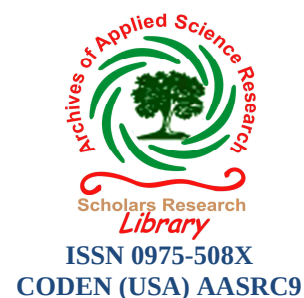




Scholars Research Library

Archives of Applied Science Research, 2013, 5 (3):104-111
(<http://scholarsresearchlibrary.com/archive.html>)



Trend of malaria incidence in the state of Karnataka, India for 2001 to 2011

Anirudh R. Acharya, Jhansi Lakshmi Magisetty, Adarsha Chandra V. R., Chaithra B. S.,
Taiyaba Khanum and Vijayan V. A.

Vector Biology Research Lab, Department of Studies in Zoology, University of Mysore,
Manasagangotri, Mysore, India

ABSTRACT

Karnataka state with the vast semi-urban areas, rich irrigated lands and good monsoon, facilitates prolific growth of mosquitoes and transmission of malaria. In 2001, Karnataka accounted for 9.47% of total malaria cases of India. However, the data from the present study revealed that, there was a significant decline in the incidence by 89.3% for the last ten years (2001 to 2011). In 2011, the annual parasite incidence (API) was 0.4 and mortality less than 5%. *Anopheles culicifacies* (species A) has been the major malaria vector in rural and semi-urban areas and *An. stephensi* being the major malaria vector in urban areas. Here the age group prone to malaria is between 21 to 30 years and there has been growing trend towards urban malaria as people from rural areas migrate to the city. The decrease in the incidence is due to implementation of various control measures, contributed by the application of biological methods as well, such as larvivorous fish, *Poecilia* and *Gambusia*. The epidemiological situation in Karnataka is much better than many other states of India. But there is need of awareness among the people to reduce the number of cases further and bring the state to a malaria free zone in the country.

Keywords: Malaria, Karnataka state, epidemiology, *Anopheles*.

INTRODUCTION

Malaria, which means bad air in Italian language, was the name given to disease which occurred seasonally with certain pronounced symptoms during 18th century. In the past many traditional methods were followed to cure malaria, but even it could not prevent fall of the Roman Empire, until the discovery of the protozoan parasite *Plasmodium* and the transmitting vector, female *Anopheline* mosquito. This disease is prevalent in tropics which have poor economic conditions, the situation being worst in sub-Saharan and rural areas. Approximately, 5% of the world's population is infected, mostly people from high-transmission zones which include African regions, which report vast number of cases (81%), followed by the South-East Asia (13%), and the Eastern Mediterranean region (5%) with over 1 million deaths each year in the world [1]. It is difficult to procure vaccine for malaria, as the *Plasmodium* species have a complex multistage lifecycle. But due to steady increase in the global funding for malaria control, introducing free distribution of insecticide treated mosquito nets (ITNs), improvised long lasting insecticide treated nets, indoor residual spraying (IRS) and usage of mosquito repellents have resulted in significant drop in both malaria cases and deaths all over the world.

Malaria in India:

India is a tropical country having distinct climatic zones, rich fauna and being the second populous country has faced many of the epidemics which severely affected the public health. Malaria being one such disease, its transmission varies with geographic areas, as the diversity and distribution of *Anopheline* and *Plasmodium* species vary. High-transmission zones are present in parts of Odisha, Jharkhand, Chhattisgarh, Maharashtra, Madhya Pradesh, West Bengal and Uttar Pradesh. Proportion of distribution of the parasites also vary with regions; Tamil Nadu predomi-

nantly has *P. vivax* cases, whilst Odisha has *P. falciparum* cases and Gujarat has seen complicated mixed infections time to time[2].

In 2001, India had population of 1.02 billion with 2.1 million malaria positive cases with about 1005 deaths, which suggests that, the API was around 2 to 3. In the present situation, malaria is in the control phase, but India still contributes 66% of the incidence recorded in South-East Asia[1]. However, the number of cases decreased by 28% from 2000 to 2010 [1] and API being 1.0 in 2011 shows that, there is decrease in the incidence by more than 50% (fig. 1). But the actual mortality rate and the malaria incidence are always greater than reported [4]. The reason for under reporting is mainly due to low annual blood smear examination rate (ABER), as NVBDCP has set an ABER target of at least 10% [5]. Other reasons include lack of awareness, misdiagnosis by the use of light microscopy and people relying on private practitioners or hospitals through which the government does not collect the data.

