year 2001. But in 2004, 16 out of 28 PHCs had more than 10% ABER and thus the performance of surveillance system was not as desired in the remaining 12 PHCs. In the year 2007, there was significant improvement as 25 PHCs had more than 10% ABER (Table 4.28).

The positive correlation between Annual Blood Examination Rate and Annual Parasite Incidence from 1963 to 2007 indicates the importance of proper surveillance for detection of malaria (Fig 4.20). On similar lines, the ABER and the Slide positivity rate for malaria were also found to be positively correlated, although such a relationship was not as so strong as in case of API (Fig 4.21). In

various earlier studies, the importance of quality surveillance with adequate collection and examination of blood smears of fever cases through Active and Passive case detection of malaria has been emphasized (Sharma et al 1996; Kumar et al 2007; Kondrachine 1992 and Pattanayak 1994).

The current study also reveals that out of the two plasmodial species, *Plasmodium vivax* was predominant as evident from a very strong relationship of Slide Vivax Rate (SVR) with Slide Positivity Rate (SPR) for malaria as well as Annual Vivax Incidence (AVI) with Annual Parasite Incidence (API). Such a relationship is comparatively weaker between Slide Falciparum Rate (SFR) and Slide Positivity Rate (SPR) and Annual Falciparum Incidence (AFI) with Annual Parasite Incidence (Fig 4.23 & 4.24). It was also observed that both *P. vivax* and *P. falciparum* were being transmitted throughout from 1963 to 2007 as is evident from the significant correlation between the Annual Vivax Incidence and Annual Falciparum Incidence (Fig 4.26).

Seasonal distribution of malaria showed that the incidence in monsoons is twice than that in the pre-monsoon and post-monsoon months which indicates that June to September are the most malarious months of the year in Goa although appreciably high incidence of malaria is reported in other months as well. Many earlier studies have also shown the seasonal variation of malaria in both urban as well as rural areas (Covell 1928; Borcar 1967; Kumar et al 1992; Sharma et al 1998; Kamal and Das 2001; Mohite et al 2002; Dev et al 2003; Devi & Jauhari 2006). Such an observation can be of a great value in organizing intervention programmes for the control of the disease.

As far as active transmission of malaria in different age groups of both sexes is concerned, all the age groups starting from infants to >50years were

vulnerable to malaria infection. However, a significantly high incidence of malaria in males than the females indicates that males in general were more vulnerable to infection either due to their clothing or sleeping behaviour, which would have facilitated their contact with vector. Similar to the Goa situation, in earlier studies more incidence of malaria has been observed in the males than in the females (Kondrashin 1992; Mishra 2003; Kumar 2007).

The present study highlights that although rainfall, relative humidity, minimum and maximum temperatures had positive correlation with malaria incidence in different months, the rainfall influenced malaria transmission the most followed by relative humidity, maximum temperature and minimum temperature (Table 4.33). It was noteworthy that both maximum and minimum temperatures showed steady rise from February to May. This would have helped in the built up of the vector populations during these months. The intermittent rains in the pre monsoon and early monsoon phase, appear to provide further fillip to the vector populations by providing greater breeding opportunities while, high relative humidity during the monsoons appeared to ensure sufficient longevity of vectors and thereby contributing to active transmission of malaria. The reduction in the temperature after the onset of monsoons from June to September between 29 to 30^{0}C does not seem to have much negative impact on active transmission (Fig. 4.40 to 4.55). A critical analysis of this data can provide clues to a Malaria control manager enabling him to organizing a vector control campaign well before the build up of vector populations for impeding and arresting the active transmission of malaria.

As far as receptivity of vectors was concerned, construction sites provided proportionately 3 times surface area than their numbers. The other breeding sites

however, provided proportionately much less breeding surface area as compared to their numbers indicating thereby that construction sites are of great importance for vector breeding and control (Fig. 4.57). Further, their double vector potential than the residential colonies indicates that they are most receptive to vector breeding (Fig. 4.58). Further most categories of habitats in construction sites were amenable to vector breeding and much lesser suitable for culicines. (Fig. 4.56). Hence the study showed that the construction sites must be adequately targeted for vector control. Also, number of breeding habitats under permanent category which are preferred by Anophelines and their total surface area were well correlated which also showed that they had better receptivity to Anophelines and must be addressed adequately.

The study showed that the vector potential of the habitats was not proportionate to their numbers. Of some categories of habitats although their number was small yet they had more vector potential than others which had more number. This information can also be productively utilized in selective vector control wherein greater priority is assigned to those habitats which have more vector potential than the others. In earlier studies also, a relative contribution of various habitats have been studied and their role in vector production is highlighted (Kumar 1992; Biswas et al. 1992).

The analysis of epidemiological data clearly suggest that the construction workers are far more vulnerable to malaria than local populations and hotel or restaurant workers. Hence, much greater attention should be paid for the detection and treatment of malaria in this economically backward population (Fig. 4.65). There is also need to have more efficient case detection than was observed in many PHCs of Goa. Such a proactive approach during

surveillance would help in timely mopping up and treatment of malaria cases. Although it was not a subject of investigation in the present study, the sensitivity of commonly used antimalarials needs to be ascertained for effective treatment of malaria cases with appropriate drug. In Goa, chloroquine sensitivity in *P. falciparum* has declined drastically as indicated by the research studies (unpublished data) and the drug has been replaced with a second line treatment with ACT (Artemisinin Combination Therapy) by the NVBDCP, New Delhi.

To conclude it may be mentioned that physiographically, different regions of Goa are receptive to three malaria vectors viz., *Anopheles stephensi*, primarily along the coast, *An. culicifacies* and *An. fluviatilis* in the interior areas in the valleys and foothill regions of the State. The rainfall, relative humidity, maximum and minimum temperatures play an important role in the vector breeding and survival as well as active transmission of malaria. There is a strong relationship between developmental activities particularly construction activities in the coastal belt and malaria outbreaks. During the course of study, it was observed that the construction sites were highly receptive to *Anopheles stephensi* and demographic distribution revealed that construction workers residing at the construction sites were the most vulnerable population and this combination was responsible for the outbreaks of malaria in the urban areas.

In Goa, malaria transmission appears to be more or less perennial with definite peak during the monsoon season and males of all ages were more prone to malaria infection than the females. From almost negligible incidence of malaria in 1985, many parts of Goa especially along the coast and in the interior were affected by the year 1998. The situation has however, shown considerable improvement in the subsequent years. Three coastal talukas of Goa viz., Bardez,

Tiswadi and Salcete are the most malaria affected currently. Since these 'talukas' also happen to be the preferred tourist destinations, the disease has cast its shadow on tourism based economy of the state as much as it is a threat to the public health in Goa.

Based on the outcome of present study a more focal paradigm specific approach has been recommended as malaria distribution as revealed by the incidence data analysis is highly variable not only from town to town or village to village but also within the endemic towns and villages as exemplified by stratification of the most affected capital city of Panaji.

Situational analysis based on entomological data shows that targeted approach to vector control is essential. Similarly, of all the demographic groups, malaria control among construction workers holds the key to the overall control of disease in the state. Since, construction sites have been recognized as important epidemiological niches of malaria transmission, it would be highly productive if vector control and disease management is given top priority at these sites. Needless to emphasize, that these intervention measures must be sustained throughout the year particularly in the pre-monsoon months which would reduce both receptivity and vulnerability to malaria in the monsoon and post monsoon months. In the hinterlands, outbreak potential still exists as *An. fluviatilis* is wide spread and outbreaks have been reported in the last decade in Sanguem and Quepem. Therefore vigil through vector monitoring and parasitic surveillance is necessary in these areas. Goa has a strong tradition of public health programmes and health services are available in the remotest area of the state through a network of 28 PHCs and sub-centres under them. This decentralized control of malaria is therefore possible in any nook and corner of the state.

Chapter 6: SUMMARY

1. An epidemiology study on the risk factors responsible for the enhanced receptivity and vulnerability to malaria in Goa was carried out from the year 2002 to 2007. The physiography, land use pattern, forest cover and soil drainage were studied in relation to malaria.

2. Meteorological data of Goa from the year 1980 to 2007 was analyzed and tabulated. The mean monthly trends of rainfall, relative humidity, maximum and minimum temperature were plotted for the years from 1980 to 2007. The meteorological data was correlated with malaria incidence during different years.

3. Developmental activities and pattern of human migration in the state of Goa were studied. The data collected revealed that over 1000 construction sites were coming up per annum in the state and in a decade, the population of migrant workers doubled (46901) in 2001 as compared to 25037 in the year 1991.

4. The 'taluka' wise analysis of migrant construction workers showed that their population was high in malaria affected zones viz., Bardez, Tiswadi, Mormugoa and Salcete. The construction workers migrated from 17 different states of India as well as from neighbouring country Nepal.

5. The data revealed that the construction activity continued uninterrupted even during the monsoon months as the number of construction workers did not drop significantly in spite of heavy rains from June to September.

6. Results of entomological studies showed that different types of permanent and temporary breeding habitats of mosquitoes were available including those preferred by malaria vectors. The temporary habitats were both rain associated and those not associated with rains. The permanent breeding sites presented more water surface area to the mosquitoes than the temporary sites. Among

temporary sites, rain associated sites were much more in number thereby provided more breeding opportunities and also surface area compared with the temporary habitats that were not associated with rains.

7. It was observed that all types of breeding habitats in the construction sites were merely 11.6% although they had 42.3% total surface area as compared to the remaining habitats which together were 88.4% but had only 57.7% surface area. Thus construction sites were more receptive to vector breeding than elsewhere. This was indicated by 63.6% vector potential as compared to 36.4% in the residential colonies.

8. Breeding surveys of vectors in Panaji, Margao, Candolim and Cortalim revealed that malaria vector *Anopheles stephensi* was breeding in Curing waters, sumps, ground cement and polyplast tanks, iron barrels, swimming pools, fountains, over head tanks and wells. In Panaji, *An. stephensi* immature were also collected from the drain with clean water stagnations. In Ponda this species was found breeding in the construction sites. In Bicholim and Sanguem, *An. stephensi* was not encountered.

9. In Bicholim, *An. culicifacies* breeding was detected in the paddy fields. In Sanguem, foot hill vector *An. fluviatilis* was encountered in stone quarry pits and puddles.

10. Adult collections of mosquitoes using pro model of Mosquito Magnet™ traps yielded 2120 mosquitoes belonging to 15 species in 34 days in Panaji. These included not only malaria vectors but also well known vectors of filariasis, dengue, chikungunya and Japanese encephalitis.

11. All night collections of mosquitoes landing on human baits during 85 nights all over Goa showed that 23 species were actively feeding on human beings. These included all the three vector species of malaria viz., *An. stephensi*, *An. culicifacies* and *An. fluviatilis*. The former species was found throughout the year, while *An. culicifacies* was predominant during the post monsoons as compared to *An. fluviatilis* which was in maximum numbers during the premonsoon months.

12. The biting rhythm of mosquitoes showed that all the three vectors were actively feeding between 18.00-06.00 hrs. However the peak biting of *An. stephensi* and *An. fluviatilis* was observed during the early hours of the day while that of *An. culicifacies* was more pronounced during the early night hours.

13. Entomological studies revealed that all the three vectors were well distributed in Goa. Whereas, *An. stephensi* was primarily distributed along the coastal belt, *An. culicifacies* and *An. fluviatilis* was distributed in the intermediate region in valleys and foothills.

14. The vector incrimination studies revealed that 3 *An. stephensi* females were positive for circumsporozoite proteins of *Plasmodium falciparum* with the help of ELISA technique. All the other anopheline species were negative. The EIR of *P. falciparum* was 18.1 and 2.35 for Panaji city and Goa respectively.

15. The in-depth analysis of parasitological data of Goa revealed that malaria was well under control till the year 1985 subsequent to which coastal parts of Goa have become endemic to malaria. The rising *P. falciparum* proportions have also led to mortality especially in 1990s. The peak malaria season in Goa was found to be from May to October, although a good number of cases were reported in all the months. The incidence of *P. vivax* was much more in all the months as compared to *P. falciparum*.

16. Seasonal analysis of malaria data revealed that 44-46% of the malaria cases were reported during the monsoon period as compared to 27-28% each in the pre-monsoon months and post-monsoon months.

17. Relationship between different malariometric indices revealed that malaria incidence was dependent on quantity of blood examination being positively correlated. The slide positive rates were better represented by slide vivax rates than slide falciparum rates in Goa.

18. The analysis of data showed that Panaji contributed to 38-44% of malaria in Goa followed by Candolim (14-18%), Margaon (12-14%), Aldona (10%), Corlim (3-6%) and together these five PHCs contributed to about 85% incidence of malaria while the remaining 23 PHCs contributed 15% of the incidence.

19. The incidence of malaria in the above five high risk areas and annual trends were worked out and discussed in detail.

20. A detailed analysis of data of all the PHCs of Goa from 1990 to 2007 was done based on ABER, SPR and API. The state of Goa was stratified based on SPR and API.

21. Microstratification of Panaji was done and localities were identified according to malaria risk for prioritizing malaria control.

22. Key risk factors responsible for receptivity and vulnerability were identified. Among the climatic factors, rainfall, relative humidity, maximum and minimum temperatures were all positively correlated to malaria. Vector receptivity was maximum in the construction sites. Construction workers were the most vulnerable populations to malaria infection. Males were much more vulnerable as

compared to females of most of the age groups, although all ages of both sexes were found vulnerable to malaria.

23. Based on the above findings a malaria control strategy was proposed for two main paradigms of Goa viz., Urban and suburban areas and rural area with out break potential. The proposed malaria control strategy includes various vector control options suitable for larval and adult control. An efficient parasitic surveillance and treatment has been emphasised with more reliance on active case detection than the passive case detection. Mobile clinics have been suggested to mop up cases among construction workers. Personal protection of this highly vulnerable demographic group with Insecticide treated nets has also been highlighted. Community participation especially of student community and public in general has been suggested. For this need for health education has been stressed. Involvement of local self Government institutions and NGOs has been suggested. Advocacy for construction sector and their greater involvement in malaria control is also highlighted. Lastly it has been suggested that the National vector Borne Disease Control Programme should retain leadership role in malaria control activities.

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ANNEXURE No. 1

Table 1: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1980

MONTH	Temperature °C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.0	20.1	0.0	N.A.	81.5
Feb	32.2	21.9	0.0	N.A.	83.5
Mar	32.5	23.2	0.0	N.A.	78.5
Apr	34.0	26.4	24.4	N.A.	78.0
May	34.4	27.3	26.2	N.A.	79.0
Jun	29.4	24.7	990.4	N.A.	92.0
Jul	29.6	25.0	605.2	N.A.	89.5
Aug	28.3	24.0	796.4	N.A.	93.0
Sep	30.1	24.3	105.0	N.A.	91.0
Oct	32.7	24.4	1.0	N.A.	90.0
Nov	33.9	23.0	66.8	N.A.	84.5
Dec	31.8	19.9	27.5	N.A.	80.5
Total			2642.9		

Table 2: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1981

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.3	19.9	0.0	0	79.5
Feb	32.5	20.8	0.0	0	80.5
Mar	32.6	23.2	0.0	0	81.0
Apr	33.0	25.7	0.3	0	79.5
May	34.1	27.2	13.0	5	78.0
Jun	29.2	24.3	1263.3	28	92.0
Jul	29.0	24.8	843.7	30	90.5
Aug	28.5	24.2	801.4	30	92.5
Sep	30.4	24.4	259.1	16	92.0
Oct	32.1	24.0	41.0	6	88.5
Nov	32.4	21.8	4.4	1	79.5
Dec	32.8	21.2	0.0	0	79.0
Total			3226.2	116	

Annexure No. 1

Table 3: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1982

MONTH	Temperature °C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.3	20.5	(mm)		82.0
Feb	31.4	21.2	0.0	0	78.5
Mar	31.5	22.1	0.0	0	81.0
Apr	32.5	24.5	0.0	0	81.5
May	33.6	25.9	0.0	0	82.5
Jun	30.6	25.1	24.6	8	91.5
Jul	29.6	24.4	1030.5	26	92.0
Aug	29.0	24.3	1017.8	26	91.0
Sep	29.2	23.9	835.4	31	91.0
Oct	32.9	24.2	138.2	15	90.5
Nov	32.4	23.1	32.0	5	85.5
Dec	33.2	21.1	37.7	7	82.5
Total			0.0	0	
			3116.2	118	

Table 4: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1983

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.6	19.3	0.0	0	83.5
Feb	30.5	19.2	0.0	0	81.0
Mar	30.8	21.5	0.0	0	84.5
Apr	31.6	23.5	0.0	0	84.5
May	33.1	26.6	10.5	2	84.0
Jun	32.0	25.8	562.2	16	86.0
Jul	29.5	24.6	1002.6	30	91.5
Aug	28.6	23.7	1192.7	31	95.0
Sep	29.1	23.9	688.6	29	94.0
Oct	31.4	23.5	104.2	12	88.5
Nov	32.2	20.4	10.9	4	85.0
Dec	32.4	21.8	14.8	2	83.0
Total			3586.5	126	

Annexure No. 1

Table 5: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1984

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.3	20.2	0.3	1	79.5
Feb	33.4	22.1	3.1	1	74.0
Mar	33.5	25.4	0.0	0	80.0
Apr	34.0	26.0	4.5	2	76.0
May	33.9	27.6	4.5	3	80.5
Jun	30.3	24.4	905.3	30	89.5
Jul	28.7	24.0	837.4	31	91.0
Aug	29.1	24.0	422.7	30	91.0
Sep	29.6	23.5	208.8	19	92.0
Oct	30.9	24.1	193.8	9	91.5
Nov	33.9	21.6	6.8	3	82.5
Dec	32.7	20.6	0.0	0	81.5
Total			2587.2	129	

Table 6: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1985

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.1	20.8	0.0	0	71.5
Feb	31.5	20.9	0.0	0	81.0
Mar	32.8	24.6	0.0	0	84.0
Apr	33.1	25.1	9.9	2	80.0
May	33.4	26.3	28.3	8	80.5
Jun	29.0	23.8	1333.0	30	90.0
Jul	28.8	24.2	513.0	27	91.0
Aug	28.9	24.0	534.0	30	92.5
Sep	30.4	24.0	91.2	14	89.0
Oct	30.6	22.8	373.5	11	90.0
Nov	32.9	21.1	7.7	3	85.0
Dec	33.3	21.3	0.0	0	82.0
Total			2890.6	125	

Annexure No. 1

Table7: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1986

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.5	20.2	0.0	0	79.0
Feb	30.7	20.8	0.0	0	82.0
Mar	32.3	23.6	0.0	0	83.0
Apr	33.0	25.6	0.6	1	82.0
May	33.9	27.2	0.6	1	77.0
Jun	31.0	25.2	661.1	27	88.0
Jul	29.5	24.9	429.1	21	88.5
Aug	28.5	23.6	508.2	22	91.5
Sep	30.9	24.4	23.7	10	90.5
Oct	32.4	24.4	32.5	1	90.0
Nov	32.9	23.2	66.4	7	86.0
Dec	32.3	21.0	0.0	0	77.0
Total			1722.2	90	

Table 8: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1987

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.6	20.7	0.0	0	80.0
Feb	32.5	20.9	0.0	0	79.5
Mar	31.8	23.1	0.0	0	82.5
Apr	33.0	25.0	0.0	0	79.5
May	34.6	26.4	4.1	5	77.5
Jun	30.7	25.2	1065.1	25	90.0
Jul	29.7	25.3	696.0	28	85.5
Aug	29.3	24.5	620.8	29	93.0
Sep	30.4	24.7	143.1	18	91.0
Oct	32.1	24.3	186.6	12	90.5
Nov	33.5	23.2	11.7	4	85.0
Dec	33.3	21.3	6.0	2	76.0
Total			2733.4	123	

Annexure No. 1

Table 9: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1988

MONTH	Temperature °C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.7	20.4	0.0	0	79.0
Feb	32.1	21.7	0.0	0	82.0
Mar	31.8	22.4	0.0	0	80.5
Apr	33.1	25.7	12.8	1	79.5
May	34.0	27.4	0.6	2	81.5
Jun	30.8	25.2	630.7	25	91.0
Jul	28.8	24.0	1230.1	31	92.5
Aug	28.6	24.2	808.4	31	93.5
Sep	28.4	23.5	366.6	26	93.5
Oct	31.4	23.3	57.4	6	90.5
Nov	33.9	20.6	0.0	0	77.0
Dec	33.3	20.7	0.0	0	77.5
Total			3106.6	122	

