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INDIAN JOURNAL OF MALARIOLOGY

INDIAN JOURNAL OF MALARIOLOGY

CONTENTS

Volume 26
Number 2
June 1989

Short Note

Chloroquine Resistant Imported *Plasmodium falciparum* in an Industrial Complex at Hardwar (U.P.) 123

S. Sinha, V.K. Dua and *V.P. Sharma*

Indian Journal of Malariology
Vol. 26, June 1989, pp. 65-74.

Studies on the Anopheline Fauna of Kheda District and Species Specific Breeding Habitats

R.S. YADAV[1], R.C. SHARMA[1], R.M. BHATT[1] and V.P. SHARMA[2]

Information on anopheline fauna of Kheda district in Gujarat dates back to 1950. Since then there have been vast ecological changes due to development projects and intensive irrigation. To study the anopheline fauna of Kheda district collections from 164 villages representing 7 talukas of the district were made. Sixteen anopheline species were recorded, of these 8 species were recorded for the first time. Maximum number of anopheline species (16) were recorded from canal irrigated area followed by 11 species from riverine area and 10 species from non-canal irrigated area. Four anopheline species namely *An.subpictus*, *An.culicifacies*, *An. annularis* and *An. stephensi* were predominant and constituted 99.9% of the total anophelines and rest of the 12 species accounted for 0.1%.

In this paper, results of the study on mosquito ecology with particular emphasis on species specific breeding preferences, associations and frequency of distribution in various types of aquatic habitats have been reported.

INTRODUCTION

Our present knowledge of the anopheline fauna of Gujarat is mainly from the works of Afridi *et al.* (1938), Jaswant Singh and Jacob (1943), Vishwanathan (1950), Nair and Samnotra (1967) and Singh *et al.* (1985). During the last three decades, there have been vast ecological changes in this area. Great importance has been given to agriculture, and there is a considerable increase in the canal irrigated area (from 500 hectares in 1950 to 61,300 hectares in 1980). Several factors like perennial irrigation and consequent multiple cropping coupled with increased water logging due to seepage and poor drainage have resulted in extensive mosquitogenic conditions. Further, deforestation, rapid urbanization, industrialisation and extensive use of insecticides in agriculture and public health may have brought about changes in the ecosystem and in the composition and bionomics of anophelines.

Thus, an attempt was made to study the anopheline fauna and their breeding preferences in Kheda district of Gujarat state. These studies should have relevance in organizing suitable antimosquito operations under the bio-environmental control strategy at present in operation in Kheda district.

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Table 1. Talukawise cultivable and irrigated land*

Taluka	Area in sq km				
	Total	Cultivable	Irrigated	Under paddy cultivation	Average no of wells per sq km
1. Anand	676	556.46	399.57	140.98	4.84
2. Kapadwanj	985.7	770.21	194.78	45.89	6.86
3. Nadiad	662.8	552.82	308.81	94.84	9.42
4. Mahemdabad	502.3	400.59	168.37	68.45	7.94
5. Matar	577	452.9	308.9	250.0	4.67
6. Petlad	475.2	414.81	232.13	100.36	8.56
7. Thasra	659.9	519.77	190.07	90.45	4.36

*As per 1982-83 Survey report, Directorate of Agriculture, Ahmedabad.

Table 2. Talukawise classification of villages

Taluka name	Canal irrigated villages	Non-canal irrigated villages	Riverine villages	Total
Adult collection				
1. Anand	10	—	1	11
2. Kapadwanj	—	19	4	23
3. Nadiad	43	30	18	91
4. Matar	11	1	4	16
5. Mahemdabad	—	11	—	11
6. Thasra	1	1	2	4
7. Petlad	8	—	—	8
Total	73	62	29	164
Larval collection				
1. Anand	16	—	1	17
2. Kapadwanj	—	4	2	6
3. Nadiad	36	26	18	80
4. Matar	11	—	1	12
5. Mahemdabad	—	9	—	9
6. Thasra	1	1	1	3
7. Petlad	5	—	—	5
Total	69	40	23	132

MATERIAL AND METHODS

Study area

Kheda district comprises of 10 talukas. It lies between 22° -7′ and 23° -18′ North latitudes and 72°-15′ and 73° -37′ East longitudes. The area is not homogenous in the sense that nearly half of the area is extensively canal irrigated and the villages are surrounded by a network of irrigation canals, distributaries and drainage systems (Table 1). Water logging and seepage from canals has created ideal mosquito breeding sources. Canal irrigation over the years has raised the subsoil water level high (upto 2 to 3 meters) even in summers. In the remaining area agriculture is dependent on tubewells and/or monsoons. Mosquitogenic potential in villages of the latter area is comparatively less in summer months. However, riverine villages continue to have perennial breeding potential.

Adult mosquito and immature collections were made from the villages of seven talukas namely Kapadwanj, Anand, Petlad, Matar, Mahemdabad, Thasra and Nadiad (Table 2). Out of these Nadiad and Kapadwanj talukas are under demonstration of bio-environmental control of malaria i.e., the application of environmental modification and manipulation and biological control methods.

Collection of immatures: Larval and pupal collections were made from all possible breeding habitats from April 1985 to May 1988. The breeding habitats surveyed, included ponds, small pools, hoof prints, river, riverbed pools, irrigation canals and channels, paddy fields, wells and various intradomestic water storage containers like earthen pots, tanks, barrels etc.

The immatures were collected by using either a dipper (9.5 cm diameter and 300 ml capacity), well net (25 cm diameter) or a teated glass dropper. The samples were brought to the laboratory in specimen tubes and reared in disposable plastic containers in the insectary, until adult emergence.

Adult collections: Regular adult mosquito collections were started from January 1984 in eight villages of Nadiad taluka. In 1985, 16 more villages were included in the study. In 1986 and 1987 collections were made from an additional 140 villages representing seven talukas of the district. Out of the total of 164 villages, 73 villages belonged to canal irrigated area, 62 to non-canal irrigated area and 29 to riverine area. The villages in which the application of water to crops was through an artificial channel using the stored water of rivers and lakes were grouped under the canal irrigated area. Non-canal irrigated area included villages in which only subsurface water from wells and/or tubewells was used to promote agriculture. Villages situated on the bank of the river or its vicinity were grouped under the riverine area.

Mosquitoes were collected from all the villages in the morning hours between 0500 to 0900 hrs using an aspirator. Collections were made from human dwellings, mixed dwellings and cattlesheds and were brought to the laboratory for species identification and record. All adult mosquitoes including those emerged from collections of immatures were killed with ether.

Mosquitoes were identified using the key of Christophers (1933).

RESULTS AND DISCUSSION

During the study period a total of 3,37,406 anopheline mosquitoes were collected representing 16 species. Table 3 gives the composition of different anopheline species in different geographical areas, namely canal irrigated, non-canal irrigated and riverine. A total of 16 species were recorded from canal irrigated area, followed by 11 from riverine and 10 from non-

Table 3. Per cent composition of different anopheline species

Species	Canal irrigated area		Non-canal irrigated area		Riverine area		Total	Per cent
	No. collected	Per cent	No. collected	Per cent	No. collected	Per cent		
1. *An. culicifacies*, Giles, 1901	9868	4.53	1629	2.43	5875	11.1	17372	5.15
2. *An. stephensi*, Liston, 1901	675	0.31	176	0.26	605	1.14	1456	0.431
3. *An. annularis*, Van der Wulp, 1884	9511	4.37	1263	1.88	710	1.34	11484	3.4
4. *An. subpictus*, Grassi, 1899	197368	90.68	63789	95.39	45648	86.28	306805	90.93
5. *An. aconitus*, Donitz, 1902	95	0.0436	1	0.0015	5	0.0094	101	0.03
6. *An. tessellatus*, Theobald, 1901	29	0.0133	3	0.0044	26	0.049	58	0.02
7. *An. turkhudi*, Liston, 1901	3	0.0013	4	0.006	27	0.051	34	0.01
8. *An. vagus*, Donitz, 1902	30	0.0137	1	0.0015	2	0.0037	33	0.01
9. *An. barbirostris*, Van der Wulp, 1884	21	0.0096	2	0.003	3	0.0056	26	0.008
10. *An. varuna*, Iyengar, 1924	23	0.0105					23	0.007
11. *An. fluviatilis*, James, 1902	4	0.0018			1	0.0018	5	0.001
12. *An. nigerrimus*, Giles, 1900	2	0.0009			1	0.0018	3	0.0008
13. *An. pallidus*, Theobald, 1901	2	0.0009					2	0.0006
14. *An. theobaldi*, Giles, 1901	1	0.0004	1	0.0015			2	0.0006
15. *An. pulcherrimus*, Theobald, 1902	1	0.0004					1	0.0003
16. *An. moghulensis*, Christophers,1924	1	0.0004					1	0.0003
Total	217634	100	66869	100	52903	100	337406	100

canal irrigated area. It was further observed that in all the three areas, *An. subpictus* was the most predominant species and it accounted for 86 to 95% of the total anopheline population. Composition of major anopheline species in three different areas has been given in Fig. 1, which shows that composition of *An. culicifacies* and *An. stephensi* was highest (11.1 and 1.14%) in riverine area followed by canal irrigated area (4.53 and 0.31%) and non-canal irrigated area (2.43 and 0.26%). Composition of *An. annularis* was highest in canal irrigated area (4.37%) followed by non-canal irrigated area (1.88%) and riverine area (1.34%). *An. subpictus* was represented highest in non-canal irrigated area (95.39%) followed by canal irrigated area (90.68%) and riverine area (86.28%). Rest of the species represented only 0.1% of the total anophelines in all the three areas.

The mosquito species also showed a marked variation in seasonal prevalence during the year. In non-canal irrigated area mosquito densities remained very low from January to June but in canal irrigated and riverine villages mosquito densities showed a peak in the month of March, apparently due to extensive canal irrigation and paddy cultivation in the former area and due to formation of river bed pools in the latter. Thereafter, the densities showed decline until the onset of monsoon in June, when an increase was deserved. Peak density occurred in

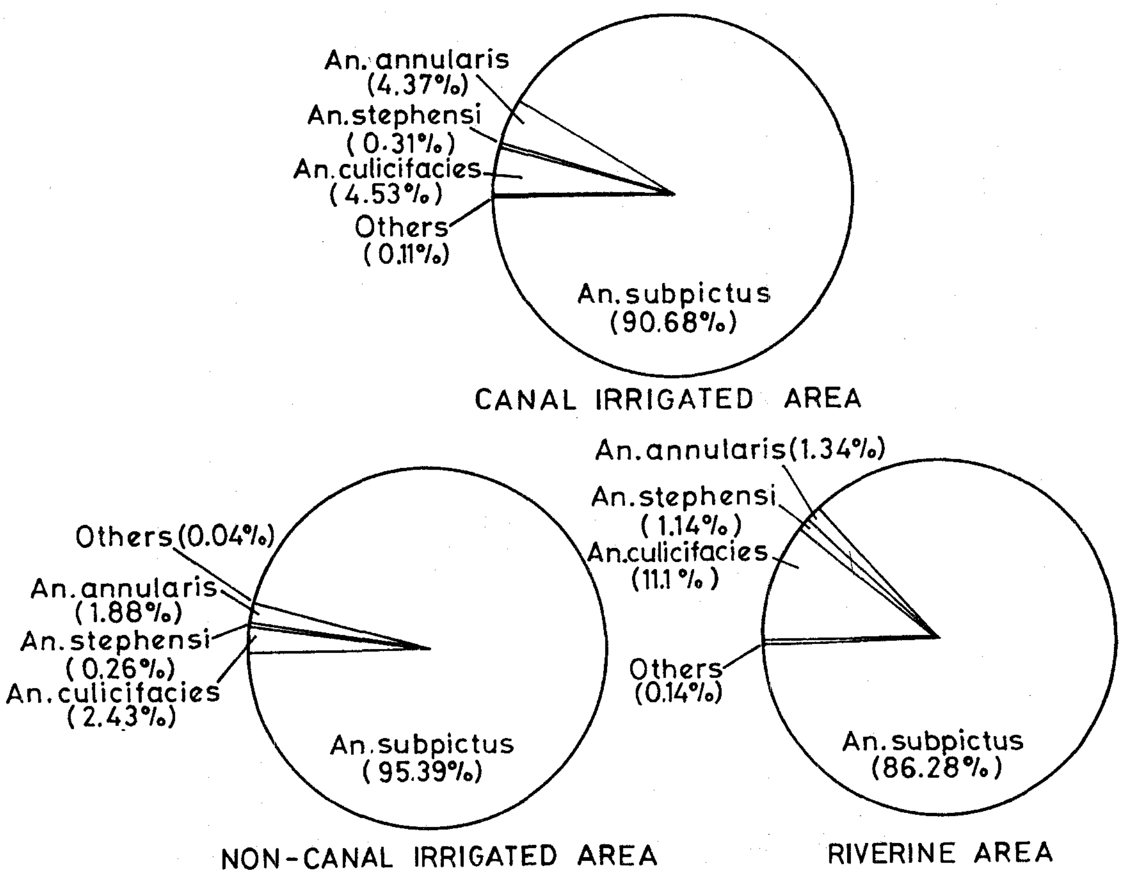

Fig. 1: Composition of anophelines.

Table 4. Per cent composition and sample positivity of anophelines in different breeding habitats

Species *	Ponds	Small pools	Hoof prints	Paddy fields	Canals	Irrigation channels	River	Riverbed pools	Wells	Intra-domestic
An. culicifacies	2.50 (12.36)	1.42 (6.20)	1.72 (5.55)	7.23 (28.13)	45.55 (53.08)	26.90 (19.76)	36.46 (60.73)	7.32 (34.78)	5.34 (14.13)	2.58 (5.60)
An. stephensi	0.74 (4.86)	0.48 (2.13)	0.69 (3.17)	1.14 (5.08)	3.24 (8.04)	0.70 (2.32)	1.16 (8.22)	1.57 (13.04)	48.35 (46.99)	69.46 (80.15)
An. annularis	8.20 (23.40)	1.94 (7.95)	1.17 (0.79)	14.70 (20.00)	9.12 '(26.27)	3.60 (18.60)	5.28 (25.57)	0.39 (13.04)	1.50 (4.59)	0.11 (0.61)
An. subpictus	86.44 (81.01)	95.54 (87.78)	96.42 (84.92)	74.60 (74.91)	40.20 (37.53)	67.94 (68.60)	56.53 (42.92)	90.72 (91.30)	40.15 (44.87)	27.84 (27.40)
An. barbirostris	1.75 (7.06)	0.29 (1.65)		1.54 (3.39)	1.32 (3.75)	0.62 (2.32)	0.51 (4.57)		4.61 (11.66)	
An. tessellatus	0.01 (0.22)	0.23 (0.48)		0.46 (1.69)		0.08 (1.16)				0.01 (0.12)
An. nigerrimus	0.25 (2.43)	0.06 (0.77)		0.15 (1.02)	0.37 (2.41)	0.16 (1.16)	0.06 (0.91)			
An. aconitus	0.08 (0.66)	0.02 (0.29)		0.12 (0.68)	0.17 (1.34)					
An. pallidus		0.01 (0.19)		0.06 (0.34)	0.03 (0.27)					
An. varuna	0.33 (0.22)								0.05 (0.35)	
An. vagus		0.01 (0.19)								
Total adults emerged	5936	19402	1455	3248	3486	1279	3354	765	2060	6624
Total species emerged	9	10	4	9	8	7	6	4	6	5
Total samples collected	453	1031	126	295	373	86	219	23	283	821

*Per cent composition among total adults emerged from all the samples of the habitat.
Figures in parentheses are per cent samples positive for the respective species.

monsoon season in all three types of areas. However, peaks in the densities of *An. subpictus*, *An. culicifacies* and *An. annularis* were generally seen in the months of August, September and November, respectively.

In earlier studies 8 anopheline species viz., *An. annularis, An. culicifacies, An. multicolor, An. pallidus, An. stephensi, An. subpictus, An. tessellatus* and *An. vagus* were reported from Kheda district (Vishwanathan, 1950). In the present investigation a total of 16 anopheline species except *An. multicolor* were recorded. Therefore, 8 new records viz., *An. fluviatilis, An. varuna, An. pulcherrimus, An. turkhudi, An. theobaldi, An. moghulensis, An. nigerrimus, An. aconitus* and *An. barbirostris* were found in the area. *An. fluviatilis* was conspicuously present in the canal irrigated and riverine areas (the species is normally recorded from foothill areas).

To study ecology of the anophelines with particular emphasis on species specific breeding preferences and frequency of the distribution of different species in various types of aquatic habitats, 3,710 samples of immatures from 10 different peri- and intradomestic mosquito breeding habitats were collected. These habitats included breeding places of temporary (hoof prints, riverbed pools), semi permanent (small pools, paddy fields, irrigation canals and channels) and permanent nature (ponds, river, wells and intradomestic sources). From the samples collected, a total of 47,609 adults emerged which represented 11 anopheline species. The samples of immatures produced five species less than those found in indoor collections.