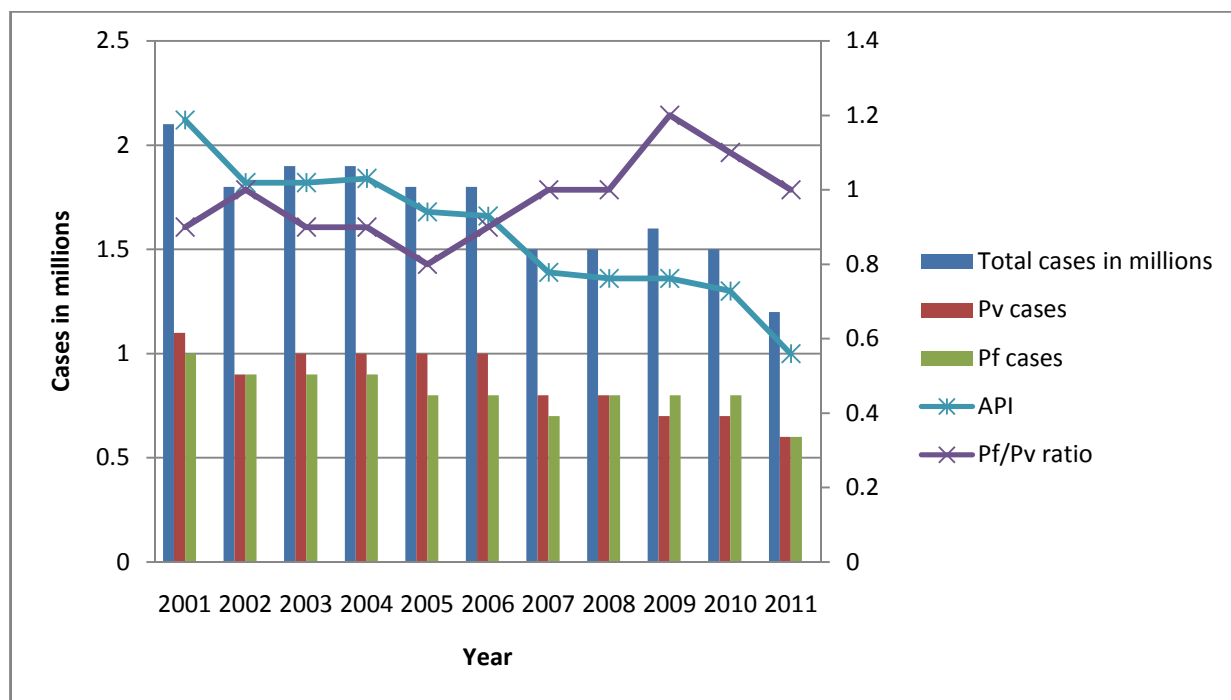


Fig. 1. Trend of malaria cases in India for the period 2001 to 2011 [7]

Malaria in Karnataka state:

Karnataka is located in western side of India, in the southern peninsular region. Previously it was categorized as one of the high-transmission zones in India, the peak of cases were observed in 1976, with approximately 630,000 cases. Later, as the control measures were improvised by employing modified plan of operation (MPO), the cases declined approximately to 30,000. The extensive use of insecticides conferred resistance to mosquitoes, which led to resurgence of malaria and the cases drastically increased to 180,000 in 1997. Continuing the trend, during the year 1998 approximately 110,000 positive cases were observed with 26,000 *P. falciparum* cases[6]. Since then Karnataka has shown steady decline in the number of malaria cases.

Since many years, the highest incidence in Karnataka were recorded in regions of Bijapur, Raichur, Kolar, Bellary, Dakshina Kannada and Mandya districts, which together accounted for more than 60% of malaria cases [8]. It also shows heterogeneity in API trends between districts and the presence of different climatic zones, due to the effect of topography [9]. In this study we considered, rural malaria of Raichur district having rain-fed areas of Deodurga and Lingasugur taluqs which showed API of 37.54 in the year 2003 [8]. Urban malaria of Mangalore city in the year 2006 gave 24% of state's malaria cases [10] and low incidence zone, such as Mysore district which had an API below 0.1 in 2011 contributed only 0.35% of state's malaria [11].

Odisha is the most troubled by malaria compared to other states of India [12]. In 2001, when Karnataka's API was 3.74, it was 12.35 in Odisha and they contributed 9.5% and 21.79% of total cases recorded in India respectively. By 2011, Karnataka showed 89.3% decrease in total malaria incidence, with an API as low as 0.4 (API-0.04), whereas Odisha showed only 43.1% decrease in the incidence, with an API being 7.02 (API-6.42). This implies that, Karnataka has reduced the malaria incidence by 46.2% compared to that of Odisha by 2011. Fig. II shows that, in Karnataka, from 2001 to 2004 there was decrease in cases and in the year 2005 it increased by 2.6% than 2004, later from

2006 to 2009 there was gradual decrease. In the year 2010, there was 19.6% rise in the cases than 2009, with the incidence being 21.9% greater than 2009 and also 35% rise in the Pf incidence, with a significant decrease in 2011 by 44.5%. Thus, the percentage of malaria cases accounted by Karnataka shows gradual decrease from the year 2001 to 2011, except in the years 2005 and 2010. In 2005, the number of cases was more than 2004; this might have been due to the examination of 1 million more blood smears. Similarly, Pf:Pv ratio showed gradual decrease from 2001 to 2011 (fig. III). The Pf:Pv ratio being less than 1 in all the ten years from 2001 to 2011, the highest being observed in 2005 with 26.42% of Pf cases. From this it is evident that, *P. vivax* is predominant in Karnataka state (fig. III). Though Deodurga and Lingasugur taluks had decreasing trend in malaria cases [8], Mangalore reached its peak of the malaria incidence in the decade in 2005 and from 2006 it tended to decrease till 2008 [10] and later increased in 2009 and 2010, whilst Mysore district has relatively less incidence compared to other districts of Karnataka [11].

