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Eco-epidemiological Settings

Malaria epidemiology is now divided into various ecotypes for better understanding of the transmission dynamics of malaria, the parasites and vectors, and human ecology. Based on the latest concept of classifying areas in eco-epidemiological settings as proposed by Bruce-Chwatt (Gilles, 1993)* and recently expanded by the World Health Organization (WHO, 2006)#, we have worked out our field stations which broadly fall into the following settings.

- **Rural plains and valleys**

  Nadiad (Gujarat)
  Haldwani (Uttaranchal)
  Bangalore (Karnataka)
  Shahjahanpur (Uttar Pradesh)
  Shankargarh (Uttar Pradesh)

- **Industrial unit in plains**

  Hardwar (Uttaranchal)

- **Urban and peri-urban areas in plains**

  Chennai (Tamil Nadu)
  Delhi
  Panaji (Goa)

- **Forest and forest-fringes in hills**

  Sonapur (Assam)
  Jabalpur (Madhya Pradesh)
  Rourkela (Orissa)
  Raipur (Chhattisgarh)
  Ranchi (Jharkhand)

- **Islands and coastal areas**

  Car Nicobar (Andaman & Nicobar Islands)

The IDVC project was implemented to study the problem of malaria and its control in representative areas in each of the above eco-epidemiological settings. A brief description of the above ecotypes, epidemiology of malaria and field units are given below.

Field Units Located in Rural Plain Ecosystem

Nearly a third of all malaria cases in India occur in rural plains, which are characterised by unstable malaria of low- to meso-endemicity associated with rainfall variations and often with epidemic proneness. In general, *P. vivax* is the predominant species in the plains. *An. culicifacies* is the major vector of malaria, which breeds in a variety of water bodies in rural areas such as rainwater collections in borrow-pits, ditches, pools, hoof prints, and river margins, river- and stream-bed pools, ponds, tanks, irrigation channels, etc. In the rural plains, *An. culicifacies* transmits malaria in irrigated areas as well as in human settlements in semi-arid areas often in close vicinity of perennial waters such as rivers, ponds and man-made rainwater tanks. *An. culicifacies* is an indoor resting species found relatively in large numbers in cattle sheds than in human dwellings. A small proportion in some areas can be found resting outdoors. Indoor residual insecticide spraying has been used as the main method to control this vector in the national malaria control programme. *An. culicifacies* is a complex comprising

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* Gilles, HM (1993). *Epidemiology of Malaria*. In Essential Malariology, 3rd edition. HM Gilles and DA Warrell (eds.), Edward Arnold, London. pp. 124-163.

WHO (2006). Malaria Vector Control and Personal Protection- Report of a Study Group. WHO Technical Report Series 936, World Health Organization, Geneva.

five sibling species, namely species A, B, C, D and E, which are morphologically similar. Distribution of these sibling species is distinct and they also differ in several biological characters, some of which are relevant in decision making for control of malaria. As a result of extensive use of insecticides during the eradication era, *An. culicifacies* had developed resistance to DDT and HCH in most areas in the country and to malathion in certain areas by the 1970s. Recently, this species has developed resistance even to pyrethroids, which were introduced into the control programme for house spraying in the mid-1990s.

Nadiad taluka in Kheda district in Gujarat state, Haldwani in Nainital district in Uttaranchal state, and Shahjahanpur district and Shankargarh PHC of Allahabad district in Uttar Pradesh state were chosen as typical sites representing malaria in rural plains for testing the feasibility of integrated malaria control strategy. Field areas in Haldwani, Nadiad and Shahjahanpur represent irrigated rural plains, while Shankargarh represents non-irrigated plains and all sites support predominantly *P. vivax* malaria. In Shankargarh area, stone quarries were the major breeding sites of *An. culicifacies*.

After gaining field experience, bioenvironmental control of malaria strategy was launched in Karnataka in an effort to transfer the technology to the states. In rural Karnataka, main breeding habitats of *An. culicifacies* were well-defined such as irrigation tanks, streams, ponds, etc. Unlike in northern India, draw wells also serve as breeding grounds of *An. culicifacies* in rural Karnataka.

Field Unit Located in Industrial Ecosystem

Hardwar in erstwhile Uttar Pradesh (now in Uttaranchal state) represents rural plains with *An. culicifacies* as the vector. In addition to the malaria characteristics typical of the ecosystem, there were additional factors such as labour settlements within the major industrial unit, namely the Bharat Heavy Electricals Limited (BHEL), Ranipur and Indian Drugs and Pharmaceuticals Limited (IDPL), Rishikesh. Pools created by a poorly maintained water supply system and rainwater accumulations in the labour colonies were the main breeding grounds of *An. culicifacies*. Poor housing and low socio-economic conditions of labourers increased the risk of malaria. Therefore, the industrial complex of BHEL at Hardwar was selected as another site where bioenvironmental control strategy was tested for its feasibility to control malaria in the setting of a typical industrial setting.

