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Note: The editor assumes no responsibility for the statements and opinions expressed by the contributors.

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Seasonal Prevalence of *Anopheles dirus* and Malaria Transmission in a Forest Fringed Village of Assam, India

ANIL PRAKASH, D.R. BHATTACHARYYA, P.K. MOHAPATRA and J. MAHANTA

Seasonal abundance of *Anopheles dirus* (s.l.) and malaria prevalence in an isolated forest fringed village was monitored at monthly intervals during August 1995 to July 1996. *An. dirus* was the only vector species detected during the study period. Its density pattern showed distinct seasonality with the peak occurring in the month of July and very low number during cool dry months. Positive correlation ($r = 0.721$) was found between the density of *An. dirus* and the amount of rainfall occurring two weeks prior to the collections. Overall sporozoite rate of 1.6% and parous rate of 64.7% were found in the study. Malaria transmission closely followed the density pattern of *An. dirus* and was seasonal with slide positivity rate and *P. falciparum* percentage of 47 and 83% respectively. Mean malaria prevalence was higher ($p < 0.05$) in females.

Keywords: *Anopheles dirus*, Bionomics, Forest malaria, Sporozoite rate

INTRODUCTION

An. dirus, Peyton and Harrison, 1979 is one of the most important vectors of malaria in entire southeast Asia[1]. In India the distribution of this mosquito is in wet forested areas of northeastern India, western Ghat in southwestern peninsular India and in Andmans[2]. Initially in northeastern India *An. minimus* was regarded as the primary vector so much so that the role of *An. dirus* as a malaria vector had been virtually overlooked. Later persistence of

Regional Medical Research Centre, Northeast Region, Post Box No. 105, Dibrugarh-786 001, India.

malaria in the northeastern region even after successfully controlling *An. minimus* with DDT under NMEP led to the recognition of role of *An. dirus* as an efficient vector of malaria[3]. Rapidly changing environment brings about frequent changes in vector behaviour which necessitate the regular generation of information on vector bionomics. In this context to fill in the gaps in the existing knowledge on bionomics of *An. dirus* in India we carried out a year long study in an isolated forest fringed village of District Dibrugarh, Assam during 1995-96, where data on ecology and bionomics of this species was generated along with the malaria prevalence in the community. The ultimate aim was to find out the attributes of *An. dirus* transmitted malaria in broken forest ecosystem for building up rational, suitable and cost-effective control measures. In this paper the seasonal abundance of *An. dirus* (s.l.) and its relationship with malaria transmission in broken forest environs is discussed.

MATERIALS AND METHODS

Study area

The study area, Soraipung is an isolated tropical rain forest fringed village under the Primary Health Centre, Tengakhat of District Dibrugarh, Assam. Soraipung, topographically a plain village, is situated at a height of 152 m above sea level at 27'35° N and 95'41° E about 75 km east of Dibrugarh town. The village is devoid of basic amenities like public transport, electricity, running water etc. and the nearest medical facility is located at a distance of 10 km.

The study was conducted between August 1995 to July 1996. The data were collected at monthly interval during third week of every month.

Meteorological data related to temperature, rainfall and relative humidity was obtained from the laboratory of Indian Oil Corporation situated in Digboi at a distance of 13 km from the study village. The study area has sub-tropical climate with mean annual rainfall of about 2800 mm. The pre-monsoon rains begin in March and wet hot season lasts till October with the peak rainfall occurring in July/August. November to February is the cool dry season, January is the coldest month. Relative humidity always remain over 70% throughout the year.

The study village was comprised 69 households with 401 inhabitants and human-cattle ratio of 1:0.9. The tribal inhabitants, mostly marginal farmers and tea garden labourers, live in mud-plastered thatched huts with indoor sleeping habits. The village was not sprayed with any residual insecticide since 1991.

Collection of *An. dirus*

From dusk-to-dawn population of *An. dirus* frequently entering houses was monitored longitudinally in two fixed indicator huts of the village with the help of battery operated CDC miniature light traps hung at a height of approximately 2.5 m for 1 to 3 nights in each month. The number of occupants sleeping in the indicator huts in the collection nights varied from 4 to 7 in different months. Trapped mosquitoes were carried to the camp laboratory next morning, identified and the densities of *An. dirus* were expressed in terms of mean numbers caught per trap per night. Suitable specimens of *An. dirus* were dissected for sporozoites and their ovaries were examined for parity status[4].

Parasitological surveys

At the time of door-to-door survey thick and thin blood smears from those having fever at the time of survey or who suffered from fever between the two surveys were collected and fever history was noted. The slides were stained with JSB stain and examined on the same day. The malaria positive cases were treated with standard regime of chloroquine only.

RESULTS

A total of 986 mosquitoes belonging to six genera and 30 species were captured in 25 trap nights during the study. The percentage of anophelines (9 species) and culicines (21 species) in the collections were 42.5 and 57.5% (1: 1.4) respectively. *An. dirus* was the only known malaria vector constituting 15.4% of total mosquitoes and 36.3% of total anophelines collected during the study. The unfed and fed *An. dirus* in light trap collections were 32 and 68% respectively.

