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DYNAMICS OF MALARIA TRANSMISSION IN FORESTED AND DEFORESTED REGIONS OF MANDLA DISTRICT, CENTRAL INDIA (MADHYA PRADESH)

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ABSTRACT. A longitudinal malaria study was undertaken in 1990–91 in 2 adjacent ecological zones in central India: villages in forest and villages away from the forest. The prevalence of *Anopheles* species varied widely between the 2 ecological settings. In the villages in forest, *Anopheles culicifacies* and *An. fluviatilis* were mainly exophilic, whereas in the villages away from forest, *An. culicifacies* was predominantly endophilic and *An. fluviatilis* was equally prevalent both indoors and outdoors. The seasonal patterns of malaria transmission were also different between the 2 zones. *Plasmodium falciparum* was the dominant parasite species in the villages in forest, whereas malaria infection was mainly due to *Plasmodium vivax* in the villages away from forest. The annual parasite incidence was high in the villages in forest. The failure to control malaria in forested areas is rooted in the terrain and a variety of poorly understood sociological factors.

INTRODUCTION

Madhya Pradesh in central India, with an area of 442,841 km², is the largest state in India. The state has a total population of 52.2 million, out of which 12 million are classed as tribal people (the highest number of tribals in the country). Forest covers 330,828 km² (75%) and is a reservoir of intense perennial malaria transmission. According to an estimate made in 1987, 54 million tribals of various ethnic origins residing in forested areas and accounting for 7% of the total population of India contributed 30% of the total malaria cases, 60% each of total *Plasmodium falciparum* cases and total malaria deaths in the country (Narasimham 1991). Chloroquine resistance in *P. falciparum* is a common feature (Ghosh et al. 1989, Singh et al. 1989b). Two vector species occur in the area, *Anopheles culicifacies* Giles and *An. fluviatilis* James (Kalra 1978, Kulkarni 1987), which are prevalent throughout the year (Singh et al. 1989a). Recent studies in the Mandla district have shown that *An. culicifacies* is a complex of 4 sibling species designated A, B, C, and D, with species C comprising 80–90% of the individuals collected (Subbarao et al. 1992). The subspecies status of *An. fluviatilis* is not known.

The Mandla district in the center of Madhya Pradesh is a region of broad valleys, hills, and rocky undulating terrain with thick dense forests at altitudes of 450–950 m. Although the large forests are preserved, virtually all the villages along the state highway have long been cleared of forest. During routine epidemiologic surveys more malaria cases were recorded from villages in forested areas. Therefore, we initiated an epidemiologic study in villages in the forested areas compared to villages in deforested areas to investigate the factors responsible for the differences in malaria prevalence.

MATERIALS AND METHODS

Mandla (23°N, 80°10′E) is a tribal district. The villages are broadly classified into 2 types: interior reserve forest villages (> 600 m elevation) and roadside, revenue villages, 15 km away from forest (< 500 m elevation). Six villages were selected (Fig. 1), 4 from the forests (site 1) and 2 from the roadsides (site 2). All 6 villages were sprayed with 2 rounds of DDT in May and July by the National Malaria Eradication Programme (NMEP). There are 3 seasons: hot (March–June), rainy (July–October), and cold (November–February). Climatic data are presented in Table 1.

Site 1: This group of 4 villages (80% Gond tribals) is located in dense forest. The villages are sparsely populated (100–300 inhabitants per village). They are 15–25 km from the main road and inaccessible for at least 4 months per year during rainy periods. Several seasonal and perennial streams crisscross the villages. The entire area is infested by snakes, scorpions, and spiders during the rains. The tropical moist, deciduous forest of the area consists mostly of *Tectona grandis* (teak), *Shorea robusta* (sal), *Madhuca indica* (mahua), and *Bambusa nutanus* (bamboo). There are no schools or health centers in these villages and people are mostly illiterate, scantily clothed, and work mainly in forest nurseries. Their houses, which are scattered in agricultural fields and forest, are made of mud, thatch, and bamboo. The houses are small with low doors and windows. Fewer than 20% have electricity (only one point connection per dwell-