Table 4 gives the per cent composition of different species among the total adults emerged from all samples of a particular habitat and sample positivity rate of anophelines in different habitats. *An. culicifacies* preferred to breed mostly in the canals, river, irrigation channels, riverbed pools and paddy fields. Per cent composition of *An. culicifacies* in the total adults emerged from the samples brought from these habitats was 45.55, 36.46, 26.9, 7.32 and 7.23% respectively. Its composition for wells and intradomestic containers was 5.34 and 2.58% respectively. Sample positivity rate of different habitats showed that *An. culicifacies* was present in 60.73% samples of immatures from river, 53.08% from irrigation canal, 34.78% from riverbed pools, 28.13% from paddy fields, 19.76% from irrigation channels, 14.13% from wells, 12.36% from ponds and between 5 to 6% in intradomestic containers, hoof prints and small pools. *An. culicifacies* has been reported ubiquitous in all types of breeding places except leaf axils and man-made cement or iron cisterns (Rao, 1984). But in the present study *An. culicifacies* breeding was observed in overhead tanks, ground level tanks, iron cisterns (barrels) and earthen pots also. Average composition of *An. culicifacies* in the total adults emerged from the samples collected from above mentioned breeding sources was 2.58% with an average sample positivity rate of 5.6%.

An. stephensi was observed breeding mainly in wells and intradomestic containers. Of the total adults emerged in the samples from wells, this species accounted for 48.35% and for 69.46% from intradomestic samples. 46.99% samples of immatures from wells and 80.15% samples from intradomestic sources were found positive for *An. stephensi* breeding. Except wells, other peridomestic habitats were not preferred by it, though its breeding was recorded from all the habitats searched. These findings further confirm the view that *An. stephensi* prefers to breed in wells and also in intradomestic containers.

An. annularis was found to breed in all types of habitats but its breeding was mainly recorded from paddy fields, irrigation canals, ponds, river and irrigation channels having some aquatic vegetation or grassy margins. Its composition in

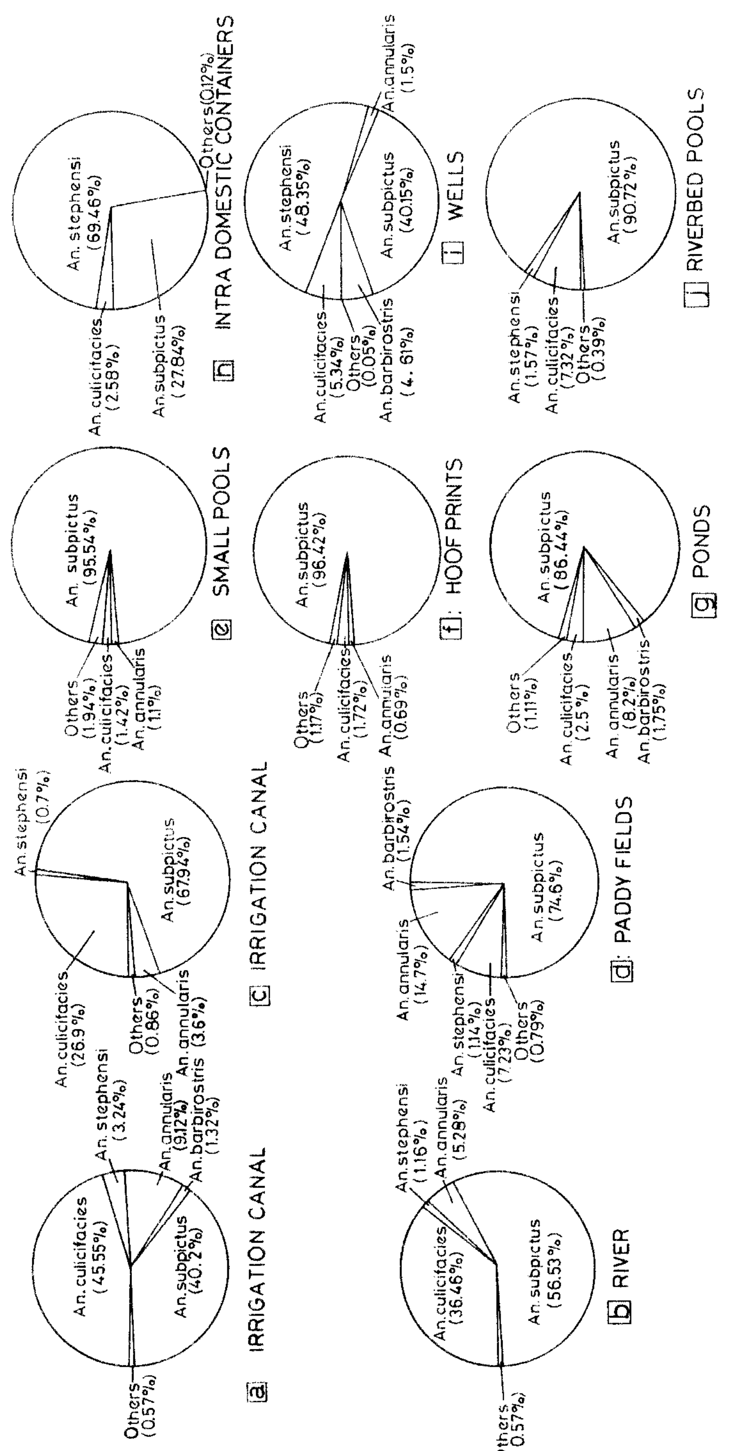

***Fig. 2:* Habitatwise composition of anophelines.**

adults emerged from samples of these habitats was 14.7, 9.12, 8.2, 5.28 and 3.6% respectively, whereas sample positivity rate was 20.0, 26.27, 23.4, 25.57 and 18.6% respectively. Russell and Rao (1941) found that *An. annularis* was breeding 13 times out of 1240 in wells (1.04%) whereas we have found that 4.59% samples of the wells were breeding for this species.

An. subpictus appeared to be an ubiquitous species as it was observed breeding prolifically in all the breeding habitats searched. Its composition in total adults emerged from peridomestic samples ranged between 40.15% in wells to 96.42% in hoof prints with a sample positivity rate ranging between 44.87 to 84.92%. Intradomestic habitats were preferred by it to a lesser extent with a composition of 27.84% and sample positivity of 27.4%. Rao (1984) also made similar observations and found that the species was widely distributed in many types of breeding habitats.

Among other species *An. barbirostris* showed a breeding preference for wells though it was recorded breeding in all peridomestic places searched except hoof prints and riverbed pools. *An. tessellatus* was found to breed in ponds, pools, paddy fields, irrigation channels and intradomestic sources; *An. nigerrimus* in ponds, small pools, river, irrigation canals, paddy fields and irrigation channels; *An. aconitus* in ponds, small pools, irrigation canals and paddy fields; *An. varuna* in ponds and wells; *An. vagus* in small pools and *An. pallidus* in small pools, paddy fields and irrigation canals.

Habitatwise per cent composition of major anopheline species found in the samples have been summarised in Fig. 2a-j. From Fig. 2 it can be seen that the irrigation canals supported maximum *An. culicifacies* breeding, whereas river, irrigation channels, paddy fields, small pools, hoof prints, ponds and riverbed pools supported maximum breeding of *An. subpictus*, wells and intradomestic sources supported the breeding of *An. stephensi*. In irrigation canals, intradomestic sources and wells *An. subpictus* was the second most predominant species. Similarly in river, irrigation channels, small pools, hoof prints and riverbed pools *An. culicifacies,* and in paddy fields and ponds *An. annularis* were the second most predominant species.

Our observations further revealed that in river, canals, irrigation channels and small pools *An. annularis* and in paddy fields, ponds, intradomestic sources and wells *An. culicifacies* were third most predominant species found to breed. In the adults emerged from samples of wells composition of *An. barbirostris* was 5% whereas in those from ponds, small pools, paddy fields, irrigation canals, irrigation channels and river it was less than two per cent each.

Looking at the number of species emerged from a particular habitat the sequence was as follows: Small pools (10), ponds and paddy fields (9 each), irrigation canal (8), irrigation channels (7), river and wells (6 each), intradomestic containers (5), and hoof prints and riverbed pools (4 each) as given in Table 4.

This study is of immense importance for planning anti-larval operations such as being tried under alternative approach through bioenvironmental control of malaria in Kheda district of Gujarat and elsewhere in India (Sharma *et al.*, 1986). For successful implementation of such an approach it is essential to identify the breeding habitats of vectors and then work towards species sanitation. For example present study revealed that *An. stephensi* prefers to breed in intradomestic water containers and wells. Mosquito breeding in intradomestic sources can be effectively controlled by introducing larvivorous fish (Guppy) and/or regular cleaning and covering the sources. Breeding in wells can be controlled by fish, by covering the water surface of disused wells with expanded polystyrene beads, as was successfully demonstrated by Sharma *et al.* (1985) and also by sealing, if feasible. Breeding in ponds can be effectively controlled by introducing larvivorous fishes after proper margining and deweeding, in small pools and riverbed pools by emptying water or by filling with earth. It was further observed that paddy fields, irrigation canals and channels and river supported extensive breeding of *An. culicifacies*. To control mosquito breeding in these habitats, besides use of fish, other methods such as use of siphons in river (Macdonald, 1939), use of biocides and intermittent irrigation of paddy fields, and flushing of canals would have to be evaluated and implemented. This study also pointed out that composition of *An. subpictus* which is a non-vector species, but a major cause of nuisance was very high in almost every habitat investigated during the study.

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Resting of Mosquitoes in Outdoor Pit Shelters in Kheda district, Gujarat

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Outdoor resting habits of mosquitoes were studied in Kheda district, Gujarat using the artificial pit shelters. Studies revealed that mosquitoes prefer to rest in pit shelters and these habitats can be used for monitoring of mosquito populations and other ecological and behavioural studies.

INTRODUCTION

Study of the resting behaviour of mosquitoes, particularly vectors of malaria is important for understanding vector bionomics. Most of the species which are in close contact with man and domestic animals are found resting inside houses or in animal shelters, thus giving the impression that these are the only resting places. However, it is a well known fact that many mosquito species including some of the major vectors of malaria prefer to rest in natural shelters in vegetation, in hollow trees, under culverts, animal burrows, crevices in the ground etc. The degree of outdoor resting varies considerably between different species and in the same species in different areas and seasons.

Search for outdoor resting mosquitoes usually proves time consuming and unrewarding. However, collection of outdoor resting mosquitoes occupies an important place in studies of mosquito ecology and behaviour. In the forested areas of Panchmahals district, Gujarat, Shalaby (1971) found large numbers of *An. culicifacies* and *An. fluviatilis* resting in specially dug artificial pit shelters. During the studies on integrated disease vector control of malaria by bio-environmental methods in the villages of Kheda district, Gujarat (Sharma *et al.*, 1986) the outdoor resting behaviour of mosquitoes was studied. Results of a one year study are reported in this paper.

MATERIAL AND METHODS

Five villages in the canal irrigated area of Kheda district namely Davda, Salun and Piplata in Nadiad taluka, Demol in Petlad taluka and Pansora in Anand taluka were selected for the study. During the study period of one year only one village i.e., Demol received DDT spray in the month of June 1988.

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Table 1. Composition of different anopheline species and culicines

Species	Pit shelter		Indoor shelter	
	No. collected	Per cent	No. collected	Per cent
1. *An. culicifacies,* Giles	784	11.44	4543	10.80
2. *An. stephensi,* Liston	14	0.20	98	0.23
3. *An. annularis,* Van der Wulp	81	1.18	698	1.66
4. *An. subpictus,* Grassi	1533	22.37	35329	83.96
5. *An. tessellatus,* Theobald	2214	32.31	9	0.02
6. *An. aconitus,* Donitz	355	5.18	3	0.007
7. *An. varuna,* Iyengar	11	0.16		
8. *An. fluviatilis,* James	3	0.04		
9. *An. pallidus,* Theobald	2	0.03	1	0.0023
10. *An. nigerrimus,* Giles	1	0.014		
11. Culicines	1855	27.07	1396	3.32
Total	6853	100	42077	100

Since it is a relatively arduous job to collect mosquitoes from a variety of natural outdoor shelters, in the present study specially dug artificial pit shelters were used from where mosquitoes could be collected conveniently. For this purpose 4 pits were dug in each study village either under trees or in a shady area between bushes. Pits were located on the outskirts of the village within 50-150 metres range between breeding sites and the village following Muirhead-Thomson (1958) technique. Each pit was 1.5 m deep, 1.2 m long and 1 m wide with three hollow cavities of 15 cm width and 30 cm depth situated about 30–40 cm above the bottom on each side. Mosquitoes were collected using an aspirator in the morning (between 0900 to 1000 hrs) on a fortnightly basis for a period of 12 months from July 1987 to June 1988. Mosquitoes were transferred to mosquito cages (30 x 30 x 30 cm size). Simultaneously, mosquitoes were collected from all the five villages in the morning hours (0600 to 0900 hrs) from human and cattle dwellings (4 each) for 15 mins each by hand collection method in order to monitor indoor resting density. Mosquitoes were brought to the laboratory, anesthetized with ether and identified using the key of Christophers (1933). Anophelines collected from both indoor and pit shelters were further examined with respect to their stomach and gonotrophic conditions. Empty, fully fed, semi-gravid and gravid females were counted and their proportions calculated. Records for all the five villages were pooled and summed up on monthly basis for indoor and pit shelters separately.

RESULTS AND DISCUSSION

During the study period a total of 6853 mosquitoes were collected from artificial pit shelters and 42,077 from indoor resting habitats by hand collection method (Table 1). Table 1 gives the composition of different anopheline species and culicines in pit shelter and indoor collections. A total of 10 anopheline species were recorded from pits whereas only 7 species were found resting indoors. *An. tessellatus* was most dominant (32.31%) in pits followed by culicines (27.07%), *An. subpictus* (22.37%), *An. culicifacies* (11.44%) and *An. aconitus* (5.18%). Rest of the six anopheline species viz. *An. stephensi, An. annularis, An. varuna, An. fluviatilis, An. pallidus* and *An. nigerrimus* contributed 1.63%. In the indoor collections *An. subpictus* contributed 83.96% of the total mosquitoes followed by *An. culicifacies* (10.80%) and culicines (3.32%). Composition of rest of the five anopheline species was only 1.92% and that of *An. tessellatus* and *An. aconitus* was merely 0.021 and 0.007%, respectively. Three species namely *An. varuna, An. fluviatilis* and *An. nigerrimus* were recorded from pit shelter collections only. Per cent composition of *An. culicifacies, An. stephensi* and *An. annularis* revealed that their distribution among pit and indoor shelters was nearly equal. Very high proportion of *An. tessellatus, An. aconitus* and culicines in pit shelters strongly indicate their preference for outdoor shelters. Russell and Rao (1941) have reported resting of *An. tessellatus* on the walls of wells.

Table 2 gives the average number of anophelines and culicines per pit in different months. Maximum number of mosquitoes were taken in the month of March (38.10) followed by September (35.87) and October (31.33). *An. culicifacies* and *An. subpictus* were also collected in large numbers during these months. *An. tessellatus, An. aconitus* and culicines were collected in large numbers nearly throughout the year and they were most abundant during the months of October, July and March respectively. *An. annularis* completely disappeared from pit shelters during the winter season. Although one of the five study villages received DDT spray in the month of June '88, no impact on the mosquito population resting outdoors could be observed.

Similar trend was observed in the density of total mosquitoes, anophelines and culicines in indoor collections (Table 3). From Table 3 it can be seen that *An. aconitus* and *An. tessellatus* were found resting in cattlesheds only and along with *An. pallidus* their densities remained below one per man hour. In both human and cattle dwellings two peaks in the density of *An. subpictus* and culicines were observed which were also reflected in the total mosquito density and followed similar pattern. Highest densities of *An. culicifacies* in human (7.4) and cattle (135.9) dwellings were recorded in the month of April and March respectively, the density considerably high in October also in both habitats. *An. stephensi* and *An. annularis* were recorded throughout the year from cattlesheds. Density of the former in both habitats and the latter in human dwellings only remained below one per man hour.

Mosquito density showed declining trend from April onwards and a similar phenomenon was observed in pits. It can be concluded that variation in the numbers of *An. subpictus, An. culicifacies* and culicines taken from pits in different months followed the trend observed in their indoor densities and as such their population size in nature. Mosquito density in the sprayed village for the month of June has been shown in parentheses for comparison with the average density in five villages. It is clear that the spraying of DDT had no impact on mosquito population.

Though Kheda district received less rainfall (318.00 mm) in 1987 than the normal (769.5 mm), the study villages showed good numbers of mosquitoes because of rice cultivation and water logging due to canal irrigation.

Proportion of mosquitoes with different abdominal condition in pit shelters and indoor collections has been given in Table 4. Table 4 shows that the proportion of unfed anophelines i.e., *An. culicifacies, An. annularis* and *An. subpictus* was less in indoor than in pit shelter collections. *An. stephensi* was not found in sufficient numbers in pit shelters and *An. tessellatus* and *An. aconitus* in indoor shelters.