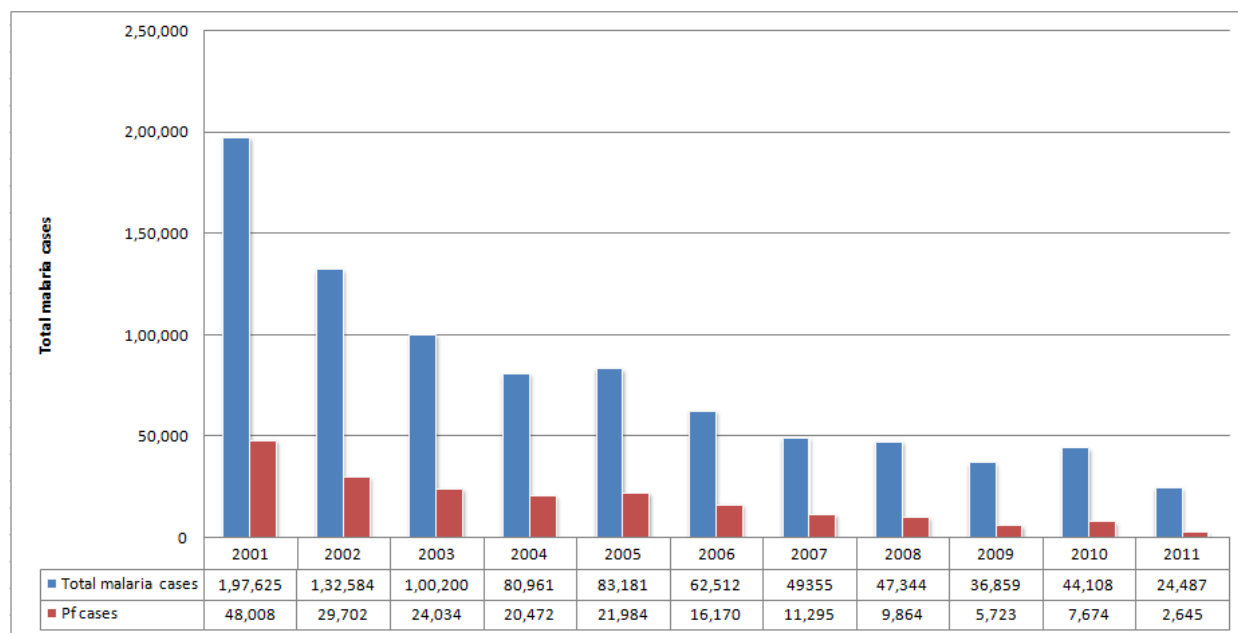


Fig. II. Trend of malaria cases in Karnataka state for the period 2001 to 2011 [7]

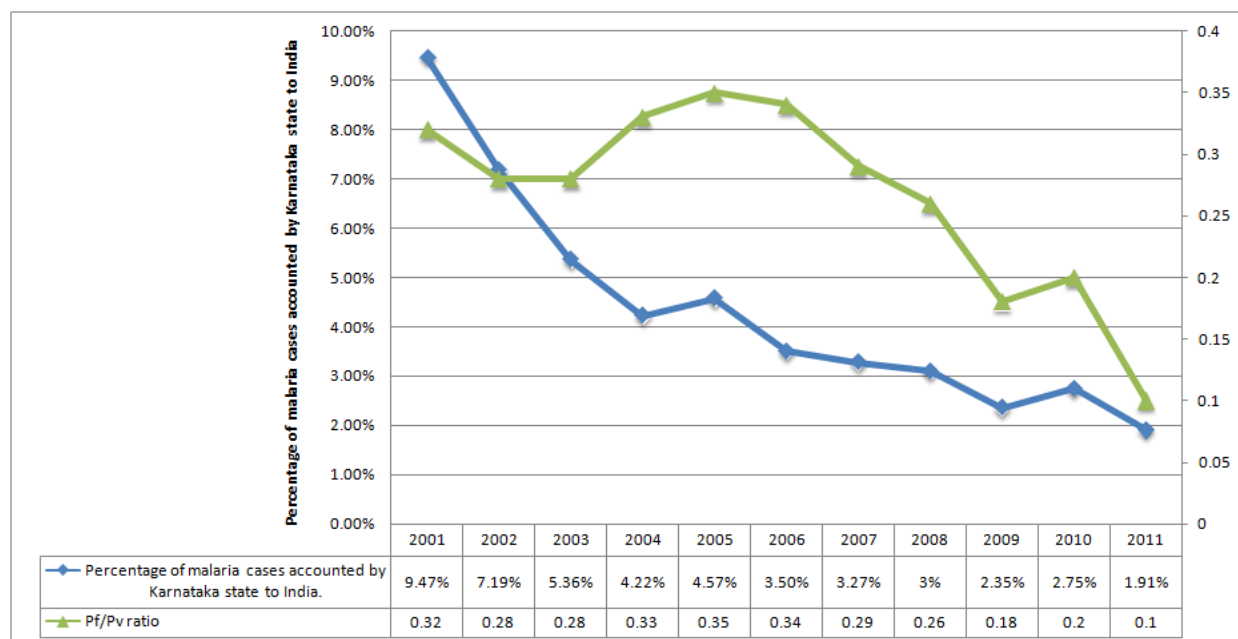


Fig. III. Percentage of malaria cases accounted by Karnataka state to India [7]

