Malariogenic Stratification

Malaria is endemic in most parts of the country. There is a lot of diversity in terrain features, ecological conditions, biology of vectors and immunological aspects. In order to use the limited resources available effectively, areas with high potential for malaria transmission with some similarities need to be identified. Stratification of areas for suitable and effective malaria control is one of the best strategies. Different entomological, parasitological and environmental parameters can be and have been used for malariogenic stratification. At NIMR several tools for stratification of mosquitogenic conditions and malaria, like sibling species prevalence, remote sensing (RS), geographical information system (GIS) and seroepidemiology have been used.

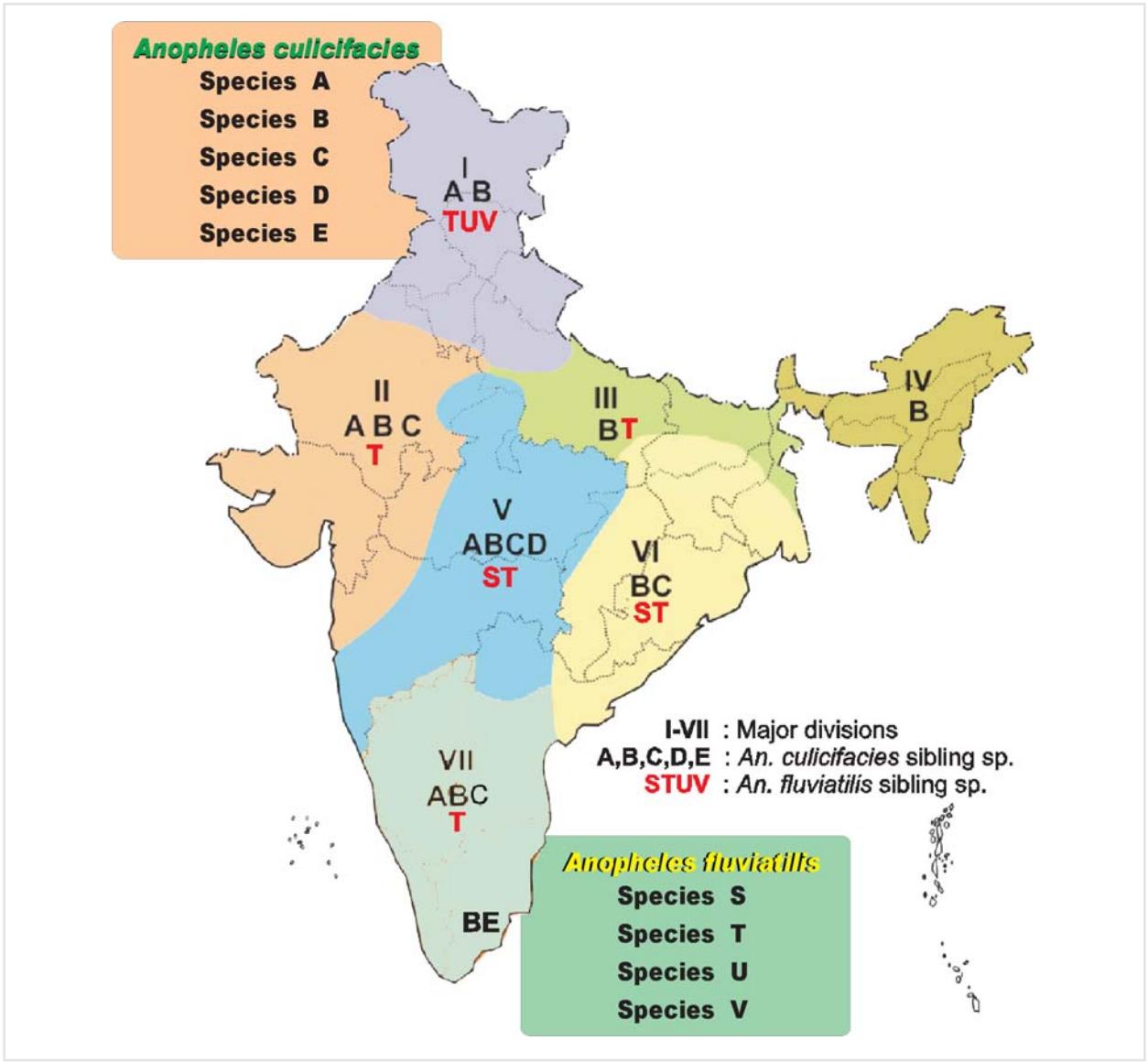

Fig. 66: Stratification of India based on *An. culicifacies* and *An. fluviatilis* sibling species distribution