Table 2. Average number of mosquitoes collected per pit

Species	Jul (31)	Aug (33)	Sep (39)	Oct (36)	Nov (37)	Dec (40)	Jan (40)	Feb (40)	Mar (40)	Apr (38)	May (40)	Jun (36)	Jun (8)*	Total adults
An. culicifacies	0.35	0.03	4.51	4.77	0.37	0.12	0.25	0.87	3.62	3.42	1.75	0.50	(0.50)	784
An. stephensi			0.20	0.05	0.05		0.025				0.025			14
An. annularis	0.77	0.12	0.20	0.44					0.17	0.15	0.17	0.25	(0.50)	81
An. subpictus	1.41	1.30	21.20	3.69	1.10	0.50	0.55	1.75	4.65	1.92	1.42	0.47	(0.75)	1533
An. tessellatus		0.15	5.17	19.69	2.86	0.47	0.62	3.85	13.17	10.97	0.95	0.33		2214
An. aconitus	3.16	1.12	1.00	0.83	0.62	0.82	0.25	0.25	1.07	0.63	0.15	0.05	(0.25)	355
An. varuna		0.03	0.12			0.07	0.025					0.027	(0.12)	11
An. fluviatilis		0.03				0.025	0.025							3
An. pallidus	0.03										0.025			2
An. nigerrimus									0.025					1
Culicines	2.96	0.81	3.43	1.83	2.81	3.87	2.67	7.75	15.37	5.42	0.75	0.53	(0.50)	1855
Total mosquitoes	8.70	3.60	35.87	31.33	7.83	5.90	4.42	14.47	38.10	22.44	5.22	2.15	(2.62)	6853

Figures in parentheses are the number of pits searched.
*DDT sprayed village.

Table 3. Man hour density of mosquitoes in indoor shelters

Species	Type of dwelling	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
An. culicifacies	HD		0.50	1.70	6.80	0.90		0.30	2.10	4.40	7.40	6.30	0.37 (4.00)
	CS	1.50	4.30	14.90	53.50	16.20	12.00	7.20	79.20	135.90	68.50	26.20	1.12 (12.50)
An. stephensi	HD				0.10							0.10	
	CS	0.90	1.10	0.60	0.30	1.30	1.30	0.70	0.20	0.60	0.80	1.10	0.12 (3.00)
An. annularis	HD	0.50	0.10	0.20	1.00		0.10			0.90	0.30		0.37 (0.50)
	CS	8.40	1.90	3.30	5.70	10.80	7.00	5.50	4.20	8.30	9.50	1.40	0.37
An. subpictus	HD	22.80	107.50	446.40	196.80	16.30	4.30	5.90	20.30	121.00	92.50	36.20	6.12 (26.00)
	CS	43.80	293.80	753.40	345.80	127.10	58.60	79.00	160.10	339.20	161.60	69.10	14.12 (50.00)
An. tessellatus	HD											0.10	
	CS				0.30				0.10	0.20	0.10		
An. aconitus	HD												
	CS				0.10		0.20						
An. pallidus	HD												
	CS					0.10							
Culicines	HD	2.40	6.40	7.10	5.10	4.20	2.70	3.90	9.40	20.40	14.20	4.30	1.00 (2.50)
	CS	1.40	3.00	7.60	3.00	3.90	2.90	5.80	5.90	13.90	5.80	4.50	0.25 (1.50)
Total mosquitoes	HD	25.70	114.50	455.40	209.80	21.40	7.10	10.10	31.80	146.70	114.40	47.00	7.87 (33.00)
	CS	56.00	304.10	779.80	408.70	159.40	82.10	98.20	249.70	498.10	246.30	102.30	16.00 (67.00)

Figures in parentheses indicate man hour density in sprayed village.
HD : Human dwelling: CS : Cattleshed.

Table 4. Proportion of different abdominal stages of anophelines in pit shelter and indoor collections

Species	Habitat	Unfed	Abdominal condition (%)			Total Adults
			Fully fed	Semi gravid	Gravid	
An. culicifacies	Pit	6.37	39.79	32.27	21.55	784
	Indoor	2.97	40.20	32.62	24.21	4543
An. stephensi	Pit	*	*	*	*	14
	Indoor	6.12	52.04	30.61	11.22	98
An. annularis	Pit	8.64	50.61	29.62	11.11	81
	Indoor	5.15	52.00	30.08	12.75	698
An. subpictus	Pit	19.50	28.50	32.74	19.24	1533
	Indoor	5.07	27.72	44.50	22.70	35329
An. tessellatus	Pit	13.55	47.40	27.56	11.47	2214
	Indoor	*	*	*	*	9
An. aconitus	Pit	6.93	56.35	30.05	6.64	355
	Indoor	*	*	*	*	3
All anophelines	Pit	13.73	41.04	30.11	15.05	4998
	Indoor	4.84	29.60	42.88	22.66	40681

* Not calculated due to small numbers.

Fully fed population of *An. annularis* in both habitats, *An. stephensi* in indoor shelters and *An. aconitus* in pit shelters was more than 50% of the total collection. There was very little difference in the proportion of fully fed *An. culicifacies* (39.79 and 40.2%) and *An. subpictus* (28.5 and 27.72%) in pit and indoor shelters.

The proportion of semi-gravid *An. subpictus* was highest (44.5%) in indoor collections. It varied between 27 to 33% in respect of rest of the anophelines in both habitats. Proportion of gravid *An. culicifacies* and *An. subpictus* was highest among all the species. Later stages of the gonotrophic cycle (semi-gravid and gravid) in *An. culicifacies* and *An. subpictus* were more than 52% of the total females of each species, ranging between 36 to 43% for rest of the anopheline species collected. Per cent composition of gravid *An. aconitus* was lowest (6.64%) among all species. Anophelines collected from pit shelters were found in all stages of gonotrophic cycle which indicate that outdoor resting was not a casual feature.

This study clearly indicates that the artificial pit shelter technique of mosquito collection is of immense value in detecting and sampling outdoor resting populations of mosquitoes. In this study, the pit shelter collections helped in detecting outdoor resting populations of *An. tessellatus* and *An. aconitus* which are otherwise encountered in very low numbers in indoor collections. Collection of *An. culicifacies* in large numbers and in all stomach and gonotrophic stages throughout the study period proved its outdoor resting habit even in absence of any insecticidal pressure.

It is emphasized, however, that collections from pit shelters should be supplemented by collections from other natural outdoor harbourages to find out which type of shelter is preferred by different mosquito species. It can be concluded that the monitoring of outdoor resting mosquitoes should be a useful parameter, in addition to monitoring of indoor densities, in any malaria control programme particularly in areas where residual insecticidal spray is carried out as mosquitoes would tend to leave the sprayed structure and prefer to rest outdoors.

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Efficacy of 5 Day Radical Treatment of Primaquine in *Plasmodium vivax* Cases at the BHEL Industrial Complex, Hardwar (U.P.)

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Studies on 725 *P. vivax* infected patients at the Bharat Heavy Electricals Ltd. produced 6.9 per cent relapse rate after administration of radical treatment of primaquine @ 15 mg daily for 5 days as followed under the National Malaria Eradication Programme. Maximum relapses were recorded in a female patient in spite of repeated radical treatment.

INTRODUCTION

Bharat Heavy Electricals Limited (BHEL) located at Hardwar, is an important industrial complex rated as one of the top profit making undertakings of the Government of India. A survey in 1985 revealed that malaria was the most important public health problem at this complex. Though the BHEL hospital has all modern medical facilities with a 180-bed hospital and an antimalaria squad on the campus, malaria cases were rising every year much to the concern of the hospital authorities. In addition, there were reports of relapses of *P. vivax* cases after administration of 15 mg primaquine daily for 5 days. A study was, therefore, taken up on the efficacy of 5 day radical treatment in *P. vivax* cases at the BHEL Complex. It is noteworthy that in September 1986 an alternate strategy known as the bio-environmental control of malaria was launched on this campus. In the first year, malaria cases were reduced by 80 per cent and in the second year indigenous transmission was significantly curtailed (Dua *et al.,* 1988). Study on the relapse pattern of *P. vivax* was taken up during the declining phase of malaria transmission (Fig. 1). Results of this study are reported below.

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MATERIAL AND METHODS

The study area comprised of industrial complex of BHEL, at Ranipur (U.P.), is located about 10 kms away from the religious city of Hardwar. It is spread over an area of 25 sq kms with a total population of about 45,000. The campus has excellent medical facilities with a hospital and six dispensaries located in different sectors. Weekly surveillance was introduced in labour colonies

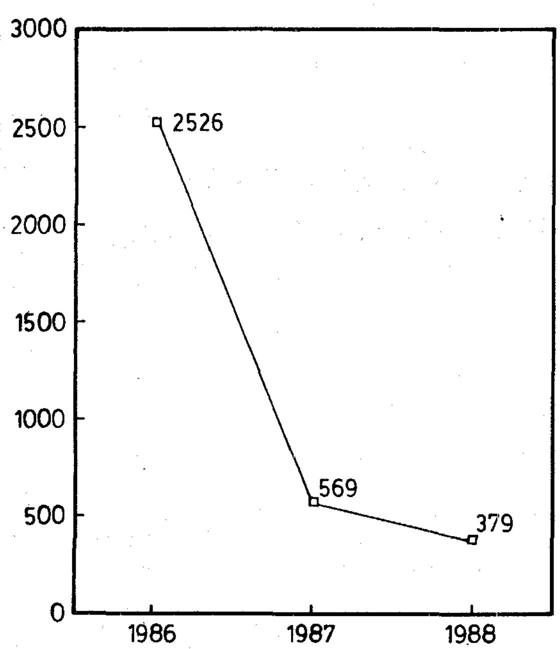

Fig. 1: *Plasmodium vivax* cases at the BHEL Complex, Hardwar, U.P.
Bio-environmental control of malaria was launched in June 1986 and vivax malaria cases have shown considerable reduction in successive years.

by the project staff. Blood smears collected by the BHEL hospital/dispensaries were also handed over to the clinic functioning at the BHEL Complex. Blood smears were fixed and stained with JSB stain followed by microscopic examination for the presence of malarial parasites. Presumptive treatment was not given, all patients were given only antipyretic treatment comprising of 2 tablets of paracetamol as adult dose. Malaria patients were given radical treatment within 24 hrs. Personal discussions with patients or with their guardians (in case of minors) were recorded by surveillance staff to elicit previous illness history and movement etc.

The study was initiated in September 1986. *P. vivax* infected patients were administered 900 mg of chloroquine base (Day-0 600 mg and Day-1 300 mg) and a 5 day course of 75 mg of primaquine base (15 mg/day). Dose schedule for chloroquine and primaquine were reduced proportionately in age groups below 15 years. All cases were given drugs under the supervision of project staff to ensure full dosage administration. A case was considered as relapse when the patient became positive again, a few weeks

Table 1. Relapse pattern in *P. vivax* at the BHEL complex, Hardwar (U.P.)

Cases treated and followed upto 548 days			Cases showing first relapse			Relapse pattern			
725			50			First relapse	Second relapse	Third relapse	Fourth relapse
Age group	Male	Female	Age group	Male	Female				
1-4	11	20	1-4	0	1	50 (6.9%)*	8 (1.1%)*	2 (0.27%)*	1 (0.14%)*
4-8	48	27	4-8	3	4				
8-14	53	43	8-14	1	2				
14 and above	355	166	14 and above	29	10				
Total	467(64.3%)	258(35.6%)	Total	33(66%)	17(34%)				

* Figures in parentheses represent relapse rates out of total cases (725) followed.

after complete clearance of parasitaemia and in spite of a full course of chloroquine and primaquine. Periodicity was also observed clinically in relapse cases by which they could be separated from fresh infections. Relapse cases were treated with both chloroquine and primaquine as administered before.

RESULTS AND DISCUSSION

Blood smear examination (during January to December 1986, September to December 1987 and till March 1988) revealed 763, 569 and 13 cases of *P. vivax*. Out of 1345 *P. vivax* cases, 725 patients were treated and followed up by the project staff, whereas the remaining cases were treated by BHEL doctors. Male patients showed more positivity (64.3%) than female (35.6%) (Table 1). This may be due to high mobility of workers in an industrial situation as recorded by Shukla *et al.* (1978). Age wise analysis indicated that age group 14 and above produced maximum infections. First relapse occurred in 50 (6.9%) patients in spite of 5 day radical treatment (Table 1). Maximum relapses were observed in age group 14 and above. Second, third and fourth relapses were observed in 8 (1.1%), 2(0.27%) and 1(0.14%) patients respectively. The observed first relapse rate (6.9%) was in agreement with earlier reports of relapse in indigenous *P. vivax* strains from different parts of India (Singh *et al.*, 1953; Basavaraj, 1960; Sharma *et al.*, 1973 and Roy *et al.*, 1979). Table 2 shows that the interval between completion of treatment and first relapse ranged from 27–395 days which is comparable to that reported from Nepal (Kondrashin and Shakya, 1981) for imported *P. vivax* cases from India. It may be noted that ninety per cent of the first relapses occurred within eight months. Comparison between initial infection and first relapse after treatment in 50 cases, suggested that persons who had acquired infection during the month of September, yielded maximum relapses i.e., 13 followed by 8 persons infected in June and 7 in April infections (Table 3). This indicates that relapse rate may also depend on the month of initial infection. Although about fifty per cent of the first relapses occurred in the transmission season, possibilities of fresh infection during 1987 and 1988 were remote due to several factors like low parasite incidence, vectors at low ebb, strong chemotherapeutic measures and no evidence of indigenous *P. falciparum* cases (Dua *et al.*, 1988).

Table 2. Interval between completion of treatment and first relapse at the BHEL complex, Hardwar U.P.

Interval (Months)	No. of relapse cases(%)
27 days to 2	11 (22)
> 2 - 3	8 (16)
> 3 - 4	7 (14)
> 4 - 5	5 (10)
> 5 - 6	3 (6)
> 6 - 7	7 (14)
> 7 - 8	4 (8)
> 8 - 9	1 (2)
> 9 - 10	1 (2)
> 10 - 11	1 (2)
395 days	2 (4)
Total	50

In the present study, four consecutive relapses were observed in a 19 year old female patient in spite of repeated primaquine therapy. This is the first report from India of such a case.

Thus, the study revealed that 5 day radical treatment with primaquine may not be adequate to prevent *P. vivax* relapses as reported by Krotosky (1980) and higher doses of primaquine may be required to ensure prevention of relapses as suggested by Clyde and McCarthy (1977).

Table 3. Comparison of months of infection and the first relapse at the BHEL complex, Hardwar (U.P.)

Primary infection	First relapses (Nos.)	Months of relapse and number of relapses in parentheses
Jan	1	Jun (1)
Feb	2	Jun (1) and Sep (1)
Mar	2	Apr (1) and Sep (1)
Apr	7	Jun (2), Jul (1), Aug (1), Sep (1), Oct (1) and Nov (1)
May	3	Jul (1), Aug (1), Sep (1)
Jun	8	Jan (2), Jul (1), Aug (3), Oct (2)
Jul	5	Jan (1), Aug (2), Sep (1), Oct (1)
Aug	3	Mar (1), Sep (1), Oct (1)
Sep	13	Jan (1), Feb (2), Mar (2), Apr (1), Aug (1), Oct (3), Nov (2), Dec (1)
Oct	5	Jan (1), Feb (1), Jun (1), Jul (1), Aug (1)
Dec	1	May (1)

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Drug resistant *P. falciparum* in Madras (Tamil Nadu) and District Jabalpur (Madhya Pradesh)

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WHO micro *in vitro* tests for chloroquine resistance in *P. falciparum* were carried out during November, 1987 in Madras city, Tamil Nadu and in Kundam PHC of Jabalpur district, Madhya Pradesh. Out of 6 samples tested from Madras city, 5 showed resistance to chloroquine. Likewise, out of 14 samples tested in Jabalpur, 12 (85.7%) showed resistance to chloroquine. All the 20 samples showed normal susceptibility to mefloquine.

INTRODUCTION

Madras city of Tamil Nadu is contributing approximately 50 to 75 per cent of the total malaria cases in this state (Table 1). *P. falciparum* cases showed a gradual increase in this city during this decade. Presently, it was found that *P. falciparum* cases were showing recrudescence after treatment with chloroquine given by the state authorities. This indicated the possibility of chloroquine resistance in *P. falciparum* in this city. Till today, there is no report of chloroquine resistance in *P. falciparum* in Tamil Nadu. Preliminary *in vivo* studies carried out by Malaria Research Centre field station in Madras city gave an indication of the presence of chloroquine resistance in this area (Chandrahas, personal communication).