Table 10: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1989

MONTH	Temperature °C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	33.2	20.1	0.0	0	79.0
Feb	33.5	19.7	0.0	0	81.0
Mar	32.6	23.3	0.9	3	81.0
Apr	33.5	25.4	0.0	0	78.5
May	34.0	26.9	11.7	6	78.5
Jun	30.4	24.7	741.5	26	90.0
Jul	29.1	24.3	762.3	28	92.0
Aug	28.8	23.7	717.4	31	93.0
Sep	29.8	24.0	316.3	16	93.5
Oct	31.7	23.9	74.9	5	91.5
Nov	34.7	21.6	0.0	0	81.0
Dec	32.8	21.5	0.0	0	78.0
Total			2625.0	115	

Annexure No. 1

Table 11: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1990

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	33.7	20.1	0.0	0	79.5
Feb	32.5	20.7	0.0	0	80.0
Mar	31.9	22.4	0.0	0	80.0
Apr	32.6	24.3	0.0	0	83.0
May	32.5	25.6	391.7	15	85.0
Jun	30.3	25.0	759.6	30	91.5
Jul	29.4	24.5	472.3	31	90.0
Aug	28.6	24.0	601.1	29	93.5
Sep	30.0	24.0	248.0	16	93.0
Oct	32.4	23.5	98.5	11	91.0
Nov	32.0	23.2	51.8	5	86.5
Dec	33.3	21.7	0.0	0	78.5
Total			2623.0	137	

Table 12: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1991

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.9	19.9	0.0	0	82.0
Feb	32.4	20.3	0.0	0	79.0
Mar	32.0	22.8	0.0	0	83.5
Apr	33.4	26.2	7.8	1	80.5
May	34.0	26.5	31.6	5	80.0
Jun	30.9	25.6	447.2	26	90.0
Jul	28.3	24.0	1137.9	31	93.0
Aug	28.9	24.0	447.4	31	92.0
Sep	30.6	24.4	60.2	9	91.5
Oct	32.5	24.3	10.8	3	89.0
Nov	33.5	23.2	9.4	3	83.5
Dec	31.9	20.7	0.0	0	78.5
Total			2152.3	109	

Annexure No. 1

Table 13: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1992

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.4	19.2	0.0	0	78.5
Feb	30.8	19.9	0.0	0	80.0
Mar	31.9	23.3	0.0	0	83.5
Apr	32.5	24.5	0.0	0	78.5
May	33.4	26.7	18.1	4	77.5
Jun	30.9	24.9	1087.7	21	90.5
Jul	29.2	24.6	730.1	26	92.0
Aug	28.7	24.0	714.3	29	93.0
Sep	30.1	24.1	170.0	13	94.0
Oct	30.9	24.0	54.5	8	89.5
Nov	33.2	23.6	3.5	2	82.0
Dec	32.4	20.5	0.0	0	77.0
Total			2778.2	103	

Table 14: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1993

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.9	20.0	0.0	0	83.0
Feb	32.5	20.3	0.0	0	79.0
Mar	31.9	22.9	0.0	0	81.0
Apr	32.3	24.7	0.0	0	88.5
May	33.2	26.6	65.3	5	89.0
Jun	30.9	25.8	401.4	16	88.0
Jul	28.7	24.2	1333.1	29	92.5
Aug	29.4	24.3	367.3	25	91.0
Sep	29.3	23.8	210.5	17	93.5
Oct	31.1	24.0	168.9	12	93.0
Nov	33.6	23.3	2.0	2	80.0
Dec	32.3	21.3	9.8	3	79.5
Total			2558.3	109	

Annexure No. 1

Table 15: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1994

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.5	20.9	0.0	0	79.5
Feb	31.4	20.8	0.0	0	79.5
Mar	32.3	24.9	0.0	0	84.0
Apr	33.1	25.4	18.7	2	82.0
May	33.4	26.7	31.6	4	79.5
Jun	29.6	25.1	767.8	25	87.5
Jul	28.6	24.1	896.5	31	91.5
Aug	29.0	24.3	666.9	25	91.5
Sep	29.9	23.4	228.7	16	90.5
Oct	31.6	23.8	283.0	14	91.5
Nov	33.2	22.5	1.2	2	78.5
Dec	32.2	19.6	0.0	0	75.5
Total			2894.4	119	

Table16: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1995

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.2	19.6	9.9	3	64.5
Feb	31.8	20.9	0.0	0	69.5
Mar	32.1	22.5	0.0	0	70.5
Apr	33.2	25.3	2.3	2	71.0
May	33.8	26.1	35.4	8	69.5
Jun	31.3	25.8	785.2	22	84.5
Jul	28.3	24.0	1526.1	31	90.5
Aug	29.7	24.5	737.9	24	88.0
Sep	30.1	27.5	200.2	17	85.5
Oct	31.5	24.1	252.4	18	83.0
Nov	32.6	21.7	6.2	2	70.5
Dec	33.0	20.6	0.0	0	66.5
Total			3555.6	127	

Annexure No. 1

Table 17: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1996

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.2	20.2	0.0	0	67.0
Feb	33.1	21.1	0.0	0	67.5
Mar	32.7	24.7	0.0	0	76.0
Apr	33.0	25.2	0.7	1	71.0
May	33.3	26.2	0.6	2	71.5
Jun	31.2	25.5	1040.8	21	78.5
Jul	29.0	24.4	1131.8	28	89.0
Aug	29.0	24.3	340.8	30	88.5
Sep	30.2	24.3	131.9	20	86.5
Oct	30.7	23.2	223.5	10	81.0
Nov	32.9	22.3	6.4	1	72.5
Dec	32.4	28.9	4.4	2	68.0
Total			2880.9	115	

Table 18: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1997

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.5	19.9	7.6	2	69.0
Feb	31.3	18.9	0.0	0	67.0
Mar	32.4	23.7	0.1	1	76.5
Apr	33.0	24.3	0.0	0	67.5
May	34.0	26.4	0.0	0	68.0
Jun	31.2	25.0	1057.3	23	80.5
Jul	29.3	24.8	1210.5	30	88.0
Aug	28.9	24.2	854.3	31	89.5
Sep	31.3	24.5	57.6	13	81.0
Oct	33.7	24.7	58.1	8	78.0
Nov	33.0	24.4	51.3	7	77.0
Dec	31.8	22.7	70.1	2	75.0
Total			3366.9	117	

Annexure No. 1

Table 19: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1998

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.2	21.4	0.0	0	70.0
Feb	32.5	20.7	0.0	0	69.0
Mar	31.8	22.9	0.0	0	73.0
Apr	33.9	26.1	0.0	0	72.5
May	34.6	27.9	68.4	4	72.0
Jun	31.0	25.6	1069.7	24	86.0
Jul	29.8	25.1	751.0	28	89.0
Aug	30.0	24.8	549.8	28	91.5
Sep	29.5	24.3	427.3	28	90.5
Oct	30.8	24.2	167.5	20	87.0
Nov	32.2	22.3	44.9	4	79.0
Dec	32.6	20.7	0.0	1	64.0
Total			3078.6	137	

Table 20: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 1999

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.9	19.4	0.0	0	69.0
Feb	33.5	21.8	0.0	0	70.0
Mar	32.5	23.8	0.0	0	74.5
Apr	32.6	26.0	0.0	0	75.5
May	31.6	25.4	341.7	15	80.5
Jun	29.1	24.0	1586.4	27	91.0
Jul	28.3	24.0	1162.1	31	92.5
Aug	29.3	24.5	182.4	23	89.5
Sep	29.9	24.1	203.6	18	88.0
Oct	32.0	24.1	200.4	11	83.0
Nov	33.0	22.6	3.8	1	73.5
Dec	32.6	20.7	0.0	0	64.5
Total			3680.4	126	

Annexure No. 1

Table 21: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2000

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.7	20.7	0.0	0	68.0
Feb	31.2	20.4	0.0	0	70.5
Mar	31.7	22.2	0.0	0	72.5
Apr	33.0	25.9	2.3	2	70.5
May	32.0	25.2	288.7	18	79.0
Jun	29.5	25.1	1176.2	27	88.5
Jul	28.3	23.9	1361.7	29	90.5
Aug	28.5	24.1	496.6	24	91.0
Sep	30.1	24.4	119.5	14	87.0
Oct	31.5	24.6	61.6	13	87.0
Nov	33.6	22.7	4.5	1	72.0
Dec	32.8	19.8	0.5	1	63.0
Total			3511.6	129	

Table 22: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2001

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.3	20.7	8.4	1	71.0
Feb	31.5	20.7	0.0	0	74.5
Mar	31.4	22.3	0.0	0	73.5
Apr	32.9	25.9	6.3	2	74.0
May	33.2	26.0	167.6	11	76.0
Jun	30.5	25.5	527.0	23	84.0
Jul	28.8	24.3	832.4	31	95.5
Aug	28.9	24.3	414.4	30	91.0
Sep	30.8	24.3	96.3	11	86.5
Oct	31.4	24.0	70.1	8	85.0
Nov	34.0	23.1	5.6	2	73.0
Dec	33.3	21.3	0.0	0	65.0
Total			2128.1	119	

Annexure No. 1

Table 23: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2002

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.3	20.1	0.0	0	67.5
Feb	32.8	22.2	0.0	0	71.5
Mar	32.7	24.2	0.0	0	77.0
Apr	33.5	26.3	0.1	1	74.0
May	34.0	27.6	63.3	10	74.5
Jun	30.2	25.3	1136.9	27	87.0
Jul	30.5	25.4	303.5	28	84.5
Aug	28.8	24.3	547.5	27	91.0
Sep	30.1	24.2	121.6	10	85.0
Oct	31.9	24.7	97.5	13	84.5
Nov	33.8	22.9	0.0	0	72.5
Dec	33.1	20.6	0.0	0	68.5
Total			2270.4	116	

Table 24: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2003

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.4	21.2	0.5	1	71.5
Feb	32.2	21.7	0.0	0	77.0
Mar	32.8	23.8	0.0	0	74.5
Apr	33.7	25.4	0.0	0	71.0
May	34.2	26.5	0.0	0	70.5
Jun	31.4	25.2	907.4	22	86.5
Jul	29.4	24.5	1115.7	31	91.0
Aug	30.3	24.6	410.4	29	87.5
Sep	30.1	24.3	190.6	22	86.0
Oct	32.5	24.6	49.1	6	82.0
Nov	34.6	23.2	9.2	2	68.5
Dec	33.3	20.1	0.0	0	66.0
Total			2682.9	113	

Annexure No. 1

Table 25: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2004

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	32.0	20.1	0.0	0	69.0
Feb	32.6	21.0	0.0	0	72.5
Mar	33.3	25.0	0.0	0	77.5
Apr	33.5	25.6	0.0	0	71.5
May	33.3	25.7	164.7	22	77.5
Jun	30.4	24.5	601.9	25	84.0
Jul	29.8	24.0	617.3	30	90.0
Aug	29.7	23.9	476.1	26	87.5
Sep	30.3	23.5	149.8	17	87.5
Oct	33.0	23.7	86.2	6	77.0
Nov	33.9	22.5	60.0	4	69.0
Dec	33.5	19.6	0.0	0	65.0
Total			2156.0	130	

Table 26: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2005

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	31.8	19.7	0.0	0	72.0
Feb	32.0	20.1	2.0	1	72.5
Mar	32.2	22.1	0.0	0	75.5
Apr	33.5	24.9	45.0	2	73.5
May	34.2	26.0	42.7	1	71.5
Jun	31.3	25.1	900.2	24	85.5
Jul	29.3	24.1	1168.3	30	90.7
Aug	30.0	24.2	422.6	24	86.5
Sep	29.6	23.7	638.5	25	90.0
Oct	31.9	23.4	125.6	7	83.0
Nov	34.0	21.0	0.0	0	67.0
Dec	33.6	19.9	0.2	1	68.0
Total			3345.1	115	

Annexure No. 1

Table 27: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2006

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	34.0	19.6	0.0	0	65.5
Feb	34.1	20.7	0.0	0	70.0
Mar	32.2	22.9	44.3	2	72.5
Apr	32.7	24.8	0.0	0	73.0
May	32.9	26.0	416.7	8	78.0
Jun	30.6	24.7	739.6	25	88.0
Jul	30.0	25.0	371.1	30	86.0
Aug	29.4	24.1	576.4	29	88.8
Sep	30.0	24.0	422.5	17	88.5
Oct	32.3	23.8	391.5	12	82.7
Nov	34.0	23.6	6.2	5	77.0
Dec	33.9	20.1	0.0	0	65.5
Total			2968.3	128	

Table 28: METEOROLOGICAL DATA OF PANAJI FOR THE YEAR 2007

MONTH	Temperature ° C		Actual Rainfall	Rainy days	Mean Relative Humidity
	(Max)	(Min)	(mm)	(No)	(%)
Jan.	33.5	20.2	0.0	0	72.0
Feb	32.6	20.7	0.0	0	74.0
Mar	32.6	23.6	0.0	0	75.0
Apr	34.0	26.3	0.0	0	74.0
May	34.0	26.6	113.8	8	71.0
Jun	30.0	25.0	1077.4	29	89.0
Jul	29.5	24.7	688.6	31	90.0
Aug	26.1	24.1	887.0	29	91.0
Sep	29.4	24.1	764.0	25	91.0
Oct	31.5	24.2	81.9	11	85.5
Nov	33.3	21.2	75.6	3	73.5
Dec	33.3	20.9	0.7	1	73.0
Total			3689.0	137	

ANNEXURE No. 2

Table 1: Monthly Parasitological Data of Goa for the year 1990

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	7225	196	38	234	3.2	2.7	0.5	83.8	16.2
Feb	7316	106	27	133	1.8	1.4	0.4	79.7	20.3
Mar	6436	154	13	167	2.6	2.4	0.2	92.2	7.8
Apr	4961	136	19	155	3.1	2.7	0.4	87.7	12.3
May	5129	319	25	344	6.7	6.2	0.5	92.7	7.3
Jun	9115	615	81	696	7.6	6.7	0.9	88.4	11.6
Jul	13981	872	138	1010	7.2	6.2	1.0	86.3	13.7
Aug	12793	514	178	692	5.4	4.0	1.4	74.3	25.7
Sep	10217	276	142	418	4.1	2.7	1.4	66.0	34.0
Oct	8237	278	93	371	4.5	3.4	1.1	74.9	25.1
Nov	7376	307	59	366	5.0	4.2	0.8	83.9	16.1
Dec	6901	246	58	304	4.4	3.6	0.8	80.9	19.1
Total	99687	4019	871	4890	4.9	4.0	0.9	82.2	17.8

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 2: Monthly Parasitological Data of Goa for the year 1991

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	6505	247	15	262	4.0	3.8	0.2	94.3	5.7
Feb	7542	217	8	225	3.0	2.9	0.1	96.4	3.6
Mar	6708	285	12	297	4.4	4.2	0.2	96.0	4.0
Apr	6178	401	65	466	7.5	6.5	1.1	86.1	13.9
May	5491	338	48	386	7.0	6.2	0.9	87.6	12.4
Jun	8902	229	58	287	3.2	2.6	0.7	79.8	20.2
Jul	8984	224	27	251	2.8	2.5	0.3	89.2	10.8
Aug	9940	151	42	193	1.9	1.5	0.4	78.2	21.8
Sep	7535	88	34	122	1.6	1.2	0.5	72.1	27.9
Oct	6753	81	77	158	2.3	1.2	1.1	51.3	48.7
Nov	5789	72	62	134	2.3	1.2	1.1	53.7	46.3
Dec	5626	47	51	98	1.7	0.8	0.9	48.0	52.0
Total	85953	2380	499	2879	3.3	2.8	0.6	82.7	17.3

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 3: Monthly Parasitological Data of Goa for the year 1992

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	6033	49	21	70	1.2	0.8	0.3	70.0	30.0
Feb	6959	25	5	30	0.4	0.4	0.1	83.3	16.7
Mar	5868	38	10	48	0.8	0.6	0.2	79.2	20.8
Apr	4618	80	23	103	2.2	1.7	0.5	77.7	22.3
May	4557	80	17	97	2.1	1.8	0.4	82.5	17.5
Jun	6139	77	22	99	1.6	1.3	0.4	77.8	22.2
Jul	9886	49	14	63	0.6	0.5	0.1	77.8	22.2
Aug	10738	52	13	65	0.6	0.5	0.1	80.0	20.0
Sep	7316	46	17	63	0.9	0.6	0.2	73.0	27.0
Oct	4993	63	14	77	1.5	1.3	0.3	81.8	18.2
Nov	6649	52	24	76	1.1	0.8	0.4	68.4	31.6
Dec	5437	37	23	60	1.1	0.7	0.4	61.7	38.3
Total	79193	648	203	851	1.1	0.8	0.3	76.1	23.9

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 4: Monthly Parasitological Data of Goa for the year 1993

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	5471	26	11	37	0.7	0.5	0.2	70.3	29.7
Feb	4853	37	11	48	1.0	0.8	0.2	77.1	22.9
Mar	4626	36	6	42	0.9	0.8	0.1	85.7	14.3
Apr	5043	49	13	62	1.2	1.0	0.3	79.0	21.0
May	3860	99	14	113	2.9	2.6	0.4	87.6	12.4
Jun	7613	198	24	222	2.9	2.6	0.3	89.2	10.8
Jul	11428	261	59	320	2.8	2.3	0.5	81.6	18.4
Aug	10707	314	23	337	3.1	2.9	0.2	93.2	6.8
Sep	10628	233	41	274	2.6	2.2	0.4	85.0	15.0
Oct	11322	254	56	310	2.7	2.2	0.5	81.9	18.1
Nov	8795	152	41	193	2.2	1.7	0.5	78.8	21.2
Dec	7692	235	34	269	3.5	3.1	0.4	87.4	12.6
Total	92038	1894	333	2227	2.4	2.1	0.4	85.0	15.0

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 5: Monthly Parasitological Data of Goa for the year 1994

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	7447	221	11	232	3.1	3.0	0.1	95.3	4.7
Feb	6489	150	6	156	2.4	2.3	0.1	96.2	3.8
Mar	6098	109	10	119	2.0	1.8	0.2	91.6	8.4
Apr	5590	155	9	164	2.9	2.8	0.2	94.5	5.5
May	8175	203	9	212	2.6	2.5	0.1	95.8	4.2
Jun	11592	487	18	505	4.4	4.2	0.2	96.4	3.6
Jul	12287	498	40	538	4.4	4.1	0.3	92.6	7.4
Aug	13565	464	76	540	4.0	3.4	0.6	85.9	14.1
Sep	10653	287	45	332	3.1	2.7	0.4	86.4	13.6
Oct	9171	249	28	277	3.0	2.7	0.3	89.9	10.1
Nov	7881	198	20	218	2.8	2.5	0.3	90.8	9.2
Dec	6637	161	16	177	2.7	2.4	0.2	91.0	9.0
Total	105585	3182	288	3470	3.3	3.0	0.3	91.7	8.3

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 6: Monthly Parasitological Data of Goa for the year 1995

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	6248	136	12	148	2.4	2.2	0.2	91.9	8.1
Feb	5616	126	8	134	2.4	2.2	0.1	94.0	6.0
Mar	6303	132	10	142	2.3	2.1	0.2	93.0	7.0
Apr	5496	83	4	87	1.6	1.5	0.1	95.4	4.6
May	6845	168	10	178	2.6	2.5	0.1	94.4	5.6
Jun	9782	350	20	370	3.8	3.6	0.2	94.6	5.4
Jul	11662	392	45	437	3.7	3.4	0.4	89.7	10.3
Aug	9804	520	28	548	5.6	5.3	0.3	94.9	5.1
Sep	10856	547	29	576	5.3	5.0	0.3	95.0	5.0
Oct	8459	392	34	426	5.0	4.6	0.4	92.0	8.0
Nov	7264	373	35	408	5.6	5.1	0.5	91.4	8.6
Dec	5043	411	21	432	8.6	8.1	0.4	95.1	4.9
Total	93378	3630	256	3886	4.2	3.9	0.3	93.4	6.6

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 7: Monthly Parasitological Data of Goa for the year 1996

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	8025	475	74	549	6.8	5.9	0.9	86.5	13.5
Feb	7131	341	46	387	5.4	4.8	0.6	88.1	11.9
Mar	6565	359	47	406	6.2	5.5	0.7	88.4	11.6
Apr	6541	552	64	616	9.4	8.4	1.0	89.6	10.4
May	7962	753	61	814	10.2	9.5	0.8	92.5	7.5
Jun	15062	978	60	1038	6.9	6.5	0.4	94.2	5.8
Jul	18983	1062	58	1120	5.9	5.6	0.3	94.8	5.2
Aug	19063	1438	148	1586	8.3	7.5	0.8	90.7	9.3
Sep	15843	1055	144	1199	7.6	6.7	0.9	88.0	12.0
Oct	17989	1093	256	1349	7.5	6.1	1.4	81.0	19.0
Nov	16803	971	315	1286	7.7	5.8	1.9	75.5	24.5
Dec	11178	1016	266	1282	11.5	9.1	2.4	79.3	20.7
Total	151145	10093	1539	11632	7.7	6.7	1.0	86.8	13.2