Mean density of *An. dirus* per trap per night was 6.1 and the density varied with the season. Its population with the onset of pre-monsoon rain (March onwards) started building up to reach the peak in July (39 per trap per night), remained high till October and, thereafter with decline in rainfall density gradually reduced and became zero in the month of December (Table 1). The relative proportion of *An. dirus* to total mosquitoes was low in monsoon and high in non-monsoon months ranging between 7.7% (March) and 45.5% in October (Fig. 1).

The density of *An. dirus* showed a significant positive correlation ($r = 0.721$) with the amount of rainfall occurring two weeks preceding mosquito collection. However, its correlations with total rainfall during the month ($r = 0.419$) and rainfall just one week preceding collection ($r = 0.140$) were poor and not significant.

Monthly prevalence of malaria in the study population is given in Fig. 1 and Table 2. Malaria was endemic in the study village throughout the year. A total of 264 fever cases were detected during the study. Distribution of fever cases showed that 171 persons suffered at least once, 60 twice, 19 thrice and 11, 2 and 1 person four, five and six times respectively. The cases were distributed uniformly in the village without any clustering. Overall slide positivity rate (SPR) was 47.0% with predominance of *P. falci-parum* infection (83.1%). The ratio of *P. vivax* and *P. falciparum* parasite in the community

Table 1. Prevalence of *Anopheles dirus* in the study village

Year/ Month		Trap collection (No.)	Mean density/trap/night			% of *An. dirus* to all mosquitoes
			An. dirus	All anophelines	All mosquitoes	
1995	Aug	2	3.5	18.0	29.0	12.1
	Sep	3	12.7	21.0	83.6	15.2
	Oct	2	10.0	13.0	22.0	45.5
	Nov	3	2.0	3.0	7.0	28.6
	Dec	2	0.0	0.0	1.0	0.0
1996	Jan	2	0.0	0.0	0.5	0.0
	Feb	2	0.0	0.0	11.0	0.0
	Mar	2	1.0	1.5	13.0	7.7
	Apr	2	2.0	4.5	14.0	14.3
	May	2	8.0	19.5	41.0	20.0
	Jun	2	10.0	13.5	31.5	31.7
	Jul	1	39.0	207.0	400.0	9.8
Total		25	6.1	16.8	39.4	15.4

Table 2. Malaria prevalence in the study village

Year/Month		BSE	(+)ve	*Pv*	*Pf*	Mix	SPR	SfR	*Pf*%
1995	Aug	30	18	0	18	0	60.0	60.0	100.0
	Sep	15	8	1	7	0	53.3	46.7	87.5
	Oct	21	11	1	10	0	52 4	47.6	90.0
	Nov	26	17	3	13	1	65.4	53.8	82.4
	Dec	17	16	3	12	1	94.1	76.5	81.1
1996	Jan	11	5	0	5	0	45.5	45.5	100.0
	Feb	19	9	0	9	0	47.4	47.4	100.0
	Mar	8	2	1	1	0	25.0	12.5	50.0
	Apr	7	1	0	1	0	14.3	14.3	100.0
	May	16	11	4	7	0	68.8	43.8	63.6
	Jun	39	14	4	10	0	35.9	25.6	71.4
	Jul	55	12	4	8	0	21.8	14.5	66.7
Total		264	124	21	101	2	47.0	39.0	83.1