In Madhya Pradesh, Ghosh *et al.* (1981) detected a focus of RI level of chloroquine resistance in Bhanupratappur in 1980 and another focus of RI, RII and RIII levels in Pakanjur (DNK Project). Houghton (1983) reported RI to RIII type of resistance in Bastar district of the same state. Recently an explosive outbreak of *P. falciparum* malaria was detected in Jabalpur and Mandla districts of this state by the Malaria Research Centre field station. *In vivo* studies carried out in Bizadandi block of Mandla district showed RI to RIII level of chloroquine resistance from this region (Singh *et al.*, 1989).There were some deaths also in this region during 1987. Since active transmission was going on in this place

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Table 1. Incidence of malaria in Tamil Nadu and Madras city, 1980-86

Year	Tamil Nadu			Madras city		
	No. of malaria cases	Pf cases	Pf %	No. of malaria cases	Pf cases	Pf %
1980	73,381	2,802	3.81	36,193	189	0.52
1981	71,517	2,531	3.53	44,951	830	1.85
1982	65,797	3,048	4.63	44,981	1,673	3.72
1983	67,192	4,841	7.20	44,817	2,971	6.63
1984	71,320	4,724	6.62	48,523	3,358	6.9
1985	71,347	4,303	6.03	51,376	3,185	6.0
1986	52,948	2,848	5.37	39,197	2,608	6.65

Source NMEP.

Table 2. Micro *in vitro* test : sensitivity of *P. falciparum* to chloroquine and mefloquine in Madras city

S.No.	Age/Sex	Asexual parasites per mm^3	MICs of	
			Chloroquine pmols/well	Mefloquine pmols/well
1.	17/M	88,000	8*	4
2.	21/M	6,500	8*	4
3.	11/M	7,500	16*	4
4.	10/F	64,000	16*	4
5.	15/F	75,000	16*	4
6.	34/F	1,560	5.7	2

*indicates resistance to chloroquine.

without any interruption, it was decided to carry out micro *in vitro* test to determine the status of resistance of *P. falciparum* to chloroquine in this area.

The results of the tests carried out in these two places are recorded in this paper.

MATERIAL AND METHODS

Studies were carried out in these two places during November, 1987. Peripheral blood smears were collected from patients attending the Municipal Corporation malaria clinic in Madras city. In Jabalpur, active fever surveys were carried out in some selected villages of Kundam PHC. The smears were stained with JSB and examined for malaria parasites. Patients having an appreciable number of *P. falciparum* rings were selected for the test. The excretion of chloroquine in the urine was checked by the test of Dill and Glazko (Lelijveld and Kortmann, 1970). Those showing presence of chloroquine were excluded from the investigation.

Micro *in vitro* tests against both chloroquine and mefloquine were carried out in pre-dosed plates supplied by WHO and as per instructions laid down by it (1982). Finger prick blood samples (100 μl) were collected aseptically from each patient and were diluted in sterile RPMI-1640 medium. The plates were charged, placed in candle jar and incubated at 37^{o} to 38^{o}C for 24 to 30 hrs. The samples showing at least 10% post-incubation schizont maturation in control well were considered valid (Draper *et al.*, 1985). The rest were discarded, schizont maturation at ≥5.7 pmols of chloroquine and at ≥16 pmols of mefloquine indicated resistance against these drugs (Smrkovski *et al.*,1985). The minimal inhibitory concentrations (MICs) of both the drugs were obtained from the results of the post-incubation smear examination.

RESULTS AND DISCUSSION

Madras city

The results obtained from Madras city are put up in Table 2. It can be seen from the table that out of the six samples tested, adequate schizont maturation in control wells occurred in all of them. The MIC values in five samples were 8 pmols in two and 16 pmols in three; thus showing resistance to chloroquine. All the six samples showed sensitivity to mefloquine.

Kundam PHC, District Jabalpur

During the investigation 122 blood smears were collected from the study area. Out of these, 75 were positive for malarial parasites. Among the

Table 3. Micro *in vitro* test : sensitivity of *P. falciparum* to chloroquine and mefloquine from Kundam PHC, Jabalpur

S.No.	Age/Sex	Asexual parasites per mm^3	MICs of	
			Chloroquine pmols/well	Mefloquine pmols/well
1.	7/F	17,000	32*	5.7
2.	4/M	4,500	16*	2
3.	22/F	92,000	16*	16
4.	4/F	9,500	16*	4
5.	30/M	17,000	8*	4
6.	7/F	58,000	16*	5.7
7.	25/M	21,000	16*	8
8.	25/M	29,600	16*	5.7
9.	27/F	2,600	16*	4
10.	8/F	5,600	16*	5.7
11.	12/M	8,800	16*	5.7
12.	18/M	2,000	4	8
13.	25/F	2,600	5.7	4
14.	8/F	60,000	16*	5.7

*indicates resistance to chloroquine. Out of 22 samples tested, 14 showed growth in control wells.

positives, 11 were *P. vivax*, 62 *P. falciparum* and 2 mixed infection of *P. vivax* and *P. falciparum*. This indicated a high prevalence of *P. falciparum* in this area during the investigation. Out of 62 *P. falciparum* cases, only 22 were found suitable for the *in vitro* drug sensitivity study. Of these, normal control maturation was found in 14 (63.6%) samples. The results of the tests are shown in Table 3. It can be seen from the table that the MIC values in two samples were 4 and 5.7 pmols respectively. In the remaining 12 samples (85.7%), the MIC values ranged between 8 and 32 pmols. Thus, it is seen that 85.7% of the samples showed resistance to chloroquine. In all the 14 samples, schizont maturation was inhibited at or below 16 pmols of mefloquine showing normal sensitivity of these samples to this drug.

Chloroquine resistance is being reported from different geographical areas of India (Sharma, 1983) since its first report from Assam in 1973 (Sehgal *et al.*, 1973). The present study reports the first evidence of chloroquine resistance against *P. falciparum* in Madras city. Choudhury *et al.* (1983) reported the first evidence of chloroquine resistance in Delhi. Sinha *et al.* (1987) reported chloroquine resistance from Calcutta which is another metropolitan city in the eastern part of India. Singh *et al.* (1989) have reported a focus of chloroquine resistant *Pf* from Mandla district (M.P.). The present study also confirms the presence of chloroquine resistance in *P. falciparum* in Jabalpur district, the indication of which was found by *in vivo* tests carried out earlier.

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Transfusion Malaria amongst Operated Neurosurgical Patients—A Prospective Study of 22 Cases

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Twenty two patients with transfusion malaria were studied over a one year period. They constituted 7.5% of all neurosurgical patients receiving blood transfusions during surgery or in the immediate post-operative period. Malaria parasites could be demonstrated in the peripheral blood smears of only eight patients, and the rest (14) were diagnosed on clinical grounds, further supported by their prompt response to chloroquine therapy. In all the patients, investigations for local and systemic infections were normal. Cerebrospinal fluid examination did not reveal any abnormality. Patients under 30 years of age had significantly higher incidence.

INTRODUCTION

Transfusion Malaria is a rare complication of blood transfusion (Bruce-Chwatt, 1972; Bruce-Chwatt, 1982; Wickramasinghe, 1976; Guerrero *et al.*, 1983). Increasing incidence has been reported from the United States following the Vietnam war (Guerrero *et al.*, 1983). Usually the cases appear in the literature as case reports (Cokkinos *et al.*,1971; Mok *et al.*, 1980), and only a few epidemiological studies are available (Bruce-Chwatt, 1972 and 1974; Guerrero *et al.*, 1983). Till date no prospective study of TM is reported in the operated cases. The present study was conducted over a one year period to assess the incidence of TM in patients undergoing surgery.

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MATERIAL AND METHODS

This is a prospective study undertaken over a one year period during which 507 patients were operated for neurosurgical problems; of these, 290 patients received blood transfusion. Hundred and five developed post-operative fever and 22 were diagnosed as having TM (Table 1). The diagnosis of malaria was suspected when a patient continued to have fever in the post-operative period and investigations revealed no evidence of local or systemic infection. CSF examination did not suggest aseptic meningitis.

In 217 patients blood transfusions were not required during surgery or in the post-operative period, amongst them only 2 developed post-operative fever (all possible investigations showed normal results). Thus these patients were taken as control. Peripheral blood smears were examined for the presence of malaria parasites. The patients were given 600 mg of chloroquine to start, 300 mg after 6 hrs and 150 mg twice daily for a period of 2 days. Malaria antibody tests were not performed.

RESULTS

The age of the patients ranged from 4 to 72 yrs and 78% patients who received blood transfusion were under 40 years of age (Table 2). Hundred and fifty four patients were below 30 years and 16 developed TM, while only 6 out of 130 patients above 30 years age group developed TM (Chi-square test=7.9). None of the 22 patients had recent history of malaria and mean

Table 1. Clinical data

Total number of operations	507
Number of patients who received blood	290
Number of patients who developed malaria	22
Number of smears positive for malaria parasites	8

Table 2. Incidence of malaria in different age groups

Age in years	Total number of patients	Patients who developed malaria
0-10	42	2(1)
11-20	50	8(3)
21-30	62	6(3)
31-40	68	3(1)
41-50	39	2
51-60	25	—
61-70	4	1
Total	290	22

Chi-square(χ^2) test between patients above and below 30 years=7.9 (significant).

Numbers in parentheses indicate smears positive for MP.

Table 3. Volume of blood transfusion and malaria

Blood volume	No. of patients	No. developed malaria
Less then 500 ml	98	2
500 to less than 1000 ml	92	5
1000 to less than 2000 ml	56	6
2000 to less than 3000 ml	35	7
More than 3000 ml	9	2
Total	290	22

pre-operative hospital stay was 9 ± 3.4 days, hence it is unlikely that the patients were infected prior to admission and were in the incubation period. In 8 patients MP was seen in the peripheral blood smears. Fourteen patients with post-operative fever, in whom all possible investigations had normal results and empirical antibiotics failed, responded to chloroquine therapy. Only two patients in the control group, who did not receive transfusion, developed fever of unknown aetiology and both of them did not respond to empirical chloroquine therapy.

Two hundred and ninety patients received an average of 600 ml of blood transfusion. The volume of blood transfused ranged from 100 ml to 3600 ml. The incidence of TM correlated directly to the volume of blood transfused (Table 3). The incidence of malaria was highest amongst patients having blood group B (14/120) followed by group O (5/83). None of the patients having AB group developed TM (Table 4). Statistical analysis, however, did not reveal significant difference in the incidence of TM among the patients with different blood groups (Chi-square test = 5.7 NS).

DISCUSSION

Transfusion Malaria is a rare condition in the developed countries (Bruce-Chwatt, 1972; 1974; 1982; Maulitz *et al.*, 1976; De Virgiliis *et*

Table 4. Incidence of malaria in different blood groups

Blood group	Number of patients	Number of malaria cases
B	120	14
O	83	5
A	67	3
AB	20	—
Total	290	22

Chi-square (χ^2) test = 5.7(Not significant).

al.,1981). In the United States of America and other developed countries cases of malaria following blood transfusion appear as case reports. Following Vietnam war the incidence of TM had increased in the United States (Guerrero *et al.*, 1983). This condition is of great importance to the countries where malaria is still an endemic disease and the incidence of TM is likely to be several times higher than the incidence reported from nonendemic countries (Wickramasinghe, 1976; Rassadi and Aflatouni, 1979). From India, however, there is no report on the subject.

The incidence of TM is reported to be 0.2–50 per million units of blood transfusions (Bruce-Chwatt, 1974). Transfusion malaria is also reported in the post-operative period in patients receiving blood transfusions (Cokkinos *et al.*, 1971; Mok *et al.*, 1980; De Virgiliis *et al.*, 1981; Lefavour *et al.*, 1980). Ajao in 1978 had emphasized the high incidence of malaria in post-operative period. However, no prospective study has been conducted in a large number of patients receiving blood transfusion. Our study is the only one of its kind in the world literature.

In the present study only 8 patients had positive peripheral blood smears for malaria parasites. Hence in them the diagnosis was not in doubt, and it is highly unlikely that the patients were in the incubation period as the mean pre-operative hospital stay in these patients was 9 ± 3.4 days.

The remaining 14 patients, had negative peripheral blood smears but responded to chloroquine therapy. Recently Greenberg *et al.*(1988) reported malaria in 112 children and 83 of them had positive peripheral smear for MP, in 19 the peripheral smears were negative for MP and in 10 patients the results of the blood smears were not available. Diagnosis was made on clinical grounds even though the peripheral smears were negative. Negative peripheral smears do not necessarily negate the diagnosis of malaria. Perhaps, independent repeat examination of the peripheral blood smears by another laboratory may have given a higher MP positivity.

The incidence of TM reported in the present study is much higher than incidence reported earlier. However, one should not forget that there are only a few reports from endemic areas. The unusually high incidence of TM recorded in the present study is probably due to high incidence of malaria in blood donors and the existing blood bank rules do not prevent any one from blood donation even if he or she has recently suffered from malaria. Ajao (1978) reported that 48.4% of all post-operative fever is due to malaria in Nigeria. It is possible that many of our undiagnosed post-operative fever cases may well be due to malaria, as a result of blood transfusion.

Thus it should be kept in mind that patients with post-operative fever who test normal for all other investigations, could be suffering from TM. Our report brings home an unusual cause of post-operative fever and awareness of this condition should initiate the screening of blood donors for malaria.

This will also avoid unnecessary use of antibiotics, which is not only costly but sometimes also problematical.

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The Importance of *Anopheles dirus (A. balabacensis)* as a Vector of Malaria in Northeast India

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Anopheles dirus (A. balabacensis) is the most prevalent among twelve anopheline species collected during the course of entomological studies carried out in Changlang district of Arunachal Pradesh during July and August, 1988. It is observed to be a forest species and is found to breed in small stagnant water pools completely or partially shaded by plants in the open jungle. Sporozoites have been detected in several specimens of *A. dirus (A. balabacensis)* supporting its role in transmission of malaria in forest areas.

INTRODUCTION

Anopheles dirus Peyton and Harrison is a primary vector of human plasmodia in Southeast Asia. It occurs in foothills and forests of malarious areas throughout Thailand and neighbouring countries (Peyton and Harrison 1979; Baimai *et al.*, 1984). The northeastern region of India has a physiography similar to Burma and Thailand. The ecosystem consists of foothills, large forests, hilly streams, rivers, rivulets and high rainfall.

In studies carried out about three decades ago, *Anopheles minimus* was considered to be the chief vector of malaria in the northeastern region of India (Ramsay *et al.*, 1936; Iyengar, 1940; Viswanathan *et al.*, 1941; Misra and Dhar, 1955; Misra, 1956). In subsequent studies, the absence of this species after application of DDT as residual insecticide was reported from the Terai region of Uttar Pradesh (Chakraborty and Singh, 1957), Burnihat area of Meghalaya (Rajagopal, 1976) and Tirap district of Arunachal Pradesh (Das *et al.*, 1986). However, the role of this species in malaria transmission in this region cannot be ruled out as recent studies indicate the presence of this species from Nagaland (Bhatnagar *et al.*, 1982); Mizoram (Das and Baruah, 1985); Tirap district of Arunachal Pradesh (Dutta and Baruah, 1987); Assam (Kareem *et al.*, 1983) and Assam, Arunachal Pradesh and Mizoram (Nagpal and Sharma, 1987). The reports of incrimination of other species as malaria vector e.g., *A. philippinensis* in Meghalaya (Rajagopal, 1976) and *A. balabacensis* in Arunachal Pradesh and Mizoram (Sen *et al.*, 1973; Das and Baruah, 1985) are available.

A study conducted by Regional Medical Research Centre (ICMR), Dibrugarh in Changlang

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district of Arunachal Pradesh reveals the high incidence of *P. falciparum* malaria and the Centre has subsequently undertaken a short term entomological study to determine the prevalence of anopheline species and their vectorial role in current transmission of malaria. The entomological observations are presented in this paper.

MATERIAL AND METHODS

A study was undertaken in Jairampur, a small town under Nampong circle of Changlang district, Arunachal Pradesh having a population about 8000. This is a foothill area just after crossing the Assam border and surrounding the population immediately there are deep forestations traversed by rivulets and hill streams. Climate is hot and humid with heavy rainfall.

Mosquito survey was done at night with suction tubes between 1800 hrs to 2200 hrs from cattlesheds, indoors and outdoors and by CDC light-traps from dusk to dawn i.e., from 1800 hrs to 0500 hrs. Bednet traps were also used in temporary jungle huts of forest labourers. Mosquitoes were collected from the bednet traps in the morning. The mosquitoes collected from different sources were identified and dissected in a laboratory, temporarily set up at Health Sub-Centre, Jairampur to detect gland or gut infections.

Larval survey was carried out from time to time in the study area to detect the breeding places of vector mosquitoes. The larvae collected were reared in the laboratory for adult emergence and identification.

RESULTS

Data of anopheline collection by suction tubes is shown in Table 1 and collection by CDC light-traps and bednet traps in Table 2.

Table 1. Suction tube night collection in July and August 1988

S. No.	Species	Outdoor	MHD	Indoor*	MHD	Number dissected**	Gland positive
1.	*A. aconitus*	1	0.05	1	0.04	2	0
2.	*A. annularis*	7	0.22	0	0	6	0
3.	*A. dirus (A. balabacensis)*	211	1.55	61	2.77	176	2
4.	*A. 'hyrcanus'* group	15	0.18	0	0	0	0
5.	*A. karwari*	2	0.88	0	0	0	0
6.	*A. kochi*	38	0.36	0	0	21	0
7.	*A. maculatus*	15	0.16	0	0	14	0
8.	*A. philippinensis*	4	0.10	2	0.08	6	0
9.	*A. splendidus*	2	0.04	0	0	0	0
10.	*A. vagus*	11	0.16	0	0	0	0

MHD = Man Hour Density.