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 8: Monthly Parasitological Data of Goa for the year 1997

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	12713	971	272	1243	9.8	7.6	2.1	78.1	21.9
Feb	10662	721	190	911	8.5	6.8	1.8	79.1	20.9
Mar	11477	630	82	712	6.2	5.5	0.7	88.5	11.5
Apr	11823	936	199	1135	9.6	7.9	1.7	82.5	17.5
May	11518	919	207	1126	9.8	8.0	1.8	81.6	18.4
Jun	21332	1227	269	1496	7.0	5.8	1.3	82.0	18.0
Jul	33295	1654	276	1930	5.8	5.0	0.8	85.7	14.3
Aug	25480	2043	580	2623	10.3	8.0	2.3	77.9	22.1
Sep	32580	1761	869	2630	8.1	5.4	2.7	67.0	33.0
Oct	28950	1549	842	2391	8.3	5.4	2.9	64.8	35.2
Nov	22490	1399	1030	2429	10.8	6.2	4.6	57.6	42.4
Dec	21590	1388	1011	2399	11.1	6.4	4.7	57.9	42.1
Total	243910	15198	5827	21025	8.6	6.2	2.4	72.3	27.7

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 9: Monthly Parasitological Data of Goa for the year 1998

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	21501	1213	806	2019	9.4	5.6	3.7	60.1	39.9
Feb	15623	950	514	1464	9.4	6.1	3.3	64.9	35.1
Mar	16330	969	385	1354	8.3	5.9	2.4	71.6	28.4
Apr	16627	1071	351	1422	8.6	6.4	2.1	75.3	24.7
May	21568	1370	322	1692	7.8	6.4	1.5	81.0	19.0
Jun	26542	1680	385	2065	7.8	6.3	1.5	81.4	18.6
Jul	36058	2564	1056	3620	10.0	7.1	2.9	70.8	29.2
Aug	37625	1958	936	2894	7.7	5.2	2.5	67.7	32.3
Sep	41025	2030	1380	3410	8.3	4.9	3.4	59.5	40.5
Oct	27429	1563	1263	2826	10.3	5.7	4.6	55.3	44.7
Nov	20036	1061	750	1811	9.0	5.3	3.7	58.6	41.4
Dec	15011	852	546	1398	9.3	5.7	3.6	60.9	39.1
Total	295375	17281	8694	25975	8.8	5.9	2.9	66.5	33.5

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 10: Monthly Parasitological Data of Goa for the year 1999

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	14324	755	394	1149	8.0	5.3	2.8	65.7	34.3
Feb	17125	637	247	884	5.2	3.7	1.4	72.1	27.9
Mar	20548	783	223	1006	4.9	3.8	1.1	77.8	22.2
Apr	22216	816	230	1046	4.7	3.7	1.0	78.0	22.0
May	24321	840	281	1121	4.6	3.5	1.2	74.9	25.1
Jun	30744	1084	507	1591	5.2	3.5	1.6	68.1	31.9
Jul	37363	1305	912	2217	5.9	3.5	2.4	58.9	41.1
Aug	35346	854	663	1517	4.3	2.4	1.9	56.3	43.7
Sep	26098	753	598	1351	5.2	2.9	2.3	55.7	44.3
Oct	23739	764	590	1354	5.7	3.2	2.5	56.4	43.6
Nov	24647	702	613	1315	5.3	2.8	2.5	53.4	46.6
Dec	22140	539	290	829	3.7	2.4	1.3	65.0	35.0
Total	298611	9832	5548	15380	5.2	3.3	1.9	63.9	36.1

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 11: Monthly Parasitological Data of Goa for the year 2000

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	21286	439	160	599	2.8	2.1	0.8	73.3	26.7
Feb	20964	367	149	516	2.5	1.8	0.7	71.1	28.9
Mar	18669	404	84	488	2.6	2.2	0.4	82.8	17.2
Apr	12922	322	40	362	2.8	2.5	0.3	89.0	11.0
May	16815	482	96	578	3.4	2.9	0.6	83.4	16.6
Jun	30488	866	201	1067	3.5	2.8	0.7	81.2	18.8
Jul	37586	999	354	1353	3.6	2.7	0.9	73.8	26.2
Aug	31859	740	302	1042	3.3	2.3	0.9	71.0	29.0
Sep	26181	544	170	714	2.7	2.1	0.6	76.2	23.8
Oct	23167	552	327	879	3.8	2.4	1.4	62.8	37.2
Nov	23746	561	354	915	3.9	2.4	1.5	61.3	38.7
Dec	17559	388	263	651	3.7	2.2	1.5	59.6	40.4
Total	281242	6664	2500	9164	3.3	2.4	0.9	72.7	27.3

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 12: Monthly Parasitological Data of Goa for the year 2001

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	21015	383	196	579	2.8	1.8	0.9	66.1	33.9
Feb	17250	272	79	351	2.0	1.6	0.5	77.5	22.5
Mar	14308	320	74	394	2.8	2.2	0.5	81.2	18.8
Apr	13207	242	45	287	2.2	1.8	0.3	84.3	15.7
May	14726	406	93	499	3.4	2.8	0.6	81.4	18.6
Jun	32383	1111	221	1332	4.1	3.4	0.7	83.4	16.6
Jul	41893	1254	502	1756	4.2	3.0	1.2	71.4	28.6
Aug	28323	1116	494	1610	5.7	3.9	1.7	69.3	30.7
Sep	32937	1328	585	1913	5.8	4.0	1.8	69.4	30.6
Oct	27355	1040	431	1471	5.4	3.8	1.6	70.7	29.3
Nov	19091	845	351	1196	6.3	4.4	1.8	70.7	29.3
Dec	14823	704	239	943	6.4	4.7	1.6	74.7	25.3
Total	277311	9021	3310	12331	4.4	3.3	1.2	73.2	26.8

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 13: Monthly Parasitological Data of Goa for the year 2002

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	19870	650	186	836	4.2	3.3	0.9	77.8	22.2
Feb	18090	559	131	690	3.8	3.1	0.7	81.0	19.0
Mar	14290	521	133	654	4.6	3.6	0.9	79.7	20.3
Apr	17034	741	184	925	5.4	4.4	1.1	80.1	19.9
May	17574	898	260	1158	6.6	5.1	1.5	77.5	22.5
Jun	26964	1257	255	1512	5.6	4.7	0.9	83.1	16.9
Jul	39744	2427	441	2868	7.2	6.1	1.1	84.6	15.4
Aug	30800	1598	323	1921	6.2	5.2	1.0	83.2	16.8
Sep	22801	1225	272	1497	6.6	5.4	1.2	81.8	18.2
Oct	22671	1266	424	1690	7.5	5.6	1.9	74.9	25.1
Nov	25470	1379	434	1813	7.1	5.4	1.7	76.1	23.9
Dec	18126	949	305	1254	6.9	5.2	1.7	75.7	24.3
Total	273434	13470	3348	16818	6.2	4.9	1.2	80.1	19.9

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 14: Monthly Parasitological Data of Goa for the year 2003

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	16969	765	187	952	5.6	4.5	1.1	80.4	19.6
Feb	17694	761	109	870	4.9	4.3	0.6	87.5	12.5
Mar	17599	727	123	850	4.8	4.1	0.7	85.5	14.5
Apr	16669	778	156	934	5.6	4.7	0.9	83.3	16.7
May	16782	617	81	698	4.2	3.7	0.5	88.4	11.6
Jun	23781	781	51	832	3.5	3.3	0.2	93.9	6.1
Jul	42689	1085	81	1166	2.7	2.5	0.2	93.1	6.9
Aug	36786	1259	124	1383	3.8	3.4	0.3	91.0	9.0
Sep	31366	885	189	1074	3.4	2.8	0.6	82.4	17.6
Oct	21606	816	153	969	4.5	3.8	0.7	84.2	15.8
Nov	19685	758	137	895	4.5	3.9	0.7	84.7	15.3
Dec	17021	635	112	747	4.4	3.7	0.7	85.0	15.0
Total	278647	9867	1503	11370	4.1	3.5	0.5	86.8	13.2

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 15: Monthly Parasitological Data of Goa for the year 2004

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	16253	470	72	542	3.3	2.9	0.4	86.7	13.3
Feb	15268	381	34	415	2.7	2.5	0.2	91.8	8.2
Mar	16876	452	36	488	2.9	2.7	0.2	92.6	7.4
Apr	18323	485	69	554	3.0	2.6	0.4	87.5	12.5
May	17546	541	112	653	3.7	3.1	0.6	82.8	17.2
Jun	23947	812	239	1051	4.4	3.4	1.0	77.3	22.7
Jul	31001	734	195	929	3.0	2.4	0.6	79.0	21.0
Aug	27677	671	121	792	2.9	2.4	0.4	84.7	15.3
Sep	19837	584	145	729	3.7	2.9	0.7	80.1	19.9
Oct	18193	453	133	586	3.2	2.5	0.7	77.3	22.7
Nov	14338	461	136	597	4.2	3.2	0.9	77.2	22.8
Dec	19784	408	95	503	2.5	2.1	0.5	81.1	18.9
Total	239043	6452	1387	7839	3.3	2.7	0.6	82.3	17.7

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

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Table 16: Monthly Parasitological Data of Goa for the year 2005

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	20105	281	48	329	1.6	1.4	0.2	85.4	14.6
Feb	19763	205	21	226	1.1	1.0	0.1	90.7	9.3
Mar	18171	107	16	123	0.7	0.6	0.1	87.0	13.0
Apr	14809	84	4	88	0.6	0.6	0.0	95.5	4.5
May	15663	186	11	197	1.3	1.2	0.1	94.4	5.6
Jun	26004	295	23	318	1.2	1.1	0.1	92.8	7.2
Jul	37962	381	32	413	1.1	1.0	0.1	92.3	7.7
Aug	35655	393	56	449	1.3	1.1	0.2	87.5	12.5
Sep	23827	379	52	431	1.8	1.6	0.2	87.9	12.1
Oct	22699	388	65	453	2.0	1.7	0.3	85.7	14.3
Nov	14942	324	70	394	2.6	2.2	0.5	82.2	17.8
Dec	14570	294	32	326	2.2	2.0	0.2	90.2	9.8
Total	264170	3317	430	3747	1.4	1.3	0.2	88.5	11.5

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 17: Monthly Parasitological Data of Goa for the year 2006

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	14285	224	43	267	1.9	1.6	0.3	83.9	16.1
Feb	14129	179	15	194	1.4	1.3	0.1	92.3	7.7
Mar	15092	169	12	181	1.2	1.1	0.1	93.4	6.6
Apr	13248	123	25	148	1.1	0.9	0.2	83.1	16.9
May	14629	215	53	268	1.8	1.5	0.4	80.2	19.8
Jun	31996	402	92	494	1.5	1.3	0.3	81.4	18.6
Jul	33505	497	126	623	1.9	1.5	0.4	79.8	20.2
Aug	29322	420	150	570	1.9	1.4	0.5	73.7	26.3
Sep	28766	442	158	600	2.1	1.5	0.5	73.7	26.3
Oct	34044	435	180	615	1.8	1.3	0.5	70.7	29.3
Nov	28853	372	192	564	2.0	1.3	0.7	66.0	34.0
Dec	20120	336	150	486	2.4	1.7	0.7	69.1	30.9
Total	277989	3814	1196	5010	1.8	1.4	0.4	76.1	23.9

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 2

Table 18: Monthly Parasitological Data of Goa for the year 2007

MONTH	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%
Jan	17563	320	137	457	2.6	1.8	0.8	70.0	30.0
Feb	18458	288	128	416	2.3	1.6	0.7	69.2	30.8
Mar	17081	276	85	361	2.1	1.6	0.5	76.5	23.5
Apr	19657	334	153	487	2.5	1.7	0.8	68.6	31.4
May	23427	655	133	788	3.4	2.8	0.6	83.1	16.9
Jun	33692	886	254	1140	3.4	2.6	0.8	77.7	22.3
Jul	51165	1103	444	1547	3.0	2.2	0.9	71.3	28.7
Aug	44300	980	655	1635	3.7	2.2	1.5	59.9	40.1
Sep	34162	849	491	1340	3.9	2.5	1.4	63.4	36.6
Oct	34438	892	558	1450	4.2	2.6	1.6	61.5	38.5
Nov	21877	888	508	1396	6.4	4.1	2.3	63.6	36.4
Dec	21380	642	302	944	4.4	3.0	1.4	68.0	32.0
Total	337200	8113	3848	11961	3.5	2.4	1.1	67.8	32.2

BSC/E = Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*

Annexure No. 3

Table:1 Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1990.

Sr. No.	PHC/CHC/UHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43166	24613	3256	739	3995	57.0	16.2	13.2	3.0	81.5	18.5	92.5
2	Mapusa	29757	2410	18	0	18	8.1	0.7	0.7	0.0	100.0	0.0	0.6
3	Pernem	38164	3940	7	0	7	10.3	0.2	0.2	0.0	100.0	0.0	0.2
4	Candolim	45294	5712	148	30	178	12.6	3.1	2.6	0.5	83.1	16.9	3.9
5	Aldona	46876	2816	14	4	18	6.0	0.6	0.5	0.1	77.8	22.2	0.4
6	Bicholim	52669	2856	13	3	16	5.4	0.6	0.5	0.1	81.3	18.8	0.3
7	Valpoi	45516	2015	2	0	2	4.4	0.1	0.1	0.0	100.0	0.0	0.0
8	Ponda	105828	8784	4	0	4	8.3	0.0	0.0	0.0	100.0	0.0	0.0
9	Betki	37566	5329	192	27	219	14.2	4.1	3.6	0.5	87.7	12.3	5.8
10	Cansarvarnem	16653	741	0	0	0	4.4	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	29297	856	0	0	0	2.9	0.0	0.0	0.0	0.0	0.0	0.0
12	Colvale	21447	654	0	0	0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
13	Corlim	61848	2449	275	64	339	4.0	13.8	11.2	2.6	81.1	18.9	5.5
14	Margao	57136	2559	15	0	15	4.5	0.6	0.6	0.0	100.0	0.0	0.3
15	Vasco	79518	3743	9	1	10	4.7	0.3	0.2	0.0	90.0	10.0	0.1
16	Cansaulim	32891	3299	1	0	1	10.0	0.0	0.0	0.0	100.0	0.0	0.0
17	Curtorim	39779	3153	0	3	3	7.9	0.1	0.0	0.1	0.0	100.0	0.1
18	Bali	32753	5591	6	0	6	17.1	0.1	0.1	0.0	100.0	0.0	0.2
19	Canacona	46994	4330	10	0	10	9.2	0.2	0.2	0.0	100.0	0.0	0.2
20	Curchorem	72126	6295	2	0	2	8.7	0.0	0.0	0.0	100.0	0.0	0.0
21	Sanguem	43370	5881	47	0	47	13.6	0.8	0.8	0.0	100.0	0.0	1.1
22	Cortalim	27628	841	0	0	0	3.0	0.0	0.0	0.0	0.0	0.0	0.0
23	Loutolim	21338	353	0	0	0	1.7	0.0	0.0	0.0	0.0	0.0	0.0
24	Chinchinim	26396	467	0	0	0	1.8	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	1054010	99687	4019	871	4890	9.5	4.9	4.0	0.9	82.2	17.8	4.6

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table:2 Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1991.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43349	17481	1471	85	1556	40.3	8.9	8.4	0.5	94.5	5.5	35.9
2	Mapusa	31667	1661	21	1	22	5.2	1.3	1.3	0.1	95.5	4.5	0.7
3	Pernem	46124	2924	0	0	0	6.3	0.0	0.0	0.0	0.0	0.0	0.0
4	Candolim	46399	4708	101	14	115	10.1	2.4	2.1	0.3	87.8	12.2	2.5
5	Aldona	47881	1632	8	1	9	3.4	0.6	0.5	0.1	88.9	11.1	0.2
6	Bicholim	47500	2438	6	1	7	5.1	0.3	0.2	0.0	85.7	14.3	0.1
7	Valpoi	49530	2304	2	0	2	4.7	0.1	0.1	0.0	100.0	0.0	0.0
8	Ponda	68145	5610	8	1	9	8.2	0.2	0.1	0.0	88.9	11.1	0.1
9	Betki	42759	3171	48	2	50	7.4	1.6	1.5	0.1	96.0	4.0	1.2
10	Cansarvarnem	20565	1378	0	0	0	6.7	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	38673	1719	1	0	1	4.4	0.1	0.1	0.0	100.0	0.0	0.0
12	Colvale	25868	1317	3	1	4	5.1	0.3	0.2	0.1	75.0	25.0	0.2
13	Corlim	73553	4997	658	391	1049	6.8	21.0	13.2	7.8	62.7	37.3	14.3
14	Margao	58951	1885	11	0	11	3.2	0.6	0.6	0.0	100.0	0.0	0.2
15	Vasco	83367	3278	27	2	29	3.9	0.9	0.8	0.1	93.1	6.9	0.3
16	Cansaulim	37009	2122	1	0	1	5.7	0.0	0.0	0.0	100.0	0.0	0.0
17	Curtorim	49239	2446	2	0	2	5.0	0.1	0.1	0.0	100.0	0.0	0.0
18	Bali	36573	3617	0	0	0	9.9	0.0	0.0	0.0	0.0	0.0	0.0
19	Canacona	40716	4372	2	0	2	10.7	0.0	0.0	0.0	100.0	0.0	0.0
20	Curchorem	43094	5963	1	0	1	13.8	0.0	0.0	0.0	100.0	0.0	0.0
21	Sanguem	41686	7311	9	0	9	17.5	0.1	0.1	0.0	100.0	0.0	0.2
22	Cortalim	35914	1814	0	0	0	5.1	0.0	0.0	0.0	0.0	0.0	0.0
23	Loutolim	24208	1205	0	0	0	5.0	0.0	0.0	0.0	0.0	0.0	0.0
24	Chinchinim	27509	600	0	0	0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL	1060279	85953	2380	499	2879	8.1	3.3	2.8	0.6	82.7	17.3	2.7

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 3: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1992.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43392	13128	347	105	452	30.3	3.4	2.6	0.8	76.8	23.2	10.4
2	Mapusa	32549	1149	6	0	6	3.5	0.5	0.5	0.0	100.0	0.0	0.2
3	Pernem	46478	3037	0	0	0	6.5	0.0	0.0	0.0	0.0	0.0	0.0
4	Candolim	47109	3843	19	9	28	8.2	0.7	0.5	0.2	67.9	32.1	0.6
5	Aldona	48866	1975	26	13	39	4.0	2.0	1.3	0.7	66.7	33.3	0.8
6	Bicholim	47879	2813	13	0	13	5.9	0.5	0.5	0.0	100.0	0.0	0.3
7	Valpoi	50422	2430	4	0	4	4.8	0.2	0.2	0.0	100.0	0.0	0.1
8	Ponda	69711	3112	9	1	10	4.5	0.3	0.3	0.0	90.0	10.0	0.1
9	Betki	43358	3303	21	2	23	7.6	0.7	0.6	0.1	91.3	8.7	0.5
10	Cansarvarnem	20742	1815	7	0	7	8.8	0.4	0.4	0.0	100.0	0.0	0.3
11	Siolim	39161	1909	4	3	7	4.9	0.4	0.2	0.2	57.1	42.9	0.2
12	Colvale	26239	1898	9	0	9	7.2	0.5	0.5	0.0	100.0	0.0	0.3
13	Corlim	74509	2828	133	67	200	3.8	7.1	4.7	2.4	66.5	33.5	2.7
14	Margao	60894	2718	9	1	10	4.5	0.4	0.3	0.0	90.0	10.0	0.2
15	Vasco	84746	3464	8	1	9	4.1	0.3	0.2	0.0	88.9	11.1	0.1
16	Cansaulim	37338	1807	1	0	1	4.8	0.1	0.1	0.0	100.0	0.0	0.0
17	Curtorim	50656	2596	4	0	4	5.1	0.2	0.2	0.0	100.0	0.0	0.1
18	Bali	36884	3374	8	0	8	9.1	0.2	0.2	0.0	100.0	0.0	0.2
19	Canacona	41044	5264	4	0	4	12.8	0.1	0.1	0.0	100.0	0.0	0.1
20	Curchorem	43682	6735	2	0	2	15.4	0.0	0.0	0.0	100.0	0.0	0.0
21	Sanguem	42059	5720	7	0	7	13.6	0.1	0.1	0.0	100.0	0.0	0.2
22	Cortalim	37067	2241	4	1	5	6.0	0.2	0.2	0.0	80.0	20.0	0.1
23	Loutolim	24427	992	0	0	0	4.1	0.0	0.0	0.0	0.0	0.0	0.0
24	Chinchinim	27626	1042	3	0	3	3.8	0.3	0.3	0.0	100.0	0.0	0.1
	TOTAL	1076838	79193	648	203	851	7.4	1.1	0.8	0.3	76.1	23.9	0.8

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 4: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1993.