Sibling Species Prevalence and Control Options

Anopheles culicifacies sibling species distinctly vary in biological characters. Species A, C, D, and E are vectors of both *Plasmodium vivax* and *P. falciparum* malaria as determined by immunoradiometric assay in areas wherever they are prevalent (Subbarao *et al* 1988, 1992). Both in laboratory and field, species B has been found to be a non-vector (Subbarao *et al* 1980). Among *An. fluviatilis* sibling species, only species S is anthropophagic and a vector, and the other two species T and U are non-vectors. Based on these distinct biological characters, their specific distribution pattern and sympatric association of *An. culicifacies* and *An. fluviatilis* sibling species prevalence, the whole country has been divided into seven major divisions (Subbarao *et al* 1999) (Fig. 66). *An. culicifacies* and *An. fluviatilis* transmit 60–70 and 15% of malaria in the country respectively (Sharma *et al* 1998). Recommended control measures in seven divisions of India, based on vector species prevalence are summarised in Table 20. Urban areas where *An. stephensi* is responsible for malaria are not being considered under these divisions.

To illustrate further possible stratification of a division to develop situation-specific strategies, stratification of Uttar Pradesh (in Divisions I and III) and Bihar (in Division III) is presented here (Fig. 67). In Uttar Pradesh and Bihar, where longitudinal studies were carried out, a good correlation has been observed between *An. culicifacies* sibling species prevalence and malaria incidence. Based on these observations Uttar Pradesh has been stratified into four zones, northern zone 1, (now falls in Uttarakhand state, western (zone 2), eastern (zone 3) and southern (zone 4) (Fig. 68). Bihar has been stratified into two, northern and southern zones (now in Jharkhand state). In zone 1, *An. culicifacies* A and B are found with high proportion of species B and malaria endemicity is low; in zone 2 species A and B with high proportion of species A and malaria endemicity is high; in zone 3, complete prevalence of species B and no indigenous malaria; and in zone 4 species A, B, C and D and in most of the areas proportion of B is high and malaria is low. In districts of northern Bihar only species B is found and there is no malaria while in southern Bihar (now in Jharkhand state) species B and C are prevalent and area is endemic for malaria. Following this stratification, location-specific control measures have ben proposed.

Geographical Information System (GIS) and Remote Sensing (RS) as Tools for Malariogenic Stratification

Case study 1: Nadiad, Kheda district (Gujarat)

A study using RS and GIS for mapping the receptivity of malaria was undertaken in Nadiad taluka comprising of 100 villages with unstable malaria and periodic epidemics. Using topo-sheets and satellite imageries, thematic maps on water table, water quality, hydrogeomorphology, soil type, relief, irrigation channels, etc. were prepared and stratified in 2–3 categories. These maps were sequentially overlaid and integrated using ARC/INFO software. The composite map resulted in 13 contours. Contours 1–12 falling in non-irrigated tract exhibited 95% matching with the ground realities, *i.e.* annual parasite incidence (API) of malaria. Contour 13, an irrigated area did not show an obvious matching but the ground verification resulted in complete reconciliation of cause and effect relationship in explaining malaria epidemiology in the region (Fig. 69). The study revealed that the parameters for high malaria in the villages of Nadiad were—high water table, soil type, irrigation and water quality (Srivastava *et al* 1999; Sharma and Srivastava 1997; Malhotra and Srivastava 1994). The technique can be used for mapping of malaria receptivity in larger areas.