Epidemiological features of malaria in Karnataka state:**Clinical features:**

Studies conducted in tertiary care hospitals in Karnataka and others in India have observed prevalence of malaria in age group of 21 to 30 years and males being affected more [13-15]. Fever was the most common symptom, followed by chills, rigors, jaundice, abdominal pain, acute renal failure, acute respiratory distress syndrome, altered consciousness were markers of severe malaria. Biochemical tests and light microscopy showed severe anaemia and thrombocytopenia quite frequent [16]. Severe malaria in the patients showed abnormal liver functions with elevated levels of SGOT and SGPT. Hyperbilirubinemia was also associated with these problematic symptoms. Jaundice was observed in severe malaria cases in addition to splenomegaly and hepatomegaly, whilst the hepatitis was unusual [13].

Burden of complicated malaria and mortality in Karnataka state:

In Karnataka, the incidence of complicated malaria and death has always been low. Infants and children are more susceptible to complicated malaria; for example, observations made in tertiary care hospital of Mangalore showed that out of 9 children with cerebral malaria, 5 of them got seizures and 3 of these children died [17]. In children, as their immune system is prone for infection, chances of getting complications are high, which often results to multiple-organ dysfunction before death and also clinical symptoms of severe malaria vary with age, as the physiology and the metabolic activities of children and adults differ [17]. There were also cases of asymptomatic malaria in children from Tumkur district [18]. Studies conducted by WHO suggests that, malnourished children were more susceptible to severe malaria.

Chloroquine (CQ) resistant malaria cases are observed in Kolar, Raichur, Bellary, Mandya, Bagalkot, Dakshina Kannada, Chamarajanagar, Gadag and Chitradurga [19]. It has been reported to be associated with the molecular marker 'K76T mutation' which has link with *Pfmdr1* gene, but incomplete correlation with CQ resistance [20]. Apart from this, *Pfmdr1* gene is believed to modulate levels of resistance and an important component when it comes to resistance associated with quinine derivatives [21]. So WHO in 2010, suggested stopping the use of monotherapies for *P. falciparum* cases, and proposed combination of drugs [22]. The burden of chloroquine-resistant *P. falciparum* cases all over the world has made Indian Government and NVBDCP to strictly implement Artesunate-based Combination Therapies (ACTs), as artesunate causes substantial reduction in the parasite biomass, irrespective of their resistance to other antimalarials [23]. There is need of combining short and long-acting drugs to prevent resistance development and minimize recrudescence [24], hence ACTs are prescribed as first line of treatment for *P. falciparum* cases [1].

Awareness and treatment seeking behaviour:

The reported incidence from PHCs will be always lower than the actual burden of the disease, one of the reasons being misdiagnosis. Light microscopy is not a very sensitive test as the observers may fail to recognize the parasites in blood smears; confusing *P. vivax* and *P. malariae* ring forms [25], therefore instead of that dipstick and QBC should be employed [26]. A survey conducted among 205 people of Mangalore who had previously suffered from malaria revealed that, 32.6% took self-medications, 27% had been to private practitioners, 9% to homeopathy and others, 8% to ayurveda and only 23.4% had gone to PHCs [27]. This clearly shows that there will be very less reported cases of malaria, so the surveillance method has to be refined.

Vectors of malaria in Karnataka state:

Previously, in Karnataka *An. fluviatilis* was the predominant vector responsible for causing malaria outbreaks, which maintained holoendemic malaria [28]. This species prefers forested areas having slow moving streams. Due to the extensive use of DDT *An. fluviatilis* and the changes in forest ecology, it disappeared from Karnataka [29]. Later, by the invasion of *An. culicifacies* species complex, malaria re-emerged in rural and semi-urban areas, and *An. stephensi* in urban areas. In the present situation *An. culicifacies* is the predominant vector distributed all over Karnataka.

An. culicifacies complex:

This species complex has A, B, C, D and E subspecies (5 types), out of which A and B are seen in Karnataka state in larger densities. Species A is the major vector for malaria and species B being the minor vector [30]. Breeding grounds include forested areas with fresh water sources, deforested, riverine, irrigated and hilly areas. They are both zoophilic and anthropophilic, which feed both indoors and outdoors. The time of biting is evening or night [31]. From the data given in table I, it is evident that districts of Raichur, Bijapur, Tumkur, Kolar, Dakshina Kannada regions are having high malaria incidence compared to other districts. Thus entomological surveys should be conducted on regular basis or at least during onset of monsoon in every district to predict the outbreak of malaria and in order to alert the people.