* Collected from open huts and cattlesheds.

** Only fresh mosquitoes dissected.

From the record of collection, it is seen that 12 anopheline species were detected during survey and *Anopheles dirus (A. balabacensis)* was the most abundant species constituting 62.6% of the total collection. Of the known vector mosquitoes, *A. annularis, A. philippinensis* and *A. dirus (A. balabacensis)* were encountered in the study area, but *A. minimus* was not detected. *A. dirus (A. balabacensis)* was collected by suction tubes in outdoor and indoor resting state in cattlesheds and open huts even from 1800 hrs onwards.

The mosquitoes were dissected to detect the gland or gut infection. Out of 609 *A. dirus (A. balabacensis)* dissected, 2 collected by suction tube and 5 collected in bednet traps were found positive with sporozoites in the salivary glands, giving a sporozoite rate of 1.14%. All the gland positive mosquitoes were collected from the

Table 2. CDC light-trap and bednet trap collection in July and August 1988 and results of dissection

S. No.	Species	Light-trap		Bednet trap		Numbers dis-sected*	Gland positive
		Numbers collected on 27 trap-nights	Collection per trap-night	Numbers collected on 16 trap-nights	Collection per trap-night		
1.	*A. annularis*	9	0.3 (1.39)	0	0	8	0
2.	*A. aconitus*	1	0.03 (0.15)	0	0	1	0
3.	*A. dirus (A. balabacensis)*	253	9.37 (39.34)	300	18.75 (98.0)	433	5
4.	*A. barbirostris*	3	0.11 (0.46)	0	0	0	0
5.	*A. 'hyrcanus'* group	155	5.74 (24.10)	0	0	0	0
6.	*A. karwari*	8	0.29 (1.24)	0	0	0	0
7.	*A. kochi*	155	5.74 (24.10)	0	0	126	0
8.	*A. maculatus*	42	1.5 (6.53)	2	0.16 (0.66)	40	0
9.	*A. philippinensis*	5	0.18 (0.77)	1	0.08 (0.33)	5	0
10.	*A. tessellatus*	1	0.03 (0.15)	0	0	0	0
11.	*A. vagus*	11	0.4 (1.71)	0	0	0	0

Figures in parentheses are percentage values.
*Only fresh mosquitoes dissected.

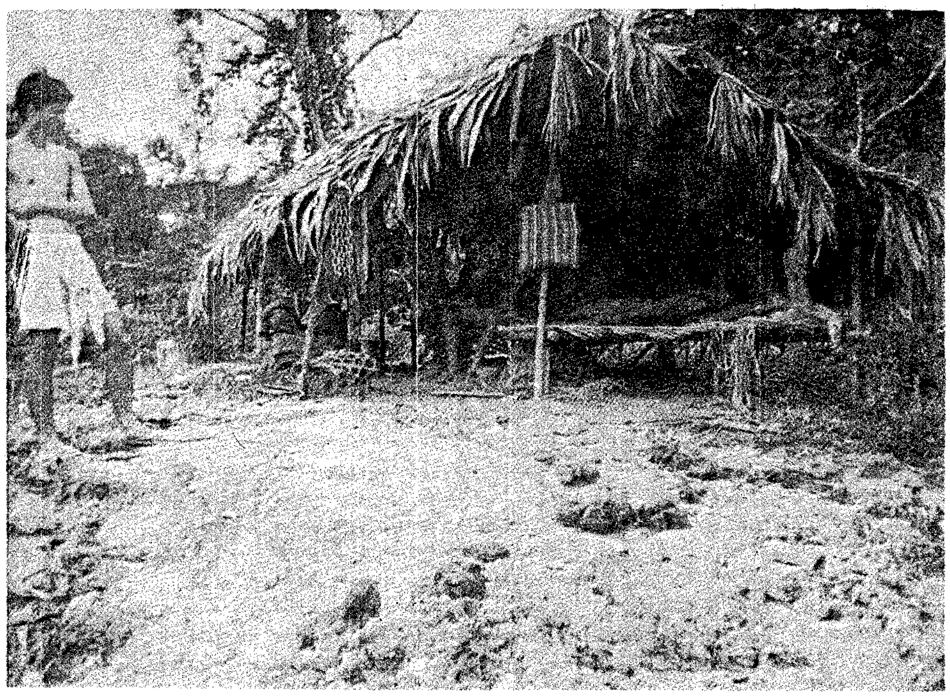

Fig.1: A temporary hut near the jungle.

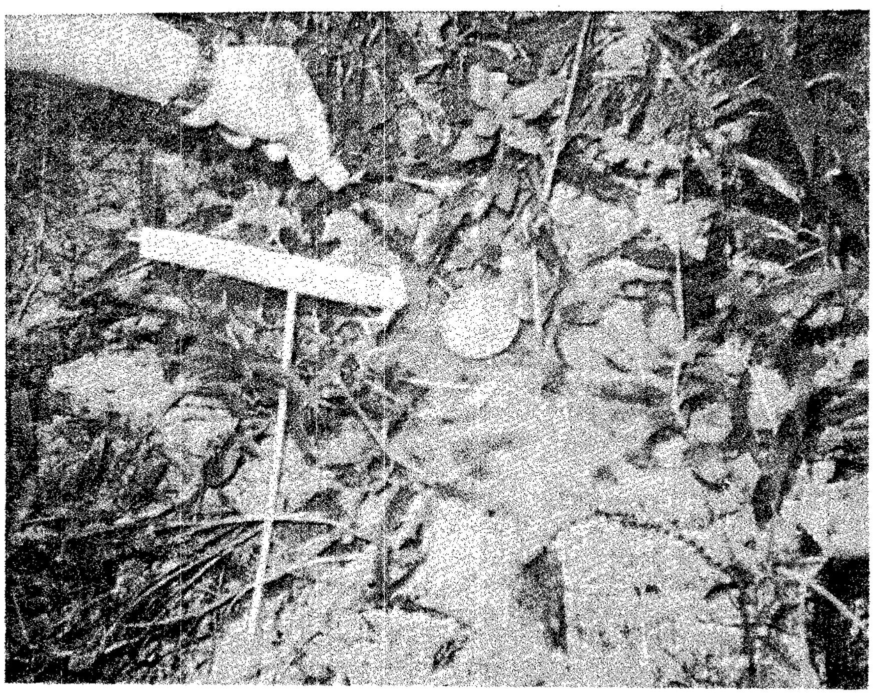

Fig. 2: A. dirus (A. balabacensis) breeding in stagnant water in bushy surroundings.

temporary huts used by the labourers of the log-contractors to stay inside or near the jungle (Fig. 1).

The preliminary larval survey of breeding places of the vector *A. dirus (A. balabacensis)* reveals that the species breeds in small stagnant water pools and also in water collected in elephant's footprints in the open jungle. It is found breeding in clean as well as turbid water. The turbid water supporting the breeding of this species is often fouled by elephants and other animals. The breeding places are completely or partially shaded by plants and never exposed to direct sunlight (Figs. 2 and 3).

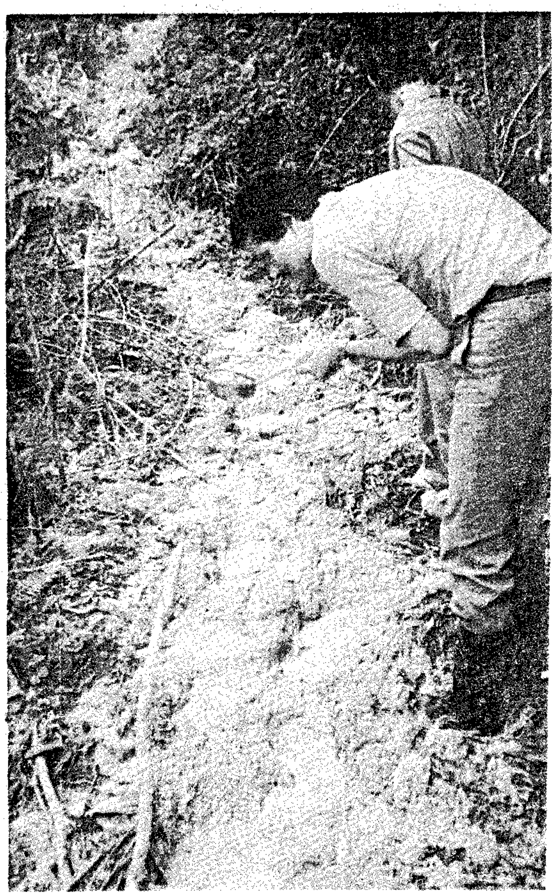

Fig. 3: A. dirus (A. balabacensis) breeding in partially shaded turbid water collection in elephant's footprints.

DISCUSSION

Our observations are in conformity with those of earlier investigators that *A. balabacensis* is a forest species breeding in small stagnant water pools or water collected in elephant's footprints in the open jungle, thus indicating the high risk of acquiring malaria in the forest areas (Clark and Choudhury, 1941; Khin-Maung-Kyi, 1971; Wilkinson *et al.*, 1978). Contrary to an earlier observation made by Clark and Choudhury (1941) that in no case were larvae of *A. balabacensis* found in partially shaded areas, we have found that *A. dirus (A. balabacensis)* breeds in partially shaded water collections in elephant's footprints.

The composition of *A. dirus (A. balabacensis)* in the present study was more (62.6%) than other anophelines from the study area under Changlang district (earlier Tirap district) of Arunachal Pradesh and seven natural infections were detected. This is similar to the earlier observation made by Sen *et al.*(1973) in Tirap district, Arunachal Pradesh that *A. balabacensis* constituted 60 per cent of the total collection with three gland infections in dissection. Thus, *A. dirus (A. balabacensis)* can be considered an important vector of malaria in Arunachal Pradesh.

A. balabacensis which actually represents a sibling species complex, has at least 4 taxa in the subspecies, *A.b. balabacensis* as evident from morphological, crossing and cytogenetic studies, apparently showing a distinct pattern in their distribution (Baimai *et al.*, 1981). *A. dirus* (one taxon) described from Thailand (Peyton and Harrison, 1979) also occurs in other mainland/ neighbouring Southeast Asian countries. Further studies revealed that in Thailand there are at least 4 isomorphic species within the taxon, *A. dirus* (Baimai *et al.*, 1988). Therefore, *A. dirus (A. balabacensis)* which is regarded as an important vector of malaria in many parts of the

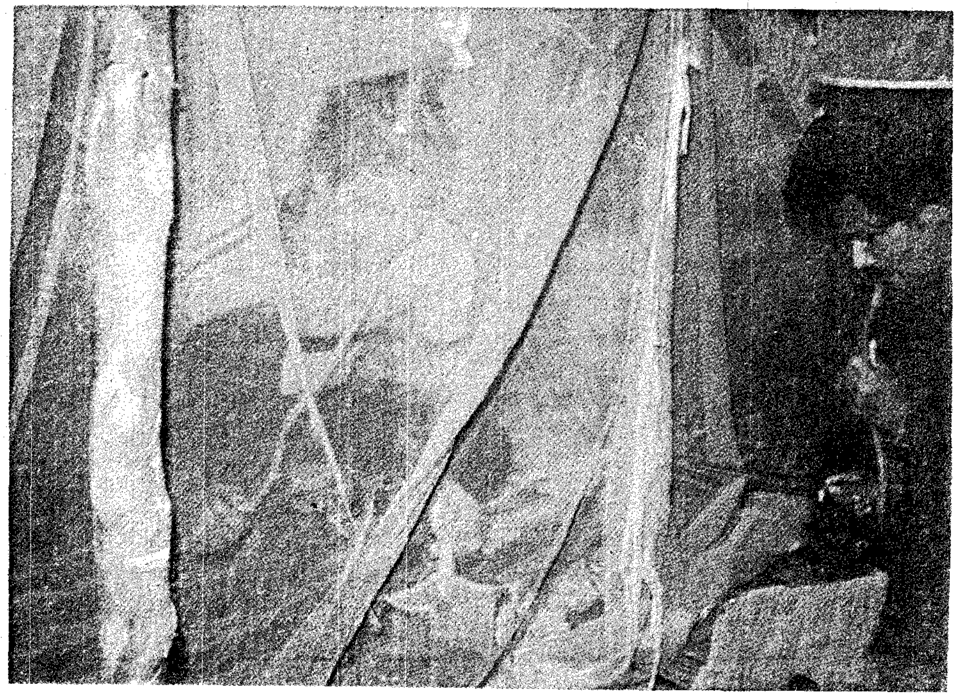

Fig. 4: A. dirus (A. balabacensis) collection by bednet trap.

northeastern region of India needs detailed studies for confirmation of the taxa/sibling species if any, in the light of morphological as well as cytogenetic studies.

In this study *A. dirus (A. balabacensis)* was observed to be a wild species and its presence was not detected in the daytime due to its exophilic nature. A good number of the species with gland infections (five) were detected by using bednet traps (Fig. 4). It is evident from the study that bednet traps can be used effectively in collecting exophilic and endophagic species like *A. dirus (A. balabacensis)*. CDC traps were also found productive for collection of this vector species. Thus both these trapping devices have an ethical advantage over human bait collection especially in areas where human baits are liable to come in contact with chloroquine resistant *P. falciparum*.

An earlier study (WHO, 1986) and a study carried out by Regional Medical Research Centre (ICMR), Dibrugarh (unpublished) in Jairampur area reveals that the area is highly endemic for *P. falciparum* malaria with foci of the chloroquine resistant strain. Blood slides, examination revealed *P. falciparum* infections among all the persons residing in the temporary open huts inside or near the jungle from where several natural infections were detected in *A. dirus (A. balabacensis)*.

These persons would take chloroquine indiscriminately whenever they felt feverish. Chloroquine can enhance infections of chloroquine resistant *P. falciparum* in *A. balabacensis* (WHO, 1987). Thus, the significance of *A. dirus (A. balabacensis)* as an efficient vector in a chloroquine resistant *P. falciparum* area is worthy of serious consideration.

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Bio-environmental Control of Malaria in a Tribal Area of Mandla District, Madhya Pradesh, India

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Bizadandi block of District Mandla was selected for demonstration of bio-environmental control of malaria. The project presently covers 80 experimental villages and 12 control villages.

In this area, because of indifferent surveillance and spraying in the past (from 1978-86) the API was reported low and the parasite reservoir in the community had built up over the years. At the outset of the study the malaria prevalence was high with preponderance of *P. falciparum*. Densities of A. culicifacies were very high and *A. fluviatilis* was also present.

P. falciparum predominated in both experimental and control area during 1988 than in 1987. Annual blood examination rate (ABER) was 73.6 and 57.5 and annual parasite incidence (API) was 114.7 and 228.0 in experimental and control villages in 1987, while in 1988, ABER and API was 63 and 73 and 112 and 316 in experimental and control, respectively. There was constant stabilization of *Pf* in neighbouring blocks in 1988 while in experimental areas *Pf* percentage has come down appreciably during March to June. It is very alarming to note that the parasite reservoir in control villages was sufficient to maintain active transmission even when antimalarial activities are at a peak.

The application of residual insecticides like DDT and HCH has no tangible impact on the reduction in vector densities and the transmission of malaria. Even if a replacement insecticide like malathion is used it may produce very limited impact on vector densities in such forested zones. Thus, there is an urgent need to intensify integrated malaria control operations in the area on long term basis.

INTRODUCTION

Mandla district in Madhya Pradesh (M.P.) is a predominantly tribal area. A preliminary survey of the villages of this district revealed that malaria was an endemic disease resulting in high morbidity, with reports of occasional deaths. The spraying of DDT had poor impact on malaria transmission. For treatment the people depend mostly on traditional methods and witchcraft. The health services were either not availed of or not easily available.