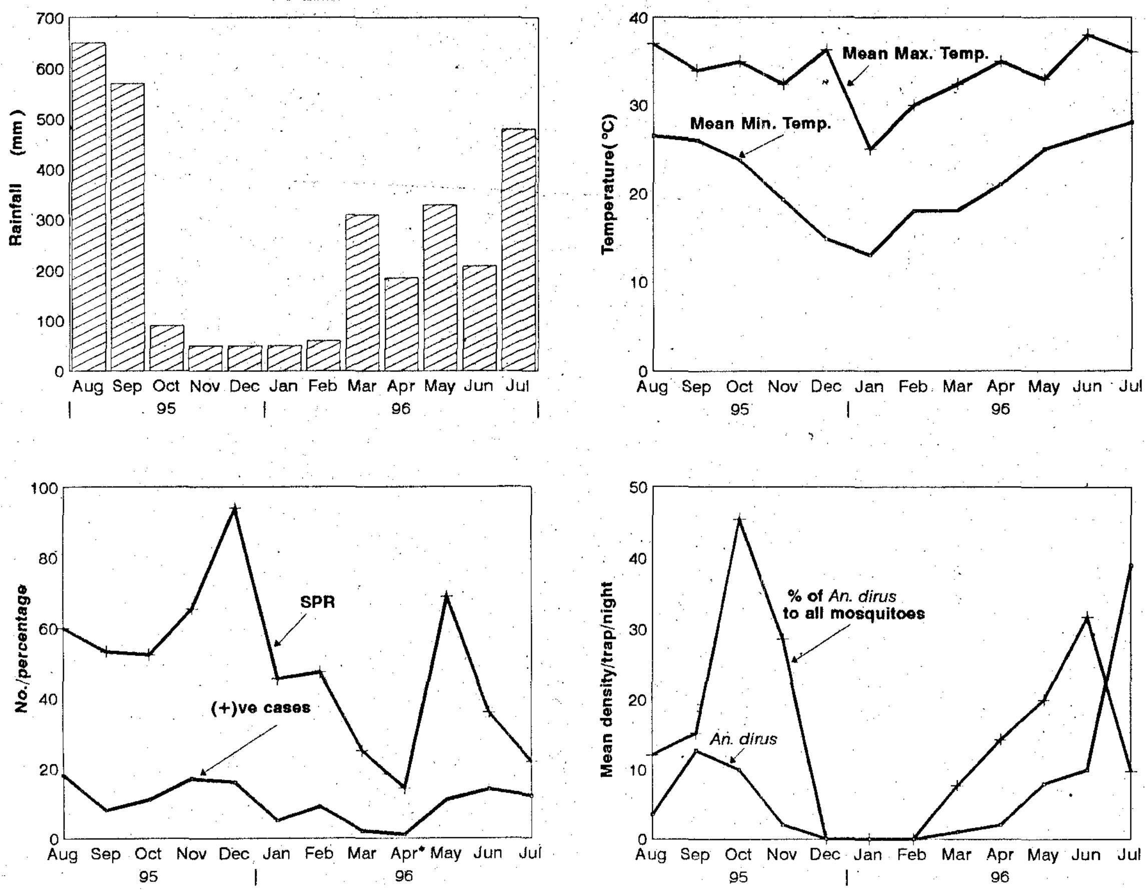

Fig. 1: Prevalence of *An. dirus* and malaira vs. meteorological data of the study village

was not consistent throughout the year. Percentage of *Pv* was high during May to July (ranging 28.6 to 36.4%) and low between August to February (0 to 19%).

Age and malaria prevalence in the community was inversely related. Accordingly, SPR in infants and children up to five years of age was higher ($p < 0.01$, $\chi^2 = 14.15$) as compred to children of 5-15 yrs and more (Table 3). Overall malaria prevalence was significantly higher ($p < 0.05$, $\chi^2 = 5.37$) in females (SPR 53.5%) than in males (SPR 39.2%).

A total of 494 *An. dirus* females were dissected out of which eight were sporozoite positive, thus, giving infection rate of 1.6% (Table 4). Parous rate in different months fluctuated between 46.6 and 100% with overall parity rate of 64.7%.

DISCUSSION

An. dirus is a hygrophilic species and is

Table 3. Age and sexwise distribution of malaria cases in the study village

Age group (yrs)	Sex	Population	BSE	(+)ve	*Pv*	*Pf*	Mix	SPR	SfR	*Pf*%
	M	10	7	5	3	2	0	71.4	28.6	40.0
< 1	F	9	6	4	0	3	1	66.7	66.7	100.0
	T	19	13	9	3	5	1	69.2	46.2	66.7
	M	20	17	8	3	5	0	47.1	29.4	62.5
1-5	F	34	39	26	5	21	0	66.7	53.8	80.8
	T	54	56	34	8	26	0	60.7	46.4	76.5
	M	47	34	17	3	14	0	50.0	41.2	82.4
5-15	F	44	28	16	2	13	1	57.1	50.0	87.5
	T	91	62	33	5	27	1	53.2	45.2	84.8
	M	127	62	17	1	16	0	27.4	25.8	94.1
>15	F	110	71	31	4	27	0	43.7	38.0	87.1
	T	237	133	48	5	43	0	36.1	32.3	89.6
	M	204	120	47	10	37	0	39.2	30.8	78.7
Total	F	197	144	77	11	64	2	53.5	45.8	85.7
	T	401	264	124	21	101	2	47.0	39.0	83.1

Malaria prevalence in different age groups ($p < 0.01$, $\chi^2 = 14.15$, df = 3); and in males and females ($p < 0.05$, $\chi^2 = 5.37$, df = 1); M — Male; F — Female; T — Total.

Table 4. Dissection results of *An. dirus* in study village

Year/ Month		No. dissected	Sporozoite (+)ve	Infection rate %	Parity rate %
1995	Aug	8	0	0.0	60.0
	Sep	66	1	1.5	100.0
	Oct	36	0	0.0	83.3
	Nov	13	1	7.7	66.7
1996	Mar	2	0	0.0	–
	Apr	39	1	2.6	73.3
	May	47	0	0.0	46.6
	Jun	88	1	1.1	78.0
	Jul	195	4	2.1	48.7
Total		494	8	1.6	64.7

responsible for hyper-endemic malaria in its areas of influence[1]. Crawford was quoted by Clark and Choudhury[5] to have first incriminated *An. balabacensis balabacensis* in 1938 in Digboi area of Assam. Later on several studies emphasized its importance as an efficient malaria vector from different northeastern states of India[6-8]. Villages near the forest fringes under the influence of *An. dirus* were found more malaria-prone than non-forested villages in Assam[9].