Table I. Percentage distribution of *An. culicifacies* in different districts of Karnataka state [31]

District	Species A %	Species B %	Species C %
<i>Kolar:</i>			
Near wells	90.6	9.4	---
Near streams	9.1	90.9	---
<i>Mandya:</i>			
Dry lands	45.1	54.9	---
Wetlands	3	97	---
<i>Tumkur</i>	71.5	28.5	---
<i>Chitradurga</i>	59.5	40.5	---
<i>Hassan</i>	70	30	---
<i>Chikmagalur</i>	71.5	28.5	---
<i>Raichur</i>	84.1	8.5	7.3
<i>Gulbarga</i>	33.3	50	16.7
<i>Bijapur</i>	92.6	1.4	5.7

An. fluviatilis subspecies T (minor vector) is still present in districts of Kolar, Mandya, Belgaum and Shimoga, *An. dirus* being present in deep forested areas of Bijapur, Chitradurga, Hassan, Shimoga and Uttara Kannada. Next important vector causing malaria in cities such as Mangalore and Bangalore is *An. stephensi*, where fresh water is available, which prefers fountains, construction sites and open vessels with water for breeding purpose. Its variant or ecotype *An. stephensi mysorensis* resides in outskirts, and its behavior is more or less the same as that of *An. culicifacies* [32].

Status of vector resistance to various insecticides in Karnataka state:

Due to selective pressure, Anopheline species started developing resistance in various countries. Presently, even in Karnataka *An. culicifacies* species complex has developed resistance to DDT, especially species B, whereas, the species A has remained susceptible, as it builds up resistance quite slowly [33]. Further, *An. culicifacies* has developed resistance to even dieldrin and malathion in Karnataka. *An. stephensi* on the other hand has remained susceptible to DDT only in Mangalore city, but it has developed resistance to malathion, DLD, fenitrothion, propoxur and DDT in Bangalore city [34]. Even biolarvicide formulations of *Bacillus sphaericus* is useful in controlling *An. stephensi* and *An. subpictus*, but not much effective against *An. culicifacies* as it developed resistance (table II) [35].

Table II. Level of insecticide resistance of malaria vectors in Karnataka state [28]

Districts	<i>An. culicifacies</i>	<i>An. Stephensi</i>	<i>An. Fluviatilis</i>
<i>Bangalore</i>	>80% resistance to DDT, dieldrin and malathion.	40-80% resistance to DDT, dieldrin, fenitrothion and propoxur.	---
<i>Mangalore</i>	---	80-100% resistance to malathion.	---
<i>Shimoga</i>	---	---	Susceptibility rate not known.

Vector control and preventive measures in Karnataka state:

In India, previously many states employed IRS (indoor residual spraying) of DDT, which approximately cost 60-70% of total malaria budget [32]. This led to development of resistance during the resurgence period. Today, with the development of various synthetic pyrethroids, combination or cycles of insecticides are employed. It is also necessary to monitor the long-term effect of these insecticides: A recent study on malathion-resistant *Culex* has indicated that they have acquired longevity at higher temperatures to which they were previously susceptible [36]. Observations made in Mangalore city hospitals, found that mosquito coils and electric liquid mosquito repellents were the major measures taken for avoiding mosquito bites [37]. Similar is being followed in various other places of the state, rather than relying on IRS. This state has employed distribution of ITNs impregnated with synthetic pyrethroids. WHO has distributed these free of cost, and also the Government of Karnataka has distributed 3,000 medicated nets in 2008, in addition to the long lasting insecticide treated nets was employed in 2009. Apart from this, it has successfully employed biological methods to control malaria. Apparently, Kolar and its adjoining areas which are involved in the production of silk, had faced deterioration in yield by the usage of insecticides, which made them to employ larvivorous fish to curb the malaria situation in these endemic regions [38]. The use of *Poecilia reticulata* (Guppy) in Kolar, Kamasundaram PHC in 1993, reduced the malaria incidence greatly from 1446 to just 517 cases in 1994, (60% reduction) and as low as 7-2 cases from the years 1999 to 2005. Scientific methodology is followed in releasing *Poecilia* for use in wells and *Gambusia* in tanks, and these two fish species are never introduced in the same water body. Grass carp fish eliminates aquatic weeds in irrigation tanks, where malaria vector breeds extensively, so 20% of carps were also released [39]. By observing the results of Karnataka state, Assam state has employed it in various districts [40]. Research is still required to promote the use of indigenous varieties of fishes, as both *Gambusia affinis* or *Poecilia reticulata* are invasive species and fishes such as *Aphani dispar* (Rüppell) which is an indigenous larvivorous fish of Gujarat may be employed [41]. Implementation of efficient water-management

practices by water user associations during Tungabhadra, a major irrigation project in Karnataka, helped in reducing the transmission of malaria [42].

Influence of environment and climate on malaria:

The prevalence of malaria is seen both in rain fed and irrigated areas of Karnataka state. Like all other states of India, the malaria incidence correlates with the onset of monsoon, as indicated for Mysore district which showed 21 out of 84 cases in June, 2011 (fig.IV). Even in Mangalore city, which receives 90% of annual rainfall between May to September experiences the increased malaria incidence from the month of June onwards [14]. Similar data available on various places suggest that, the people have to take extra precaution against communicable and vector-borne diseases during monsoon.