Field Units Located in Urban Ecosystem

In urban areas, *An. stephensi* is the major vector of malaria while in the periphery *An. culicifacies* is responsible for malaria transmission. The breeding sites of *An. stephensi* were very different from ground water collections seen for *An. culicifacies* in peri-urban areas. Chennai City in Tamil Nadu has had serious shortage of drinking water supply. Many of the housing complexes and dwelling premises have wells and large overhead tanks for storing water. Most of these overhead tanks are not properly covered. *An. stephensi*, a vector which breeds in wells, overhead tanks and other contained waters, transmits enormous malaria cases in Chennai City, which annually contributes to about 70% of all malaria cases of Tamil Nadu state. A small percentage of malaria cases may be contributed by *An. culicifacies*.

Similarly, Panaji City in Goa also suffers from malaria transmitted by *An. stephensi.* Due to a sudden increase in the construction activities in the 1980s, a large number of breeding places of *An. stephensi* were created. These are temporary wells, cement tanks, cisterns, etc. built at the construction sites. Both these cities were selected to test the feasibility of demonstrating integrated approach to malaria control in urban settings.

Delhi attracts a large number of migrant population from different parts of the country everyday. This unregulated movement of people into the city has led to establishment of urban slums with poor sanitation creating favourable conditions for the nuisance mosquito, *Cx. quinquefasciatus*. In 1987, Delhi unit was established to develop possible methods for controlling mosquito nuisance in urban slums, but also to provide logistic support for implementation of IDVC project at other field units in the country.

Field Units Located in Forest and Forest-fringe Ecosystem

In India, forested areas are predominantly inhabited by different groups of tribes. In these terrains, *An. fluviatilis*, *An. minimus* and *An. dirus* are the major vectors of malaria. In the foothills, *An. culicifacies,* and in the hills of northeastern states of India, *An. minimus* and *An. philippinensis/nivipes* act as malaria vectors. Both *An. fluviatilis* and *An. minimus* breed in streams, while *An. dirus*, which is an exophilic species, breeds in puddles in deep forests. *An. fluviatilis* and *An. minimus* are still susceptible to DDT in most areas as shown recently by a multi-centre study. These species are highly anthropophagic and maintain a very high transmission load of malaria even at very low densities. *P. falciparum* is the predominant parasite and malaria is stable in these areas. *P. vivax* prevalence is low, and in the deep forests of the eastern plateau, *P. malariae* is also found in low numbers. Resistance of *P. falciparum* to chloroquine in many of these areas causes serious problems in the treatment. Deaths due to malaria are common in forest ecosystem where accessibility to health services has remained a challenge. Failure to approach houses in rainy season and sparsely distributed houses make surveillance difficult to organise. Further, environmental conditions contribute to the better survival of vector species and make them very efficient in these areas.

To test the feasibility of the integrated control strategy in the forested area, initially three field units were opened representing areas under the influence of various sylvatic vectors. Sonapur primary health centre in Kamrup district in Assam state where *An. minimus* is the major malaria vector and *An. dirus* plays a supplementary role was selected. Mandla district in Madhya Pradesh represents undulating forest ecosystem with *An. culicifacies* as the major vector. *An. fluviatilis* is also found in this area. To work in this area, a field unit was started in Mandla. Sundargarh district in Orissa with *An. fluviatilis* as the major vector and *An. culici-facies* supplementing to the transmission was chosen; and a field unit was set up in Rourkela. Two more field units in the forest ecosystem have been opened in 2006—one at Raipur in Chhattisgarh state and the other at Ranchi in Jharkhand state. *An. culicifacies* and *An. fluviatilis* are malaria vectors in these areas with predominance of *P. falciparum.* These areas are inhabited mainly by tribals.

Field Unit Located in Island Ecosystem

An. sundaicus is a brackish water species and an efficient vector of malaria. Though this species was earlier found on the mainland in coastal belt of Orissa, Andhra Pradesh and West Bengal, now it is found only in Andaman and Nicobar Islands. Car Nicobar group of islands of Andaman and Nicobar was selected to demonstrate the feasibility of controlling malaria. On these islands, *An. sundaicus* was found breeding both in brackish and fresh water collections in creeks. *P. vivax* is the main malaria parasite on these islands. ❑

Situation analysis of malaria in India

- About 80% population at risk of malaria
- About 2 million cases reported annually by National Vector Borne Disease Control Programme
- 800–1000 malaria deaths reported anually by NVBDCP
- Six major malaria vectors with exophilic and/or endophilic behaviour
- Quadriple insecticide resistance in *An. culicifacies*, the main rural malaria vector in plains
- New malaria ecotypes identified
- Malaria is closely linked with poverty
- Wide-spread drug resistance in *Plasmodium falciparum*
- 10 million population under sulphadoxine-pyrimethamine treatment of *P. falciparum*
- Inadequate resources