Pattern of seasonal prevalence of *An. dirus* as found in our study may be related to the proliferation of its breeding habitats (small jungle pools and elephant foot prints) during rainy season and their scarcity in dry season in the forest fringe areas. Similar pattern of high densities of *An. dirus* in monsoon and post-monsoon months and low densities in cool dry months were reported from Assam[9], and Arunachal Pradesh[7] of India, Bangladesh[10], Myanmar[11] and Thailand[12]. The seasonal fluctuation of *An. dirus* can be explained and better understood on the basis of the phenomenon of 'horizontal pulsation' exhibited by this mosquito (adaptation). In this phenomenon during dry season, due to drying up of breeding sites and reduction in humidity gradient, the population of *An. dirus* recedes from the forest fringes to the 'mother foci' in deep forest where favourable conditions exist. During rainy season as breeding sites are created and humidity increases its population expands to forest fringes forming 'secondary foci'[13-15].

Our study indicated that the abundance of *An. dirus* at any point of time during its period of prevalence is likely to be influenced by the amount and pattern of rainfall 15 days prior to that of collection. Studies elsewhere[13,16] also showed close correlation of rainfall with the densities of *An. balabacensis balabacensis*.

Malaria prevalence closely followed the pattern of *An. dirus* abundance in the study area. It was apparent from malaria data that the transmission was seasonal and intense between May to December. *An. dirus* supported malaria transmission in monsoon and post-monsoon months in the study was evident from sporozoite positivity and parity data of mosquitoes. Kondrashin *et al.*[17] attributed the prolonged seasonal malaria transmission in the forest fringed areas to the survival of vector due to the existence of various habitats in the two adjacent ecosystems. In our study the high SPR in cool dry months (January to March) when *An. dirus'* density was at its lowest ebb and no other vector was present could be atributed to recrudescence of *P. falciparum* cases. The season of malaria transmission in our study differed from Myanmar[11] and Thailand[12] studies which reported high malaria transmission in cool dry months. However, differences in types of biotope, i.e. forest fringed biotope in our study in contrast to deep forest biotope in the above quoted studies along with the phenomenon of horizontal pulsation seen in *An. dirus* explains the different transmission season in these studies. The findings of significantly higher malaria prevalence among females in the present study is a unique observation. Though we did not observe any special malaria risk behaviour in females of the study area and as such found both the sexes equally exposed to the chances of getting infective bites, this aspect needs further investigations.

Forests in Assam occupy 27% of the land area[18], are evergreen rain forests. Approximately 37,61,000 population, mostly tribals (17% of state population) living in forest areas of Assam is served by Primary Health Care System[19]. Malaria transmission in forest areas is intense and prolonged because of highly efficient vector(s) and favourable ecological conditions resulting in high morbidity and mortality. *An. dirus*, though a vector of local importance in Assam and other northeastern states, is not only one of the most efficient vectors of forest malaria particularly in forest fringes but also one of the least amenable to control by residual insecticides due to its exophilic behaviour and low irritability threshold to DDT. The application of residual insecticides, therefore, is unlikely to produce any tangible impact on *An. dirus* transmitted malaria on long-term basis which necessitates some alternate strategy in tune with the cultural and social frame work of the community to be adopted for vector control in conjunction with strengthening of surveillance mechanism for early case detection and treatment. An ecological approach for controlling malaria supported by hygrophilic species in forest fringes was suggested by Kalra[20] who proposed 'forest clearing' of width greater than the flight range of the vector species as an ecological barrier. This concept is worthy of serious consideration in areas under the influence of *An. dirus*.

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REFERENCES

1. Rosenberg, R. and N.P. Maheswary (1982). Forest malaria in Bangladesh. II. Transmission by *Anopheles dirus*. *American J. Trop. Med. Hyg.*, **31**(2): 183-191.
2. Bhat, H.R. (1988). A note on *Anopheles dirus* Peyton and Harrison, 1979 [*An. balabacensis* (sensu lato) Baisas, 1936] in India. *Indian J. Malariol.*, **25:** 103-105.
3. Rao, T. Ramachandra (1984). *The Anophelines of India*. Rev. ed. (Malaria Research Centre, ICMR, Delhi): 269.
4. Detinova, T. (1962). Age-grouping methods in Diptera of medical importance. WHO Monograph Ser.: 47.
5. Clark, R.H.P. and M.A. Choudhury (1941). Observations on *Anopheles leucosphyrus* in Digboi area of upper Assam. *J. Mal. Inst. India*, **4:** 103-107.
6. Dutta, P., D.R. Bhattacharyya, C.K. Sharma and L.P. Dutta (1989). The importance of *Anopheles dirus (An. balabacensis)* as a vector of malaria in northeast India. *Indian J. Malariol.*, **26**(2): 95-101.
7. Sen, A.K., V.M. John, K.S. Krishnan and R. Rajagopal (1973). Studies on malaria

transmission in Tirap district, Arunachal Pradesh (NEFA). *J. Com. Dis.*, **5**(2): 98-110.