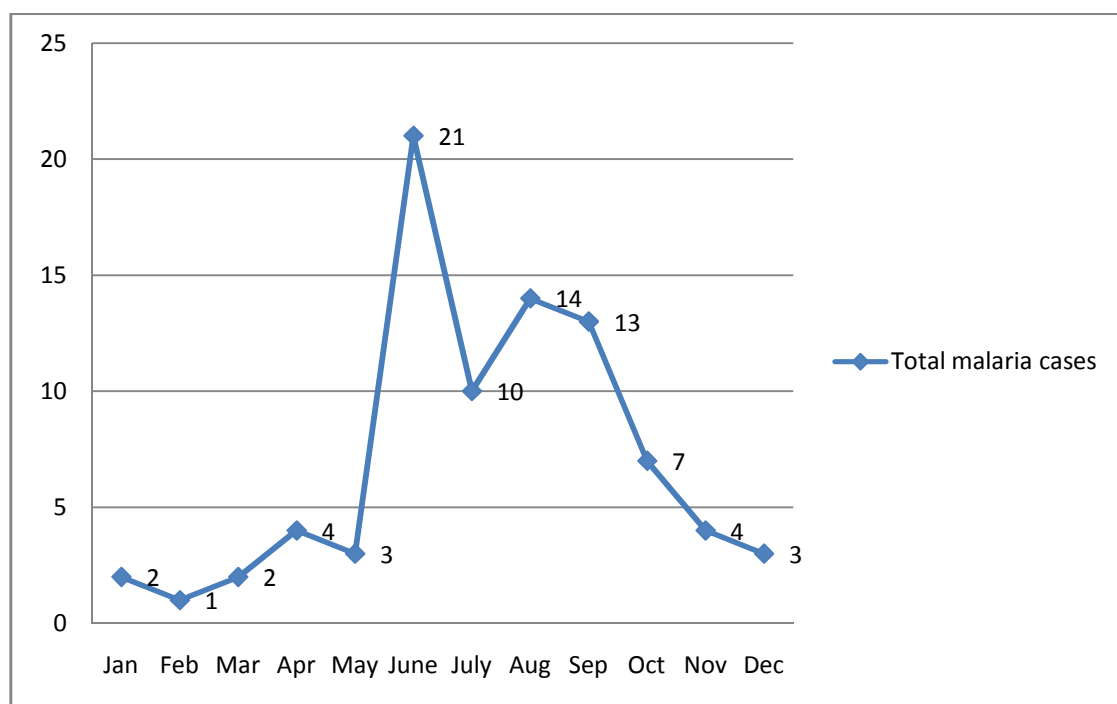


Fig. IV. Seasonal prevalence of malaria in Mysore district 2011 [11]

Studies conducted in Raichur district suggested that, rain-fed areas of Lingasugur and Deodurga taluks had higher incidence of malaria than in irrigated areas, as the pesticides used for the crops and plants would get diluted and washed off [43]. Whilst in irrigated areas, due to the usage of fertilizers and organophosphate insecticides which are retained in the fields prevent breeding of mosquitoes [43], so Lingasugur and Deodurga taluks experience more outbreaks of malaria, even though they are having comparatively less amount of irrigated areas.

According to Intergovernmental Panel on Climate Change (IPCC), central India may experience rise in local temperature from 1.4° C-5.8° C by 2050. This increases the fecundity rate of the mosquitoes and also makes them increase their population faster as their lifespan gets reduced and may cause mosquitoes of Central India to invade Southwest India including Karnataka state, resulting in unforeseen malaria outbreaks [44,45]. So, regions of Belgaum, Bijapur and parts of Northern Karnataka which has high temperature and receives moderate amount of rainfall, may experience malaria outbreaks.

Social and behavioral influence on malaria:

Economic conditions and awareness plays a very important role in epidemiological situation of malaria. It has been well recognized in the past that, malaria outbreaks occurred in developing cities due to labourer migration from malaria-endemic villages [14]. Thereby, the rural disease emerged in urban areas. Mangalore city is a clear example which experienced malaria outbreak in 1990, due to industrialization and urbanization which steadily kept on increasing in later years [10]. Similar growths were observed in Accra in Ghana [46] and Lagos in Southwestern Nigeria [47] where man-made breeding grounds and water receptacles were plenty. Active surveillance conducted by DVBDGP in Mangalore city in the year 2004, revealed that, 47.93% malaria positive cases were from construction labourers [10]. Another observation made in Belgaum (2007), revealed that, 250 migrant labourers from Andhra Pradesh were carrying malaria and transmitted it in the population [48]. Even the data of Mysore district conveys

that, from the years 2007 to 2011, out of 298 cases recorded, 100 being recorded in the city, which denotes transition of malaria from rural to urban. In all the observations made in India, including Karnataka, the prevalence of malaria cases was seen in the age group of 21 to 30 years and it is high in males, mainly due to socio-economic conditions, such as travelling in search of jobs and occupation [49].

In Karnataka, the literacy rate was 68.86% and 86.21% in rural and urban areas respectively in 2011. However, most of the people were unaware about the transmission and burden of malaria. For example, a survey conducted in Mangalore city, revealed that out of 205 people, 166 (81%) were not given health education on malaria as a result people had not taken medications properly [27]. The common reasons for not taking the prescribed medications were due to adverse effects, disappearance of symptoms, saving for future use and inadequate dosage instructions [27]. ACTs cost around Rs. 200 in private hospitals for a three-day course, and complete treatment for complicated malaria costs Rs. 915 per head, they are provided by government for free of cost. Three thousand mosquito nets were distributed by Mangalore City Corporation in 2008 and a penalty of Rs. 5000 was set on the people who create breeding grounds for mosquitoes [37]. Control measures were employed to curb the situation, along with information education and communication (IEC). Kalajatha, a rural folk of Karnataka, implemented in villages of Raichur was able to make people aware about malaria [50]. But misbeliefs like cutting or burning of shrubs, bushes and grass removes malaria vectors and not taking prescribed medications properly and poor economic conditions has caused morbidity and mortality in the present condition [51].