Bio-environmental control of malaria was launched in Bizadandi block in May 1986 with the objective to test the feasibility of environ-

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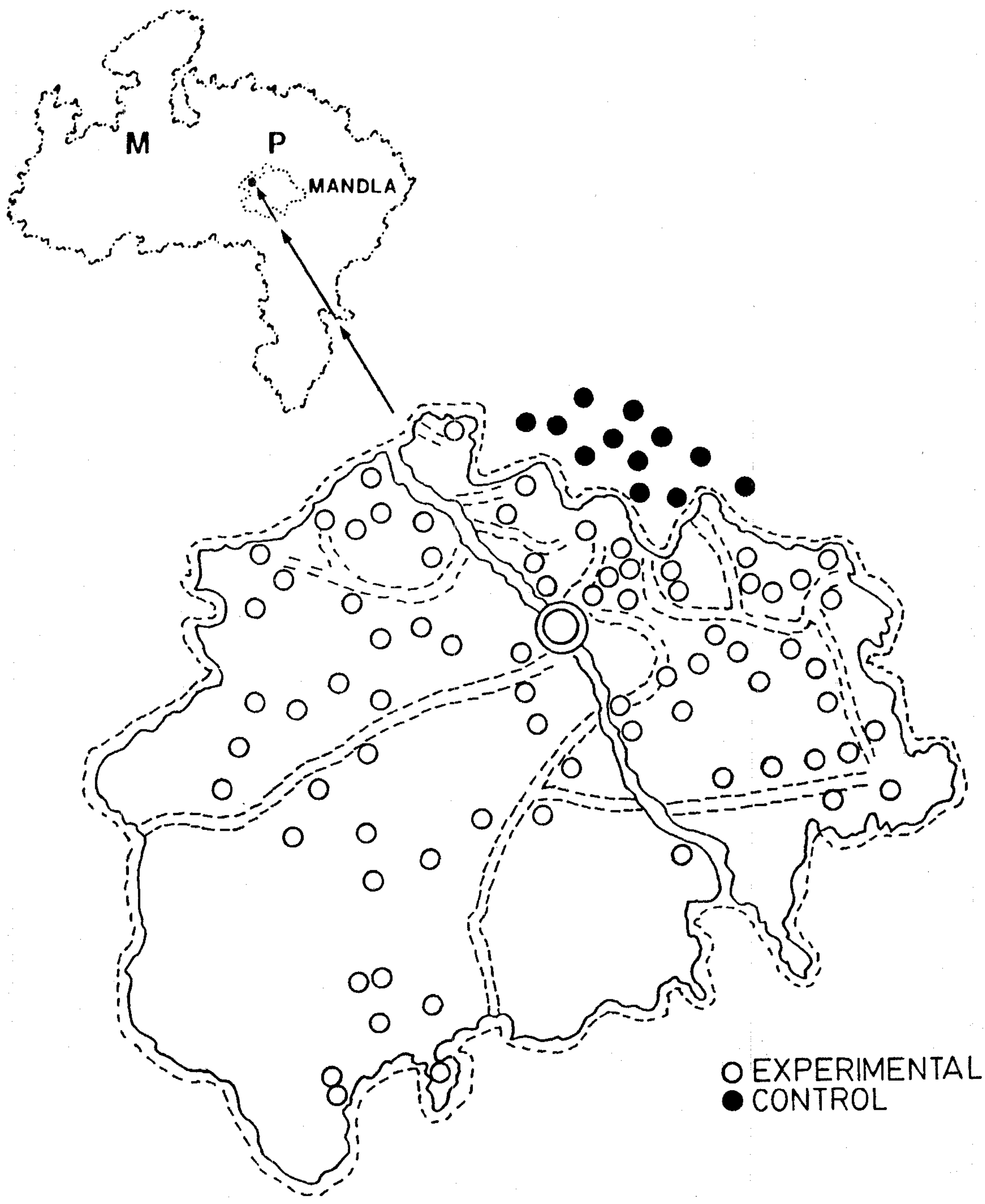

Fig. 1: Location of experimental villages in Bizadandi block, District Mandla (M.P.).

mental and biological control methods in reducing adult vector densities through control of mosquito breeding involving the community. It was envisaged that if demonstration of malaria control by these methods was successful, it would be worthwhile to extend the study to similar forested terrain of the region. Results of a two year study (1987 and 1988) are reported in this paper.

MATERIAL AND METHODS

Study Area

Bizadandi block or primary health centre (PHC) of District Mandla (M.P.) covers an area of 471 sq kms. Almost all the villages are located either on low hillocks or in shallow valleys near perennial streams. Villages usually comprise of a group of hamlets in which 10 to 20 families live. Houses are made of bamboo and mud plastered, without windows or ventilation and invariably have a cattleshed attached. The main crops are maize, *Kodon-Kutki* (a wild millet) and rice. Though rice is grown, there are no irrigation facilities, the tribals collect rain water in their fields for irrigation. Bizadandi block has a population of about 55,000 of which 80% belong to the Gond tribe.

The forests of Mandla district produce the best quality of teak wood. Road communication is very poor except for some fair weather tracks for the transport of forest material. Houses are scattered among the fields and forest. During the hot and humid season people usually sleep outdoors. From October to January, a considerable number of villagers (males only) spend the whole night in the fields in temporary shelters and guard their crops from wild animals. People wear scant clothes and the prime occupation of the tribals is agriculture, small jobs in the forest nurseries or road construction work. They are also engaged in wood cutting and leaf collection for *bidi* (country cigarette) making. Further, since there is no irrigation in these villages, rainfall is just sufficient for one sowing. When this is done, a considerable number of people move to adjoining areas to find work. They return with the onset of rains to sow the fields.

In order to optimize agriculture production one dam (catchment area, 14556 km^2) was constructed (1974-1988) and a network of canals and their distributaries was established for irrigation (1978-79). As a result of dam construction, 162 villages of districts Jabalpur, Mandla and Seoni are affected, of these 29 villages were situated in Bizadandi block, three villages have been completely submerged (population 10,000; land 5615.48 hectares) and 9 other villages (270 hectares) have been adversely affected. During the peak construction period (1974-1988) of the dam 27,000 labourers were employed.

Average yearly rainfall in Mandla district from 1984 to 1988 was 1326, 2340, 1051, 1002 and 1228 mm respectively. Peak precipitation occurs from mid June to mid October.

Villages of Bizadandi block were taken up for studying the feasibility of malaria control through bio-environmental methods. The study was launched in May 1986 and by January 1987, almost all the villages (80, population 40,000) were brought under the alternate strategy. Simultaneously, 12 control (population 7,000) and socio-economically comparable villages were taken up in the same terrain (Fig. 1). Study villages are 25-60 kms away from Bizadandi block office and the project office, and 40-80 kms away from Jabalpur town, HQs of the project office. In the experimental villages, the National Malaria Eradication Programme (NMEP) has withdrawn spraying and surveillance, and all work related to malaria is done by the project staff. The area was under regular DDT spray before the commencement of the project (Table 1). Bizadandi block was selected for operational ease and adequate supervision. This block has the highest concentration of tribals in the district. Malaria history of Bizadandi block was obtained from NMEP and the results are given in Table 2.

Table 1. DDT spray record of PHC Bizadandi, district Mandla

Year	Ist round		II round	
1980	4.7.80 to 1.9.80 Rooms 91%	All 136 villages HD 92% CS 100%	25.9.80 to 3.10.80 Rooms 90%	Only 8 villages sprayed HD 93% CS 100%
1981	1.5.81 to 3.7.81 Rooms 92%	136 villages HD 92% CS 100%	15.9.81 to 30.9.81 Rooms 99%	Only 33 villages sprayed HD 93% CS 100%
1982	1.5.82 to 7.7.82 Rooms 93%	All 136 villages HD 85% CS 100%	31.7.82 to 23.9.82 Rooms 94%	136 villages sprayed HD 84% CS 100%
1983	16.6.83 to 30.8.83 Rooms 87%	94 villages sprayed HD 89% CS 100%	Only one round	
1984	1.5.84 to 7.7.84 Rooms 87%	136 villages HD 87% CS 100%	16.7.84 to 30.9.84 Rooms 89%	136 villages sprayed HD 91% CS 100%
1985	1.5.85 to 7.7. 85 Rooms 90%	136 villages HD 93% CS 100%	16.7.85 to 18.9.85 Rooms 85%	136 villages sprayed HD 93% CS 100%
1986	10.5.86 to 9.6.86 Rooms 86%	Only 56 villages HD 90% CS 100%	16.7.86 to 24.8.86 Rooms 85%	Only 56 villages HD 93% CS 100%
1987	11.6.87 to 15.7.87 Rooms 88%	Only 44 villages* HD 92% CS 100%	1.9.87 to 30.9.87 Rooms 91%	Only 44 villages* HD 94% CS 100%

*Remaining villages transferred to bio-environmental control strategy; HD = Human dwellings; CS = Cattleshed.

Table 2. Malaria incidence in Bizadandi block Mandla district (M.P.)

Year	BSC	BSE	Total +ve	*Pf*	SPR
1978	7744	7744	218	9	2.8
1979	9436	9436	144	13	1.5
1980	11,278	11,278	525	29	4.6
1981	11,346	11,346	401	13	3.5
1982	12,714	12,714	145	4	1.1
1983	11,179	11,179	140	39	1.2
1984	10,457	10,457	67	32	0.6
1985	8,772	8,772	71	17	0.8
1986	10,840	10,840	136	84	2.2

Source— NMEP.

Mosquito collection

Mosquitoes were collected fortnightly with the help of suction tubes to ascertain man hour density (MHD) of each species. Collections were made in the morning (between 0600 to 0800 hrs) from 4 human dwellings (2 fixed and 2 random) and 2 cattlesheds (1 fixed and 1 random). Mosquitoes were collected from one dwelling for 15 mins. duration and then from the next and so on. Total mosquitoes collected per man hour was used as the man hour density (MHD) index. Further classification of anophelines and culicines and their species was done to derive the MHD of a particular species or genus.

Insecticide susceptibility tests

Tests were carried out between June to November 1987 in the Bizadandi experimental area which was under DDT spray (1 gm/sq m) before the start of the experiment (Table 1) and Kundam villages held as control which were sprayed by the NMEP with HCH @200 mg/sq m. Field collected *Anopheles culicifacies* (half gravid females) were selected for insecticide susceptibility tests using the WHO test kits. Mosquitoes were exposed for 1 hr on DDT (4%), dieldrin (0.4%) and malathion (5%) impregnated papers. Mortality of the adult mosquitoes was recorded after 24 hrs post-exposure period and corrected using Abbott's formula.

Fish fauna

All water bodies of the experimental villages were searched for fishes. The fishes were identified at the Zoological Survey of India, Madras. Laboratory and field experiments were carried out on the larvivorous capacity of the indigenous fishes.

Surveillance

In the project area (experimental villages) active surveillance was carried out on weekly basis by a project worker who belonged to the same village. This worker also collected slides as a passive agency. All fever cases were given presumptive treatment at the time of blood smear collection and parasite positive cases were administered radical treatment by the same worker. Slides were brought to the laboratory, stained with JSB and examined within 1-2 days after collection.

Spray operations in control villages

In control villages NMEP carried out spraying operations. To cover the entire transmission season 3 rounds of DDT were sprayed in villages of Niwas PHC and 4 rounds of HCH were sprayed in Kundam PHC (1987-88). In these villages NMEPs activities were retained and surveillance was organized jointly. Surveillance was carried out at fortnightly intervals and slides were examined by the project staff. Results of slide examination were communicated to NMEP for radical treatment.

Chemotherapy

All fever cases were given 600 mg chloroquine as presumptive treatment in the experimental and control group of villages. Parasite positive cases were given radical treatment. *P. vivax* cases were given 600 mg chloroquine followed by 15 mg primaquine daily for 5 days. *P. falciparum* cases were given 600 mg and 300 mg chloroquine on day 1 and 2 and 45 mg primaquine. Children were given proportionately low dosages, pregnant women and children were not given primaquine. *P. falciparum* cases which did not respond to chloroquine were administered 2 tablets of sulfalene and pyrimethamine combination (Metakelfin) and 45 mg primaquine.

Spleen surveys

In September-October 1987-88, spleen surveys were carried out in children between 2-9 years age by Hackett's method. Blood films were also collected from the children at the time of spleen surveys.

Source reduction

A weekly survey of all inter- and intradomestic containers was organized and all breeding was eliminated. Small ponds, borrow pits and ditches etc., were filled with earth and levelled. In disused wells expanded polystyrene (EPS) beads were introduced. Drainage was improved near hand pumps and in other water logged areas to eliminate stagnant water.

Biological control

Studies of the local fish fauna revealed that local fishes like *Rasbora* and *Danio* were good larvivorous fishes. Stocks of Guppy fishes were obtained from the Fisheries Department, Nagpur. Fish hatcheries were established to mass produce larvivorous fishes in the experimental villages in abandoned wells, *jherias* (natural springs) and ditches. Fishes from the hatcheries were transported in oxygen filled containers and released in ponds, wells, streams and *jherias*. The fishes survived extremely well in nature. Grassy margins of the ponds etc., were cleaned periodically to enable the fishes to negotiate better and reduce the larval density along the margins of water bodies.

Health education

Exhibitions on various activities of the project were organized periodically along with health education camps in which live demonstrations were held. Villagers were shown fishes and how they feed on mosquito larvae, various developmental stages of the mosquitoes, malaria parasite under the microscope and how to eliminate inter- and intradomestic breeding etc. Brief talks were given in schools and villages and discussions were held with various village communities on all aspects of the project activities and how they could help in the control of mosquito breeding. A variety of health education materials were prepared such as folders, charts, hand outs, and slogans were printed on the walls.

Community participation

The villagers were invited to participate in vector control activities and take help from the project workers in case of fever. *Shramdans* (voluntary labour camps) were organized to fill the low-lying areas. Villagers also participated in fish introduction, raising of nurseries, and elimination of intradomestic breeding.

Interdepartmental collaboration

The cooperation of various government departments was elicited for mosquito control work and environmental improvement. In marshy areas, *Eucalyptus* and in waste land, mostly fruit bearing trees were planted. These plants were supplied free by the forest department. In addition a few nurseries were also maintained by the field staff. Medical and Health Departments helped in the treatment of conjunctivitis and scabies and in organizing nutrition camps. Department of alternate energy sources provided help in launching of imporved *chulhas*, *sigris*, and solar cooker demonstrations. District administration was most helpful in the implementation of the strategy and provided all help as and when required.

RESULTS AND DISCUSSION

Intervention strategy in experimental villages

Intense breeding was found in temporary water collection sites. Breeding was sometimes washed away during heavy rain but resumed soon thereafter, and pools created by the streams were found positive for breeding in all seasons. In summer, as the water level in streams receded, algal growth was pronounced and provided protection to the mosquito larvae from predation. Removal of algae was, therefore, necessary not only to expose the larvae, but also to facilitate water flow in the streams. This was helpful in the naturalistic control of mosquito breeding. As source reduction is the main plank of the bio-environmental control strategy several tons of algal growth was removed manually from the streams and pools. However, the countless rocky riverbed pools that exist in every village cannot possibly be eliminated and they are a major hurdle.

During the rains, water level of wells rises to ground level, the entire area becomes water logged, and ideal grounds for anopheline breeding are created. Mosquito breeding was controlled using larvivorous fishes and approximately 4.0 lakhs fishes (*Rasbora* and Guppies) were released in different potential breeding sites. Expanded polystyrene (EPS) beads were applied to all disused wells but wells in this area are generally shallow. As a result the beads were often disturbed by the wind leaving patches of uncovered water. Moreover, women and children removed beads from shallow wells and used these for decoration purposes and for making jewellery for personal adornment (tribals were seen wearing these ornaments during festivals and ceremonies). Therefore, application of EPS beads which was so effective in the control of mosquito breeding in wells and overhead tanks etc., in other areas (Sharma *et al.*, 1986; Chandrahas and Sharma, 1987) was found unsuitable for this area. Instead larvivorous fishes (*Rasbora* sp.) were used in wells for the control of mosquito breeding on long term basis.

Surveys of all water bodies of the experimental villages revealed the presence of 7 fish species viz., *Colisa fasciatus, Punctius ticto, Danio rerio, Channa gachus, Rasbora daniconius, Lepidocephalus guntea* and *Chanda ranga*. Of these 5 species were reported larvivorous by field studies in Kheda, Gujarat (Sharma *et al.*, 1987). These fishes breed during the rainy season in the wild. Laboratory experiments were carried out to test the larvivorous capacity of promising fishes. Tests showed that *Punctius ticto* consumed maximum mosquito larvae but it was not available in good numbers for mass production and *Colisa fasciatus* because of its good size was taken away by tribals for food. Therefore, *Rasbora,* an indigenous fish found equally larvivorous and active was used for biological control.

Guppies, commonly known as 'Nityagani' as they breed profusely, were released in disused wells and *jherias* for mass production. Guppies are very effective in wells, ponds and ditches. However, some mosquito breeding always remains in small rocky patches and pools because of the algal cover. Guppies cannot survive in flowing streams because of their small size and are invariably washed away.

Approximately 10 lakhs *Guppies* and over 6 lakhs *Rasbora* and *Danio* are being maintained in stock (23 hatcheries). Table 3 gives a summary of work done in the experimental villages during 1987 and 1988. During these years, 90 medical camps were organized and more than 1245 meetings were held with school children, teachers and local leaders. A massive door to door health education campaign was carried out to create awareness regarding vectors and vector-borne diseases. The importance of the involvement of people in malaria control operations was emphasized and their active participation solicited.