8. Das, S.C. and I. Baruah (1985). Incrimination of *Anopheles minimus* Theobald and *Anopheles balabacensis balabacensis* Baisas (*An. dirus*) as malaria vectors in Mizoram. *Indian J. Malariol.*, **22**(2): 53-55.

9. Dutta, P., D.R. Bhattacharyya and L.P. Dutta (1991). Epidemiological observations on malaria in some parts of Tengakhat PHC, Dibrugarh district, Assam. *Indian J. Malariol.*, **28**(2): 121-128.

10. Rahman, M., M.D. Elias and Mahmud-ul Ameen (1977). Bionomics of *Anopheles balabacensis balabacensis* (Diptera: Culicidae) in Bangladesh and its relation to malaria. *Bangladesh Z. Zool.*, **5**(1): 1-23.

11. Tun-Lin, W., Myat-Myat-Thu, Sein-Maung-Than and Maung-Maung-Mya (1995). Hyper-endemic malaria in a forested, hilly Myanmar village. *J. Amer. Mosq. Contr. Assoc.*, **11**(4): 401-407.

12. Rosenberg, R., G. Andre and Somchit (1990). Highly efficient dry season transmission of malaria in Thailand. *Trans. R. Soc. Trop. Med. Hyg.*, **84:** 22-28.

13. Ismail, I.A.H., V. Notanand and J. Scheplens (1974). Studies on malaria and responses of *Anopheles balabacensis balabacensis* and *Anopheles minimus* to DDT residual spraying in Thailand. Pt I. Pre-spraying observations. *Acta Trop.*, **31:** 129-164.

14. Wilkinson, R.N., D.J. Gould, P. Boonyakanist and H.E. Segal (1978). Observations of *An. balabacensis* (Diptera: Culicidae) in Thailand. *J. Med. Entomol.*, **14**(6): 666-671.

15. Kalra, N.L. (1986). Ecology of malaria vectors in Island ecosystem with particular reference to Nusa Tenggara Timur (NTT), Nusa Tenggara Barat (NTB) and Irian Jaya, Indonesia. SEA/VBC/27 (WHO Mimeographed document).

16. Scanlon, J.E. and V. Sandhinand (1965). The distribution and biology of *Anopheles balabacensis* in Thailand (Diptera: Culicidae). *J. Med. Entomol.*, **2**(1): 61-69.

17. Kondrashin, A.V., R.K. Jung and J. Akiyama (1991). Ecological aspects of forest malria in southeast Asia. In *Forest Malaria in Southeast Asia*, edited by V.P. Sharma and A.V. Kondrashin. Proceedings of an informal consultative meeting, WHO/MRC, New Delhi: 1-28.

18. Anon. (1993). *Statistical Hand Book, Assam* (Directorate of Economics and Statistics, Government of Assam, Guwahati, India).

19. Narasimham, M.V.V.L. (1991). Perspectives of forest malaria in India. In *Forest Malria in Southeast Asia*, edited by V.P. Sharma and A.V. Kondrashin. Proceedings of an informal consultative meeting, WHO/MRC, New Delhi: 81-91.

20. Kalra, N.L. (1991). Forest malaria vectors in India: Ecological characteristics and epidemiological implications. In *Forest Malaria in Southeast Asia*, edited by V.P. Sharma and A.V. Kondrashin. Proceedings of an informal consultative meeting, WHO/MRC, New Delhi: 93-114.

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HCH and DDT Residues in Human and Bovine Milk at Hardwar, India

V.K. DUA, C.S. PANT and V.P. SHARMA[a]

Concentrations of HCH and DDT in human and bovine milk were determined in two areas under malaria control namely, BHEL, Hardwar with bioenvironmental control strategy and rural and urban areas of Bahadrabad PHC of Hardwar district with residual spraying of insecticides. Mean HCH and DDT residues in human milk in BHEL were 0.027 and 0.021 mg/kg, while from Bahadrabad were 0.089 and 0.149 mg/kg respectively. Similarly, mean HCH and DDT contents in bovine milk from BHEL were 0.019 and 0.008 mg/kg, while 0.058 and 0.029 mg/kg, respectively from Bahadrabad. Statistically significant differences were recorded in HCH and DDT levels in human and bovine milk samples between BHEL and Bahadrabad areas of Hardwar district. The mean levels of HCH and DDT in bovine milk samples did not exceed the maximum residual limit of 0.05 mg/kg from BHEL whereas, 38.5% samples from Bahadrabad area exceeded this limit.

Keywords: DDT and HCH residues, Hardwar, Human and bovine milk, Malaria control

INTRODUCTION

The organochlorine insecticides HCH and DDT have been extensively used in India for the control of vector-borne diseases. However, due to their chemical stability they have been detected in human blood[1] and adipose tissue[2] besides food chain[3]. Human and bovine milk have also been contaminated with HCH and DDT residues[4,5]. Recently Dua *et al.*[6] have determined levels of HCH and DDT in soil-water and whole blood from bioenvironmental and in-

Malaria Research Centre (Field Station), BHEL Complex, Ranipur, Hardwar-249 403, India.
[a]Malaria Research Centre, 22-Sham Nath Marg, Delhi-110 054, India.

secticide sprayed areas of malaria control. Bouwman *et al.*[7] have studied factors affecting levels of DDT and its metabolites in human breast milk from Kwa-Zulu. Battu *et al.*[4] have found the contamination of bovine milk from indoor use of DDT and HCH in malaria control. The aim of this study was to determine the levels of HCH and DDT in human and bovine milk samples from the area where DDT and HCH were used for malaria control and from bioenvironmental control area[8].