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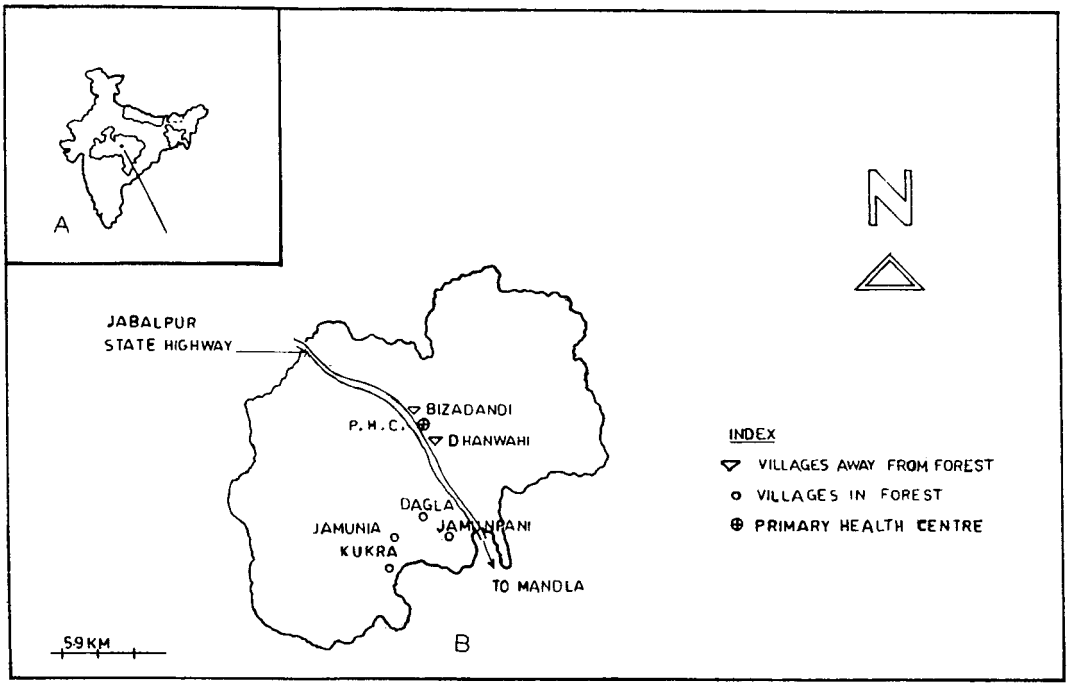

Fig. 1. A. Map of India showing the location of Madhya Pradesh and the Mandla district. B. Bizadandi Primary Health Centre, showing study villages.

ing). Very often cattle are also sheltered in the houses. Drinking water is brought from wells or seepages.

Site 2: These 2 villages are densely populated (60% Gond tribals) and relatively prosperous. Residents seldom work away from the villages. Two medical officers stay at the Primary Health Centre (PHC), about 0.5 km from Bizadandi village. The other village, Dhanwahi, is about 5 km away from the PHC. Houses are better ventilated, have electricity, and are made of brick and mud with tiled roofs. There are numerous fresh water springs, seepages, and pools along the shallow streams during rains.

Mosquito sampling: Indoor resting mosquitoes (per man-hour) were collected twice per month for 4 consecutive days from 4 villages (2 from each site) for 1 year (1990–91). Anophelines resting inside 4 fixed (the same structures were sampled each time) houses located in different parts of the villages (2 human dwellings and 2 cattle sheds) were sampled during the early morning (0600 h) for 15 min at each place. A team of 2 insect collectors was assigned to each village. The same collectors caught mosquitoes with flashlights and mouth aspirators at each study village (24 collections). After indoor resting collections were made, anophelines rest-

Table 1. Rainfall in villages of the Mandla district.[1]

	Year											
	1990						1991					
Villages	Total rainfall (mm)	Rainy days (No.)	Temperature (°C) Max.	Temperature (°C) Min.	Humidity (%) Max.	Humidity (%) Min.	Total rainfall (mm)	Rainy days (No.)	Temperature (°C) Max.	Temperature (°C) Min.	Humidity (%) Max.	Humidity (%) Min.
Away from forest	1,766.5	74	42.3	7.7	90	25	1,302.2	53	44.4	3.9	88	20
In forest	2,077.3	82	41.5	3.5	98	45	1,452.5	72	44.6	0.5	95	40

[1] Measurements are from the Meteorological Department, Nagpur.

Table 2. Mean indoor resting density (per man-hour) of anophelines in villages of Bizadandi, in the Mandla district.