CONCLUSION

By analyzing the data for the last ten years it is evident that, malaria cases and the incidence in Karnataka state have decreased due to implementation of various programmes and research work carried out by the government and non-governmental organizations. But it should be kept in mind that, 70 to 80% of patients were relying on private practitioners, rather than PHCs. Thus the ABER set to 10%, misdiagnosis and negligence among malaria officers may also be the direct cause of reporting less number of malaria positive cases. There is a need to set up entomological department in each district to monitor the vector densities. It is a well known fact that most of the people cannot be reached in a programme conducted in an area. Instead of that it is better to include health education for children, which deals with various common diseases including malaria, and much of the population could be reached through mass communication devices. A large population can be made aware by taking the help of public figures, reaching them through regional television channels would be a lot easier.

With the recent advancement in drugs and hope of developing a vaccine, might end the fear for this dreadful disease. However, due to the emergence of Artemisinin resistant *P. falciparum* in western Cambodia and western Thailand raised doubts over the elimination of the parasites [52]. But, WHO has managed to bring down malaria cases by half and mortality down by 38% over the past decade. WHO with all associated countries including India plans to eliminate malaria and other diseases by 2015, by implementing millennium development goals [1].

Acknowledgement

This work was carried out for the partial fulfilment of M.Sc degree. The authors appreciate, the chairman of department of studies in Zoology, University of Mysore, Manasagangothri for providing the facilities to carry out this work, the research scholars of Vector biology laboratory for the support and guidance, and DVBD CPO Mysore district, for providing the data of Mysore district to carry out this work.

REFERENCES

- [1] World Malaria Report 2011, (World Health Organization, Geneva, 2012).
- [2] A. Das, A.R. Anvikar, L.J. Catorb, R.C. Dhiman, A. Eapen, N. Mishra *et al.*, *Acta. Trop.*, **2012**, 121, 267–273.
- [3] Malaria in India, National Vector Borne Disease Control Programme, Available from: <http://nvbdcp.gov.in/malaria9.html>
- [4] S.I. Hay, P.W. Gething, R.W. Snow, *Lancet*, **2010**, 376, 1716-1717.
- [5] Estimation of true malaria burden in India: A profile of National Institute of Malaria Research, (National Institute of Malaria Research, New Delhi, **2009**), 2nd edition.
- [6] R. Bhise, M.D. thesis, Karnataka Institute of Medical sciences (Hubli, India, **2008**). Available from: <http://119.82.96.198:8080/jspui/bitstream/123456789/1261/1/CDMGENM00207.pdf>
- [7] Malaria situation in India, National Vector Borne Disease Control Programme, New Delhi, **2011**.
- [8] A.S. Talwar & H.S. Pujar, *Karnataka J. Agric. Sci.*, **2011**, 24 (2), 198-200.
- [9] C. Reid, Ph.D thesis, Brown University, (St. Providence, U.S.A, **2000**).
- [10] malariasite.com. Mangalore : Malaria site, all about malaria (2011-2013), Available from: <http://www.malariasite.com/malaria/MalariaInMangalore.htm>, cited 23/02/2012.