MATERIALS AND METHODS

Human and bovine milk samples were collected from different areas of Bharat Heavy Electricals Limited (BHEL), Ranipur, Hardwar where no insecticide was used for malaria control since 1986 and from Bahadrabad PHC, Hardwar, where HCH and DDT were used for malaria control. Two rounds of DDT (50% wp) @ 2g/sq m and three rounds of HCH (50% wp) @ 0.3g/sq m were sprayed for malaria control in Hardwar district.

The yearly usage of HCH during 1987-1993 were 9.0, 4.6, 0.5, 0.6, 1.2 and 1 MT respectively, while average DDT consumption was 2 MT/yr in Hardwar district. In addition to this about 6 MT of HCH and 2 MT of DDT was used covering an area of 130 sq km for the control of mosquitoes and house flies during *Ardh Kumbh* congregation.

Twenty human milk samples (5 to 10 ml) were collected from lactating mothers in the month of November, 1994 from BHEL and Bahadrabad area. Mothers were supplied with 25 ml conical flask having 0.5 ml preservative (saturated potassium dichromate with 1% amyl alcohol). Mothers were asked to extract manually about 10 ml of milk. The milk samples were stored in ice until they were frozen on the same day. Twenty-four bovine milk samples (250 ml) each were collected from BHEL and Bahadrabad in November 1994. 1.0 ml of milk preservative was added and samples were stored in frozen condition till analysis. Extraction and clean-up of the milk samples were done according to the method reported earlier[9].

All samples were analysed for HCH and DDT residues on Hewlett-Packard Gas Chromatograph 5890-A fitted with Ni^{63} electron capture detector on fused silica capillary column $PTE^{TM}5$. The chromatographic conditions were column 190°C, injector 210°C and detector 220°C. Nitrogen @ 3 ml/min and split ratio of 100:1 was used as a carrier gas, while the aldrin was used as an internal standard. The identity of DDE and HCH residues in some samples was further confirmed by Gas Chromatography-Mass Spectrometry (GC-MS). The extraction recoveries were found above 85%. However, the data presented here have not been corrected for recovery. The minimum detection limit of HCH and DDT residues were 0.0001 mg/kg.

RESULTS

The average age of mothers was 24.1 yrs (range 22 to 30 yrs). The fat contents in human milk ranged from 0.45 to 8.27% with a mean of 3.31%. While in bovine milk fat ranged from 3 to 8.9% with a mean of 5.09%.

Twenty samples each of human milk from BHEL and Bahadrabad were analysed for HCH and DDT contamination and the results are given in Table 1. Mean HCH and DDT in human milk from BHEL were 0.027 and 0.021 mg/kg while from Bahadrabad were 0.089 and 0.149 mg/kg respectively. β-HCH contributed maximum among HCH isomers in BHEL (81.4%) and in Bahadrabad (87.6%) samples. Similarly p,p'-DDE was 61.9% of the total DDT contents in BHEL samples while p,p'-DDT (62.7%) followed by p,p'-DDE (24.8%) were the major constituents of total DDT present in Bahadrabad samples. The average daily intake (ADI) of total DDT by infants through human milk from BHEL and Bahadrabad were 0.004 and 0.029 mg/kg respectively. Similarly ADI of HCH by the infants through human milk from BHEL and Bahadrabad were 0.005

Table 1. Levels of HCH and DDT residues in human milk samples from BHEL, Ranipur and Bahadrabad of District Hardwar

Residue	Concentration (mg/kg)	
	BHEL	Bahadrabad
α-HCH	0.002 (0.001-0.004)	0.003 (0.001-0.009)
γ-HCH	0.002 (0.001-0.003)	0.006 (0.001-0.025)
β-HCH	0.022 (0.011-0.037)	0.078 (0.008-0.273)
δ-HCH	0.001 (ND-0.003)	0.002 (ND-0.003)
Total HCH	0.027 (0.013-0.037)	0.089 (0.011-0.294)
p,p'-DDE	0.013 (0.002-0.079)	0.036 (0.006-0.080)
p,p'-DDD	0.002 (ND-0.009)	0.018 (ND-0.122)
p,p'-DDT	0.006 (ND-0.019)	0.091 (ND-0.492)
Total DDT	0.021 (0.002-0.085)	0.145 (0.020-0.503)

ND— Not detected; Figures in parentheses indicate range.