Month	Villages in forest			Villages away from forest		
	All *Anopheles*	*An. culicifacies*	*An. fluviatilis*	All *Anopheles*	*An. culicifacies*	*An. fluviatilis*
Jan.	18.0	9.5	1.4	32.8	26.5	0.5
Feb.	7.0	2.0	1.0	27.3	22.5	0.0
March	7.0	2.0	0.8	15.0	12.0	0.0
April	1.0	1.0	0.0	13.5	9.3	0.0
May[1]	0.0	0.0	0.0	5.0	4.0	0.0
June	1.0	1.0	0.0	7.5	5.5	0.0
July[1]	40.5	36.0	0.8	44.5	31.5	0.0
Aug.	80.0	70.5	0.5	51.5	34.3	0.0
Sept.	53.0	42.5	0.5	62.5	31.5	1.5
Oct.	57.5	36.5	3.5	68.0	28.8	2.0
Nov.	30.0	21.5	2.5	61.0	26.5	2.0
Dec.	16.5	15.0	1.0	32.0	15.5	2.0
Total	311.5	237.5	12.0	420.6	247.9	8.0

[1] DDT sprayed, first round in May and second round in July.

ing outdoors were collected by the same team of 2 collectors for 2 h from stone quarries, bushes, small plants near streams, on fences, and from tree holes, etc.

Although human biting catches were planned once each month in these 4 villages, human bait catches were terminated due to many operational difficulties.[3] An alternative sampling method, CDC light trapping, was used once a month for 4 consecutive nights for 1 year. The traps were run for a period of 48 nights (12 nights at each village) from 1800 to 0600 h. Traps were always placed at a constant height of 5.5 ft., at fixed locations, outdoors near occupied human dwellings and indoors in human dwellings (12 outside and 12 inside in each village). Each trap was emptied manually at hourly intervals until morning. The human dwellings were without windows but had many eaves, holes, and large cracks in the walls and roofs. The catch house had been treated with DDT in May and July. All the houses in these experiments were occupied during the nights of observation. It was not possible to use mosquito bed nets, as the occupants of the houses would not sleep under bed nets because of their superstitious beliefs. Mosquitoes collected every hour were kept in labelled test tubes. Humidity, temperature, and cloud cover were recorded at the collection sites.

[3] Due to a snake bite received by one of the field staff during outdoor catches in a forest village, human bait catches were terminated. Further, the forest is impenetrable after the rains except on foot. It was considered unsafe to be out at night in remote villages due to the high risk of exposure to wild animals.

Mosquitoes were identified in the laboratory using standard keys (Christophers 1933, Puri 1955, Wattal and Kalra 1961). Only *An. culicifacies* and *An. fluviatilis* were dissected for the presence of sporozoites in salivary glands, as the remaining species were only abundant during limited periods of the year. Further, because both *An. culicifacies* and *An. fluviatilis* comprise sibling species, and separation of these sibling species require cytogenetic studies, we decided to lump these species rather than risk errors in sorting under primitive field conditions.

Malaria surveillance: Blood smears were prepared twice a month from all fever cases and people with fever during the preceding 14 days (active case detection). All fever cases were given 600 mg chloroquine as presumptive treatment. Blood smears were stained with JSB stain (Singh and Bhattacharji 1944) and thick smear-examined under oil immersion in the laboratory. Statistical significance of the data was determined by chi-square analysis and Z-test.

Socioeconomic and cultural studies: A team carried out community interviews during February–June 1991, covering a population of approximately 300 people in 2 villages at each site in order to determine behavioral risk factors.

RESULTS

Density per man-hour: Table 2 summarizes the mean number of hand catches of indoor-resting individuals of all *Anopheles, An. culicifacies,* and *An. fluviatilis.* At site 1, the number of *An. culicifacies* was high from July to November and low during December–January and almost

zero during February–June. At site 2, *An. culicifacies* densities were high from July to February and low during March–June. *Anopheles fluviatilis* was found during monsoon and postmonsoon periods at site 1 and occasionally during postmonsoon months at site 2. *Anopheles subpictus* Grassi was the second predominant species at both the sites. During winter, *Anopheles theobaldi* Giles was the second most common species at site 1, whereas *Anopheles annularis* Van der Wulp was second at site 2.