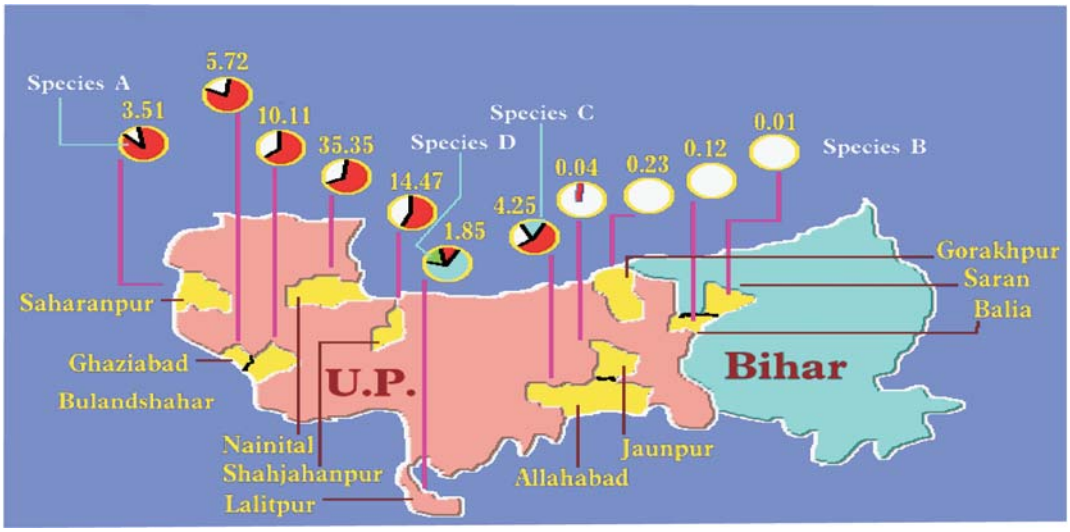

Fig. 67: Relationship between *An. culicifacies* sibling species prevalence and malaria incidence (Nos. indicate API) (undivided Uttar Pradesh and Bihar states)

Fig. 68: Stratification of Uttarakhand and Uttar Pradesh states and suggested control measures

Table 20. Recommended control measures in seven divisions of India based on vector species prevalence

Divisions	Vector species	Malaria endemicity	Recommended control strategy	Remarks
Division I				
J&K, H.P., Punjab, Haryana, Delhi, Uttarakhand, north-west U.P. & Part of north-west Rajasthan	*An. culicifacies* A, B *An. fluviatilis* T, U	Low	• No routine vector control activities. • Regular monitoring of densities of vector and passive parasitological data.	Major influence of *An. culicifacies* species A. If insecticides are to be used, susceptibility status of this species to be checked. Today this species is fully susceptible to synthetic pyrethroids and susceptibility to malathion is variable and fully resistant to DDT.
Division II				
Gujarat, parts of north-west and southern Rajasthan, western M.P. and north-west Maharashtra	*An. culicifacies* A, B, C *An. fluviatilis* T	Moderate to high	• Insecticide spray. • Selection of insecticide based on susceptibility status of *An. culicifacies* species A or C.	Major influence of *An. culicifacies* species A or C or A & C. *An. culicifacies* is mostly resistant to DDT and in some areas to malathion and even to synthetic pyrethroids.
Division III				
Parts of eastern U.P., southern U.P., Bihar and northern region of Jharkhand	*An. culicifacies* A, B *An. fluviatilis* T	Very low	• No vector control measures. • Effective chemotherapy to treat imported cases.	Most prevalent *An. culicifacies* species B, is a non-vector.
Division IV				
All seven northeastern states	*An. dirus* *An. minimus* *An. fluviatilis* *An. nivipes* / *An. philippinensis*	High	• DDT spray to continue.	Major influence of *An. minimus* and *An. dirus*, which are susceptible to DDT. Other vectors play a secondary role.

(contd...)

Table 20. ***Contd...***

Divisions	Vector species	Malaria endemicity	Recommended control strategy	Remarks
Division V				
Most districts of M.P., Chhattisgarh, northern A.P., southern U.P. and western Maharashtra	*An. culicifacies* A, B, C, D *An. fluviatilis* S, T	High	• Insecticide spray (DDT not recommended). • Selection of insecticide-based on susceptibility status of *An. culicifacies* species C.	Major influence of *An. culicifacies*. Species A, C, D and S are vectors. Selection of insecticide can be based on species C as this species has developed resistance to most insecticides to variable levels.
Division VI				
Orissa, most of the districts of Jharkhand, northeastern districts of A.P. Madhya Pradesh	*An. culicifacies* B, C *An. fluviatilis* S, T, U	Moderate to high	• Insecticide spray. • Selection of insecticide-based on prevalence of the major species. • In *An. culicifacies* prevalent areas, selection of insecticide depending on the susceptibility of species C. • In *An. fluviatilis* areas DDT spray.	Major influence of *An. culicifacies* in plains and of *An. fluviatilis* in hilly forested areas. Species C and S are vectors.
Division VII				
Southern A.P., Karnataka, Kerala, Tamil Nadu	*An. culicifacies* A, B, C, E *An. fluviatilis* T	Low to moderate	• Insecticide spray, larvivorous fishes. • In Kerala chemotherapy and in Karnataka larvivorous fishes are very effective.	Major influence of *An. culicifacies*. Species A, C and E are vectors and B and T are non-vectors. Species E has been identified in Rameswaram Island and a few areas on mainland.