Sr. No.	PHC/UHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43455	15348	1111	225	1336	35.3	8.7	7.2	1.5	83.2	16.8	30.7
2	Mapusa	33456	2331	35	3	38	7.0	1.6	1.5	0.1	92.1	7.9	1.1
3	Pernem	46834	3594	9	3	12	7.7	0.3	0.3	0.1	75.0	25.0	0.3
4	Candolim	47531	3988	247	14	261	8.4	6.5	6.2	0.4	94.6	5.4	5.5
5	Aldona	49871	2638	178	48	226	5.3	8.6	6.7	1.8	78.8	21.2	4.5
6	Bicholim	48261	3017	30	1	31	6.3	1.0	1.0	0.0	96.8	3.2	0.6
7	Valpoi	51330	2890	7	1	8	5.6	0.3	0.2	0.0	87.5	12.5	0.2
8	Ponda	71313	7618	9	1	10	10.7	0.1	0.1	0.0	90.0	10.0	0.1
9	Betki	43965	2975	53	10	63	6.8	2.1	1.8	0.3	84.1	15.9	1.4
10	Cansarvarnem	20921	2086	0	0	0	10.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	39655	1831	4	0	4	4.6	0.2	0.2	0.0	100.0	0.0	0.1
12	Colvale	26616	1612	10	1	11	6.1	0.7	0.6	0.1	90.9	9.1	0.4
13	Corlim	75478	2934	102	7	109	3.9	3.7	3.5	0.2	93.6	6.4	1.4
14	Margao	62901	5149	15	1	16	8.2	0.3	0.3	0.0	93.8	6.3	0.3
15	Vasco	86147	3350	14	3	17	3.9	0.5	0.4	0.1	82.4	17.6	0.2
16	Cansaulim	37670	1832	4	1	5	4.9	0.3	0.2	0.1	80.0	20.0	0.1
17	Curtorim	52114	1479	15	8	23	2.8	1.6	1.0	0.5	65.2	34.8	0.4
18	Bali	37197	3678	10	1	11	9.9	0.3	0.3	0.0	90.9	9.1	0.3
19	Canacona	41375	6086	13	1	14	14.7	0.2	0.2	0.0	92.9	7.1	0.3
20	Curchorem	44277	7343	11	0	11	16.6	0.1	0.1	0.0	100.0	0.0	0.2
21	Sanguem	42435	5767	3	0	3	13.6	0.1	0.1	0.0	100.0	0.0	0.1
22	Cortalim	38257	2460	1	2	3	6.4	0.1	0.0	0.1	33.3	66.7	0.1
23	Loutolim	24647	840	4	0	4	3.4	0.5	0.5	0.0	100.0	0.0	0.2
24	Chinchinim	27743	1192	9	2	11	4.3	0.9	0.8	0.2	81.8	18.2	0.4
	TOTAL	1093449	92038	1894	333	2227	8.4	2.4	2.1	0.4	85.0	15.0	2.0

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 5: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1994.

Sr. No.	PHC/UHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43478	11203	662	79	741	25.8	6.6	5.9	0.7	89.3	10.7	17.0
2	Mapusa	34387	2084	49	3	52	6.1	2.5	2.4	0.1	94.2	5.8	1.5
3	Pernem	47194	3467	9	1	10	7.3	0.3	0.3	0.0	90.0	10.0	0.2
4	Candolim	48691	9752	1356	77	1433	20.0	14.7	13.9	0.8	94.6	5.4	29.4
5	Aldona	50897	3817	368	43	411	7.5	10.8	9.6	1.1	89.5	10.5	8.1
6	Bicholim	48647	3745	60	1	61	7.7	1.6	1.6	0.0	98.4	1.6	1.3
7	Valpoi	52254	2083	1	0	1	4.0	0.0	0.0	0.0	100.0	0.0	0.0
8	Ponda	72952	13528	15	4	19	18.5	0.1	0.1	0.0	78.9	21.1	0.3
9	Betki	44581	1960	21	0	21	4.4	1.1	1.1	0.0	100.0	0.0	0.5
10	Cansarvarnem	21101	2154	7	1	8	10.2	0.4	0.3	0.0	87.5	12.5	0.4
11	Siolim	40156	1948	3	0	3	4.9	0.2	0.2	0.0	100.0	0.0	0.1
12	Colvale	26998	1869	32	0	32	6.9	1.7	1.7	0.0	100.0	0.0	1.2
13	Corlim	76459	2537	161	20	181	3.3	7.1	6.3	0.8	89.0	11.0	2.4
14	Margao	64975	6598	205	53	258	10.2	3.9	3.1	0.8	79.5	20.5	4.0
15	Vasco	87572	2843	31	4	35	3.2	1.2	1.1	0.1	88.6	11.4	0.4
16	Cansaulim	38004	1779	13	1	14	4.7	0.8	0.7	0.1	92.9	7.1	0.4
17	Curtorim	53614	2851	12	0	12	5.3	0.4	0.4	0.0	100.0	0.0	0.2
18	Bali	37514	4218	46	0	46	11.2	1.1	1.1	0.0	100.0	0.0	1.2
19	Canacona	41708	6934	58	0	58	16.6	0.8	0.8	0.0	100.0	0.0	1.4
20	Curchorem	44881	10978	33	0	33	24.5	0.3	0.3	0.0	100.0	0.0	0.7
21	Sanguem	42815	5219	7	0	7	12.2	0.1	0.1	0.0	100.0	0.0	0.2
22	Cortalim	39485	2536	8	1	9	6.4	0.4	0.3	0.0	88.9	11.1	0.2
23	Loutolim	24870	773	7	0	7	3.1	0.9	0.9	0.0	100.0	0.0	0.3
24	Chinchinim	27861	709	18	0	18	2.5	2.5	2.5	0.0	100.0	0.0	0.6
	TOTAL	1111094	105585	3182	288	3470	9.5	3.3	3.0	0.3	91.7	8.3	3.1

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 6: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1995.

Sr. No.	PHC/UHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43521	17095	1474	69	1543	39.3	9.0	8.6	0.4	95.5	4.5	35.5
2	Mapusa	35345	2116	102	5	107	6.0	5.1	4.8	0.2	95.3	4.7	3.0
3	Pernem	47556	2587	5	3	8	5.4	0.3	0.2	0.1	62.5	37.5	0.2
4	Candolim	49879	4441	385	29	414	8.9	9.3	8.7	0.7	93.0	7.0	8.3
5	Aldona	51944	2423	525	62	587	4.7	24.2	21.7	2.6	89.4	10.6	11.3
6	Bicholim	49035	3186	22	0	22	6.5	0.7	0.7	0.0	100.0	0.0	0.4
7	Valpoi	53195	3030	7	0	7	5.7	0.2	0.2	0.0	100.0	0.0	0.1
8	Ponda	74629	11282	17	0	17	15.1	0.2	0.2	0.0	100.0	0.0	0.2
9	Betki	45205	2330	14	1	15	5.2	0.6	0.6	0.0	93.3	6.7	0.3
10	Cansarvarnem	21283	2218	10	0	10	10.4	0.5	0.5	0.0	100.0	0.0	0.5
11	Siolim	40662	1362	4	0	4	3.3	0.3	0.3	0.0	100.0	0.0	0.1
12	Colvale	27385	1566	8	0	8	5.7	0.5	0.5	0.0	100.0	0.0	0.3
13	Corlim	77453	2495	328	19	347	3.2	13.9	13.1	0.8	94.5	5.5	4.5
14	Margao	67116	8205	417	52	469	12.2	5.7	5.1	0.6	88.9	11.1	7.0
15	Vasco	89020	3239	135	0	135	3.6	4.2	4.2	0.0	100.0	0.0	1.5
16	Cansaulim	38342	1645	58	12	70	4.3	4.3	3.5	0.7	82.9	17.1	1.8
17	Curtorim	55156	1418	15	1	16	2.6	1.1	1.1	0.1	93.8	6.3	0.3
18	Bali	37833	3618	50	0	50	9.6	1.4	1.4	0.0	100.0	0.0	1.3
19	Canacona	42044	4334	28	0	28	10.3	0.6	0.6	0.0	100.0	0.0	0.7
20	Curchorem	45493	7614	6	0	6	16.7	0.1	0.1	0.0	100.0	0.0	0.1
21	Sanguem	43198	3917	4	0	4	9.1	0.1	0.1	0.0	100.0	0.0	0.1
22	Cortalim	40752	1556	2	1	3	3.8	0.2	0.1	0.1	66.7	33.3	0.1
23	Loutolim	25095	668	12	2	14	2.7	2.1	1.8	0.3	85.7	14.3	0.6
24	Chinchinim	27980	1033	2	0	2	3.7	0.2	0.2	0.0	100.0	0.0	0.1
	TOTAL	1129121	93378	3630	256	3886	8.3	4.2	3.9	0.3	93.4	6.6	3.4

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 7: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1996.

Sr. No.	PHC/UHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43565	42063	3716	607	4323	96.6	10.3	8.8	1.4	86.0	14.0	99.2
2	Mapusa	36330	5649	225	15	240	15.5	4.2	4.0	0.3	93.8	6.3	6.6
3	Pernem	47920	3146	19	0	19	6.6	0.6	0.6	0.0	100.0	0.0	0.4
4	Candolim	51096	15756	2935	401	3336	30.8	21.2	18.6	2.5	88.0	12.0	65.3
5	Aldona	53012	8588	912	285	1197	16.2	13.9	10.6	3.3	76.2	23.8	22.6
6	Bicholim	49427	4375	71	0	71	8.9	1.6	1.6	0.0	100.0	0.0	1.4
7	Valpoi	54153	2196	10	9	19	4.1	0.9	0.5	0.4	52.6	47.4	0.4
8	Ponda	76344	11556	123	2	125	15.1	1.1	1.1	0.0	98.4	1.6	1.6
9	Betki	45838	2223	42	6	48	4.8	2.2	1.9	0.3	87.5	12.5	1.0
10	Cansarvarnem	21466	1458	7	0	7	6.8	0.5	0.5	0.0	100.0	0.0	0.3
11	Siolim	41175	1712	12	0	12	4.2	0.7	0.7	0.0	100.0	0.0	0.3
12	Colvale	27778	984	13	1	14	3.5	1.4	1.3	0.1	92.9	7.1	0.5
13	Corlim	78460	7685	632	105	737	9.8	9.6	8.2	1.4	85.8	14.2	9.4
14	Margao	69328	8092	779	93	872	11.7	10.8	9.6	1.1	89.3	10.7	12.6
15	Vasco	90492	4864	270	0	270	5.4	5.6	5.6	0.0	100.0	0.0	3.0
16	Cansaulim	38682	1674	69	13	82	4.3	4.9	4.1	0.8	84.1	15.9	2.1
17	Curtorim	56744	2315	20	0	20	4.1	0.9	0.9	0.0	100.0	0.0	0.4
18	Bali	38154	3222	40	0	40	8.4	1.2	1.2	0.0	100.0	0.0	1.0
19	Canacona	42383	8174	71	1	72	19.3	0.9	0.9	0.0	98.6	1.4	1.7
20	Curchorem	46114	6567	50	0	50	14.2	0.8	0.8	0.0	100.0	0.0	1.1
21	Sanguem	43585	4466	16	0	16	10.2	0.4	0.4	0.0	100.0	0.0	0.4
22	Cortalim	42060	1680	7	0	7	4.0	0.4	0.4	0.0	100.0	0.0	0.2
23	Loutolim	25321	1312	49	1	50	5.2	3.8	3.7	0.1	98.0	2.0	2.0
24	Chinchinim	28098	1388	5	0	5	4.9	0.4	0.4	0.0	100.0	0.0	0.2
	TOTAL	1147525	151145	10093	1539	11632	13.2	7.7	6.7	1.0	86.8	13.2	10.1

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 8: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1997.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43609	51150	5148	2442	7590	117.3	14.8	10.1	4.8	67.8	32.2	174.0
2	Mapusa	37341	8505	230	35	265	22.8	3.1	2.7	0.4	86.8	13.2	7.1
3	Pernem	48288	2924	13	1	14	6.1	0.5	0.4	0.0	92.9	7.1	0.3
4	Candolim	52342	24572	3316	1517	4833	46.9	19.7	13.5	6.2	68.6	31.4	92.3
5	Aldona	54103	15518	1339	939	2278	28.7	14.7	8.6	6.1	58.8	41.2	42.1
6	Bicholim	49821	8047	165	23	188	16.2	2.3	2.1	0.3	87.8	12.2	3.8
7	Valpoi	55128	3862	46	19	65	7.0	1.7	1.2	0.5	70.8	29.2	1.2
8	Ponda	78098	18908	207	4	211	24.2	1.1	1.1	0.0	98.1	1.9	2.7
9	Betki	46480	5578	91	14	105	12.0	1.9	1.6	0.3	86.7	13.3	2.3
10	Cansarvarnem	21651	2315	7	0	7	10.7	0.3	0.3	0.0	100.0	0.0	0.3
11	Siolim	41695	3293	70	3	73	7.9	2.2	2.1	0.1	95.9	4.1	1.8
12	Colvale	28177	1418	25	8	33	5.0	2.3	1.8	0.6	75.8	24.2	1.2
13	Corlim	79478	14043	1145	279	1424	17.7	10.1	8.2	2.0	80.4	19.6	17.9
14	Marcaim	20790	1431	17	2	19	6.9	1.3	1.2	0.1	89.5	10.5	0.9
15	Margao	71614	22658	1958	408	2366	31.6	10.4	8.6	1.8	82.8	17.2	33.0
16	Vasco	91989	6924	301	33	334	7.5	4.8	4.3	0.5	90.1	9.9	3.6
17	Cansaulim	39026	1818	49	6	55	4.7	3.0	2.7	0.3	89.1	10.9	1.4
18	Curtorim	58377	8040	329	6	335	13.8	4.2	4.1	0.1	98.2	1.8	5.7
19	Bali	38478	4249	143	11	154	11.0	3.6	3.4	0.3	92.9	7.1	4.0
20	Canacona	42725	7091	105	5	110	16.6	1.6	1.5	0.1	95.5	4.5	2.6
21	Curchorem	46743	10496	195	17	212	22.5	2.0	1.9	0.2	92.0	8.0	4.5
22	Sanguem	43975	6103	109	5	114	13.9	1.9	1.8	0.1	95.6	4.4	2.6
23	Cortalim	43410	8862	88	2	90	20.4	1.0	1.0	0.0	97.8	2.2	2.1
24	Loutolim	25550	1823	22	12	34	7.1	1.9	1.2	0.7	64.7	35.3	1.3
25	Chinchinim	28218	4282	80	36	116	15.2	2.7	1.9	0.8	69.0	31.0	4.1
	TOTAL	1187106	243910	15198	5827	21025	20.5	8.6	6.2	2.4	72.3	27.7	17.7

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate.
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 9: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1998.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43653	55215	5316	3377	8693	126.5	15.7	9.6	6.1	61.2	38.8	199.1
2	Mapusa	38382	14484	264	114	378	37.7	2.6	1.8	0.8	69.8	30.2	9.8
3	Pednem	48658	4502	17	3	20	9.3	0.4	0.4	0.1	85.0	15.0	0.4
4	Candolim	53620	25157	3696	1476	5172	46.9	20.6	14.7	5.9	71.5	28.5	96.5
5	Aldona	55216	20422	2136	2101	4237	37.0	20.7	10.5	10.3	50.4	49.6	76.7
6	Bicholim	50219	15971	209	42	251	31.8	1.6	1.3	0.3	83.3	16.7	5.0
7	Valpoi	56120	5319	55	14	69	9.5	1.3	1.0	0.3	79.7	20.3	1.2
8	Ponda	79893	15788	365	5	370	19.8	2.3	2.3	0.0	98.6	1.4	4.6
9	Betki	47131	10039	52	12	64	21.3	0.6	0.5	0.1	81.3	18.8	1.4
10	Cansarvarnem	21838	1705	8	0	8	7.8	0.5	0.5	0.0	100.0	0.0	0.4
11	Siolim	42221	4428	107	3	110	10.5	2.5	2.4	0.1	97.3	2.7	2.6
12	Colvala	28581	2223	66	11	77	7.8	3.5	3.0	0.5	85.7	14.3	2.7
13	Corlim	80511	13147	1139	449	1588	16.3	12.1	8.7	3.4	71.7	28.3	19.7
14	Marcaim	20883	2624	15	2	17	12.6	0.6	0.6	0.1	88.2	11.8	0.8
15	Margao	73974	26131	2207	795	3002	35.3	11.5	8.4	3.0	73.5	26.5	40.6
16	Vasco	93510	12298	364	80	444	13.2	3.6	3.0	0.7	82.0	18.0	4.7
17	Cansaulim	39373	6154	185	85	270	15.6	4.4	3.0	1.4	68.5	31.5	6.9
18	Curtorim	60057	6711	78	1	79	11.2	1.2	1.2	0.0	98.7	1.3	1.3
19	Bali	38806	4465	87	11	98	11.5	2.2	1.9	0.2	88.8	11.2	2.5
20	Canacona	43069	10498	65	10	75	24.4	0.7	0.6	0.1	86.7	13.3	1.7
21	Curchorem	47380	10380	167	14	181	21.9	1.7	1.6	0.1	92.3	7.7	3.8
22	Sanguem	44368	8425	252	34	286	19.0	3.4	3.0	0.4	88.1	11.9	6.4
23	Cortalim	44804	7250	163	3	166	16.2	2.3	2.2	0.0	98.2	1.8	3.7
24	Loutolim	25781	2787	62	32	94	10.8	3.4	2.2	1.1	66.0	34.0	3.6
25	Chinchinim	28338	4313	79	13	92	15.2	2.1	1.8	0.3	85.9	14.1	3.2
26	Quepem	32706	4939	127	7	134	15.1	2.7	2.6	0.1	94.8	5.2	4.1
	TOTAL	1239092	295375	17281	8694	25975	23.8	8.8	5.9	2.9	66.5	33.5	21.0

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 10: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 1999.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43697	62620	2784	1734	4518	143.3	7.2	4.4	2.8	61.6	38.4	103.4
2	Mapusa	39451	19255	220	64	284	48.8	1.5	1.1	0.3	77.5	22.5	7.2
3	Pernem	49032	4011	19	0	19	8.2	0.5	0.5	0.0	100.0	0.0	0.4
4	Candolim	54928	27419	2001	929	2930	49.9	10.7	7.3	3.4	68.3	31.7	53.3
5	Aldona	56351	24695	1152	1107	2259	43.8	9.1	4.7	4.5	51.0	49.0	40.1
6	Bicholim	50620	12653	155	28	183	25.0	1.4	1.2	0.2	84.7	15.3	3.6
7	Valpoi	57130	4842	35	7	42	8.5	0.9	0.7	0.1	83.3	16.7	0.7
8	Ponda	81729	8064	73	7	80	9.9	1.0	0.9	0.1	91.3	8.8	1.0
9	Betki	47791	10578	93	12	105	22.1	1.0	0.9	0.1	88.6	11.4	2.2
10	Cansarvarnem	22026	1100	6	2	8	5.0	0.7	0.5	0.2	75.0	25.0	0.4
11	Siolim	42754	4076	48	13	61	9.5	1.5	1.2	0.3	78.7	21.3	1.4
12	Colvale	28991	1422	19	6	25	4.9	1.8	1.3	0.4	76.0	24.0	0.9
13	Corlim	81558	12704	533	175	708	15.6	5.6	4.2	1.4	75.3	24.7	8.7
14	Marcaim	20977	2299	6	2	8	11.0	0.3	0.3	0.1	75.0	25.0	0.4
15	Margao	76412	33526	1584	1093	2677	43.9	8.0	4.7	3.3	59.2	40.8	35.0
16	Vasco	95057	15201	300	113	413	16.0	2.7	2.0	0.7	72.6	27.4	4.3
17	Cansaulim	39723	4986	137	71	208	12.6	4.2	2.7	1.4	65.9	34.1	5.2
18	Curtorim	61785	4847	73	9	82	7.8	1.7	1.5	0.2	89.0	11.0	1.3
19	Bali	39135	4430	36	1	37	11.3	0.8	0.8	0.0	97.3	2.7	0.9
20	Canacona	43416	8630	63	13	76	19.9	0.9	0.7	0.2	82.9	17.1	1.8
21	Curchorem	48026	8665	157	26	183	18.0	2.1	1.8	0.3	85.8	14.2	3.8
22	Sanguem	44765	5698	130	19	149	12.7	2.6	2.3	0.3	87.2	12.8	3.3
23	Cortalim	46242	8296	92	68	160	17.9	1.9	1.1	0.8	57.5	42.5	3.5
24	Loutolim	26014	2228	57	38	95	8.6	4.3	2.6	1.7	60.0	40.0	3.7
25	Chinchinim	28458	2917	26	7	33	10.3	1.1	0.9	0.2	78.8	21.2	1.2
26	Quepem	32964	3449	33	4	37	10.5	1.1	1.0	0.1	89.2	10.8	1.1
	TOTAL	1259032	298611	9832	5548	15380	23.7	5.2	3.3	1.9	63.9	36.1	12.2