Vigorous efforts were made for the direct collection of resting adults outdoors for more than 3 months. Only 5 *An. culicifacies,* 2 *An. fluviatilis,* 2 *An. theobaldi,* one *An. subpictus,* and one *An. annularis* were collected after nearly 34 man-hours of effort at site 1 during April, May, and June. A majority of the specimens had taken a blood meal. At site 2, only 3 male *An. culicifacies* and one male *Anopheles vagus* Dönitz were found during the same period of time from stream banks, tree holes, firewood stored outside the houses, and fences, etc.

Vector incrimination: From site 2, 921 *An. culicifacies* and 28 *An. fluviatilis* found resting indoors were dissected. Salivary glands in 3 *An. culicifacies* were positive for sporozoites in the July and November collections. Almost all mosquitoes from site 1 died during transportation before reaching the laboratory.[4]

Light trap collections: Table 3 summarizes the mean number of anophelines caught by light traps. A total of 374 *Anopheles* representing 9 species were collected from site 1. *Anopheles culicifacies* was the predominant species, forming 47% of the total, followed by *An. theobaldi* (23%). *Anopheles fluviatilis* was more than 7% of the total and was prevalent during the monsoon and postmonsoon period. At site 2, 545 anophelines were collected, representing 11 species of which 418 (76.7%) were *An. culicifacies* followed by *An. subpictus* (9.0%). Only 15 *An. fluviatilis* were caught, mainly during the postmonsoon season.

A breakdown by trap location shows that the highest numbers of *An. culicifacies* and *An. fluviatilis* were obtained outdoors at site 1, whereas the highest numbers of *An. culicifacies* were recorded indoors at site 2 (> 60% of total *An. culicifacies*). *Anopheles fluviatilis* were equally prevalent indoors and outdoors at site 2. The per trap per night catches of anophelines differ significantly between 2 sites when compared by 2 × 2 contingency chi-square within indoors or outdoors ($\chi^2 = 5.2$, $P < 0.025$, df = 1). The difference in per trap per night catches of *An. culicifacies* between the 2 sites (2 × 2 contingency chi-square) within indoors or outdoors was also significant ($\chi^2 = 5.0$, $P \geq 0.025$, df = 1). Further analysis of data showed that peak activity for *An. culicifacies* appeared to be between 1900 and 2400 h at site 2. This species was active throughout the night at site 1. More than 50% of the trapped *An. culicifacies* were freshly fed at both the sites. About 80% of trapped *An. fluviatilis* were obtained between 2000 and 2400 h at both the sites, and a majority of them (55%) were unfed.

Pattern of malaria prevalence: At site 1, the gross slide positivity rate varied between 13.5 and 40%; the maximum number of positive cases was found in October (Table 4). *Plasmodium falciparum* cases increased from August until February, peaked in October, then gradually declined. Gametocytes were present in 60% of *P. falciparum* infections. Three probable malaria deaths were also recorded during the rainy season. Slide positivity rate, slide falciparum rate, and *P. falciparum* percentages remained the same during both years, whereas the average annual parasite incidence (API) was reduced from 250 during 1990 to 220 in 1991. The monthly prevalence of malaria was not correlated with the monthly abundance of *Anopheles* females resting indoors. However, at site 2, monthly malaria prevalence generally followed the fluctuations of *An. culicifacies.* Both the gross malaria prevalence and the proportion of *P. falciparum* were significantly lower (Z-test, $P < 0.0001$) at site 2 (Table 5). The average annual blood examination rate (ABER) and average annual parasite incidence (API) were also much lower. Malaria incidence at site 2 decreased from 62 in 1990 to 38 in 1991 (Fig. 2); however, there was no decline in number of *P. falciparum* cases (26 *P. falciparum* out of 141 total positive during 1990 and 27 *P. falciparum* out of 87 total positive during 1991).

Human risk behavior/economic activities: People from both the sites spent nights in the open throughout the year to gather a variety of forest produce for their own consumption and for sale. Tendue leaves (for making country cigarettes) and mahua (for making liquor) are important items in the tribal economy. These activities usually are carried out between 0300 and 0600 h every day from March 15 to June 15. About 20–60% of the people at both sites sleep in agriculture fields for 6 months a year to tend and guard crops (Table 6).