- Insecticide-treated mosquito nets are recommended in the areas where vector species are prevalent, depending on the feasibility, acceptability and sustainability of this intervention.
- It is assumed that treatment of malaria cases are done routinely in all the areas.
- Recommended strategy is based on the present knowledge on the prevalence of vector species and their susceptibility status.

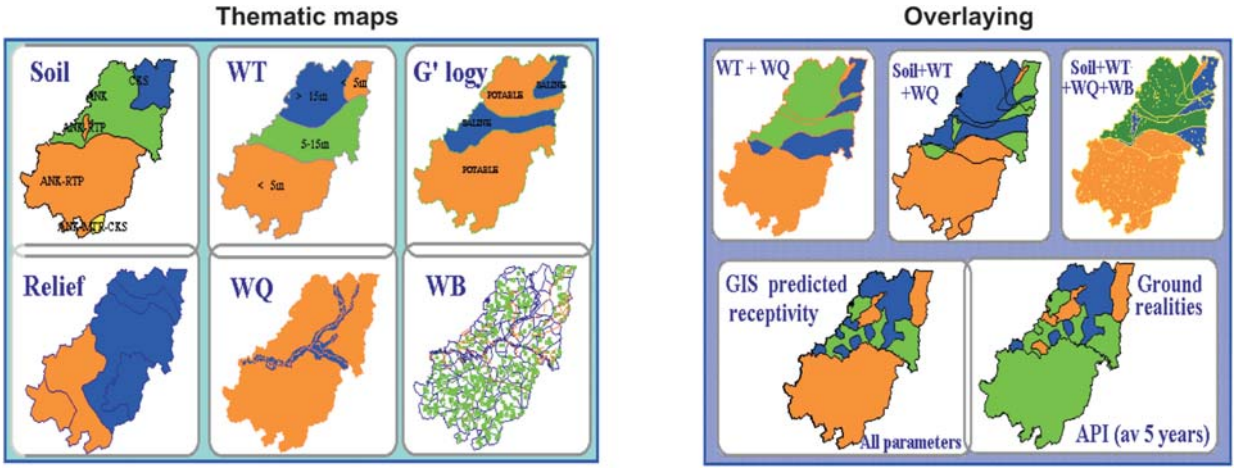

Fig. 69: Thematic maps of Nadiad taluka, Kheda district, Gujarat; and overlaying and integration of maps

Case study 2: Mewat Region, District Gurgaon (Haryana)

Mewat region, Haryana situated at Lat. 26° and 30°N, Long. 76° and 78°E, comprised of six blocks Nuh, Nagina, Taroru, Ferozepur Jhirka and Punhana of Gurgaon district and a small portion of Hatin block of Faridabad district of Haryana (Fig.70a and b). The total population of the region is 0.8 million spread over 491 villages under 84 sections.

A GIS-based study was initiated to aim at the objectives: (i) delimitation of malaria paradigms at macro-level and their epidemiological characteristics; (ii) situation analysis of each paradigm to identify transmission risk factors and to suggest mitigating measures at micro-level; and (iii) identify epidemic risk factors and development of epidemiological information system to assist forecasting of epidemics. The study was conducted in collaboration with Haryana Space Application Centre, Hissar, Haryana.

As per NVBDCP records, malaria in Mewat follows a cyclic epidemic pattern. Soon after resurgence during 1975–76 malaria decreased gradually from 62 API to about 3 API in 1980. In 1981 and 1982 there was a spurt of malaria cases and API went up to 6 and in later years it decreased steadily and remained below 2 API between 1984 and 1994. In 1996, this region experienced an epidemic. In post-epidemic period (1997–99) using GIS, sections having high malaria were identified. It was found that the section Sunehra consistently had high API in all the five years (1995–99), while Gulata (150) for last four years from 1996–99, Nuh and Kherla for three years out of 5 years. Rest of the sections had high malaria in two years out of five year period. As the malaria had decreasing trend, sections with persistent malaria during 1998–99 were identified as sections with residual malaria. These are Sunhera (157), Gulata (150), Sihari (145), Bisro (152), Dudoli (154), Naheda (158), Tirwara (163), Indana (165), Neemka (166) of Punhana block and Kherla (87) of Nuh Block (Figures given in parentheses indicate section number) (Fig. 70b).