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 11: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2000.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43741	59497	2455	1369	3824	136.0	6.4	4.1	2.3	64.2	35.8	87.4
2	Mapusa	40487	14967	135	23	158	37.0	1.1	0.9	0.2	85.4	14.6	3.9
3	Pernem	49408	5651	24	0	24	11.4	0.4	0.4	0.0	100.0	0.0	0.5
4	Candolim	56268	22679	719	175	894	40.3	3.9	3.2	0.8	80.4	19.6	15.9
5	Aldona	57511	20398	450	123	573	35.5	2.8	2.2	0.6	78.5	21.5	10.0
6	Bicholim	51024	12095	69	7	76	23.7	0.6	0.6	0.1	90.8	9.2	1.5
7	Valpoi	58158	7620	48	2	50	13.1	0.7	0.6	0.0	96.0	4.0	0.9
8	Ponda	83608	7746	35	4	39	9.3	0.5	0.5	0.1	89.7	10.3	0.5
9	Betki	48460	10383	62	17	79	21.4	0.8	0.6	0.2	78.5	21.5	1.6
10	Cansarvarnem	22216	2201	22	4	26	9.9	1.2	1.0	0.2	84.6	15.4	1.2
11	Siolim	43293	4502	40	11	51	10.4	1.1	0.9	0.2	78.4	21.6	1.2
12	Colvale	29407	1158	6	0	6	3.9	0.5	0.5	0.0	100.0	0.0	0.2
13	Corlim	82618	11109	353	107	460	13.4	4.1	3.2	1.0	76.7	23.3	5.6
14	Marcaim	21071	2813	7	2	9	13.4	0.3	0.2	0.1	77.8	22.2	0.4
15	Shiroda	24323	989	6	0	6	4.1	0.6	0.6	0.0	100.0	0.0	0.2
16	Sankhali	39258	245	1	0	1	0.6	0.4	0.4	0.0	100.0	0.0	0.0
17	Margao	78031	32038	1362	402	1764	41.1	5.5	4.3	1.3	77.2	22.8	22.6
18	Vasco	96629	13336	110	40	150	13.8	1.1	0.8	0.3	73.3	26.7	1.6
19	Cansaulim	40076	6525	103	100	203	16.3	3.1	1.6	1.5	50.7	49.3	5.1
20	Curtorim	63563	6759	205	25	230	10.6	3.4	3.0	0.4	89.1	10.9	3.6
21	Bali	39468	4134	31	0	31	10.5	0.7	0.7	0.0	100.0	0.0	0.8
22	Canacona	43766	6965	69	2	71	15.9	1.0	1.0	0.0	97.2	2.8	1.6
23	Curchorem	48681	6256	52	10	62	12.9	1.0	0.8	0.2	83.9	16.1	1.3
24	Sanguem	45166	5568	37	9	46	12.3	0.8	0.7	0.2	80.4	19.6	1.0
25	Cortalim	47726	6793	144	37	181	14.2	2.7	2.1	0.5	79.6	20.4	3.8
26	Loutolim	26249	3129	78	27	105	11.9	3.4	2.5	0.9	74.3	25.7	4.0
27	Chinchinim	28579	2910	28	4	32	10.2	1.1	1.0	0.1	87.5	12.5	1.1
28	Quepem	33224	2776	13	0	13	8.4	0.5	0.5	0.0	100.0	0.0	0.4
	TOTAL	1342009	281242	6664	2500	9164	21.0	3.3	2.4	0.9	72.7	27.3	6.8

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 12: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2001.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43867	50626	3251	1873	5124	115.4	10.1	6.4	3.7	63.4	36.6	116.8
2	Mapusa	40549	16575	58	13	71	40.9	0.4	0.3	0.1	81.7	18.3	1.8
3	Pernem	49662	5550	22	0	22	11.2	0.4	0.4	0.0	100.0	0.0	0.4
4	Candolim	56345	20602	809	178	987	36.6	4.8	3.9	0.9	82.0	18.0	17.5
5	Aldona	57730	16561	465	74	539	28.7	3.3	2.8	0.4	86.3	13.7	9.3
6	Bicholim	51292	7061	35	9	44	13.8	0.6	0.5	0.1	79.5	20.5	0.9
7	Valpoi	58613	5045	35	3	38	8.6	0.8	0.7	0.1	92.1	7.9	0.6
8	Ponda	83806	5942	16	2	18	7.1	0.3	0.3	0.0	88.9	11.1	0.2
9	Betki	48817	7785	80	22	102	15.9	1.3	1.0	0.3	78.4	21.6	2.1
10	Cansarvarnem	22337	2703	21	6	27	12.1	1.0	0.8	0.2	77.8	22.2	1.2
11	Siolim	43553	4166	35	12	47	9.6	1.1	0.8	0.3	74.5	25.5	1.1
12	Colvale	29580	1850	23	2	25	6.3	1.4	1.2	0.1	92.0	8.0	0.8
13	Corlim	83277	9687	226	57	283	11.6	2.9	2.3	0.6	79.9	20.1	3.4
14	Marcaim	21147	3459	7	1	8	16.4	0.2	0.2	0.0	87.5	12.5	0.4
15	Shiroda	24460	1406	1	0	1	5.7	0.1	0.1	0.0	100.0	0.0	0.0
16	Sankhali	39442	6463	36	12	48	16.4	0.7	0.6	0.2	75.0	25.0	1.2
17	Margao	78383	33629	1404	412	1816	42.9	5.4	4.2	1.2	77.3	22.7	23.2
18	Vasco	97154	12931	124	88	212	13.3	1.6	1.0	0.7	58.5	41.5	2.2
19	Cansaulim	40297	6495	158	49	207	16.1	3.2	2.4	0.8	76.3	23.7	5.1
20	Curtorim	63409	6944	151	49	200	11.0	2.9	2.2	0.7	75.5	24.5	3.2
21	Bali	39682	4462	22	0	22	11.2	0.5	0.5	0.0	100.0	0.0	0.6
22	Canacona	43996	7993	331	66	397	18.2	5.0	4.1	0.8	83.4	16.6	9.0
23	Curchorem	48971	6531	143	22	165	13.3	2.5	2.2	0.3	86.7	13.3	3.4
24	Sanguem	45417	12572	787	84	871	27.7	6.9	6.3	0.7	90.4	9.6	19.2
25	Cortalim	47442	10344	670	250	920	21.8	8.9	6.5	2.4	72.8	27.2	19.4
26	Loutolim	26395	3141	57	24	81	11.9	2.6	1.8	0.8	70.4	29.6	3.1
27	Chinchinim	28678	3145	36	2	38	11.0	1.2	1.1	0.1	94.7	5.3	1.3
28	Quepem	33430	3643	18	0	18	10.9	0.5	0.5	0.0	100.0	0.0	0.5
	TOTAL	1347731	277311	9021	3310	12331	20.6	4.4	3.3	1.2	73.2	26.8	9.1

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 13: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2002.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43911	57982	5646	2247	7893	132.0	13.6	9.7	3.9	71.5	28.5	179.7
2	Mapusa	40630	15053	61	7	68	37.0	0.5	0.4	0.0	89.7	10.3	1.7
3	Pernem	49697	4804	28	0	28	9.7	0.6	0.6	0.0	100.0	0.0	0.6
4	Candolim	56458	17204	1386	262	1648	30.5	9.6	8.1	1.5	84.1	15.9	29.2
5	Aldona	57845	15151	1167	233	1400	26.2	9.2	7.7	1.5	83.4	16.6	24.2
6	Bicholim	55344	7442	64	20	84	13.4	1.1	0.9	0.3	76.2	23.8	1.5
7	Valpoi	59668	3175	40	2	42	5.3	1.3	1.3	0.1	95.2	4.8	0.7
8	Ponda	83974	8214	106	4	110	9.8	1.3	1.3	0.0	96.4	3.6	1.3
9	Betki	49500	7045	87	10	97	14.2	1.4	1.2	0.1	89.7	10.3	2.0
10	Cansarvarnem	22516	2960	31	2	33	13.1	1.1	1.0	0.1	93.9	6.1	1.5
11	Siolim	43597	3413	35	2	37	7.8	1.1	1.0	0.1	94.6	5.4	0.8
12	Colvale	29610	1859	17	7	24	6.3	1.3	0.9	0.4	70.8	29.2	0.8
13	Corlim	83360	8285	226	22	248	9.9	3.0	2.7	0.3	91.1	8.9	3.0
14	Marcaim	21155	3500	22	1	23	16.5	0.7	0.6	0.0	95.7	4.3	1.1
15	Shiroda	24482	1258	8	0	8	5.1	0.6	0.6	0.0	100.0	0.0	0.3
16	Sankhali	39466	3701	11	2	13	9.4	0.4	0.3	0.1	84.6	15.4	0.3
17	Margao	78618	36954	2387	190	2577	47.0	7.0	6.5	0.5	92.6	7.4	32.8
18	Vasco	97251	12799	147	43	190	13.2	1.5	1.1	0.3	77.4	22.6	2.0
19	Cansaulim	40329	5719	248	53	301	14.2	5.3	4.3	0.9	82.4	17.6	7.5
20	Curtorim	63536	7052	173	18	191	11.1	2.7	2.5	0.3	90.6	9.4	3.0
21	Bali	39999	4752	47	3	50	11.9	1.1	1.0	0.1	94.0	6.0	1.3
22	Canacona	44031	8288	547	142	689	18.8	8.3	6.6	1.7	79.4	20.6	15.6
23	Curchorem	49020	6083	74	2	76	12.4	1.2	1.2	0.0	97.4	2.6	1.6
24	Sanguem	45453	10049	352	15	367	22.1	3.7	3.5	0.1	95.9	4.1	8.1
25	Cortalim	47584	11192	386	52	438	23.5	3.9	3.4	0.5	88.1	11.9	9.2
26	Loutolim	26419	3958	97	6	103	15.0	2.6	2.5	0.2	94.2	5.8	3.9
27	Chinchinim	28689	2554	46	1	47	8.9	1.8	1.8	0.0	97.9	2.1	1.6
28	Quepem	33453	2988	31	2	33	8.9	1.1	1.0	0.1	93.9	6.1	1.0
	TOTAL	1355595	273434	13470	3348	16818	20.2	6.2	4.9	1.2	80.1	19.9	12.4

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 14: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2003.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43955	57061	4612	951	5563	129.8	9.7	8.1	1.7	82.9	17.1	126.6
2	Mapusa	40711	13155	75	7	82	32.3	0.6	0.6	0.1	91.5	8.5	2.0
3	Pernem	49731	6254	35	0	35	12.6	0.6	0.6	0.0	100.0	0.0	0.7
4	Candolim	56571	20538	1270	176	1446	36.3	7.0	6.2	0.9	87.8	12.2	25.6
5	Aldona	57961	14605	1052	99	1151	25.2	7.9	7.2	0.7	91.4	8.6	19.9
6	Bicholim	59716	6992	22	9	31	11.7	0.4	0.3	0.1	71.0	29.0	0.5
7	Valpoi	60742	6042	53	0	53	9.9	0.9	0.9	0.0	100.0	0.0	0.9
8	Ponda	84142	7270	17	0	17	8.6	0.2	0.2	0.0	100.0	0.0	0.2
9	Betki	50193	7556	59	0	59	15.1	0.8	0.8	0.0	100.0	0.0	1.2
10	Cansarvarnem	22696	2801	10	0	10	12.3	0.4	0.4	0.0	100.0	0.0	0.4
11	Siolim	43640	4374	37	7	44	10.0	1.0	0.8	0.2	84.1	15.9	1.0
12	Colvale	29639	3549	9	1	10	12.0	0.3	0.3	0.0	90.0	10.0	0.3
13	Corlim	83444	9341	197	12	209	11.2	2.2	2.1	0.1	94.3	5.7	2.5
14	Marcaim	21164	3568	2	0	2	16.9	0.1	0.1	0.0	100.0	0.0	0.1
15	Shiroda	24504	1894	15	0	15	7.7	0.8	0.8	0.0	100.0	0.0	0.6
16	Sankhali	39489	4553	13	0	13	11.5	0.3	0.3	0.0	100.0	0.0	0.3
17	Margao	78854	36363	1195	151	1346	46.1	3.7	3.3	0.4	88.8	11.2	17.1
18	Vasco	97348	10800	130	10	140	11.1	1.3	1.2	0.1	92.9	7.1	1.4
19	Cansaulim	40362	4039	100	22	122	10.0	3.0	2.5	0.5	82.0	18.0	3.0
20	Curtorim	63663	7205	36	0	36	11.3	0.5	0.5	0.0	100.0	0.0	0.6
21	Bali	40319	4330	136	0	136	10.7	3.1	3.1	0.0	100.0	0.0	3.4
22	Canacona	44066	4915	130	8	138	11.2	2.8	2.6	0.2	94.2	5.8	3.1
23	Curchorem	49069	5759	37	2	39	11.7	0.7	0.6	0.0	94.9	5.1	0.8
24	Sanguem	45490	6950	51	0	51	15.3	0.7	0.7	0.0	100.0	0.0	1.1
25	Cortalim	47727	16407	482	42	524	34.4	3.2	2.9	0.3	92.0	8.0	11.0
26	Loutolim	26443	4279	54	0	54	16.2	1.3	1.3	0.0	100.0	0.0	2.0
27	Chinchinim	28701	4494	24	6	30	15.7	0.7	0.5	0.1	80.0	20.0	1.0
28	Quepem	33477	3553	14	0	14	10.6	0.4	0.4	0.0	100.0	0.0	0.4
	TOTAL	1363817	278647	9867	1503	11370	20.4	4.1	3.5	0.5	86.8	13.2	8.3

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 15: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2004.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	43999	51408	3925	1063	4988	116.8	9.7	7.6	2.1	78.7	21.3	113.4
2	Mapusa	40792	12723	35	0	35	31.2	0.3	0.3	0.0	100.0	0.0	0.9
3	Pernem	49766	6025	1	0	1	12.1	0.0	0.0	0.0	100.0	0.0	0.0
4	Candolim	56684	18337	561	66	627	32.3	3.4	3.1	0.4	89.5	10.5	11.1
5	Aldona	58077	11461	648	156	804	19.7	7.0	5.7	1.4	80.6	19.4	13.8
6	Bicholim	64434	4182	0	0	0	6.5	0.0	0.0	0.0	0.0	0.0	0.0
7	Valpoi	61835	4681	1	0	1	7.6	0.0	0.0	0.0	100.0	0.0	0.0
8	Ponda	84310	6040	15	0	15	7.2	0.2	0.2	0.0	100.0	0.0	0.2
9	Betki	50896	4840	11	0	11	9.5	0.2	0.2	0.0	100.0	0.0	0.2
10	Cansarvarnem	22877	2460	0	0	0	10.8	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	43684	3835	0	0	0	8.8	0.0	0.0	0.0	0.0	0.0	0.0
12	Colvale	29669	2154	3	1	4	7.3	0.2	0.1	0.0	75.0	25.0	0.1
13	Corlim	83527	9129	110	11	121	10.9	1.3	1.2	0.1	90.9	9.1	1.4
14	Marcaim	21172	2324	0	0	0	11.0	0.0	0.0	0.0	0.0	0.0	0.0
15	Shiroda	24526	1411	0	0	0	5.8	0.0	0.0	0.0	0.0	0.0	0.0
16	Sankhali	39513	5914	2	1	3	15.0	0.1	0.0	0.0	66.7	33.3	0.1
17	Margao	79091	29681	633	60	693	37.5	2.3	2.1	0.2	91.3	8.7	8.8
18	Vasco	97446	7826	61	1	62	8.0	0.6	0.8	0.0	98.4	1.6	0.6
19	Cansaulim	40394	2973	15	0	15	7.4	0.5	0.5	0.0	100.0	0.0	0.4
20	Curtorim	63790	6194	29	0	29	9.7	0.5	0.5	0.0	100.0	0.0	0.5
21	Bali	40642	4516	35	2	37	11.1	0.8	0.8	0.0	94.6	5.4	0.9
22	Canacona	44102	3826	25	1	26	8.7	0.7	0.7	0.0	96.2	3.8	0.6
23	Curchorem	49118	5814	13	2	15	11.8	0.3	0.2	0.0	86.7	13.3	0.3
24	Sanguem	45526	7869	14	0	14	17.3	0.2	0.2	0.0	100.0	0.0	0.3
25	Cortalim	47870	14464	309	22	331	30.2	2.3	2.1	0.2	93.4	6.6	6.9
26	Loutolim	26466	2381	2	0	2	9.0	0.1	0.1	0.0	100.0	0.0	0.1
27	Chinchinim	28712	3169	1	0	1	11.0	0.0	0.0	0.0	100.0	0.0	0.0
28	Quepem	33500	3406	3	1	4	10.2	0.1	0.1	0.0	75.0	25.0	0.1
	TOTAL	1372418	239043	6452	1387	7839	17.4	3.3	2.7	0.6	82.3	17.7	5.7

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 16: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2005.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	44036	40833	853	159	1012	92.7	2.5	2.1	0.4	84.3	15.7	23.0
2	Mapusa	43097	16262	31	1	32	37.7	0.2	0.2	0.0	96.9	3.1	0.7
3	Pernem	50604	6897	0	0	0	13.6	0.0	0.0	0.0	0.0	0.0	0.0
4	Candolim	59523	23839	597	83	680	40.1	2.9	2.5	0.3	87.8	12.2	11.4
5	Aldona	60538	11620	455	32	487	19.2	4.2	3.9	0.3	93.4	6.6	8.0
6	Bicholim	59019	7900	0	0	0	13.4	0.0	0.0	0.0	0.0	0.0	0.0
7	Valpoi	62643	4938	0	0	0	7.9	0.0	0.0	0.0	0.0	0.0	0.0
8	Ponda	86338	7541	17	0	17	8.7	0.2	0.2	0.0	100.0	0.0	0.2
9	Betki	51452	5831	8	0	8	11.3	0.1	0.1	0.0	100.0	0.0	0.2
10	Cansarvarnem	22554	2999	0	0	0	13.3	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	44203	6130	5	1	6	13.9	0.1	0.1	0.0	83.3	16.7	0.1
12	Colvale	30092	3827	0	0	0	12.7	0.0	0.0	0.0	0.0	0.0	0.0
13	Corlim	84455	13972	222	14	236	16.5	1.7	1.6	0.1	94.1	5.9	2.8
14	Marcaim	21248	2723	0	0	0	12.8	0.0	0.0	0.0	0.0	0.0	0.0
15	Shiroda	24716	3307	0	0	0	13.4	0.0	0.0	0.0	0.0	0.0	0.0
16	Sankhali	39723	8223	0	0	0	20.7	0.0	0.0	0.0	0.0	0.0	0.0
17	Margao	82080	31748	1043	134	1177	38.7	3.7	3.3	0.4	88.6	11.4	14.3
18	Vasco	99137	8340	36	2	38	8.4	0.5	0.4	0.0	94.7	5.3	0.4
19	Cansaulim	40702	4649	0	0	0	11.4	0.0	0.0	0.0	0.0	0.0	0.0
20	Curtorim	65934	6102	13	0	13	9.3	0.2	0.2	0.0	100.0	0.0	0.2
21	Ball	40062	5318	10	0	10	13.3	0.2	0.2	0.0	100.0	0.0	0.2
22	Canacona	44394	6356	9	0	9	14.3	0.1	0.1	0.0	100.0	0.0	0.2
23	Curchorem	49770	6331	1	0	1	12.7	0.0	0.0	0.0	100.0	0.0	0.0
24	Sanguem	45877	6891	2	0	2	15.0	0.0	0.0	0.0	100.0	0.0	0.0
25	Cortalim	49607	10278	11	2	13	20.7	0.1	0.1	0.0	84.6	15.4	0.3
26	Loutolim	26665	3433	0	2	2	12.9	0.1	0.0	0.1	0.0	100.0	0.1
27	Chinchinim	28808	3673	1	0	1	12.8	0.0	0.0	0.0	100.0	0.0	0.0
28	Quepem	33704	4209	3	0	3	12.5	0.1	0.1	0.0	100.0	0.0	0.1
	TOTAL	1390981	264170	3317	430	3747	19.0	1.4	1.3	0.2	88.5	11.5	2.7