[4] Mosquitoes were transported to the laboratory in mosquito cages that were made of Thermocol, with the top roof made of nylon net. Mosquitoes were also provided with cotton wool soaked with sugar solution placed in the cage in an attempt to minimize the deaths of mosquitoes.

Table 3. *Anopheles*[1] collected by indoor and outdoor CDC light traps with black light in villages of Bizadandi, in the Mandla district.

Species	Villages in forest				Villages away from forest			
	Indoor	(%)	Outdoor	(%)	Indoor	(%)	Outdoor	(%)
An. culicifacies	60	(34)	117	(66)	285	(68)	133	(32)
An. fluviatilis	10	(34)	19	(66)	8	(53)	7	(47)
An. annularis	13	(32)	28	(68)	10	(36)	18	(64)
An. subpictus	6	(35)	11	(65)	27	(59)	23	(46)
An. theobaldi	38	(45)	47	(55)	6	(50)	6	(50)
An. splendidus	2	(50)	2	(50)	4	(40)	6	(60)
An. jeyporiensis	10	(100)	0	(0)	0	(0)	0	(0)
An. nigerrimus	0	(0)	3	(100)	0	(0)	2	(100)
An. pallidus	0	(0)	0	(0)	3	(100)	0	(0)
An. barbirostris	0	(0)	8	(100)	0	(0)	1	(100)
An. vagus	0	(0)	0	(0)	2	(100)	0	(0)
An. tessellatus	0	(0)	0	(0)	1	(25)	3	(75)
Per trap per night	11.6		19.6		29		16.6	

[1] Mean number of anopheles trapped outdoors or indoors. Numbers in parentheses indicate percentages.

DISCUSSION

Malaria transmission is focal (Rosenberg and Maheswari 1982). There were 2 malaria transmission cycles in the Mandla district. In the forest villages, malaria was predominately due to *P. falciparum,* but in the villages away from forest, *P. vivax* was the primary causative agent. The climatic conditions in forest villages appear to be more conducive for higher survival of vectors, which is associated with a predominance of *P. falciparum* (Chandrahas et al. 1984). In these villages *P. vivax* prevalence began to increase from March to April when anopheline densities were very low, perhaps as a result of late relapses (Fox and Strickland 1989).

Vector prevalence also varied between the 2 groups of villages. In the villages away from forest *An. culicifacies,* the principal vector, was most abundant inside houses, whereas in villages in forest, the mosquito was found mostly

Table 4. Epidemiologic situation of malaria in villages in the forest of Bizadandi, in the Mandla district (1990–91).[1]

Month	BSE[2]	+ve[3]	Pv[4]	Pf[5]	SPR[6]	SFR[7]	Pf%[8]
Jan.	129	36	5	30	27.9	23.3	83.3
Feb.	71	24	7	17	33.8	23.9	70.8
March	65	13	9	4	20.0	6.2	30.8
April	74	10	9	1	13.5	1.4	10.0
May	73	20	19	1	27.4	1.4	5.0
June	98	23	20	3	23.5	3.1	13.0
July	76	15	10	5	19.7	6.6	33.3
Aug.	153	32	10	21	20.9	13.7	65.6
Sept.	242	47	23	24	19.4	9.9	51.1
Oct.	223	77	15	62	34.5	27.8	80.5
Nov.	110	38	4	34	34.6	30.9	89.5
Dec.	96	38	5	33	39.6	34.4	86.8
Total	1,410	373[9]	136	235	26.5	16.7	63.0

[1] Pooled data.
[2] BSE = Blood slides examined.
[3] +ve = Malaria positive.
[4] Pv = *Plasmodium vivax.*
[5] Pf = *P. falciparum.*
[6] SPR = Slide positivity rate.
[7] SFR = Slide falciparum rate.
[8] Pf% = *P. falciparum* percentage.
[9] Mixed infection of *P. vivax* and *P. falciparum* = 2.