- [11] DVBDGP, Malaria in Mysore district, (DVBDGP, Mysore, **2011**)
- [12] L.K. Das & S.P. Pani, *J. Vect. Borne Dis.*, **2006**, 43, 140–143.
- [13] U.K. Chandrashekar, K.A.S. Murthy, A. Sunil, *C.M.J.*, **2011**, 9(3), 6.
- [14] M. Muddaih & P.S. Prakash, *J. Vect. Borne Dis.*, **2006**, 43(1), 29–33.
- [15] A. Kumar, N. Valecha, T. Jain, A.P. Dash, *Am. J. Trop. Med. Hyg.*, **2007**; 77(6), 69–78.
- [16] N. Bhandary, G.S. Vikram, H. Shetty, *Biomedical Research*, **2011**, 22 (4), 489–491.
- [17] G. Peter, A.L. Manuel, S. Anil, *Asian Pac. J. of Tropical Dis.*, **2011**, 35–37.
- [18] Annual report 2002, (National Institute of Malaria Research, New Delhi, **2003**).
- [19] Guidelines for diagnosis and treatment of Malaria in India, (National Institute of Malaria Research, New Delhi, **2009**), 14–15.
- [20] S. Vinayak, S. Biswas, V. Dev, A. Kumar, M.A. Ansari, Y.D. Sharma, *Acta. Trop.*, **2003**, 87, 287–293.
- [21] M.T. Durasingh & A.F. Cowman, *Acta. Trop.*, **2005**, 94(3), 183–190.
- [22] Guidelines for the treatment of malaria, (World Health Organization, Geneva, **2010**), 2nd edition.
- [23] W.R.J. Taylor, J. Rigala, P.L. Olliaro, *J. Vector Borne Dis.*, **2003**, 40, 65–72.
- [24] A. Gautam, T. Ahmed, P. Sharma, B. Varshney, M. Kothari, N. Saha et al., *J. Clin Pharmacol.*, **2011**, 51(11), 1519–28.
- [25] S. Matta, S.L. Kantharia, V.K. Desai, *J. Vector Borne Dis.*, **2004**, 41, 76–79.
- [26] M.P. Salmani, P.B. Mindolli, B.V. Peerapu, *Journal of Clinical and Diagnostic Research*, **2011**, 5(5), 967–969.
- [27] B. Unnikrishnan, A. Jaiswal, B. Reshmi, *Iranian J. Publ. Health*, **2008**, 37(1), 119–123.
- [28] P.K. Mittal, P. Wijeyaratne, S. Pandey Status of Insecticide Resistance of Malaria, Kala-azar and Japanese Encephalitis Vectors in Bangladesh, Bhutan, India and Nepal (BBIN). Environmental Health Project, 2004, Office of Health, Infectious Diseases and Nutrition Bureau for Global Health U.S. Agency for International Development Washington DC.
- [29] V.P. Sharma, *Indian J. Med. Res.*, **1996**, 103, 26–45.
- [30] mrcindia.org, Delhi: NIMR field stations, National Institute of Malaria Research. Available from: <http://www.mrcindia.org/bangalore.htm>, cited: 16/03/2012.
- [31] map.ox.ac.uk, UK: Malaria Atlas Project, Available from: <http://www.map.ox.ac.uk/explore/countries/IND/#!mosquito-vectors>, cited: 08/03/2012.
- [32] A.P. Dash, T. Adak, K. Raghavendra, O.P. Singh, *Curr. Sci.*, **2007**, 92(11), 1571–1578.
- [33] S.K. Subbarao, K. Vasantha, V.P. Sharma, *Med. Vet. Entomol.*, **1988**, 2, 219–223.
- [34] S. Tiwari, S.K. Ghosh, V.P. Ojha, A.P. Dash, K. Raghavendra, *Malaria J.*, **2010**, 9: 179.
- [35] P.K. Mittal, *J. Vect. Borne Dis.*, **2003**, 40, 20–32.
- [36] V. Swain, R.K. Seth, S.S. Mohanty, *Parasitol. Res.*, **2008**, 103(2), 299–303.
- [37] B. Bhaskar, H. Nidugala, R. Avadhani, B. Bhagya, *N.U.J.H.S.*, **2011**, 1(4), 33–34.
- [38] S.K. Ghosh, S. Tiwari, V.P. Ohja, *Front. Physio.*, **2012**, 3, 194.
- [39] Bangalore report; IVDC project: a profile, National Institute of Malaria Research, New Delhi. Available from: http://www.mrcindia.org/idvc-profile/idvc_profile.htm.
- [40] Integrated disease control of malaria a success story based on Assam, Northeastern India. *ICMR bulletin*, **2009**; 39, 4–6.
- [41] S. Haq & R.S. Yadav, *J. Vector Borne Dis.*, **2011**, 48, 236–240.
- [42] G. Mini & A. Jyotishi, In: E.K. Boelee & F.W. Hoek (Ed.), Working paper 47 - Malaria in Irrigated agriculture, papers and abstracts for the SIMA special seminar at the ICID 18th international congress on irrigation and drainage, (IWMI, Montreal, **2002**) 50.
- [43] H. Lokesh, A.S. Talawar, S. Pol, In: E.K. Boelee & F.W. Hoek (Ed.), Working paper 47 - Malaria in Irrigated agriculture, papers and abstracts for the SIMA special seminar at the ICID 18th international congress on irrigation and drainage, (IWMI, Montreal, **2002**) 41.
- [44] R.C. Dhiman, S. Pahwa, A.P. Dash, *Regional Health Forum*, **2008**, 12(1), 27–31.
- [45] Impacts of climate change on Malaria. *WHO India*, **2008**, Available from: www.whoindia.org/World_Health_Day_whd2008_factsheet4.pdf
- [46] W.A. Chinery, *Ghana J. Sci.*, **1999**, 39, 111–115.
- [47] I.O. Oyewole & T.S. Awolola, *J. Vector Borne Dis.*, **2006**, 43, 173–178.
- [48] M.K. Muralidhar, A.S. Wantamutte, *Indian J. Community Med.*, **2007**, 32, 153.
- [49] P. Saini, B.S. Joshi, T. Sharma, *Researcher*, **2010**, 2(6), 50–53.
- [50] S.K. Ghosh, R.R. Patil, S. Tiwari, A.P. Dash, *Malaria J.*, **2006**, 5, 123–130.
- [51] A.K. Sharma, S. Bhasin, S. Chaturvedi, *J. Vector Borne Dis.*, **2007**, 44, 189–197.
- [52] I.H. Cheeseman, B.A. Miller, S. Nair, S. Nkhoma, A. Tan, J.C. Tan, et al., *Science*, **2012**, 336 (6077), 7.