Based on geographic reconnaissance, ecological and socioeconomic profile, five malaria paradigms were identified, namely, Irrigation command area, Catchment area, Mining area, Urban area and Flood prone areas (Fig. 71).

Sections falling in each paradigm were extracted, maps were prepared and overlaid successively on high API/residual malaria sections to study their ecoepidemiological characteristics (Fig. 72). Analysis revealed that section Akera (83) has three ecoepidemiological characteristics—irrigation command area, low-lying topography within catchment area and flood prone area. Section Malab (84) has irrigation, whereas sections Nuh (86) and F. Namak (88) have urban/mining and mining malaria ecoepidemiological profiles respectively. Sections Gulata (150), Bisro (152) and Sunhera (157) fall within catchment area. It is worthy to mention that section Sunhera (157) which consistently had high malaria since last five years has four ecoepidemiological characteristics, namely low-lying area within catchment area, mining, urban centre and flood prone areas. Other problematic sections are Kherla (87), Sihari (145), Dudoli (154), Naheda (158) and Tirwara (163) fall in flood prone areas except sections Indana (165) and Neemka (166) which have problems due to Bichchore minor of Gurgaon canal. The surveys are being conducted in Mewat area in the villages of residual malaria sections to identify risk factors at the micro level.

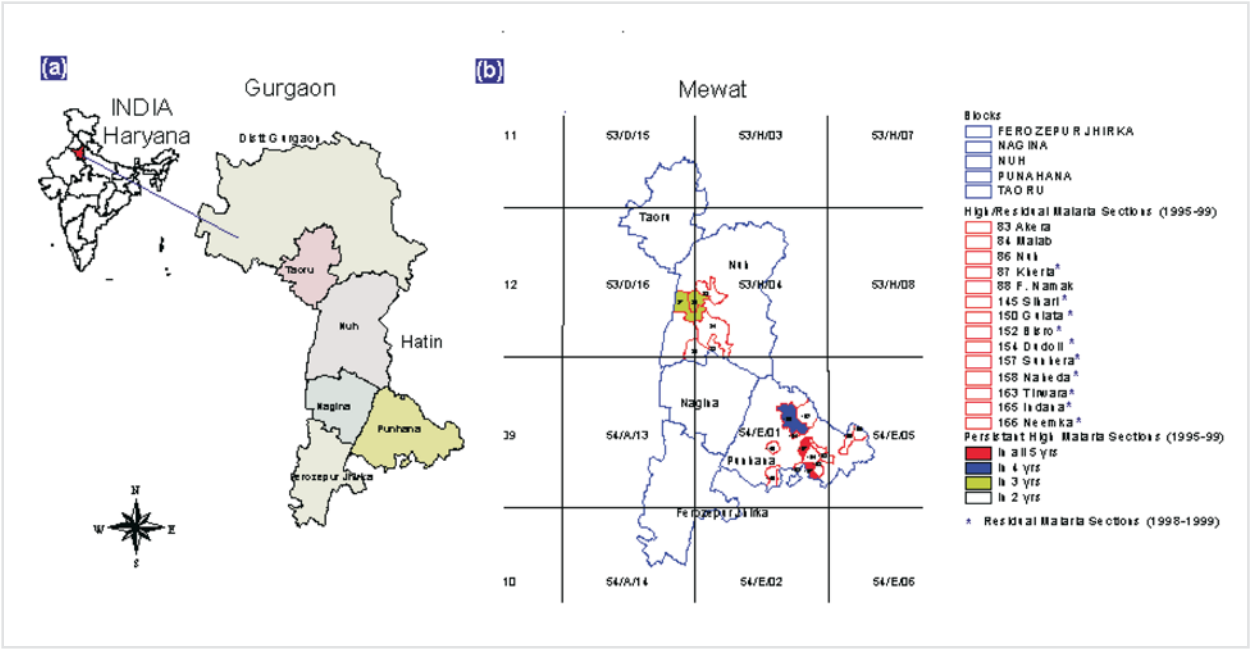

Fig. 70 a & b: Map showing (a) location of study area Mewat in Gurgaon, Haryana; and (b) sections with high/residual malaria (1995–99)