Table 5. Epidemiologic situation of malaria in villages away from forest of Bizadandi, in the Mandla district (1990–91).[1]

Month	BSE[2]	+ve[3]	Pv[4]	Pf[5]	SPR[6]	SFR[7]	Pf%[8]
Jan.	73	16	12	4	21.9	5.5	25.0
Feb.	61	10	9	1	16.4	1.6	10.0
March	62	11	8	3	17.7	4.8	27.3
April	61	12	10	1	19.7	1.6	8.3
May	77	13	13	0	16.9	0.0	0.0
June	106	27	26	1	25.5	0.9	3.7
July	176	46	40	6	26.1	3.4	13.0
Aug.	148	17	16	1	11.5	0.7	5.9
Sept.	189	35	22	13	18.5	6.9	37.1
Oct.	140	30	14	16	21.4	11.4	53.3
Nov.	72	9	4	5	12.5	6.9	55.6
Dec.	28	2	0	2	7.1	7.1	100.0
Total	1,193	228[9]	174	53	19.1	4.4	23.2

[1] Pooled data.
[2] BSE = Blood slides examined.
[3] +ve = Malaria positive.
[4] Pv = *Plasmodium vivax.*
[5] Pf = *P. falciparum.*
[6] SPR = Slide positivity rate.
[7] SFR = Slide falciparum rate.
[8] Pf% = *P. falciparum* percentage.
[9] Mixed infection of *P. vivax* and *P. falciparum* = 1.

outside. These differences in prevalence might either be related to geographical variations in seasonal temperatures, rainfall, and the availability of forest, etc.; or, because *An. culicifacies* is a complex of sibling species, differences in behavior may be indicative of different sibling species. The outdoor abundance of *An. culicifacies* and *An. fluviatilis* was of significance from a malaria control standpoint because these vectors may avoid contact with insecticide sprayed inside the houses. However, spraying may not control even the indoor species. Earlier studies carried out in this area showed only 19% mortality of *An. culicifacies* to 4% DDT (Singh et al. 1989a). These vectors breed in many widely dispersed streambed pools, slow-running streams, and seepages, so larval control is especially difficult (Singh et al. 1993).

Although sampling human-biting mosquitoes by light trap might have several technical disadvantages (Garrett-Jones 1970, Service 1976), the technique is likely to remain indispensable for many field studies such as ours. To obtain a nonbiased sample of biting females a large field staff is required (Chandler et al. 1975). Practically, in such forested areas, the number of human baits and their catching stations has to be limited to one or 2, therefore the chances of sampling error are likely to be greater. In such situations results from light traps may therefore be more representative of biting densities in a village as a whole and less subject to what happens in a single household (Lines et al. 1991).

In the villages in forest, routine malaria surveillance by NMEP was poor and because of inaccessibility, blood slides were not made during the rainy season, which coincides with the active *P. falciparum* transmission season. Presumptive treatment given at the time of blood smear collections is of no help in providing radical cure because of considerable delays before examination and a high degree of chloroquine resistance in *P. falciparum* (Singh et al. 1989b, Singh and Shukla 1990). People were aware of malaria yet the average time taken to report to a hospital or dispensary was about 7 days after the first fever, which extended to 10–15 days during the rainy season. Out of 3 probable malaria deaths during the rainy season, one patient from Kukra village (25 km from PHC) died, as he could not go to the hospital for more than 10 days and was under treatment by a village quack (Singh et al. 1992). In villages away from forest, people can go to the hospital at any time. In these villages the annual parasite incidence and slide positivity rate are on a decline but the number of *P. falciparum* cases remained constant. The drop in prevalence of *P. vivax* could be due to a differential species response to chloroquine, which was used intensively by patients to treat presumptive malaria. Also, the free use of chloroquine and other antimalarials might have sup-