During 1987-88 about 14661 small to medium breeding sites were eliminated by emptying or filling. In addition to this 3823 ditches of various size were filled using 2062 trolleys of soil, 4858 drains were canalized and 4087 blocked drains were cleaned. EPS beads were introduced in 150 wells and fishes in 450 wells. Social forestry was introduced with the help of community to make profitable use of waste land. About 57,900 plants were raised in 6 nurseries and 29 orchards were

Table 3. Summary of intervention and developmental work done in Bizadandi during 1987-88

Number of villages	80
Ditches filled	14,661
No. of tractor trolley loads used for earth work	2,062
Drains channelised	4,858
Margins cleaned	22,993
Guppy and *Rasbora* sp. released	3.9 Lakhs
	(Guppy 2.7, *Rasbora* 1.2)
Nurseries maintained	6
Trees planted	57,900
Improved chulhas installed	641
Solar street light installed	28
Solar cooker demonstrations	7
Sigri distributed	223
Gardens	29
Scabies cases treated	12,781
Conjunctivitis cases treated	7,030
Health camps organised	90
Health meetings organised	1,245
Programmes of food and nutrition	24
Roads constructed by villagers	44
Roads constructed by district administration	8
Shramdans organised	63
Hand pumps installed	6
School buildings repaired	4
Panchayat building repaired	1

prepared. Besides, 2000 saplings were planted near streams and low-lying areas. Alternate energy sources were introduced to save wood. A total of 641 *chulhas* and 223 *sigris* (improved portable stove) were installed and 24 programmes for food and nutrition were organised.

With so many development activities going on in the area it was easy to convince the illiterate tribals about the importance of participatory developmental work. The project staff obtained help from government agencies for the redressal of grievances. Problems of drinking water were solved by repair of the existing pumps and the installation of 6 hand pumps. The district administration helped the project staff in the construction of approach roads, provision of electricity and repair of school and panchayat buildings etc. These activities were very useful in motivating the villagers and eliciting community participation. Some of the achievements that have proved particularly useful for achieving a good rapport with the local people are given below.

(i) A field unit was established in Bizadandi block in a remote village.

(ii) Eight approach roads were constructed by district administration at the cost of Rs. 50,000 each at the instance of the project workers.

(iii) Urja Vikas Nigam installed solar photo voltaic system for street lighting in one village which was not electrified earlier.

(iv) Food and Nutrition Extension Department organized camps and celebrated a "Food and Nutrition Week" in Bizadandi block to show the value of improved nutrition.

(v) The project staff assisted by the health department of M.P. Govt. provided treatment for scabies and conjunctivitis. A total of 12,781 cases of scabies and 7030 cases of conjunctivitis were treated.

(vi) Villagers realized the benefits of the project and contributed labour by offering the help of one man from each family. More than 60 *Shramdans* or free labour camps were organised in which 28 approach roads were constructed many small pools which were highly mosquitogenic were eliminated. This activity eliminated a large number of borrow pits which were otherwise supporting mosquito breeding and helped in filling of adjoining low-lying areas. A proposal to convert a dumping ground into a garden was accepted by the villagers and within a week men, women and children prepared the site for an orchard which now has 200 fruit bearing plants.

Intervention strategy in control villages

In the control villages certain attempts were made by the State Public Health Department to cope with the malaria situation.

(i) Insecticidal operations were intensified with better supervision i.e., three regular rounds and one special round of spraying was done in both the districts (Jabalpur and Mandla) leaving no block unsprayed except the experimental block.

(ii) Chloroquine was made available to all fever cases more promptly than ever before.

(iii) Administration of metakelfin to all parasite positive *Pf* cases was carried out from March 1987 onwards.

(iv) Health education materials were circulated and publicity was given through newspapers and public address system. Surveillance was intensified by hiring additional staff and establishing a field laboratory to administer early radical treatment. Because of an epidemic situation in the entire area, refusals for spraying were few and chemotherapeutic measures were welcomed by the community.

(v) The Jabalpur Headquarters of the Assistant Malaria Officer were shifted to Kundam block.

Entomological assessment

Mosquito collections of the adults and immatures revealed that the anopheline fauna of the area comprised of 13 species i.e., *A. culicifacies, A. fluviatilis, A. annularis, A. subpictus, A. hyrcanus, A. splendidus, A. vagus, A. pallidus, A. barbirostris, A. turkhudi, A. jeyporiensis, A. maculatus* and *A. theobaldi*. The following mosquito species of genus *Aedes, Mansonia, Culex* and *Megarhinus* were also recorded from experimental villages i.e., *Culex vishnui, Cx. quinquefasciatus, Cx. whitmorei, Ae. aegypti, Ae. vittatus, Ae. pseudalbopictus, Ma. annulifera, Ma. longipalpis, Ma. uniformis* and *Megarhinus*. Out of these species, *Ae. aegypti, Ae. albopictus* and *Cx. quinquefasciatus* were found breeding in tree holes in the dense forests. *A. culicifacies* was also found breeding in tree holes, although very rarely.

There are a variety of mosquito breeding sites in Bizadandi block. A record was maintained of all sites that supported mosquito breeding during 1977-78. During this period, commonly encountered breeding sites were streams, rice fields, wells, drinking water pits, borrow pits, brick fields, stone quarries, drains, *jherias*, seepages, rocky pools/pits, ponds and slit trenches. The villages are intersected by a large number of streams and tributaries. Most of these sites supported moderate to heavy *A. culicifacies* breeding along with other speices. *A. fluviatilis* was found in slow flowing water streams. *Culex quinquefasciatus* was found breeding in polluted waters. Table 4 gives the pooled results of monitoring of anopheline populations in 35 experimental and 5 control villages. As seen from the table, the bulk of mosquito population is comprised of *Anopheles culicifacies*. The second vector species found in the area is *A. fluviatilis*. Adult populations were generally less than 1 MHD in both areas. *A. fluviatilis* is perhaps exophilic in nature as studies showed that *A. fluviatilis* were found in good

Table 4. Monitoring of Entomological Indices (MHD) 1987-1988

Months		1987						1988					
		Total anopheline	Total vector	*An. Culicifacies*	*An. fluviatilis*+	*An. subpictus*	*An. annularis*	Total anopheline	Total vector	*An. culicifacies*	*An. fluviatilis*	*An. subpictus*	*An. annularis*
Jan	E	128.42	106.26	104.78	1.48	1.83	18.19	41.13	30.38	29.58	0.80	1.25	8.48
	C	246.00	231.25	230.50	0.75	2.25	11.50	106.30	87.00	87.00	—	0.10	16.20
Feb	E	70.84	60.76	60.10	0.66	0.40	7.96	44.06	33.47	32.59	0.88	0.51	8.92
	C	142.75	135.00	134.25	0.75	0.50	7.25	145.75	118.50	118.50	—	0.25	16.75
Mar	E	60.19	54.18	53.75	0.43	0.92	5.17	36.70	30.26	29.56	0.70	1.60	4.32
	C	92.83	87.67	87.00	0.67	1.25	2.67	108.25	101.75	100.75	1.00	1.00	5.00
Apr	E	39.53	35.11	35.02	0.09	1.26	2.37	22.23	20.45	20.21	0.24	0.45	1.13
	C	84.92	77.04	76.16	0.42	0.75	5.42	242.60	232.40	231.40	1.00	2.80	5.40
May	E	26.67	23.95	23.81	0.17	1.93	0.52	20.80	18.29	18.19	0.10	1.10	1.05
	C	61.21	55.02	54.69	0.33	3.56	1.71	83.37*	76.50	67.50	—	5.50	1.25
Jun	E	31.08	23.78	23.59	0.19	5.45	0.85	33.47	28.57	28.29	0.28	2.32	1.98
	C	83.44*	64.85	64.52	0.33	11.60	6.29	55.75	48.06	48.06	—	4.68	0.93
Jul	E	61.43	48.72+	48.62+	0.10	9.03	2.22	116.24	92.86	92.44+	0.42	15.47	5.36
	C	107.14	87.31	86.31	1.00	14.41	4.58	106.00**	84.75	84.75	—	13.60	5.60
Aug	E	97.68	68.32	68.20	0.12	26.76	1.79	250.43	195.49	195.05	0.44	41.44	9.92
	C	150.83**	122.83	122.00	0.83	23.38	3.08	215.05	191.25	190.75	0.50	15.75	8.70
Sep	E	159.38	117.77	117.58	0.20	37.12	3.06	103.89	85.46	85.25	0.39	12.22	4.36
	C	273.83	236.33	236.33	0.00	33.83	3.00	118.50***	108.62	108.37	0.25	7.00	2.87
Oct	E	93.49	77.06	76.84	0.22	10.12	5.45	76.14	62.39+	61.30+	1.09	5.20	6.54
	C	157.83	146.70	146.03	0.67	1.75	5.83	91.83	77.38	76.14	1.52	4.87	8.25
Nov	E	68.22	49.54	48.25	1.29	5.90	12.19	77.63	66.51	65.40	1.11	3.83	5.96
	C	117.37***	102.33	100.67	1.67	6.25	7.67	185.09	169.32	168.66	0.66	2.75	10.63
Dec	E	44.35	32.75	31.71	0.79	2.93	8.06	69.53	58.44	57.39	1.05	3.79	6.10
	C	107.33****	86.93	85.33	1.60	8.25	12.15	98.75****	86.80	84.13	2.67	2.00	8.38

*1st round spray; **IInd round spray; ***IIIrd round spray; ****IVth round spray; +Difference between the means is non-significant; E = Experimental; C = Control.

numbers only in night collections. Populations of *A. annularis* were low throughout the year. Of particular interest was the low occurrence of *A. subpictus*. In most parts of the country this mosquito invariably breeds extensively and makes up a major proportion of anopheline populations.

Monitoring of *Culex* densities revealed that *Cx. quinquefasciatus* and *Cx. vishnui* were encountered throughout the year but only in small numbers. The intradomestic breeding was very limited as out of 11,86,483 containers checked only 4533 were found breeding, mostly for *Culex* species. The effect of intervention was visible in the reduction in adult densities throughout the year, except during rains.

The most important fact in the distribution pattern of *A. culicifacies* between the experimental and control area is that the MHD of this vector is usually 2 to 2.5 times higher in the DDT sprayed control area than in the experimental areas. Repeated spraying of DDT and HCH in control villages resulted in the development of resistant populations. These mosquitoes continued to survive and find breeding grounds in the innumerable rocky pools and in low-lying ground. The presence of numerous natural depressions resulting in stagnant water for long periods and the primitive method of rice cultivation are the potential mosquitogenic factors.

Results of insecticide susceptibility tests with wild caught fully fed *A. culicifacies* females revealed that mortality of adults to 4% DDT impregnated papers was 19.45%, to 0.4% Dieldrin 31.47% and to 5% malathion mortality was 59%.

Monthly epidemiological indices of malaria surveillance in the experimental and control villages are given in Table 5. Both *P. vivax* and *P. falciparum* were prevalent and a few mixed (*Pv*+*Pf*) infections were found.

The peak transmission season coincided with the post-monsoon season and *P. falciparum* cases also peaked during the same period. It is likely that transmission of malaria is maintained throughout the year but there are two distinct "Malaria seasons". July to January can be called the "Autumn malaria season" and February to June the "Spring malaria season" (Table 6).

In the experimental area, out of the total positive cases recorded *P. falciparum* constituted 45% and 53% in the "Autumn season" and 11% and 16% in "Spring season" of 1987 and 1988 respectively (Table 6). In the control area the distribution of *Pf* was 66% and 81% in "Autumn season" and 24% and 41% in "Spring season" in 1987 and 1988 respectively, while *P. vivax* was 89% and 84% in the "Spring season" and only 55% and 46% in the "Autumn season" in the experimental area. In the control *Pv* was only 33% and 18% in "Autumn season" and 75% and 56% in "Spring Season" in 1987 and 1988, respectively. Mixed infections were less than 1% in experimental areas during the study period. In control area in 1988 "Spring season" there were 3.08% mixed infections and nearly 1% in both seasons of 1987.

Results of spleen surveys showed high rate of enlarged spleen in children (Table 7) in control villages (37% and 45%) as compared to the experimental villages (10%) in 1987 and 1988.

Malaria incidence in the experimental block cannot be viewed in isolation, it should be studied along with that in the neighbouring blocks of the districts (Table 5).

It is seen that the monthly SPR in control area is usually 1.5 times to 4.8 times higher than in experimental area and appears to be greatly influenced by higher *A. culicifacies* densities which are also 2 to 2.5 times higher (except for the month of April '88 when *A. culicifacies* density was 11 times higher in control area as compared to that in experimental area and there

Table 5. Epidemiological situation of malaria

(80 experimental villages block-Bizadandi, distt. Mandla and 12 control

Month		1987*						
		Total BSE	Positive cases				SPR	SFR
			Total +ve	*Pv*	*Pf*	Mix		
1	2	3	4	5	6	7	8	9
Jan	E	755	13	5	8	0	1.72	1.06
	C	54	4	2	2	0	7.41	3.70
Feb	E	746	10	7	3	0	1.34	0.40
	C	51	4	0	4	0	7.84	7.84
Mar	E	1065	12	11	1	0	1.13	0.09
	C	101	5	3	2	0	4.95	1.98
Apr	E	1896	68	47	21	0	3.59	1.11
	C	184	15	5	10	0	8.15	5.43
May	E	1900	186	160	26	0	9.79	1.37
	C	309	72	60	10	2	23.26	3.24
Jun	E	2168	262	254	8	0	12.08	0.37
	C	170	40	34	6	0	23.52	3.53
Jul	E	3714	356	323	33	0	9.59	0.89
	C	150	30	26	4	0	20.00	6.67
Aug	E	2957	582	470	110	2	19.68	3.72
	C	452	218	123	93	2	48.23	20.58
Sep	E	2677	677	495	180	2	25.29	6.72
	C	696	447	208	237	2	64.22	34.05
Oct	E	6586	1523	740	775	8	23.12	11.77
	C	928	568	167	393	8	61.21	42.35
Nov	E	2871	603	142	456	5	21.00	15.88
	C	637	436	65	363	8	68.45	56.99
Dec	E	2108	294	34	258	2	13.95	12.24
	C	298	177	13	160	4	59.40	53.69
Total	E	29443	4586	2688	1879	19	15.58	6.38
	C	4023	2016	706	1284	26	50.11	31.92

E — Experimental
C — Control

Pop. E — 40,000, C — 7,000

ABER E — 73.6, C — 57.5

API E — 114.7, C — 288.0

*Month wise analysis of data shown 1% level of significant difference between SPR of experimental and control in 1987. Only in Jan. '87 the SfR between experimental and control is non-significant, in all other months difference is significant at 1% level.

in Mandla and Jabalpur districts 1987-88

villages, Niwas and Kundam blocks, district-Mandla and Jabalpur),

1988**						
Total BSE		Positive Cases			SPR	SFR
	Total +ve	Pv	*Pf*	Mix		
10	11	12	13	14	15	16
1545	139	34	105	0	9.00	6.80
295	128	14	108	6	43.39	36.61
1110	92	48	42	2	8.28	3.78
257	69	7	60	2	26.85	23.35
1272	128	100	28	—	10.06	2.20
251	89	57	28	4	35.46	11.16
1694	248	194	54	—	14.63	3.18
474	205	128	72	5	43.25	15.19
3684	715	638	75	2	19.40	2.03
521	196	141	52	3	37.62	9.98
2646	262	232	39	1	9.90	1.09
466	167	96	66	5	35.84	14.16
2323	565	464	100	1	24.32	4.30
395	151	67	82	2	38.23	20.16
3563	789	480	307	2	22.14	8.61
603	303	94	204	5	50.25	33.83
3980	800	304	494	2	20.10	12.41
864	432	88	342	2	50.00	39.58
1948	385	80	303	2	19.76	15.55
723	324	22	301	1	44.81	41.63
1020	252	43	206	3	24.70	20.19
629	280	12	265	3	44.52	42.13
893	216	45	167	4	24.18	18.70
389	187	18	166	3	48.07	42.67
25678	4391	2662	1910	19	17.88	7.44
5867	2531	744	1746	41	43.14	29.76

Pop. E — 41,000; C — 8,000 ABER E — 62.63; C — 73.34 API E — 111.98; C — 316.38

** SPR in all months between experimental and control differs significantly at 1% level.

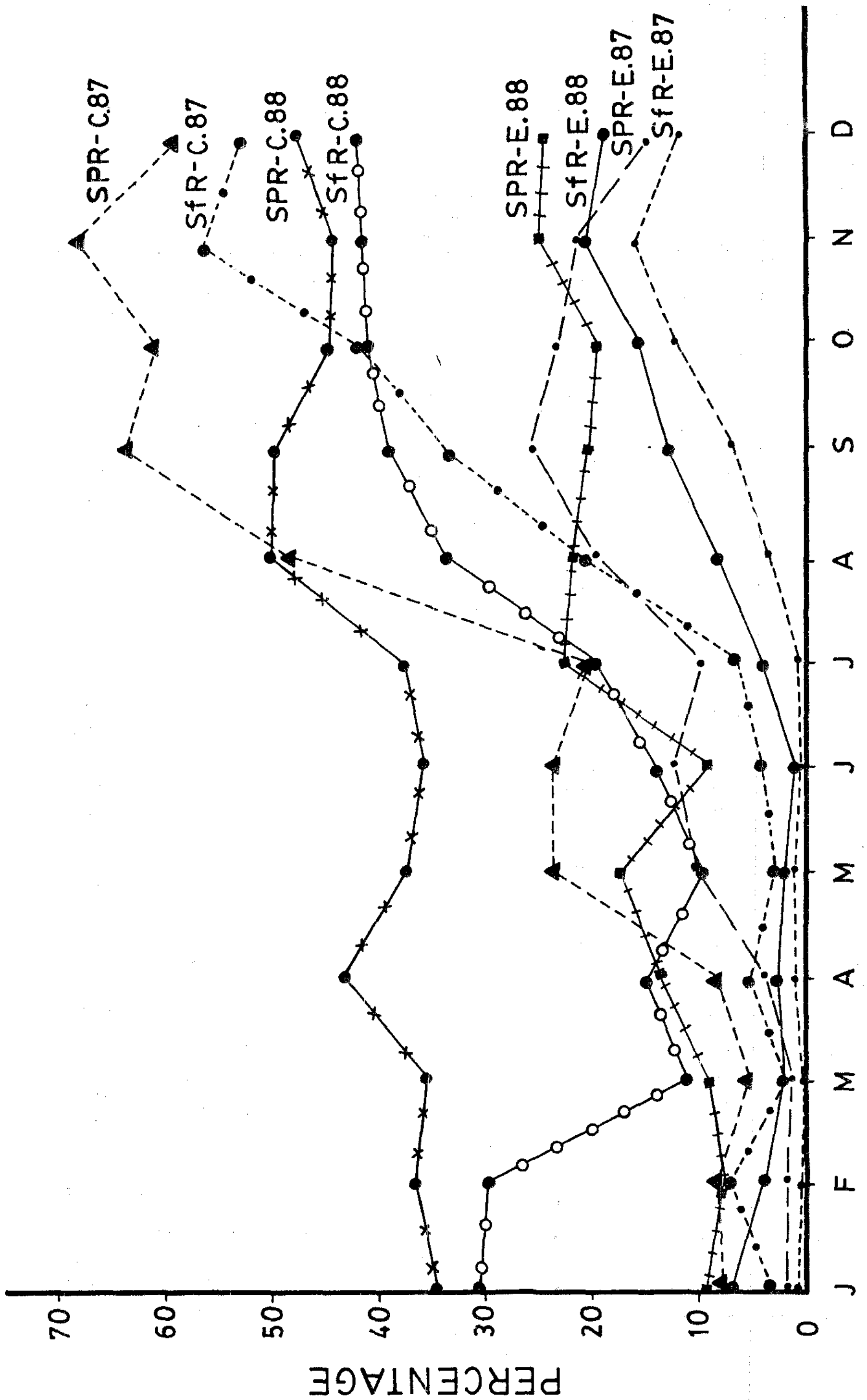

Fig. 2: SPR and SfR in experimental and control villages (1987-88).