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 17: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2006.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	44086	36240	1196	392	1588	82.2	4.4	3.3	1.1	75.3	24.7	36.0
2	Mapusa	43871	12845	36	3	39	29.3	0.3	0.3	0.0	92.3	7.7	0.9
3	Pernem	50910	8300	2	0	2	16.3	0.0	0.0	0.0	100.0	0.0	0.0
4	Candolim	60487	27788	858	404	1262	45.9	4.5	3.1	1.5	68.0	32.0	20.9
5	Aldona	61398	15643	651	107	758	25.5	4.8	4.2	0.7	85.9	14.1	12.3
6	Bicholim	60000	5184	0	0	0	8.6	0.0	0.0	0.0	0.0	0.0	0.0
7	Valpoi	63583	4135	0	0	0	6.5	0.0	0.0	0.0	0.0	0.0	0.0
8	Ponda	87997	8536	16	4	20	9.7	0.2	0.2	0.0	80.0	20.0	0.2
9	Betki	52075	6572	25	2	27	12.6	0.4	0.4	0.0	92.6	7.4	0.5
10	Cansarvarnem	22735	3037	0	0	0	13.4	0.0	0.0	0.0	0.0	0.0	0.0
11	Siolim	44706	8101	6	6	12	18.1	0.1	0.1	0.1	50.0	50.0	0.3
12	Colvale	30476	4127	1	0	1	13.5	0.0	0.0	0.0	100.0	0.0	0.0
13	Corlim	85450	15839	185	59	244	18.5	1.5	1.2	0.4	75.8	24.2	2.9
14	Marcaim	21340	4205	6	0	6	19.7	0.1	0.1	0.0	100.0	0.0	0.3
15	Shiroda	24928	3386	1	0	1	13.6	0.0	0.0	0.0	100.0	0.0	0.0
16	Sankhali	39968	8263	6	0	6	20.7	0.1	0.1	0.0	100.0	0.0	0.2
17	Margao	84192	32139	736	203	939	38.2	2.9	2.3	0.6	78.4	21.6	11.2
18	Vasco	100574	9922	44	2	46	9.9	0.5	0.4	0.0	95.7	4.3	0.5
19	Cansaulim	41038	6840	3	1	4	16.7	0.1	0.0	0.0	75.0	25.0	0.1
20	Curtorim	67458	8695	7	4	11	12.9	0.1	0.1	0.0	63.6	36.4	0.2
21	Bali	40379	6487	2	0	2	16.1	0.0	0.0	0.0	100.0	0.0	0.0
22	Canacona	44728	7059	5	0	5	15.8	0.1	0.1	0.0	100.0	0.0	0.1
23	Curchorem	50378	6794	7	1	8	13.5	0.1	0.1	0.0	87.5	12.5	0.2
24	Sanguem	46258	7309	7	0	7	15.8	0.1	0.1	0.0	100.0	0.0	0.2
25	Cortalim	50857	7398	8	8	16	14.5	0.2	0.1	0.1	50.0	50.0	0.3
26	Loutolim	26889	4136	5	0	5	15.4	0.1	0.1	0.0	100.0	0.0	0.2
27	Chinchinim	28926	5552	0	0	0	19.2	0.0	0.0	0.0	0.0	0.0	0.0
28	Quepem	33954	3457	1	0	1	10.2	0.0	0.0	0.0	100.0	0.0	0.0
	TOTAL	1409643	277989	3814	1196	5010	19.7	1.8	1.4	0.4	76.1	23.9	3.6

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

Table 18: Malaria Parasitological Data of Goa (PHC/CHC/UHC wise) for the year 2007.

Sr. No.	PHC/UHC/CHC	POP	BSC/E	Pv	Pf	TOTAL	ABER	SPR	SVR	SFR	PV%	PF%	API
1	Panaji	44137	42343	2460	1596	4056	95.9	9.6	5.8	3.8	60.7	39.3	91.9
2	Mapusa	44645	20043	431	152	583	44.9	2.9	2.2	0.8	73.9	26.1	13.1
3	Pernem	51216	9520	14	5	19	18.6	0.2	0.1	0.1	73.7	26.3	0.4
4	Candolim	61451	34849	1711	1036	2747	56.7	7.9	4.9	3.0	62.3	37.7	44.7
5	Aldona	62257	19308	910	152	1062	31.0	5.5	4.7	0.8	85.7	14.3	17.1
6	Bicholim	60982	5938	1	0	1	9.7	0.0	0.0	0.0	100.0	0.0	0.0
7	Valpoi	64523	6174	5	4	9	9.6	0.1	0.1	0.1	55.6	44.4	0.1
8	Ponda	89657	7917	22	2	24	8.8	0.3	0.3	0.0	91.7	8.3	0.3
9	Betki	52697	6529	51	6	57	12.4	0.9	0.8	0.1	89.5	10.5	1.1
10	Cansarvarnem	22916	2511	3	5	8	11.0	0.3	0.1	0.2	37.5	62.5	0.3
11	Siolim	45210	11574	88	38	126	25.6	1.1	0.8	0.3	69.8	30.2	2.8
12	Colvale	30861	4880	22	5	27	15.8	0.6	0.5	0.1	81.5	18.5	0.9
13	Corlim	86445	20959	456	178	634	24.2	3.0	2.2	0.8	71.9	28.1	7.3
14	Marcaim	21432	4762	10	0	10	22.2	0.2	0.2	0.0	100.0	0.0	0.5
15	Shiroda	25139	4885	4	0	4	19.4	0.1	0.1	0.0	100.0	0.0	0.2
16	Sankhali	40213	9317	35	3	38	23.2	0.4	0.4	0.0	92.1	7.9	0.9
17	Margao	86304	40276	1001	292	1293	46.7	3.2	2.5	0.7	77.4	22.6	15.0
18	Vasco	102011	12491	109	35	144	12.2	1.2	0.9	0.3	75.7	24.3	1.4
19	Cansaulim	41374	10560	329	216	545	25.5	5.2	3.1	2.0	60.4	39.6	13.2
20	Curtorim	68981	9428	33	7	40	13.7	0.4	0.4	0.1	82.5	17.5	0.6
21	Bali	40697	6971	19	5	24	17.1	0.3	0.3	0.1	79.2	20.8	0.6
22	Canacona	45063	7073	21	6	27	15.7	0.4	0.3	0.1	77.8	22.2	0.6
23	Curchorem	50986	8700	32	5	37	17.1	0.4	0.4	0.1	86.5	13.5	0.7
24	Sanguem	46639	5704	8	0	8	12.2	0.1	0.1	0.0	100.0	0.0	0.2
25	Cortalim	52107	9016	191	78	269	17.3	3.0	2.1	0.9	71.0	29.0	5.2
26	Loutolim	27113	5286	142	16	158	19.5	3.0	2.7	0.3	89.9	10.1	5.8
27	Chinchinim	29044	6283	3	5	8	21.6	0.1	0.0	0.1	37.5	62.5	0.3
28	Quepem	34205	3903	2	1	3	11.4	0.1	0.1	0.0	66.7	33.3	0.1
	TOTAL	1428305	337200	8113	3848	11961	23.6	3.5	2.4	1.1	67.8	32.2	8.4

BSC/E=Blood slides collected/examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SFR = Slide Falciparum Rate
SVR = Slide Vivax Rate
PV% = Proportion of *P. vivax*
PF% = Proportion of *P. falciparum*
API = Annual Parasite Incidence

ANNEXURE No. 4

Table 1: Monthly Parasitological Data of Panaji for the year 1984

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42065	94	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Feb	42065	65	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Mar	42065	195	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Apr	42065	44	3	0	3	6.8	6.8	0.0	100.0	0.0	0.07
May	42065	43	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Jun	42065	126	2	0	2	1.6	1.6	0.0	0.0	0.0	0.05
Jul	42065	171	3	0	3	1.8	1.8	0.0	0.0	0.0	0.07
Aug	42065	379	1	0	1	0.3	0.3	0.0	100.0	0.0	0.02
Sep	42065	185	2	0	2	1.1	1.1	0.0	100.0	0.0	0.05
Oct	42065	187	1	0	1	0.5	0.5	0.0	100.0	0.0	0.02
Nov	42065	123	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Dec	42065	163	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Total	42065	1775	12	0	12	0.7	0.7	0.0	100.0	0.0	0.29

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 2: Monthly Parasitological Data of Panaji for the year 1985

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42249	239	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Feb	42249	118	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Mar	42249	46	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Apr	42249	52	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
May	42249	14	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Jun	42249	63	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Jul	42249	543	2	1	3	0.6	0.4	0.2	66.7	33.3	0.07
Aug	42249	676	2	0	2	0.3	0.3	0.0	100.0	0.0	0.05
Sep	42249	317	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Oct	42249	110	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Nov	42249	209	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Dec	42249	110	0	0	0	0.0	0.0	0.0	0.0	0.0	0.00
Total	42249	2497	4	1	5	0.2	0.2	0.0	80.0	20.0	0.12

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 3: Monthly Parasitological Data of Panaji for the year 1986

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42432	293	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	42432	74	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Mar	42432	45	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Apr	42432	225	1	0	1	0.4	0.4	0.0	100.0	0.0	0.0
May	42432	149	10	0	10	6.7	6.7	0.0	100.0	0.0	0.2
Jun	42432	1164	94	1	95	8.2	8.1	0.1	98.9	1.1	2.2
Jul	42432	981	167	0	167	17.0	17.0	0.0	100.0	0.0	3.9
Aug	42432	928	34	0	34	3.7	3.7	0.0	100.0	0.0	0.8
Sep	42432	1089	19	0	19	1.7	1.7	0.0	100.0	0.0	0.4
Oct	42432	906	7	0	7	0.8	0.8	0.0	100.0	0.0	0.2
Nov	42432	420	13	0	13	3.1	3.1	0.0	100.0	0.0	0.3
Dec	42432	265	6	0	6	2.3	2.3	0.0	100.0	0.0	0.1
Total	42432	6539	351	1	352	5.4	5.4	0.0	99.7	0.3	8.3

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 4: Monthly Parasitological Data of Panaji for the year 1987

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42616	330	4	0	4	1.2	1.2	0.0	100.0	0.0	0.1
Feb	42616	522	16	0	16	3.1	3.1	0.0	100.0	0.0	0.4
Mar	42616	1567	69	0	69	4.4	4.4	0.0	100.0	0.0	1.6
Apr	42616	1574	80	0	80	5.1	5.1	0.0	100.0	0.0	1.9
May	42616	725	153	0	153	21.1	21.1	0.0	100.0	0.0	3.6
Jun	42616	2796	345	1	346	12.4	12.3	0.0	99.7	0.3	8.1
Jul	42616	4015	985	0	985	24.5	24.5	0.0	100.0	0.0	23.1
Aug	42616	3980	729	0	729	18.3	18.3	0.0	100.0	0.0	17.1
Sep	42616	2257	649	1	650	28.8	28.8	0.0	99.8	0.2	15.3
Oct	42616	1305	435	1	436	33.4	33.3	0.1	99.8	0.2	10.2
Nov	42616	1306	489	0	489	37.4	37.4	0.0	100.0	0.0	11.5
Dec	42616	1333	455	4	459	34.4	34.1	0.3	99.1	0.9	10.8
Total	42616	21710	4409	7	4416	20.3	20.3	0.0	99.8	0.2	103.6

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 5: Monthly Parasitological Data of Panaji for the year 1988

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42799	1801	431	4	435	24.2	23.9	0.2	99.1	0.9	10.2
Feb	42799	1380	381	4	385	27.9	27.6	0.3	99.0	1.0	9.0
Mar	42799	1740	441	8	449	25.8	25.3	0.5	98.2	1.8	10.5
Apr	42799	1919	417	2	419	21.8	21.7	0.1	99.5	0.5	9.8
May	42799	2705	549	6	555	20.5	20.3	0.2	98.9	1.1	13.0
Jun	42799	3231	550	3	553	17.1	17.0	0.1	99.5	0.5	12.9
Jul	42799	4352	726	6	732	16.8	16.7	0.1	99.2	0.8	17.1
Aug	42799	4233	753	21	774	18.3	17.8	0.5	97.3	2.7	18.1
Sep	42799	2964	401	40	441	14.9	13.5	1.3	90.9	9.1	10.3
Oct	42799	2587	327	45	372	14.4	12.6	1.7	87.9	12.1	8.7
Nov	42799	1430	208	51	259	18.1	14.5	3.6	80.3	19.7	6.1
Dec	42799	1511	251	52	303	20.1	16.6	3.4	82.8	17.2	7.1
Total	42799	29853	5435	242	5677	19.0	18.2	0.8	95.7	4.3	132.6

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 6: Monthly Parasitological Data of Panaji for the year 1989

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	42983	1629	190	47	237	14.5	11.7	2.9	80.2	19.8	5.5
Feb	42983	1720	186	35	221	12.8	10.8	2.0	84.2	15.8	5.1
Mar	42983	1695	284	21	305	18.0	16.8	1.2	93.1	6.9	7.1
Apr	42983	1780	328	43	371	20.8	18.4	2.4	88.4	11.6	8.6
May	42983	1405	371	48	419	29.8	26.4	3.4	88.5	11.5	9.7
Jun	42983	1939	435	54	489	25.2	22.4	2.8	89.0	11.0	11.4
Jul	42983	3072	404	71	475	15.5	13.2	2.3	85.1	14.9	11.1
Aug	42983	3035	320	58	378	12.5	10.5	1.9	84.7	15.3	8.8
Sep	42983	1465	141	32	173	11.8	9.6	2.2	81.5	18.5	4.0
Oct	42983	1331	132	26	158	11.9	9.9	2.0	83.5	16.5	3.7
Nov	42983	1013	100	36	136	13.4	9.9	3.6	73.5	26.5	3.2
Dec	42983	892	112	49	161	18.0	12.6	5.5	69.6	30.4	3.7
Total	42983	20976	3003	520	3523	16.8	14.3	2.5	85.2	14.8	82.0

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 7: Monthly Parasitological Data of Panaji for the year 1990

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43166	1515	126	26	152	10.0	8.3	1.7	82.9	17.1	3.5
Feb	43166	1044	87	22	109	10.4	8.3	2.1	79.8	20.2	2.5
Mar	43166	890	103	13	116	13.0	11.6	1.5	88.8	11.2	2.7
Apr	43166	1820	88	28	116	6.4	4.8	1.5	75.9	24.1	2.7
May	43166	1831	340	23	363	19.8	18.6	1.3	93.7	6.3	8.4
Jun	43166	3902	658	75	733	18.8	16.9	1.9	89.8	10.2	17.0
Jul	43166	4974	773	126	899	18.1	15.5	2.5	86.0	14.0	20.8
Aug	43166	2665	361	158	519	19.5	13.5	5.9	69.6	30.4	12.0
Sep	43166	1948	208	116	324	16.6	10.7	6.0	64.2	35.8	7.5
Oct	43166	1556	169	85	254	16.3	10.9	5.5	66.5	33.5	5.9
Nov	43166	1597	198	38	236	14.8	12.4	2.4	83.9	16.1	5.5
Dec	43166	871	145	29	174	20.0	16.6	3.3	83.3	16.7	4.0
Total	43166	24613	3256	739	3995	16.2	13.2	3.0	81.5	18.5	92.5

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 8: Monthly Parasitological Data of Panaji for the year 1991

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43349	2368	255	11	266	11.2	10.8	0.5	95.9	4.1	6.1
Feb	43349	1144	236	7	243	21.2	20.6	0.6	97.1	2.9	5.6
Mar	43349	1633	189	6	195	11.9	11.6	0.4	96.9	3.1	4.5
Apr	43349	1657	212	2	214	12.9	12.8	0.1	99.1	0.9	4.9
May	43349	1281	155	9	164	12.8	12.1	0.7	94.5	5.5	3.8
Jun	43349	1774	132	2	134	7.6	7.4	0.1	98.5	1.5	3.1
Jul	43349	1761	109	7	116	6.6	6.2	0.4	94.0	6.0	2.7
Aug	43349	1532	63	6	69	4.5	4.1	0.4	91.3	8.7	1.6
Sep	43349	1119	32	5	37	3.3	2.9	0.4	86.5	13.5	0.9
Oct	43349	1298	25	13	38	2.9	1.9	1.0	65.8	34.2	0.9
Nov	43349	1027	36	10	46	4.5	3.5	1.0	78.3	21.7	1.1
Dec	43349	887	27	7	34	3.8	3.0	0.8	79.4	20.6	0.8
Total	43349	17481	1471	85	1556	8.9	8.4	0.5	94.5	5.5	35.9

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 9: Monthly Parasitological Data of Panaji for the year 1992

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43392	1038	30	0	30	2.9	2.9	0.0	100.0	0.0	0.7
Feb	43392	981	8	0	8	0.8	0.8	0.0	100.0	0.0	0.2
Mar	43392	762	20	7	27	3.5	2.6	0.9	74.1	25.9	0.6
Apr	43392	945	19	10	29	3.1	2.0	1.1	65.5	34.5	0.7
May	43392	1091	38	5	43	3.9	3.5	0.5	88.4	11.6	1.0
Jun	43392	820	37	12	49	6.0	4.5	1.5	75.5	24.5	1.1
Jul	43392	1524	23	8	31	2.0	1.5	0.5	74.2	25.8	0.7
Aug	43392	1561	30	9	39	2.5	1.9	0.6	76.9	23.1	0.9
Sep	43392	1320	30	14	44	3.3	2.3	1.1	68.2	31.8	1.0
Oct	43392	1072	52	5	57	5.3	4.9	0.5	91.2	8.8	1.3
Nov	43392	1022	36	14	50	4.9	3.5	1.4	72.0	28.0	1.2
Dec	43392	992	24	21	45	4.5	2.4	2.1	53.3	46.7	1.0
Total	43392	13128	347	105	452*	3.4	2.6	0.8	76.8	23.2	10.4

*Two *P. malariae* cases reported

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 10: Monthly Parasitological Data of Panaji for the year 1993

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43455	715	14	6	20	2.8	2.0	0.8	70.0	30.0	0.5
Feb	43455	696	16	2	18	2.6	2.3	0.3	88.9	11.1	0.4
Mar	43455	746	20	4	24	3.2	2.7	0.5	83.3	16.7	0.6
Apr	43455	561	48	0	48	8.6	8.6	0.0	100.0	0.0	1.1
May	43455	1160	76	5	81	7.0	6.6	0.4	93.8	6.2	1.9
Jun	43455	1192	136	16	152	12.8	11.4	1.3	89.5	10.5	3.5
Jul	43455	2178	197	37	234	10.7	9.0	1.7	84.2	15.8	5.4
Aug	43455	1785	185	23	208	11.7	10.4	1.3	88.9	11.1	4.8
Sep	43455	2226	146	37	183	8.2	6.6	1.7	79.8	20.2	4.2
Oct	43455	1644	127	43	170	10.3	7.7	2.6	74.7	25.3	3.9
Nov	43455	1447	85	29	114	7.9	5.9	2.0	74.6	25.4	2.6
Dec	43455	998	61	23	84	8.4	6.1	2.3	72.6	27.4	1.9
Total	43455	15348	1111	225	1336	8.7	7.2	1.5	83.2	16.8	30.7

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

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Table 11: Monthly Parasitological Data of Panaji for the year 1994

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43478	984	57	6	63	6.4	5.8	0.6	90.5	9.5	1.4
Feb	43478	821	56	3	59	7.2	6.8	0.4	94.9	5.1	1.4
Mar	43478	824	44	4	48	5.8	5.3	0.5	91.7	8.3	1.1
Apr	43478	721	46	4	50	6.9	6.4	0.6	92.0	8.0	1.2
May	43478	605	60	1	61	10.1	9.9	0.2	98.4	1.6	1.4
Jun	43478	1353	106	3	109	8.1	7.8	0.2	97.2	2.8	2.5
Jul	43478	1479	75	7	82	5.5	5.1	0.5	91.5	8.5	1.9
Aug	43478	1094	68	18	86	7.9	6.2	1.6	79.1	20.9	2.0
Sep	43478	979	34	9	43	4.4	3.5	0.9	79.1	20.9	1.0
Oct	43478	861	38	12	50	5.8	4.4	1.4	76.0	24.0	1.2
Nov	43478	842	58	6	64	7.6	6.9	0.7	90.6	9.4	1.5
Dec	43478	640	20	6	26	4.1	3.1	0.9	76.9	23.1	0.6
Total	43478	11203	662	79	741	6.6	5.9	0.7	89.3	10.7	17.0

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

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Table 12: Monthly Parasitological Data of Panaji for the year 1995