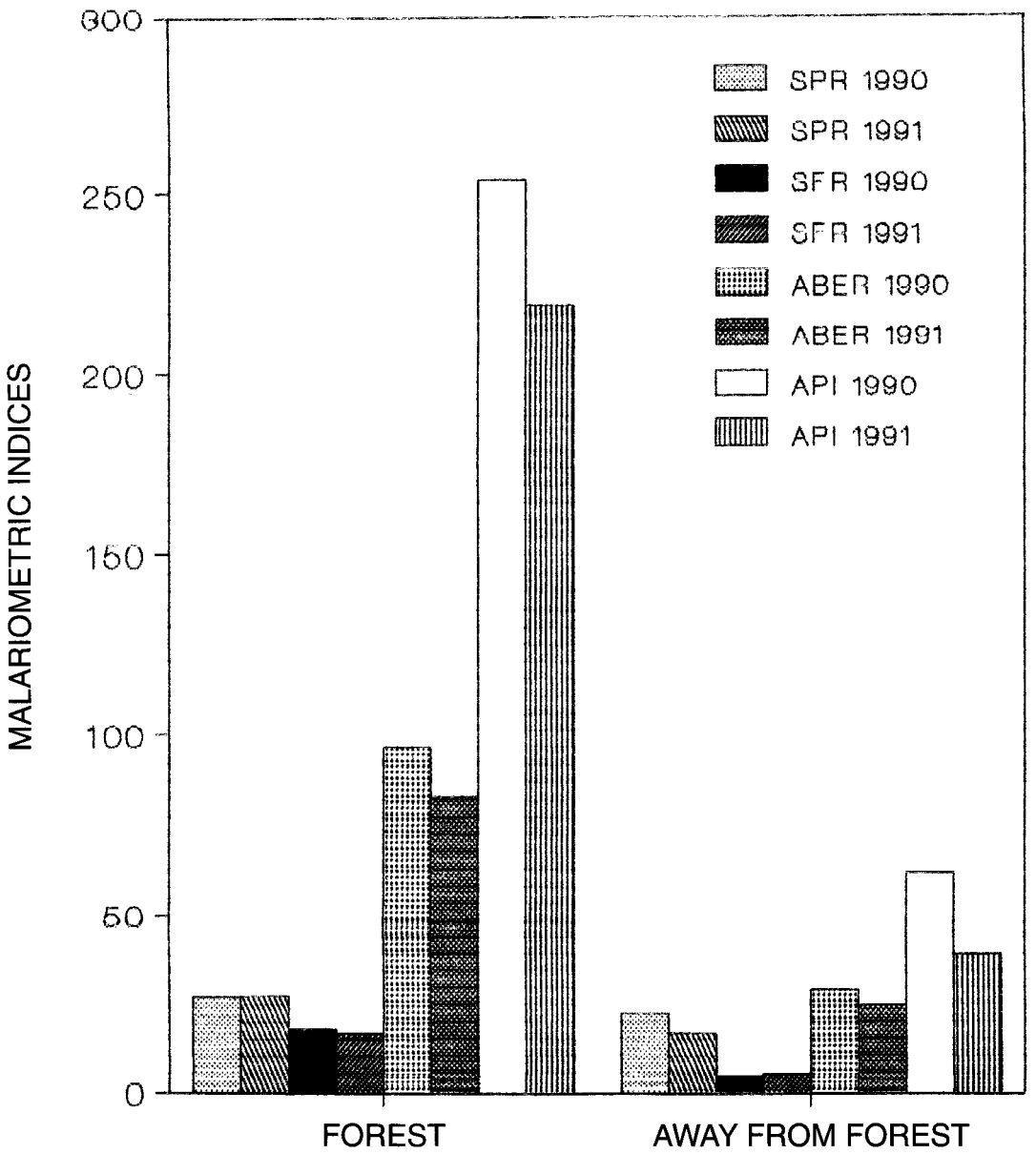

Fig. 2. Epidemiological situation of malaria in villages in forest and away from forest during 1990–91. SPR = slide positivity rate, SFR = slide falciparum rate, ABER = annual blood examination rate, and API = annual parasite incidence.

pressed *P. vivax* (Basavaraj 1960, Sharma et al. 1973, Fox and Strickland 1989). Alternatively, a shift towards *P. falciparum* could be due to an increase in chloroquine resistance (Clyde 1984[5], Kondrashin et al. 1987).

During this investigation the vectors of malaria could not be determined by dissection of mosquitoes in villages in forest because of many operational problems. Earlier entomological studies in a similar ecological situation (Subbarao et al. 1992) indicated that out of 1,175 *An. culicifacies* assayed by immunoradiometric assay (IRMA), 6 were sporozoite-positive (2 *P. vivax* and 4 *P. falciparum*). Both *An. culicifacies* species C and D were incriminated for *P. vivax*

[5] Clyde, D. F. 1984. Tour report to Burma from 6–12 May. Unpublished WHO/SEARO document.

Table 6. Economic activities of tribals of Mandla in relation to malaria.