Table 2. Levels of HCH and DDT residues in bovine milk samples from BHEL, Ranipur and Bahadrabad PHC of District Hardwar

Residue	Concentration (mg/kg)	
	BHEL	Bahadrabad
α-HCH	0.0045 (0.0006-0.021)	0.012 (0.002-0.042)
γ-HCH	0.002 (ND-0.006)	0.015 (0.002-0.153)
β-HCH	0.0105 (0.001-0.085)	0.028 (0.001-0.229)
δ-HCH	0.002 (ND-0.023)	0.003 (ND-0.015)
Total HCH	0.019 (0.003-0.112)	0.058 (0.011-0.308)
p,p'-DDE	0.005 (0.0002-0.015)	0.013 (0.001-0.100)
p,p'-DDD	0.001 (ND-0.013)	0.004 (ND-0.026)
p,p'-DDT	0.001 (ND-0.013)	0.012 (ND-0.086)
Total DDT	0.008 (0.0002-0.040)	0.029 (0.001-0.133)

ND— Not detected; Figures in parentheses indicate range.

and 0.017 mg/kg respectively. Statistically significant difference was recorded in HCH and DDT levels between human milk samples from BHEL and Bahadrabad area [t(HCH) = 2.225), $p < 0.05$; t (DDT) = 2.206, $p < 0.05$].

The mean HCH and DDT contents in bovine milk samples collected from BHEL and Bahadrabad area are given in Table 2. Mean HCH and DDT residues from BHEL were 0.019 and 0.008 mg/kg respectively while from Bahadrabad HCH and DDT levels were 0.058 and 0.029 mg/kg respectively. β-HCH contributed 55.26 and 48.7% of total HCH present in BHEL and Bahadrabad. Similarly p,p'-DDE were 62.5 and 44.8% of total DDT content in bovine milk samples from BHEL and Bahadrabad respectively. Statistical analysis of residual level of HCH and DDT in the bovine milk samples from BHEL and Bahadrabad showed significant difference [t(HCH) = 4.5, $p < 0.001$; t(DDT) = 3.527, $p < 0.001$]. Average daily intake of HCH through bovine milk for a adult of weight 60 kg from BHEL and

Bahadrabad were 0.00009 and 0.0003 mg/kg respectively while the ADI of DDT through bovine milk from BHEL and Bahadrabad were 0.00004 and 0.00014 mg/kg respectively.

DISCUSSION

The mean levels of HCH isomers and DDT metabolites in bovine milk samples did not exceed the maximum residual limits of 0.05 mg/kg recommended by Codex Eliminators Commission from BHEL samples while 38.5% samples from Bahadrabad exceed maximum residual limits[10]. 69 per cent samples from Bahadrabad and 20% samples from BHEL exceed the tolerance limit of β-HCH (0.02 mg/kg), 27% samples from BHEL and 54% samples from Bahadrabad exceed the γ-HCH limit of 0.02 mg/kg. δ-HCH was with in the limit of 0.02 mg/kg in any samples from both the areas. While the α-HCH in all bovine samples from both the areas exceeded its maximum residue limit. 38 per cent bovine samples from Bahadrabad exceed the limit of 0.05 mg/kg of total DDT. Recent survey conducted by ICMR task force[3] revealed that 36% samples of bovine milk collected from 13 states of India exceed the DDT limit of 0.05 mg/kg prescribed by WHO[11] and Codex[10]. It is found that the ADI of DDT through human milk from BHEL area is well below the acceptable daily intake of 0.05 mg/kg whereas ADI from Bahadrabad is 5.96 times higher than that of the recommended value by WHO[11]. A comparison of mean HCH and DDT in whole milk from Bahadrabad and BHEL clearly showed that the HCH and DDT levels in human milk from Bahadrabad area were 3.3 and 6.9 times higher than the corresponding value from BHEL. It may be noted that Bouwman *et al.*[7] have reported 15 to 37 times higher DDT concentration in human milk from exposed group than the control group. Lower difference ratio in the present study may be due to lesser use of DDT in Bahadrabad. The mean HCH and DDT residues in bovine milk from Bahadrabad were 3.2 and 3.5 times higher than their mean values from BHEL area. Battu *et. al.*[4], have reported that the level of DDT in bovine milk from DDT sprayed area were 4-12 times higher than HCH sprayed area and HCH levels from HCH sprayed area was 2-11 times higher than DDT sprayed area.

Present study reveals a direct correlation between intradomicillary application of DDT and HCH for malaria control and their residues in human and bovine milk. Although no HCH or DDT were sprayed in BHEL since 1986 but these residues were detected in human and bovine milk. The levels present in such an area are generally referred to as background levels and the source were mainly due to their use in agriculture and drift from insecticide sprayed areas. Therefore, the first line of action to control malaria should be the non-insecticidal methods and if insecticides have to be used in malaria control, these should be sprayed selectively and to control epidemic emergencies.