Table 6. Seasonal distribution of parasite species

Year	Area	Autumn season			Spring season		
		Pv%	*Pf%*	Mix	*Pv%*	*Pf%*	Mix
1987	EXP.	54.57	44.96	0.47	89.41	10.59	0.00
	CON.	32.66	66.06	1.28	75.00	23.53	1.47
1988	EXP.	46.09	53.46	0.45	83.88	15.78	0.34
	CON.	17.58	81.45	0.97	55.97	40.95	3.08

Table 7. Results of spleen survey in 15 experimental and 4 control villages

Months	No.of children examined	No. of children with enlarged spleen	No. of BS +ve	Enlarged spleen rate (%)
Sep.-Oct. 1987				
Experimental	2228	227	48	10.1
Control	432	163	98	37.2
Sep.-Oct. 1988				
Experimental	1208	125	38	10.3
Control	236	107	48	45.3

was no unusual rise in SPR or SfR in April/May 1988).

As regards the pattern of SfR during 1987 and 88 it is observed that the SfR starts rising from July onwards and reaches its peak in November/December. The *Pf* percentage to total positive is near about 60% in August and reaches nearly 84 to 94% in October/November, thereafter it starts declining. *Pv* dominates only from February/March onwards upto May/June.

The ABER was 73.6 in 1987 and 62% in 1988 in experimental area. API in experimental area was 114 and 112 in 1987 and 1988, respectively. Similarly SPR was 15.6 and 17.8 and SfR 6.4 and 7.4. These are marginal differences epidemiologically and it can be concluded that the parasite reservoir in the study area remained practically the same. The ABER was 57% in 1987 in control villages while in 1988 it was 73% API in control area was 288 in 1987 which increased to 316 in 1988, an apparent increase of nearly 9% (Fig. 3). In the control the slide positivity rate was 43% and *P. falciparum* constituted 69% of the cases in 1988. Though there is a decline in SPR in 1988, the proportion of *P. falciparum* remained quite high and fluctuated between 27% to 94% during the year. The administration of sulfonamide and pyrimethamine drug combination appears to have affected the SPR only, as the falciparum cases had increased considerably. The above seasonal distribution of parasite species and high incidence of malaria indicates that this is a highly endemic area.

Malaria is essentially a disease of waste land, waste water and waste man (Venkat Rao, 1949). In tribal villages, where the land is allowed to deteriorate, where water is not properly conser-

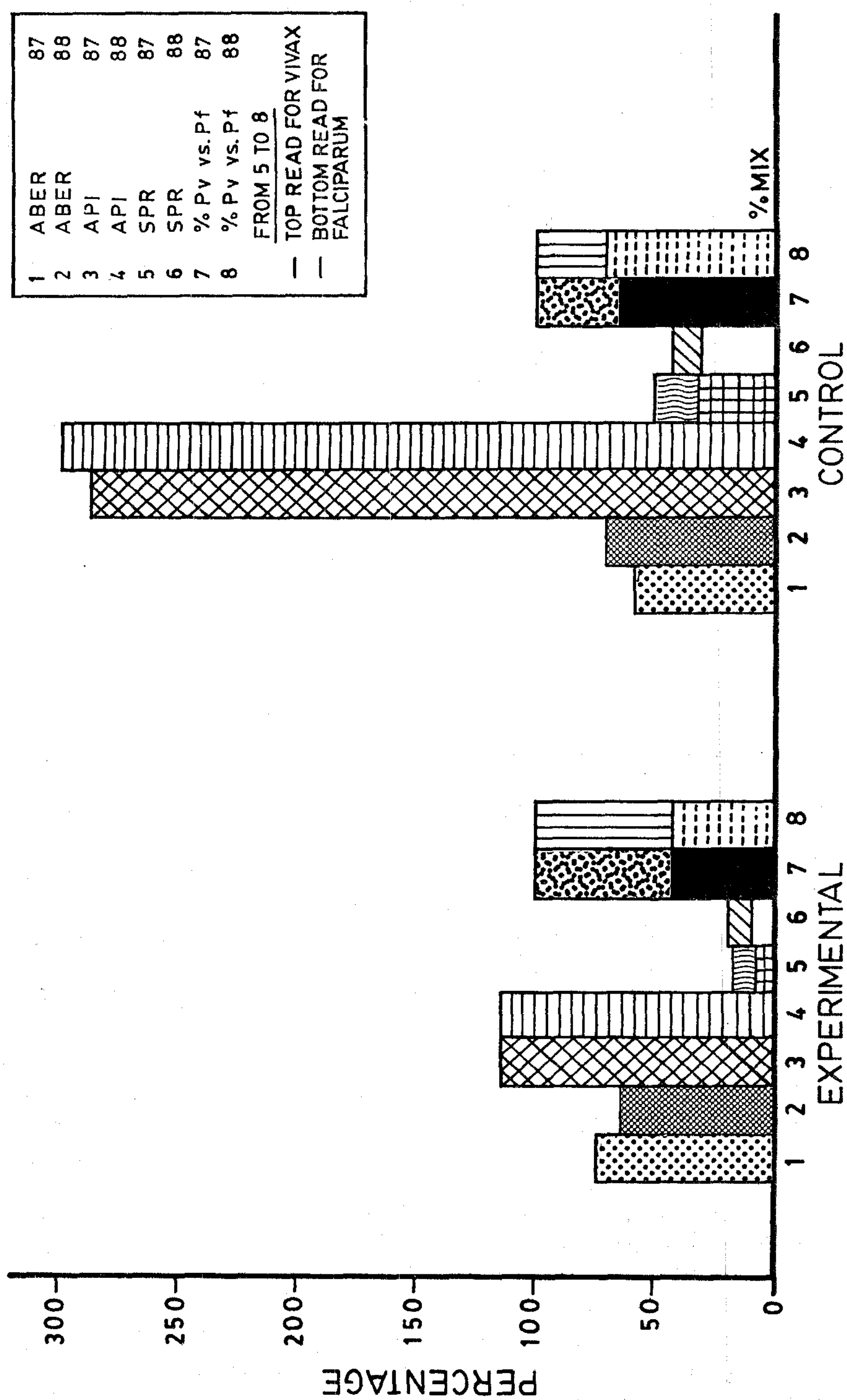

Fig. 3: Malaria situation (1987-88).

ved and utilised, malaria is firmly established. Malaria control by integrated methods should be considered in terms of conservation of land, water and manpower and their diversion for useful and productive purposes.

In the rocky hills of Bizadandi many breeding places are the result of continuous soil erosion. Larval control is especially difficult during rainy season. As the population density is low and the breeding sites are very extensive occupying vast expanses of territory and are covered by dense vegetation this makes any control strategy difficult to employ. Fish cannot be used in scattered temporary water beds even with re-stocking. Patches of swamps and seepage exist all along the streams and tributaries. A logical solution to the problem is better water management and drainage to eliminate all standing water and the siting of villages on higher elevations away from the breeding sites.

During the construction of the Bargi dam (1974-88) the malaria incidence went up because of re-settlement of the people (1986-87) from the submerged areas. If the Bargi dam project is successful in reducing the amount of flooding in the tract, the incidence of malaria can be kept under control, if this does not occur and if the effect of the dam is to raise the general level of the sub soil water a manifold increase in the level of endemic malaria may be expected.

The second major problem is the prolonged transmission in this area. Outdoor sleeping habits of the villagers also appear to facilitate better man-vector contact for exophilic and exophagic mosquitoes. Observations clearly indicate that spraying had negligible impact, if at all, on adult densities and different species of anophelines enter newly sprayed structures in large numbers and rest. This is a definite indication of the high degree of vector resistance to insecticides. Continuation of DDT and HCH spraying would not be of any use and is only resulting in financial loss and environmental contamination. Immediate replacement with malathion or a synthetic pyrethroid should be taken upto eliminate the foci of drug resistant malaria. The implementation of integrated vector control of malaria incorporating the use of environmental management methods with judicious use of a suitable insecticide should prove to be the most appropriate method of malaria control in this area.

The bio-environmental methodology has many collateral benefits which are not easily quantifiable e.g., as a result of our work in that area, we discovered an outbreak of falciparum malaria (Singh *et al.*, 1988) and a focus of drug resistance (Singh *et al.*, 1989). The outbreak could have been more widespread and damaging if the project staff had not been there. Relief from other common ailments, awakening of health consciousness in the neglected tribal population and environmental improvement are other such benefits. This strategy in symbiosis with rural development has removed the veil of ignorance from the minds of the Gonds of Bizadandi and has released the springs of popular action.

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SHORT NOTE

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Chloroquine Resistant Imported *Plasmodium falciparum* in an Industrial Complex at Hardwar (U.P.)

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Bharat Heavy Electricals Limited (BHEL), is a leading industry in the country. For the last few years an increasing trend of *P. falciparum* cases and clinically diagnosed drug failure in falciparum malaria were reported. This campus has a population of about 45,000. To control malaria an alternate strategy known as the bio-environmental control of malaria was launched in September 1986, and as a result malaria transmission has been interrupted (Dua *et al.*, 1989). The present study was undertaken during 1987 to study the role of population movement in the dissemination of *P. falciparum* strains and its susceptibility to chloroquine and other antimalarials.

In vivo test (WHO 28 day extended test) for chloroquine was performed where each patient received a total dose of 1500 mg of chloroquine base (Resochin, Bayer, Germany), followed by a single dose of 45 mg primaquine base. Absorption of chloroquine was confirmed by the urine test (Lelijveld and Kortmann, 1970) on Day 3 (D-3).

Blood smears were collected on D-0, D-3, D-14, D-21 and D-28 or whenever any patient complained of recurrent fever after completion of prescribed dosage. Asexual parasites were examined from Giemsa stained smears. Chloroquine resistant cases were treated with single dose of sulfadoxine (1000 mg) plus pyrimethamine (50 mg) combination (Rimodar, The Anglo-French Drug Co.) and 45 mg of primaquine base and followed up to 28 days.

Micro *in vitro* tests for choroquine and quinine were conducted with infected blood samples collected from selected patients as per standard procedure in pre-dosed micro culture plates supplied by WHO. Procedures for incubation, staining of pre- and post-incubation smears were the same as described by WHO, 1981. A test was considered valid when at least >10 per cent schizont maturation was observed in post incubation control wells (Draper *et al.*, 1985). Schizont formation at >5.7 pmol of chloroquine and at >64 pmol of quinine was considered an indication of resistance (Smrkovski *et al.*, 1985). Minimum inhibitory concentrations (MICs) of both the drugs were assessed by microscopic examination from post-incubation smears.

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Table 1. Sensitivity of *P. falciparum* isolates to chloroquine (CQ), quinine (Q), sulfadoxine (SDX) and pyrimethamine (PY)

S. No.	Sex/ Age	Place of infection	Sensitivity status			
			In vivo		*In vitro* MICs† of	
			CQ	SDX/PY	CQ	Q
		UTTAR PRADESH				
1.	M/8	BHEL Complex, Hardwar	S	—	—	—
2.	M/14	BHEL Complex, Hardwar	S	—	—	—
3.	M/28	BHEL Complex, Hardwar	S	—	—	—
4.	M/26	Jwalapur, Neighbouring town	S	—	—	—
5.	M/30	Salempur	S	—	—	—
6.	F/75	Kotdwar	S	—	—	—
7.	M/35	Garhwal	S	—	8	32
8.	M/28	Etawah	S	—	—	—
9.	M/20	Sultanpur	S	—	—	—
10.	M/25	Tanakpur	RI(D-21)	S	32	32
11.	M/34	Tanakpur	RI(D-15)	S	32	64
12.	M/26	Tanakpur	RI(D-14)	S	32	64
13.	M/28	Tanakpur	S	—	16	32
14.	M/30	Tanakpur	RI(D-35)	S	—	—
15.	M/22	Tanakpur	S	—	—	—
16.	M/30	Tanakpur	S	—	—	—
17.	M/31	Tanakpur	RI(D-28)	S	N.G.	
18.	M/40	Tanakpur	RI(D-14)	S	—	—
19.	M/35	Tanakpur	RI(D-21)	S	—	—
		MADHYA PRADESH				
20.	M/41	Satpura Sarni	RI(D-16)*	—	16	64
			RI(D-14)	S	—	—
21.	F/21	Guna	S	—	—	—
22.	M/34	Bhopal	RI(D-14)	S	N.G.	
		PUNJAB				
23.	M/54	Hoshiarpur	S	—	—	—

S = Sensitive ; N.G. = Not grown ; — = Not tested ; * repetition of 1.5 gm chloroquine dosage ; † = pmol/well.

Blood smear examination during 1987 revealed 23 cases of *P. falciparum* and maximum cases were recorded in the month of November. Out of 23 cases, 19 (82.6%) were imported from Uttar Pradesh (U.P.), Madhya Pradesh (M.P.) and Punjab (Table 1). Maximum number (10) of imported cases were found in the labour from Tibri area, who frequently visited highly malaria endemic areas in Terai such as Tanakpur (U.P.). The remaining cases belonged to BHEL employees, their families and relations, who were infected from different parts of India as shown in Table 1.

In vivo tests revealed that out of 23 cases tested, 9 (39%) were resistant to chloroquine at RI level and the remaining were sensitive. Out of nine cases, five became positive on D-14 to D-16, two on D-21 and two on D-28 and D-35. In one case (S. No. 20) chloroquine dosage of 1500 mg base was repeated but recrudescence was observed on D-14. All chloroquine resistant cases responded to a combination of sulfadoxine/pyrimethamine without any further recrudescence.

Falciparum malaria cases among labourers who acquired infection from Tanakpur (Terai, U.P.) showed high prevalence (70%) of chloroquine resistance, which is the first report of resistance from that area.

Eight specimens were eligible for micro *in vitro* test, of which adequate schizont growth was observed in 6 specimens. All six isolates were resistant to chloroquine as their MICs ranged from 8 to 32 pmol, but sensitive to quinine (MICs 32 or 64 pmol). There was correlation between *in vivo* and *in vitro* test results in respect of chloroquine except in two cases, *viz.*, S. Nos. 7 and 13 where discrepancies were noted (Table 1). This may be due to high immune status of the patients as was also reported by Spencer *et al.* (1983).

The present study indicated that imported cases of chloroquine resistant falciparum malaria through labour movement and population migration poses a serious health hazard to BHEL residents. It is, therefore, suggested that all incoming labour and their accompanying families should be screened on entry in BHEL and those found positive for *P. falciparum* should be given the standard treatment with Sulfadoxine/Pyrimethamine combination and primaquine and thereafter followed for a minimum period of 28 days so as to prevent the establishment of chloroquine resistant falciparum malaria in this industrial complex.

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