Month	Activity	Exposure to *Anopheles*	No. of nights in a month[1] spent: In forest	No. of nights in a month[1] spent: Away from forest[2]
Jan.–Feb.	Watching crops (wheat, pulses)	Sleeping in agriculture field	25	13
Feb.–March	Wheat harvesting		30	15
March–April	1. Mahua flower collection	Outdoor activities (0300–0600 h)	16	13
	2. Hunting/fishing		10	5
	3. Herb collection		13	3
May–June	1. Tendue leaves collection	Outdoor activities started at 0300 h besides outdoor sleeping during hot and humid season	28	15
	2. Hunting/fishing		14	13
Sept.–Oct.	Watching crop in field		20	5
Oct.–Nov.	Harvesting of rice	Sleeping in agricultural field	25	10
Nov.–Dec.	Sowing of wheat and harvesting of pulses		25	10

[1] They sleep in temporary watch huts on bare floor near fires during winter months without any warm clothes.
[2] On an average, 2.5 persons/household in villages in forest and one person/household in villages away from forest.

and *P. falciparum* sporozoites, although species A is an efficient vector. Out of 8 *An. fluviatilis* assayed, one was positive for sporozoites of both *P. vivax* and *P. falciparum.* The positive specimens were found in January, April, and October. The higher number of *P. falciparum* sporozoite-positive specimens as compared to *P. vivax*-positive specimens is in agreement with our parasitological data, in which *P. falciparum* cases were more numerous than *P. vivax* cases. Further cytogenetic and parasitologic studies are required to identify the taxonomic status of *An. culicifacies* and *An. fluviatilis* and their possible role in forest malaria transmission.

Food gathering and cultivation are the main activities of tribals. The infertility of the land, lack of irrigation, and primitive mode of cultivation make sustenance of life difficult even for 6 months a year. During the remaining 6 months the tribals depend exclusively on forest products or on forest labor. Even very young children (4–6 years) go with their parents to collect mahua. The flowers drop after midnight and people sleep under the trees to justify their claim to them. The constant movement of people makes it difficult to treat individuals and the malaria gametocyte load remains high in communities. Although the site of anopheline infection in forest villages was obscure, the villagers frequently spent the night in the open, presumably providing a source of infection to the anophelines prevalent outdoors. There is a strong possibility of extradomiciliary transmission and many cases may have gone unrecorded.

There are no records of any study carried out either on malaria epidemiology or on vectors of malaria in this region. This study shows that the impact of spraying is poor and malaria prevalence remains high throughout the year in villages in forest. Another problem in forest villages is the people's immense faith in sorcery and witchcraft. They still believe that diseases are due to the effect of an "evil spirit" and also due to wrong doing. They usually go to a Guniya (local priest) before going to a PHC. The local priest hails from the same community, lives among them, and is readily available. Only when people cannot obtain relief from a priest will they report to the doctor/PHC. Often they change villages temporarily to protect themselves from the effects of evil spirits. Thus, a variety of poorly understood sociological factors profoundly affect the transmission dynamics of malaria. Impregnated bed nets that are so effective in other parts of the world (Njunwa et al. 1991) were not found effective in this area because of the outdoor life and forest-based economy of the tribals (Singh et al. 1994). Thus, there is a need to test the feasibility and effectiveness of other methods of control in consonance within the cultural and social framework of the population. For example:

1. Health education should be given top priority to encourage villagers to become involved in the control and prevention of malaria.
2. Rapid and accurate new diagnostic tools such as the antigen detection dipstick test, Para-

sight™ F (Shiff et al. 1993), may be used to identify and treat *P. falciparum* immediately to prevent human suffering and further spread of transmission (Singh et al. 1996).

3. Surveillance should be strengthened and single-dose radical treatment should be given to control malaria in forested areas where vector control is less feasible and people are rarely accessible for extended courses of treatment.
4. A feasibility study on impregnated bed nets showed that during the hot and humid season, a majority of people sleep outdoors on the bare floor and there is no place to hang mosquito nets. Hence they wrapped the nets around their body while sleeping (Singh et al. 1994). There is a need to adapt the design of mosquito nets to make their use feasible. Hence, villagers should be given specially designed impregnated mosquito nets that can be hung somewhere during outdoor sleeping.
5. A change should be made to a more efficacious insecticide, and insecticide spraying should be carried out systematically to cover the periods February–April and October–November in order to prevent the peaks of malaria that occur during these times. Carefully monitored small-scale trials on spraying of temporary watch huts in agricultural fields where people stay overnight may also be tried to control extradomiciliary transmission.

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