Peptide ELISA: A Simple Indicator of Malaria Endemicity in Communities

Microscopic examination of blood slides, though excellent for clinical diagnosis, is not a practical tool for mass malaria survey in a community. Annual parasite index (API) measurement in a huge population during transmission season is time consuming and greatly dependent on diligence and expertise of primary health workers and microscopists. As a result, API values may not be exact due to human error or shortage of manpower and it is recognised that malaria incidence is under

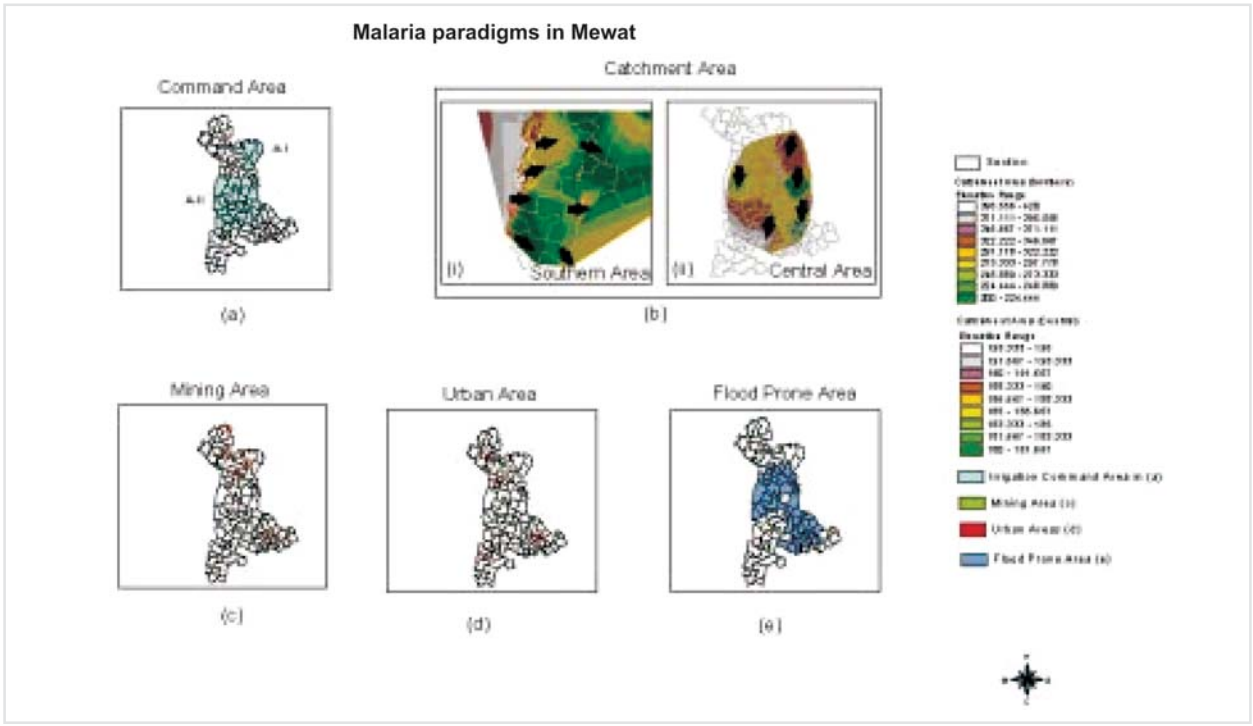

Fig. 71: (a) Showing the two command areas A-I and A-II in Mewat; (b)– (i) 3-D Tin model shows depression areas in part of southern and central Mewat, and (ii) Tin model was regenerated for central Mewat by taking dense contour lines; (c) & (d) Mining and urban areas respectively; and (e) Flood prone areas