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43521	702	26	3	29	4.1	3.7	0.4	89.7	10.3	0.7
Feb	43521	835	26	0	26	3.1	3.1	0.0	100.0	0.0	0.6
Mar	43521	597	30	1	31	5.2	5.0	0.2	96.8	3.2	0.7
Apr	43521	550	13	1	14	2.5	2.4	0.2	92.9	7.1	0.3
May	43521	1077	27	1	28	2.6	2.5	0.1	96.4	3.6	0.6
Jun	43521	1568	126	1	127	8.1	8.0	0.1	99.2	0.8	2.9
Jul	43521	3001	214	14	228	7.6	7.1	0.5	93.9	6.1	5.2
Aug	43521	2460	254	4	258	10.5	10.3	0.2	98.4	1.6	5.9
Sep	43521	2445	283	8	291	11.9	11.6	0.3	97.3	2.7	6.7
Oct	43521	1876	198	12	210	11.2	10.6	0.6	94.3	5.7	4.8
Nov	43521	1673	186	14	200	12.0	11.1	0.8	93.0	7.0	4.6
Dec	43521	311	91	10	101	32.5	29.3	3.2	90.1	9.9	2.3
Total	43521	17095	1474	69	1543	9.0	8.6	0.4	95.5	4.5	35.5

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 13: Monthly Parasitological Data of Panaji for the year 1996

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43565	1461	204	26	230	15.7	14.0	1.8	88.7	11.3	5.3
Feb	43565	1429	174	8	182	12.7	12.2	0.6	95.6	4.4	4.2
Mar	43565	1375	170	16	186	13.5	12.4	1.2	91.4	8.6	4.3
Apr	43565	1683	279	21	300	17.8	16.6	1.2	93.0	7.0	6.9
May	43565	2675	382	15	397	14.8	14.3	0.6	96.2	3.8	9.1
Jun	43565	5013	384	22	406	8.1	7.7	0.4	94.6	5.4	9.3
Jul	43565	5485	401	32	433	7.9	7.3	0.6	92.6	7.4	9.9
Aug	43565	5674	500	72	572	10.1	8.8	1.3	87.4	12.6	13.1
Sep	43565	4197	336	62	398	9.5	8.0	1.5	84.4	15.6	9.1
Oct	43565	4552	283	102	385	8.5	6.2	2.2	73.5	26.5	8.8
Nov	43565	4593	287	114	401	8.7	6.2	2.5	71.6	28.4	9.2
Dec	43565	3926	316	117	433	11.0	8.0	3.0	73.0	27.0	9.9
Total	43565	42063	3716	607	4323	10.3	8.8	1.4	86.0	14.0	99.2

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 14: Monthly Parasitological Data of Panaji for the year 1997

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43609	3645	388	134	522	14.3	10.6	3.7	74.3	25.7	12.0
Feb	43609	2642	292	100	392	14.8	11.1	3.8	74.5	25.5	9.0
Mar	43609	2142	221	27	248	11.6	10.3	1.3	89.1	10.9	5.7
Apr	43609	3353	410	119	529	15.8	12.2	3.5	77.5	22.5	12.1
May	43609	3357	418	131	549	16.4	12.5	3.9	76.1	23.9	12.6
Jun	43609	4999	405	161	566	11.3	8.1	3.2	71.6	28.4	13.0
Jul	43609	7656	421	102	523	6.8	5.5	1.3	80.5	19.5	12.0
Aug	43609	5309	598	218	816	15.4	11.3	4.1	73.3	26.7	18.7
Sep	43609	6398	553	339	892	13.9	8.6	5.3	62.0	38.0	20.5
Oct	43609	5051	506	338	844	16.7	10.0	6.7	60.0	40.0	19.4
Nov	43609	2797	545	415	960	34.3	19.5	14.8	56.8	43.2	22.0
Dec	43609	3801	391	358	749	19.7	10.3	9.4	52.2	47.8	17.2
Total	43609	51150	5148	2442	7590	14.8	10.1	4.8	67.8	32.2	174.0

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of P. *vivax*
Pf% = Proportion of P. *falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 15: Monthly Parasitological Data of Panaji for the year 1998

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43653	3854	368	365	733	19.0	9.5	9.5	50.2	49.8	16.8
Feb	43653	2900	345	259	604	20.8	11.9	8.9	57.1	42.9	13.8
Mar	43653	2745	295	204	499	18.2	10.7	7.4	59.1	40.9	11.4
Apr	43653	3795	332	179	511	13.5	8.7	4.7	65.0	35.0	11.7
May	43653	3417	402	193	595	17.4	11.8	5.6	67.6	32.4	13.6
Jun	43653	4077	527	157	684	16.8	12.9	3.9	77.0	23.0	15.7
Jul	43653	5393	892	312	1204	22.3	16.5	5.8	74.1	25.9	27.6
Aug	43653	7438	593	317	910	12.2	8.0	4.3	65.2	34.8	20.8
Sep	43653	7741	564	481	1045	13.5	7.3	6.2	54.0	46.0	23.9
Oct	43653	5875	416	376	792	13.5	7.1	6.4	52.5	47.5	18.1
Nov	43653	4827	304	302	606	12.6	6.3	6.3	50.2	49.8	13.9
Dec	43653	3153	278	232	510	16.2	8.8	7.4	54.5	45.5	11.7
Total	43653	55215	5316	3377	8693	15.7	9.6	6.1	61.2	38.8	199.1

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 16: Monthly Parasitological Data of Panaji for the year 1999

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43697	3123	233	160	393	12.6	7.5	5.1	59.3	40.7	9.0
Feb	43697	2589	181	106	287	11.1	7.0	4.1	63.1	36.9	6.6
Mar	43697	5180	216	91	307	5.9	4.2	1.8	70.4	29.6	7.0
Apr	43697	6087	280	96	376	6.2	4.6	1.6	74.5	25.5	8.6
May	43697	5583	236	82	318	5.7	4.2	1.5	74.2	25.8	7.3
Jun	43697	6324	210	151	361	5.7	3.3	2.4	58.2	41.8	8.3
Jul	43697	7000	401	327	728	10.4	5.7	4.7	55.1	44.9	16.7
Aug	43697	7000	207	234	441	6.3	3.0	3.3	46.9	53.1	10.1
Sep	43697	5179	207	161	368	7.1	4.0	3.1	56.3	43.8	8.4
Oct	43697	5008	234	106	340	6.8	4.7	2.1	68.8	31.2	7.8
Nov	43697	5225	207	91	298	5.7	4.0	1.7	69.5	30.5	6.8
Dec	43697	4322	172	129	301	7.0	4.0	3.0	57.1	42.9	6.9
Total	43697	62620	2784	1734	4518	7.2	4.4	2.8	61.6	38.4	103.4

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 17: Monthly Parasitological Data of Panaji for the year 2000

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43741	4901	140	93	233	4.8	2.9	1.9	60.1	39.9	5.3
Feb	43741	4088	91	71	162	4.0	2.2	1.7	56.2	43.8	3.7
Mar	43741	4387	132	40	172	3.9	3.0	0.9	76.7	23.3	3.9
Apr	43741	2405	100	24	124	5.2	4.2	1.0	80.6	19.4	2.8
May	43741	4697	191	43	234	5.0	4.1	0.9	81.6	18.4	5.3
Jun	43741	6467	266	92	358	5.5	4.1	1.4	74.3	25.7	8.2
Jul	43741	7270	326	134	460	6.3	4.5	1.8	70.9	29.1	10.5
Aug	43741	6513	304	152	456	7.0	4.7	2.3	66.7	33.3	10.4
Sep	43741	5024	208	97	305	6.1	4.1	1.9	68.2	31.8	7.0
Oct	43741	4702	258	232	490	10.4	5.5	4.9	52.7	47.3	11.2
Nov	43741	5223	265	242	507	9.7	5.1	4.6	52.3	47.7	11.6
Dec	43741	3820	174	149	323	8.5	4.6	3.9	53.9	46.1	7.4
Total	43741	59497	2455	1369	3824	6.4	4.1	2.3	64.2	35.8	87.4

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 18: Monthly Parasitological Data of Panaji for the year 2001

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43867	4182	186	102	288	6.9	4.4	2.4	64.6	35.4	6.6
Feb	43867	3218	123	39	162	5.0	3.8	1.2	75.9	24.1	3.7
Mar	43867	2832	166	36	202	7.1	5.9	1.3	82.2	17.8	4.6
Apr	43867	2776	106	29	135	4.9	3.8	1.0	78.5	21.5	3.1
May	43867	3025	203	48	251	8.3	6.7	1.6	80.9	19.1	5.7
Jun	43867	5133	248	112	360	7.0	4.8	2.2	68.9	31.1	8.2
Jul	43867	6408	339	238	577	9.0	5.3	3.7	58.8	41.2	13.2
Aug	43867	4756	415	292	707	14.9	8.7	6.1	58.7	41.3	16.1
Sep	43867	6002	493	405	898	15.0	8.2	6.7	54.9	45.1	20.5
Oct	43867	5443	352	257	609	11.2	6.5	4.7	57.8	42.2	13.9
Nov	43867	4016	332	200	532	13.2	8.3	5.0	62.4	37.6	12.1
Dec	43867	2835	288	115	403	14.2	10.2	4.1	71.5	28.5	9.2
Total	43867	50626	3251	1873	5124	10.1	6.4	3.7	63.4	36.6	116.8

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 19: Monthly Parasitological Data of Panaji for the year 2002

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43911	4176	237	103	340	8.1	5.7	2.5	69.7	30.3	7.7
Feb	43911	4520	205	92	297	6.6	4.5	2.0	69.0	31.0	6.8
Mar	43911	3025	218	110	328	10.8	7.2	3.6	66.5	33.5	7.5
Apr	43911	3959	370	160	530	13.4	9.3	4.0	69.8	30.2	12.1
May	43911	3995	453	227	680	17.0	11.3	5.7	66.6	33.4	15.5
Jun	43911	4673	456	166	622	13.3	9.8	3.6	73.3	26.7	14.2
Jul	43911	7563	834	318	1152	15.2	11.0	4.2	72.4	27.6	26.2
Aug	43911	6012	633	196	829	13.8	10.5	3.3	76.4	23.6	18.9
Sep	43911	4567	561	144	705	15.4	12.3	3.2	79.6	20.4	16.1
Oct	43911	5401	592	262	854	15.8	11.0	4.9	69.3	30.7	19.4
Nov	43911	5729	598	265	863	15.1	10.4	4.6	69.3	30.7	19.7
Dec	43911	4362	489	204	693	15.9	11.2	4.7	70.6	29.4	15.8
Total	43911	57982	5646	2247	7893	13.6	9.7	3.9	71.5	28.5	179.7

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 20: Monthly Parasitological Data of Panaji for the year 2003

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43955	4047	412	106	518	12.8	10.2	2.6	79.5	20.5	11.8
Feb	43955	3442	371	73	444	12.9	10.8	2.1	83.6	16.4	10.1
Mar	43955	3917	370	92	462	11.8	9.4	2.3	80.1	19.9	10.5
Apr	43955	3770	394	109	503	13.3	10.5	2.9	78.3	21.7	11.4
May	43955	4137	273	49	322	7.8	6.6	1.2	84.8	15.2	7.3
Jun	43955	5271	374	39	413	7.8	7.1	0.7	90.6	9.4	9.4
Jul	43955	7947	406	45	451	5.7	5.1	0.6	90.0	10.0	10.3
Aug	43955	6988	530	88	618	8.8	7.6	1.3	85.8	14.2	14.1
Sep	43955	5776	386	108	494	8.6	6.7	1.9	78.1	21.9	11.2
Oct	43955	4406	375	106	481	10.9	8.5	2.4	78.0	22.0	10.9
Nov	43955	3988	378	73	451	11.3	9.5	1.8	83.8	16.2	10.3
Dec	43955	3372	343	63	406	12.0	10.2	1.9	84.5	15.5	9.2
Total	43955	57061	4612	951	5563	9.7	8.1	1.7	82.9	17.1	126.6

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 21: Monthly Parasitological Data of Panaji for the year 2004

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	43999	3233	261	45	306	9.5	8.1	1.4	85.3	14.7	7.0
Feb	43999	3291	207	12	219	6.7	6.3	0.4	94.5	5.5	5.0
Mar	43999	4098	270	28	298	7.3	6.6	0.7	90.6	9.4	6.8
Apr	43999	3751	316	63	379	10.1	8.4	1.7	83.4	16.6	8.6
May	43999	3736	365	97	462	12.4	9.8	2.6	79.0	21.0	10.5
Jun	43999	5144	505	191	696	13.5	9.8	3.7	72.6	27.4	15.8
Jul	43999	7064	426	153	579	8.2	6.0	2.2	73.6	26.4	13.2
Aug	43999	5485	399	84	483	8.8	7.3	1.5	82.6	17.4	11.0
Sep	43999	4158	407	120	527	12.7	9.8	2.9	77.2	22.8	12.0
Oct	43999	3606	256	107	363	10.1	7.1	3.0	70.5	29.5	8.3
Nov	43999	3714	292	98	390	10.5	7.9	2.6	74.9	25.1	8.9
Dec	43999	4128	221	65	286	6.9	5.4	1.6	77.3	22.7	6.5
Total	43999	51408	3925	1063	4988	9.7	7.6	2.1	78.7	21.3	113.4

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 22: Monthly Parasitological Data of Panaji for the year 2005

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	44036	4180	152	27	179	4.3	3.6	0.6	84.9	15.1	4.1
Feb	44036	3797	88	13	101	2.7	2.3	0.3	87.1	12.9	2.3
Mar	44036	3244	44	10	54	1.7	1.4	0.3	81.5	18.5	1.2
Apr	44036	2475	31	4	35	1.4	1.3	0.2	88.6	11.4	0.8
May	44036	2462	50	9	59	2.4	2.0	0.4	84.7	15.3	1.3
Jun	44036	3715	62	13	75	2.0	1.7	0.3	82.7	17.3	1.7
Jul	44036	5593	78	19	97	1.7	1.4	0.3	80.4	19.6	2.2
Aug	44036	5229	75	13	88	1.7	1.4	0.2	85.2	14.8	2.0
Sep	44036	3026	84	8	92	3.0	2.8	0.3	91.3	8.7	2.1
Oct	44036	3250	68	15	83	2.6	2.1	0.5	81.9	18.1	1.9
Nov	44036	2193	70	15	85	3.9	3.2	0.7	82.4	17.6	1.9
Dec	44036	1669	51	13	64	3.8	3.1	0.8	79.7	20.3	1.5
Total	44036	40833	853	159	1012	2.5	2.1	0.4	84.3	15.7	23.0

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 23: Monthly Parasitological Data of Panaji for the year 2006

MONTH	POP	BSC/E	Pv	Pf	TOTAL	SPR	SVR	SFR	PV%	PF%	MPI
Jan	44086	1588	46	11	57	3.6	2.9	0.7	80.7	19.3	1.3
Feb	44086	1747	25	6	31	1.8	1.4	0.3	80.6	19.4	0.7
Mar	44086	1613	28	2	30	1.9	1.7	0.1	93.3	6.7	0.7
Apr	44086	1782	32	6	38	2.1	1.8	0.3	84.2	15.8	0.9
May	44086	1859	87	10	97	5.2	4.7	0.5	89.7	10.3	2.2
Jun	44086	3476	113	23	136	3.9	3.3	0.7	83.1	16.9	3.1
Jul	44086	3497	156	31	187	5.3	4.5	0.9	83.4	16.6	4.2
Aug	44086	3789	157	71	228	6.0	4.1	1.9	68.9	31.1	5.2
Sep	44086	3186	139	45	184	5.8	4.4	1.4	75.5	24.5	4.2
Oct	44086	5574	180	62	242	4.3	3.2	1.1	74.4	25.6	5.5
Nov	44086	4598	132	65	197	4.3	2.9	1.4	67.0	33.0	4.5
Dec	44086	3531	101	60	161	4.6	2.9	1.7	62.7	37.3	3.7
Total	44086	36240	1196	392	1588	4.4	3.3	1.1	75.3	24.7	36.0

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

Annexure No. 4

Table 24: Monthly Parasitological Data of Panaji for the year 2007

MONTH	POP	BSC/E	Pv	Pf	Total	SPR	SVR	SFR	PV%	PF%	MPI
Jan	44137	1454	139	42	181	12.4	9.6	2.9	76.8	23.2	4.1
Feb	44137	1555	117	43	160	10.3	7.5	2.8	73.1	26.9	3.6
Mar	44137	1548	120	33	153	9.9	7.8	2.1	78.4	21.6	3.5
Apr	44137	1735	134	64	198	11.4	7.7	3.7	67.7	32.3	4.5
May	44137	2170	301	46	347	16.0	13.9	2.1	86.7	13.3	7.9
Jun	44137	5672	363	174	537	9.5	6.4	3.1	67.6	32.4	12.2
Jul	44137	7768	276	253	529	6.8	3.6	3.3	52.2	47.8	12.0
Aug	44137	6193	233	261	494	8.0	3.8	4.2	47.2	52.8	11.2
Sep	44137	4488	177	160	337	7.5	3.9	3.6	52.5	47.5	7.6
Oct	44137	4862	231	204	435	8.9	4.8	4.2	53.1	46.9	9.9
Nov	44137	2207	213	190	403	18.3	9.7	8.6	52.9	47.1	9.1
Dec	44137	2691	156	126	282	10.5	5.8	4.7	55.3	44.7	6.4
Total	44137	42343	2460	1596	4056	9.6	5.8	3.8	60.7	39.3	91.9

Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pv% = Proportion of *P. vivax*
Pf% = Proportion of *P. falciparum*
MPI =Monthly Parasite Incidence

ANNEXURE 5

Table1: Malaria Incidence in UHC - Panaji (1984-2007)

YEAR	POP	BSC/E	PV	PF	TOTAL CASES	ABER	SPR	SVR	SFR	Pf%	API
1984	42065	1775	12	0	12	4.2	0.7	0.7	0.0	0	0.3
1985	42249	2497	4	1	5	5.9	0.2	0.2	0.0	20	0.1
1986	42432	6539	351	1	352	15.4	5.4	5.4	0.0	0.3	8.3
1987	42616	21710	4409	7	4416	50.9	20.3	20.3	0.0	0.2	103.6
1988	42799	29853	5435	242	5677	69.8	19.0	18.2	0.8	4.3	132.6
1989	42983	20976	3003	520	3523	48.8	16.8	14.3	2.5	14.8	82.0
1990	43166	24613	3256	739	3995	57.0	16.2	13.2	3.0	18.5	92.5
1991	43349	17481	1471	85	1556	40.3	8.9	8.4	0.5	5.5	35.9
1992	43392	13128	347	105	452*	30.3	3.4	2.6	0.8	23.2	10.4
1993	43455	15348	1111	225	1336	35.3	8.7	7.2	1.5	16.8	30.7
1994	43478	11203	662	79	741	25.8	6.6	5.9	0.7	10.7	17.0
1995	43521	17095	1474	69	1543	39.3	9.0	8.6	0.4	4.5	35.5
1996	43565	42063	3716	607	4323	96.6	10.3	8.8	1.4	14.0	99.2
1997	43609	51150	5148	2442	7590	117.3	14.8	10.1	4.8	32.2	174.0
1998	43653	55215	5316	3377	8693	126.5	15.7	9.6	6.1	38.8	199.1
1999	43697	62620	2784	1734	4518	143.3	7.2	4.4	2.8	38.4	103.4
2000	43741	59497	2455	1369	3824	136.0	6.4	4.1	2.3	35.8	87.4
2001	43867	50626	3251	1873	5124	115.4	10.1	6.4	3.7	36.6	116.8
2002	43911	57982	5646	2247	7893	132.0	13.6	9.7	3.9	28.5	179.7
2003	43955	57061	4612	951	5563	129.8	9.7	8.1	1.7	17.1	126.6
2004	43999	51408	3925	1063	4988	116.8	9.7	7.6	2.1	21.3	113.4
2005	44036	40833	853	159	1012	92.7	2.5	2.1	0.4	15.7	23.0
2006	44086	36240	1196	392	1588	82.2	4.4	3.3	1.1	24.7	36.0
2007	44137	42343	2460	1596	4056	95.9	9.6	5.8	3.8	39.3	91.9

* Two *P. malariae* cases reported

POP = Population
BSC/E=Blood slides collected/Examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pf% = Proportion of *P. falciparum*
API =Annual Parasite Incidence

Annexure No. 5

Table 2: Malaria Incidence in UHC - Margao (1990-2007)