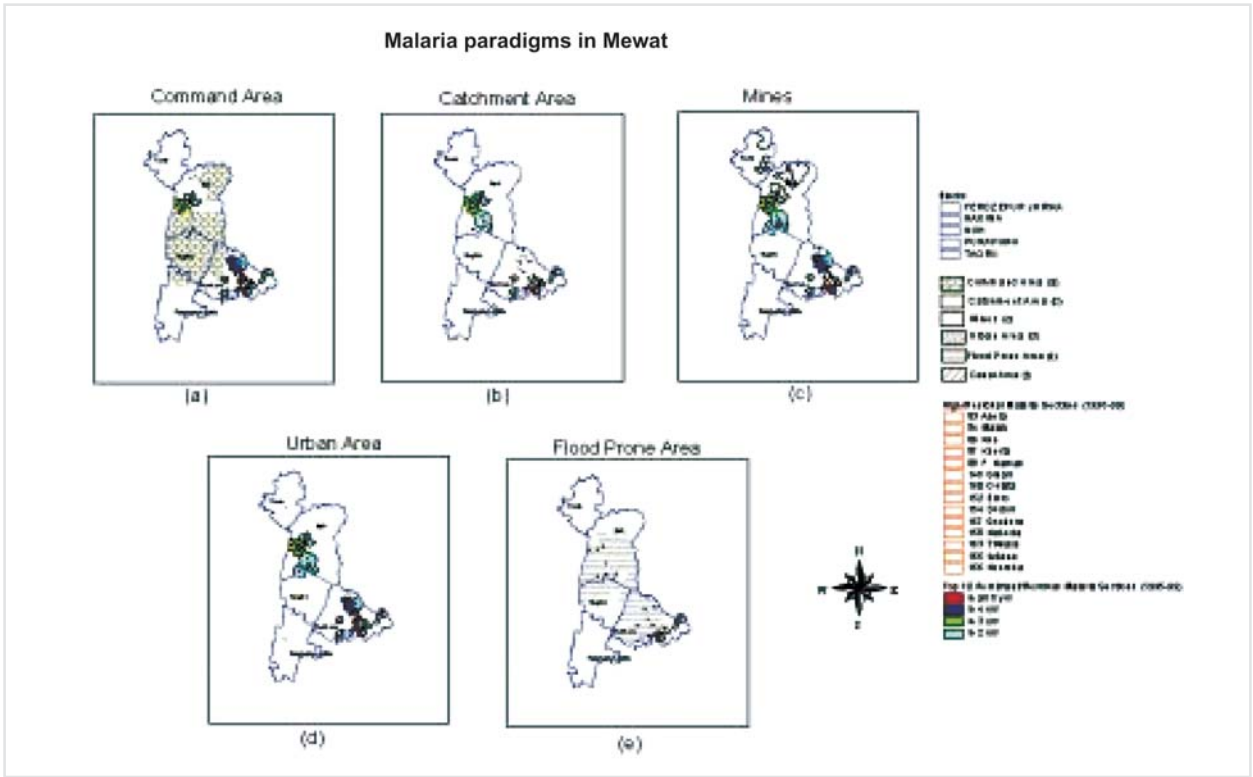

Fig. 72: Persistent high malaria and residual malaria (1995–99) and their eco-epidemiological characteristics as revealed by overlaying maps of each paradigm on high risk sections

Table 21. Comparison of seroreactivity with different malarial peptides and blood samples under different malarial situations

Area	History of malaria exposure	No. examined	Current status of malaria endemicity	ELISA OD of malarial peptide antigens						
				AR1	*Pf*	LSAR	HRP	CSP-60	$EENV_4$	SC-5 non-malarial peptide
Hindu Rao Hospital, Delhi	(0-2) yrs infants, no history of malaria	42	Non-endemic locality	0.141 ± 0.03	0.205 ± 0.024	0.191 ± 0.050	0.192 ± 0.047	0.165 ± 0.048	0.100 ± 0.035	0.164 ± 0.049
Jaisalmer, Rajasthan	Non-endemic	62	Epidemic	0.153 ± 0.058	0.162 ± 0.126	0.273 ± 0.089	0.160 ± 0.102	0.195 ± 0.061	0.147 ± 0.104	0.242 ± 0.134
Raigarh Hospital O.P.D.	Non-endemic	42	Epidemic	0.151 ± 0.059	0.159 ± 0.059	0.091 ± 0.03	0.082 ± 0.03	0.16 ± 0.05	0.069 ± 0.046	0.366 ± 0.076
Ghaziabad (village-Piyawali)	Endemic perennial transmission	42	Highly endemic	0.677 ± 0.075	0.452 ± 0.059	0.498 ± 0.119	0.47 ± 0.170	0.494 ± 0.069	0.355 ± 0.047	0.277 ± 0.054

AR1 —Non-apeptide (EENVEHDACYS of RESA—*Pf*155 of *P. falciparum; Pf*—Crude parasite antigen; LSAR—Liver specific antigen repeat; HRP—Histidine rich protein; CSP-60—Circumsporozoite protein-60; $EENV_4$—Synthetic peptide of *Pf* 155/RESA tandom repeats of 4–amino acids.