YEAR	POP	BSC/E	PV	PF	TOTAL CASES	ABER	SPR	SVR	SFR	Pf%	API
1990	57136	2559	15	0	15	4.5	0.6	0.6	0.0	0.0	0.26
1991	58951	1885	11	0	11	3.2	0.6	0.6	0.0	0.0	0.19
1992	60894	2718	9	1	10	4.5	0.4	0.3	0.0	10.0	0.16
1993	62901	5149	15	1	16	8.2	0.3	0.3	0.0	6.3	0.25
1994	64975	6598	205	53	258	10.2	3.9	3.1	0.8	20.5	3.97
1995	67116	8205	417	52	469	12.2	5.7	5.1	0.6	11.1	6.99
1996	69328	8092	779	93	872	11.7	10.8	9.6	1.1	10.7	12.58
1997	71614	22658	1958	408	2366	31.6	10.4	8.6	1.8	17.2	33.04
1998	73974	26131	2207	795	3002	35.3	11.5	8.4	3.0	26.5	40.58
1999	76412	33526	1584	1093	2677	43.9	8.0	4.7	3.3	40.8	35.03
2000	78031	32038	1362	402	1764	41.1	5.5	4.3	1.3	22.8	22.61
2001	78383	33629	1404	412	1816	42.9	5.4	4.2	1.2	22.7	23.17
2002	78618	36954	2387	190	2577	47.0	7.0	6.5	0.5	7.4	32.78
2003	78854	36363	1195	151	1346	46.1	3.7	3.3	0.4	11.2	17.07
2004	79091	29681	633	60	693	37.5	2.3	2.1	0.2	8.7	8.76
2005	82080	31748	1043	134	1177	38.7	3.7	3.3	0.4	11.4	14.34
2006	84192	32139	736	203	939	38.2	2.9	2.3	0.6	21.6	11.15
2007	86304	40276	1001	292	1293	46.7	3.2	2.5	0.7	22.6	14.98

POP = Population
BSC/E=Blood slides collected/Examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pf% = Proportion of *P. falciparum*
API =Annual Parasite Incidence

Annexure No. 5

Table 3: Malaria Incidence in PHC - Aldona (1990-2007)

YEAR	POP	BSC/E	PV	PF	TOTAL CASES	ABER	SPR	SVR	SPR	Pf%	API
1990	46876	2816	14	4	18	6.0	0.6	0.5	0.1	22.2	0.4
1991	47881	1632	8	1	9	3.4	0.6	0.5	0.1	11.1	0.2
1992	48866	1975	26	13	39	4.0	2.0	1.3	0.7	33.3	0.8
1993	49871	2638	178	48	226	5.3	8.6	6.7	1.8	21.2	4.5
1994	50897	3817	368	43	411	7.5	10.8	9.6	1.1	10.5	8.1
1995	51944	2423	525	62	587	4.7	24.2	21.7	2.6	10.6	11.3
1996	53012	8588	912	285	1197	16.2	13.9	10.6	3.3	23.8	22.6
1997	54103	15518	1339	939	2278	28.7	14.7	8.6	6.1	41.2	42.1
1998	55216	20422	2136	2101	4237	37.0	20.7	10.5	10.3	49.6	76.7
1999	56351	24695	1152	1107	2259	43.8	9.1	4.7	4.5	49.0	40.1
2000	57511	20398	450	123	573	35.5	2.8	2.2	0.6	21.5	10.0
2001	57730	16561	465	74	539	28.7	3.3	2.8	0.4	13.7	9.3
2002	57845	15151	1167	233	1400	26.2	9.2	7.7	1.5	16.6	24.2
2003	57961	14605	1052	99	1151	25.2	7.9	7.2	0.7	8.6	19.9
2004	58077	11461	648	156	804	19.7	7.0	5.7	1.4	19.4	13.8
2005	60538	11620	455	32	487	19.2	4.2	3.9	0.3	6.6	8.0
2006	61398	15643	651	107	758	25.5	4.8	4.2	0.7	14.1	12.3
2007	62257	19308	910	152	1062	31.0	5.5	4.7	0.8	14.3	17.1

POP = Population
BSC/E=Blood slides collected/Examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pf% = Proportion of *P. falciparum*
API =Annual Parasite Incidence

Annexure No. 5

Table 4: Malaria Incidence in PHC - Candolim (1990-2007)

YEAR	POP	BSC	PV	PF	TOTAL	ABER	SPR	SVR	SFR	Pf%	API
1990	45294	5712	148	30	178	12.6	3.1	2.6	0.5	16.9	3.8
1991	46399	4708	101	14	115	10.1	2.4	2.1	0.3	12.2	2.5
1992	47109	3843	19	9	28	8.2	0.7	0.5	0.2	32.1	0.6
1993	47531	3988	247	14	261	8.4	6.5	6.2	0.4	5.4	5.5
1994	48691	9752	1356	77	1433	20.0	14.7	13.9	0.8	5.4	29.4
1995	49879	4441	385	29	414	8.9	9.3	8.7	0.7	7.0	8.3
1996	51096	15756	2935	401	3336	30.8	21.2	18.6	2.5	12.0	65.3
1997	52342	24572	3316	1517	4833	46.9	19.7	13.5	6.2	31.4	92.3
1998	53620	25157	3696	1476	5172	46.9	20.6	14.7	5.9	28.5	96.5
1999	54928	27419	2001	929	2930	49.9	10.7	7.3	3.4	31.7	53.3
2000	56268	22679	719	175	894	40.3	3.9	3.2	0.8	19.6	15.9
2001	56345	20602	809	178	987	36.6	4.8	3.9	0.9	18.0	17.5
2002	56458	17204	1386	262	1648	30.5	9.6	8.1	1.5	15.9	29.2
2003	56571	20538	1270	176	1446	36.3	7.0	6.2	0.9	12.2	25.6
2004	56684	18337	561	66	627	32.3	3.4	3.1	0.4	10.5	11.1
2005	59523	23839	597	83	680	40.1	2.9	2.5	0.3	12.2	11.4
2006	60487	27788	858	404	1262	45.9	4.5	3.1	1.5	32.0	20.9
2007	61451	34849	1711	1036	2747	56.7	7.9	4.9	3.0	37.7	44.7

POP = Population
BSC/E=Blood slides collected/Examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pf% = Proportion of *P. falciparum*
API =Annual Parasite Incidence

Annexure No. 5

Table 5: Malaria Incidence in PHC - Corlim (1990-2007)

YEAR	POP	BSC	PV	PF	TOTAL	ABER	SPR	SVR	SFR	Pf%	API
1990	61848	2449	275	64	339	4.0	13.8	11.2	2.6	18.9	5.5
1991	73553	4997	658	391	1049	6.8	21.0	13.2	7.8	37.3	14.3
1992	74509	2828	133	67	200	3.8	7.1	4.7	2.4	33.5	2.7
1993	75478	2934	102	7	109	3.9	3.7	3.5	0.2	6.4	1.4
1994	76459	2537	161	20	181	3.3	7.1	6.3	0.8	11.0	2.4
1995	77453	2495	328	19	347	3.2	13.9	13.1	0.8	5.5	4.5
1996	78460	7685	632	105	737	9.8	9.6	8.2	1.4	14.2	9.4
1997	79478	14043	1145	279	1424	17.7	10.1	8.2	2.0	19.6	17.9
1998	80511	13147	1139	449	1588	16.3	12.1	8.7	3.4	28.3	19.7
1999	81558	12704	533	175	708	15.6	5.6	4.2	1.4	24.7	8.7
2000	82618	11109	353	107	460	13.4	4.1	3.2	1.0	23.3	5.6
2001	83277	9687	226	57	283	11.6	2.9	2.3	0.6	20.1	3.4
2002	83360	8285	226	22	248	9.9	3.0	2.7	0.3	8.9	3.0
2003	83444	9341	197	12	209	11.2	2.2	2.1	0.1	5.7	2.5
2004	83527	9129	110	11	121	10.9	1.3	1.2	0.1	9.1	1.4
2005	84455	13972	222	14	236	16.5	1.7	1.6	0.1	5.9	2.8
2006	85450	15839	185	59	244	18.5	1.5	1.2	0.4	24.2	2.9
2007	86445	20959	456	178	634	24.2	3.0	2.2	0.8	28.1	7.3

POP = Population
BSC/E=Blood slides collected/Examined
Pv = *Plasmodium vivax*
Pf = *Plasmodium falciparum*
ABER =Annual Blood Examination Rate
SPR = Slide Positivity Rate
SVR = Slide Vivax Rate
SFR = Slide Falciparum Rate
Pf% = Proportion of *P. falciparum*
API =Annual Parasite Incidence

Publications and presentations concerning the present research work

1. **Korgaonkar NS, Kumar A, Yadav RS, Kabadi D, Dash AP**, 2008. Sampling of adult mosquito vectors with Mosquito Magnet^{TM} PRO in Panaji Goa, India. *J Am Mosq Contr Assoc* 24(4):604-607.

2. **Korgaonkar NS, Kumar A, Yadav RS, Kabadi D, Dash AP**, 2008. Mosquito landing on human baits and detection of *P. falciparum* infection in *Anopheles stephensi* in Goa, India. Communicated to *J Am Mosq. Contr Assoc*

Journal of the American Mosquito Control Association, 24(4):604–607, 2008

OPERATIONAL NOTE

SAMPLING OF ADULT MOSQUITO VECTORS WITH MOSQUITO MAGNET™ PRO IN PANAJI, GOA, INDIA

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ABSTRACT. For mosquito vector population monitoring, a new commercial trap, Mosquito Magnet™ Pro (MM-PRO), was tested for its usefulness in Goa, India. *Anopheles stephensi* was tested for the presence of *Plasmodium* sporozoite infection in the salivary glands. Using the MM-PRO 24 h a day for 34 days, 2,329 mosquitoes belonging to 16 species were collected. These included 6 species each of the genera *Anopheles* and *Culex*, 2 species of *Aedes*, and 1 each of *Mansonia* and *Armigeres*. Most (91%) of the mosquitoes caught were females. Among these the number and percentage of each species were *Anopheles stephensi* 59 (2.78%), *Culex quinquefasciatus* 1013 (47.78%), *Culex vishnui* 551 (26.0%), *Mansonia uniformis* 216 (10.19%), and *Aedes albopictus* 1 (0.04%). Of the 54 *An. stephensi* females tested for the presence of circumsporozoite protein (CSP) by an ELISA technique, 1 was found to be *Plasmodium falciparum* CSP positive. The MM-PRO device was found useful for mosquito population sampling in the urban setting of Goa.

KEY WORDS Mosquitoes, Mosquito Magnet, circumsporozoite protein, ELISA

Among the mosquito-borne diseases, malaria, filariasis, and Japanese encephalitis are endemic to the Indian state of Goa, which is a major domestic and international tourist destination. Goa has an area of 3,702 square kilometers with a population of 1.4 million and is located on the western coast of India. Until 1985 malaria was localized to the rural areas in the eastern hilly regions characterized by springs, streams, dense forests, and iron and manganese ore mining activity. Following an outbreak of malaria in Panaji in 1986, malaria has become endemic to coastal towns and periurban areas in Goa with *Anopheles stephensi* as the principal vector (Kumar and Thavaselvam 1992, Kumar et al. 1998, Sumodan et al. 2004). Developmental activities and aggregation of migrant construction workers have sustained transmission of malaria in the urban areas (Kumar et al. 1991). While the state has been endemic to bancroftian filariasis for decades, in 2006 there were outbreaks of dengue and chikungunya in Goa (Goa State Health Services, unpublished data).

In view of the present high risk of malaria and other vector-borne diseases in Goa, continuous monitoring of mosquito vectors has become necessary. Collection of adult mosquitoes using pyrethrum space spraying or hand collection gives a poor yield, especially of *Anopheles stephensi* Liston (Sumodan et al. 2004). Recognizing the need for an efficient mosquito sampling method, we deployed Mosquito Magnet™ Pro (MM-PRO), a commercial adult mosquito trapping device, for the collection of mosquitoes in Panaji, Goa, during September and October 2004. The results of the study are presented in this paper.

The study was conducted in Panaji, which is the capital city of Goa State. Panaji is situated at 15°31′N latitude and 23°52′E longitude along the western coast of India, where about 69,000 people live in an area of 7.5 square kilometers. There are between 1,012–8,693 cases of malaria reported each year in the city. Topographically the city has the Altinho hillock in the middle, around which major inhabitation and commercial centers are situated. The Mandovi River runs along the northern expanse of the city. With a tropical climate (18–36.2°C), weather conditions are perennially mild with maximum temperature fluctuating between 30.8 and 36.2°C and minimum between 18 and 23.2°C and RH varying from 75% to 95%. Rains start in May and continue up to October with a 2,500–3,500 mm rainfall recorded annually during the southwest monsoons (Kumar and Thavaselvam 1992). The Vector Borne Disease Control Program of Goa state monitors indoor resting populations of mosquitoes in human dwellings with hand catch techniques that are not done often enough because of inadequate skilled manpower.

In the present study we used a commercial trap, Mosquito Magnet™ (MM)-PRO model (Ameri-

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Fig. 1. Mosquito Magnet Trap (Pro model) used for mosquito sampling in Goa, India.

can Biophysics Corporation, North Kingstown, RI) (Fig. 1). The trap was run on a 15 kg liquefied petroleum gas cylinder. The MM-PRO trap mimics human breath and uses a counterflow technology. The trap emits a plume of carbon dioxide, heat, and moisture, while Octenol is used as supplemental mosquito attractant. A small fan blows the mosquitoes approaching the trap down into a net cage.

Four localities of Panaji city—the market area, Boca-de-Vaca, Caranzalem, and Miramar—were selected for sampling of adult mosquitoes during September and October 2004. The market area is situated in the central part of the town with multistory shopping complexes interspersed with residential buildings. The Boca-de-Vaca is situated along the Altinho hillock having mostly traditional low-roofed houses. The Miramar locality has concrete residential buildings and bungalows, while the Caranzalem locality is undergoing transformation with many multistory residential complexes being built. In each of the localities, the MM-PRO trap was operated up to 9 times during this period. The device was run for 24 h to trap both nocturnal and diurnal mosquito adults in a removable bag. The insects trapped were transferred to labeled zipper bags twice daily, at 10:00 a.m. and 5:00 p.m. In the laboratory the mosquitoes were segregated from other insects and identified using the standard identification keys (Christophers 1933, Barraud 1934). The data collected were to species by locality.

For an ELISA test, *An. stephensi* females were dried and stored individually in plastic vials containing dried silica gel under cold conditions (0–4°C). The head and thoraces of 54 females were tested by sporozoite ELISA method (Burkot et al. 1984) using antibodies to circumsporozoite proteins of *Plasmodium falciparum*, *Plasmodium vivax*-210, and *P. vivax*-247. End point results were read visually and confirmed at 450 nm using a Vmax kinetic microplate reader (Molecular Devices Corporation, Sunnyvale, CA).

During 34 days of trapping with the MM-PRO trap, a total of 2,329 mosquitoes (68.5/day) were collected, out of which 2,120 (91%) were females and 210 (9%) males (Table 1). These mosquitoes belonged to 16 species and were identified as *An.*

Table 1. Number of adult female mosquitoes collected from 4 sites in 34 nights of collection using Mosquito Magnet in Panaji.

Species no.	Mosquito species	No. females collected	%	Mean ± SD/collected per day
1	*Anopheles stephensi*	59	2.78	1.73 ± 2.43
2	*An. subpictus*	65	3.06	1.91 ± 2.90
3	*An. vagus*	19	0.89	0.56 ± 1.57
4	*An. barbirostris*	4	0.18	0.12 ± 0.40
5	*An. jamesi*	5	0.23	0.15 ± 0.43
6	*An. nigerrimus*	1	0.04	0.03 ± 0.17
7	*Culex quinquefasciatus*	1,013	47.78	29.79 ± 53.97
8	*Cx. vishnui*	180	8.49	5.29 ± 14.39
9	*Cx. tritaeniorhynchus*	365	17.21	10.73 ± 23.52
10	*Cx. bitaeniorhynchus*	51	2.40	1.50 ± 3.75
11	*Cx. gelidus*	60	2.83	1.76 ± 3.24
12	*Cx. pseudovishnui*	6	0.28	0.18 ± 0.86
13	*M. uniformis*	216	10.18	6.35 ± 10.89
14	*Ae. albopictus*	1	0.04	0.03 ± 0.17
15	*A. subalbatus*	75	3.53	2.20 ± 3.04
Total		2,120[1]		

[1] In addition, 1 *Ae. vittatus* was collected.

Table 2. Distribution of adult female mosquitoes collected in 4 different localities of Panaji city, Goa, data of all trap collections pooled by locality.

Locality	*An. stephensi*	*Cx. quinquefasciatus*	*Cx. vishnui* group	*Ma. uniformis*	Total
Market area	41 (69.0%)	923 (91.1%)	100 (18.2%)	12 (5.6%)	1,076
Miramar	0	59 (5.8%)	41 (7.4%)	82 (37.9%)	182
Caranzalem	18 (30.5%)	24 (2.4%)	404 (73.3%)	122 (56.5%)	568
Boca-de-Vaca	0	7 (0.7%)	6 (1.1%)	0	13
Total	59	1,013	551	216	1,839[1]

[1] In addition, 1 *Ae. albopictus* was collected from Caranzalem.

stephensi Liston, *An. subpictus* Grassi, *An. vagus* Doenitz, *An. barbirostris* Van der Wulp, *An. jamesi* Theo., *An. nigerrimus* Giles, *Culex quinquefasciatus* Say, *Cx. vishnui* Theo., *Cx. tritaeniorhynchus* Giles, *Cx. gelidus* Theo., *Cx. bitaeniorhynchus* Giles, *Cx. pseudovishnui* Colless, *Mansonia uniformis* Theobald, *Aedes albopictus* Skuse, *Ae. vittatus* Biggot (only 1 male was trapped), and *Armigeres subalbatus* Coq.

The mosquitoes of public health importance collected included, 59 (2.78%) of the malaria vector *An. stephensi*, 1,013 (47.8%) of the filariasis vector *Cx. quinquefasciatus*, 551 (26.0%) of the Japanese encephalitis vectors in the *Cx. vishnui* group, 216 (10.2%) of the filariasis vector *Ma. uniformis*, and 1 (0.04%) dengue/chikungunya vector *Ae. albopictus*. The remaining 13.2% mosquitoes are not considered vectors of disease in Goa. Thus, of the total 2,120 female mosquitoes, 1,840 (86.8%) were known vectors of different mosquito-borne diseases.

The highest number of *An. stephensi* were trapped in the market locality (41, 69%) followed by Caranzalem locality (18, 30.5%). The filariasis vector, *Cx. quinquefasciatus*, was the most predominant species in the market area (923, 91.1%), followed by Miramar (5.8%) and Caranzalem (2.4%), but only a few were collected in the Boca-de-Vaca locality. Japanese encephalitis vectors belonging to the *Cx. vishnui* group of mosquitoes were collected from all 4 study localities with highest numbers collected in Caranzalem (404, 73.3%), followed by the market (100, 28.2%), Miramar (41, 7.4%), and only a few in the Boca-de-Vaca (6, 1%). Last, *Ma. uniformis*, a vector of Brugian filariasis was present in 3 out of 4 localities with the highest number (122, 56.5%) in Caranzalem, followed by Miramar (82, 37.9%) and the market area (12, 5.6%) with none in the Boca-de-Vaca locality. Among the vector species trapped, *Cx. quinquefasciatus* was the most prevalent species (55%) followed by the members of the *Cx. vishnui* group (30%), *Ma. uniformis* (12%), and the least were *An. stephensi* (3%) (Table 2).

Of the 54 *An. stephensi* females evaluated for CSP by ELISA technique, 1 specimen collected from the market locality was found to contain *Plasmodium falciparum* CSP.

Recurrent monitoring of mosquito vector populations is an essential element of disease control program that enables to formulate an effective vector control strategy. In the present study the Mosquito Magnet trap used as sampling device helped in capturing all the major vector species. The relative abundance of these vectors observed in different localities of the study area can prove handy in planning selective and focused vector control program. In previously published studies, the MM-PRO has proved to be an effective trap for capturing mosquitoes and other biting insects (Burkett et al. 2001, Kline 2002). In an earlier study conducted in Goa, the hand catch collection of *An. stephensi* has proven to be cumbersome and less productive where only 38 adult females could be collected after spending 218 nights with an average of 0.17 female *An. stephensi* per night (Sumodan et al. 2004). Moreover, the proportion of the female *An. stephensi* to the total mosquitoes was 0.8% in that study employing the hand catch technique, less than 2.8% found in the present study using MM-PRO trap. Hence it can be concluded that Mosquito Magnet is a relatively more efficient sampling device that does not require much skill, at least for the collection of mosquitoes. The hand catch method of mosquitoes has another disadvantage because people do not readily allow collection of mosquitoes in their dwellings during the early morning hours because it disturbs their sleep. Given the advantage of the number of mosquito vectors trapped simultaneously and the operational convenience, the MM-Pro can be used for sampling of mosquitoes. Costwise, the recurrent running cost is limited to the refilling of octanol and LPG gas cylinders after 100 days of nonstop 24 h of use.

The co-operation of A. V. Salelkar, Kiran Shirodkar, M. B. Kaliwal, and the staff of National Vector-Borne Disease Control Programme, Government of Goa and National Institute of Malaria Research (ICMR), Field Station, Goa, India, is gratefully acknowledged.

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