Table 22. Comparison of entomological, parasitological and serological data in three different riverine areas of Allahabad district

Area (No. of villages)	*An. culicifacies* sibling species A (%)	Density per structure (HD only)	Human blood index species A	Malaria incidence SPR (Parasite Index)	Infant parasite rate	Child parasite rate	Serological indices AR1 ELISA OD (No. examined)	Status of endemicity
Gangapar (5)	4 (12.5)	2.3	0 1.8	(1.9)	0	1.5	0.194 ± 0.11 (534)	Low
Doaba (9)	26 (9.7)	11.2	0 2.8	(3.1)	0	1.7	0.119 ± 0.12 (817)	Low
Yamunapar (13)	192 (36.9)	17.1	0.035 8.8	(14.4)	7.7	5.0	0.718 ± 0.18 (1105)	High

HD—Human dwelling.

Table 23. Derivation of ETI values from (AR1) ELISA OD for comparison with API value (ETI = 270.55 × AR1 ELISA OD ± 7.4079)

Area (Endemicity)	Village	Sample size	AR1 ELISA OD	API observed	ETI calculated
Haldwani (Low)	Baira Pokhra	13	0.125 ± 0.06	19	41.23
	Badi Mukhani	14	0.242 ± 0.15	5.8	72.88
	Ratanpur	9	0.099 ± 0.04	35	34.19
	Manpur	16	0.138 ± 0.08	3	44.74
	Jeetpur Negi	14	0.136 ± 0.07	9	44.20
	Anandpur	17	0.134 ± 0.07	22	43.66
	Himmatpur	13	0.160 ± 0.04	42	50.70
	Gusaipur	17	0.134 ± 0.06	31	43.66
Mandla (Moderate)	Chargaon	69	0.42 ± 0.07	100	121.04
	Ghota	81	0.44 ± 0.22	189	126.45
	Somnopur	90	0.29 ± 0.10	291	85.87
	Vijaypur	118	0.32 ± 0.16	81	93.98
Jabalpur (High)	Tarwani	58	0.85 ± 0.11	235	237.38
	Dandwa	58	0.85 ± 0.19	210	240.08
	Magardha	116	1.00 ± 0.13	195	277.96
	Chargaonkala	103	1.19 ± 0.05	293	329.36
	Majhgaon	92	0.91 ± 0.10	381	254.42

reported in our country. We developed a malaria surveillance system (Roy *et al* 1994, 1995) by employing ELISA technique to estimate malaria-specific antibodies in the blood using RESA derived nonapeptide (AR1) as antigen. This nonapeptide has been found to be superior to parasite lysate and several other synthetic peptide epitopes (Table 21). A comparison of parasitological and serological data under different malaria situations led us to develop a hypothesis. Stratification of malaria endemicity (Ansari *et al* 2001) by ELISA method indicates low, moderate and high status depending on AR1 ELISA OD values, <0.3, 0.4–0.7 and >0.7 respectively (Table 22). It is shown that anti-AR1 antibody level is a simple indicator of malaria transmission dynamics in the recent past.

Reliability of the test was evaluated by comparing entomological, parasitological and serological data in Gangapar, Doaba, Yamunapar, three different ecosystems in District Allahabad, Uttar Pradesh (Tiwari *et al* 1994), and a longitudinal study has been done in Piyawali village of District Ghaziabad (Roy *et al* 1998) and Haldwani from 1989–93 in order to check the effect of a control programme (Roy *et al* 1996). AR1 ELISA OD has been used to derive a new parameter—equivalent transmission index (ETI) for determining malaria situation. All the parameters (ETI, API, AR1 ELISA OD) have good correlations (Table 23). Association between infection and seropositivity in individual level from high, moderate and low endemic population has been done. Serology is more meaningful for malaria surveillance in moderate and high endemic areas as well as malaria outbreak situation. Seroreactivity is directly related with the number of malaria episodes for detecting intensity of malaria transmission which can stratify endemicity. Further, the method does not need year long mass survey, sample collection is required once in a year only during non-transmission season. Introduction of new technology is a need. The emphasis of technology improvement is warranted for the communities affected by the incidence of communicable diseases. ❑