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REFERENCES

1. Dua, V.K., C.S. Pant, V.P. Sharma, G.K. Pathak (1996). Determination of HCH and DDT in fingerprick whole blood dried on filter paper and its field application for monitoring concentrations in blood. *Bull. Environ. Conta. Toxicol.*, **56**: 50-57.
2. Kaphalia, B.S. and T.D. Seth (1983). Chlorinated pesticide residues in blood plasma and adipose tissues of normal and exposed human population. *Indian J. Med. Res.*, **77**: 245-247.
3. Anon. (1993). *Surveillance of food contaminants in India* (Indian Council of Medical Research, New Delhi, India).
4 Battu, R.S., P.P. Singh, B.S. Joia and R.L. Kalra (1989). Contamination of bovine (buffalo—*Bubalus bubalis* (L)) milk from indoor use of DDT and HCH in malaria control programmes. *Sci. Tot. Environ.*, **86**: 281-287.
5. Nair, A., R. Mandapali, P. Dureja and M.K.K. Pillai (1996). DDT and HCH load in mothers and their infants in Delhi, India. *Bull. Environ. Conta. Toxicol.*, **56**: 58-68.
6. Dua, V.K., C.S. Pant and V.P. Sharma (1996). Determination of levels of HCH and DDT in soil, water and whole blood from bioenvironmental and insecticide sprayed areas of malaria control. *Indian J. Malariol.*, **33**: 7-15.
7. Bouwman, H., R.M. Coopan, A.J. Reincke, P.J. Backer (1990). Levels of DDT and metabolites in breast milk from Kwa-Zulu mothers after DDT application for malaria control. *Bull. WHO*, **68**(6): 761-768.
8. Dua, V.K., V.P. Sharma and S.K. Sharma (1989). Bioenvironmental control of malaria in an industrial complex at Hardwar (U.P.), India. *J. Amer. Mosq. Contr. Assoc.*, **4**: 426-430.
9. Anon. (1991). *Laboratory Manual for Pesticide Analysis* (National Institute of Occupational Health, ICMR, Ahmedabad, India).
10. Anon. (1986). Joint FAO/WHO Food Standards Programme (Codex Alimentarious Commission, XII Rome).
11. WHO (1976). WHO expert committee on pesticide residues. *WHO Tech. Rep. Ser.* No. 525.

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Seasonality of Indoor Resting Anophelines in Stone Quarry Area of District Allahabad, U.P.

S.N. TIWARI, ANIL PRAKASH[a] and S.K. GHOSH

A longitudinal study was conducted in four indicator villages of PHC Shankargarh, District Allahabad, U.P. from July 1991 to June 1992 to have information on seasonality of indoor resting anopheline species in silica sand/hard stone quarry area. Fourteen anopheline species namely, *An. aconitus* (0.35%), *An. annularis* (17.03%), *An. barbirostris* (0.09%), *An. culicifacies* (36.74%), *An. fluviatilis* (0.13%), *An. nigerrimus* (0.01%), *An. pallidus* (4.40%), *An. splendidus* (0.02%), *An. stephensi* (0.01%), *An. subpictus* (40.84%), *An. tessellatus* (0.15%), *An. turkhudi* (0.004%), *An. vagus* (0.20%) and *An. varuna* (0.02%) were collected. *An. culicifacies*, *An. subpictus* and *An. annularis* were found throughout the year. *An. fluviatilis*, *An. pallidus*, *An. vagus* and *An. aconitus* were also observed in all the seasons except extreme summer. However, *An. barbirostris* and *An. splendidus* were collected only in monsoon/post-monsoon and winter seasons. *An. tessellatus* and *An. stephensi* were recorded in winter and spring seasons. *An. nigerrimus* and *An. varuna* were recorded in winter, while *An. turkhudi* in spring. Prolonged high vector density may be attributed to the extended malaria transmission in this area.

Keywords: Anophelines, Seasonality, Stone quarry

INTRODUCTION

Primary Health Centre (PHC), Shankargarh in Allahabad district, U.P. is characterized by numerous silica sand and hard stone quarries. These are usually 5 to 10 m deep surface quarries. Once quarrying is over, the quarry pits are left

Malaria Research Centre (Field Station), Epidemic Diseases Hospital Campus, Bangalore-560 038, India.
[a]Regional Medical Research Centre (ICMR), Post Box No. 105, Dibrugarh-786 001, India.

undressed by the contractors and as a result of rain water collection and canal seepages these become highly favourable breeding sites for mosquitoes. Frequent labour movement from the adjoining districts and state of Madhya Pradesh for quarrying provide ample parasite reservoir which has rendered Shankargarh PHC highly endemic for malaria with high *Plasmodium falciparum* incidence[1]. Under such situation malaria transmission can be better understood if entomological information of this particular area is available. Hence in order to generate information on prevalence and seasonality of indoor resting anophelines, a longitudinal study was carried out in four indicator villages of PHC Shankargarh for a year from July 1991 to June 1992 and the results are presented in this paper.

Study area

Shankargarh PHC covers an area of 480 sq km with 80,000 population. It is situated about 50 km southwest from Allahabad city bordering Banda and Rewa districts of Madhya Pradesh. There are three rivers around the PHC, i.e. River Yamuna in northwest and Rivers Tons and Balen in the southeast (Fig. 1). Most of the land is lying barren with numerous silica sand/hard stone

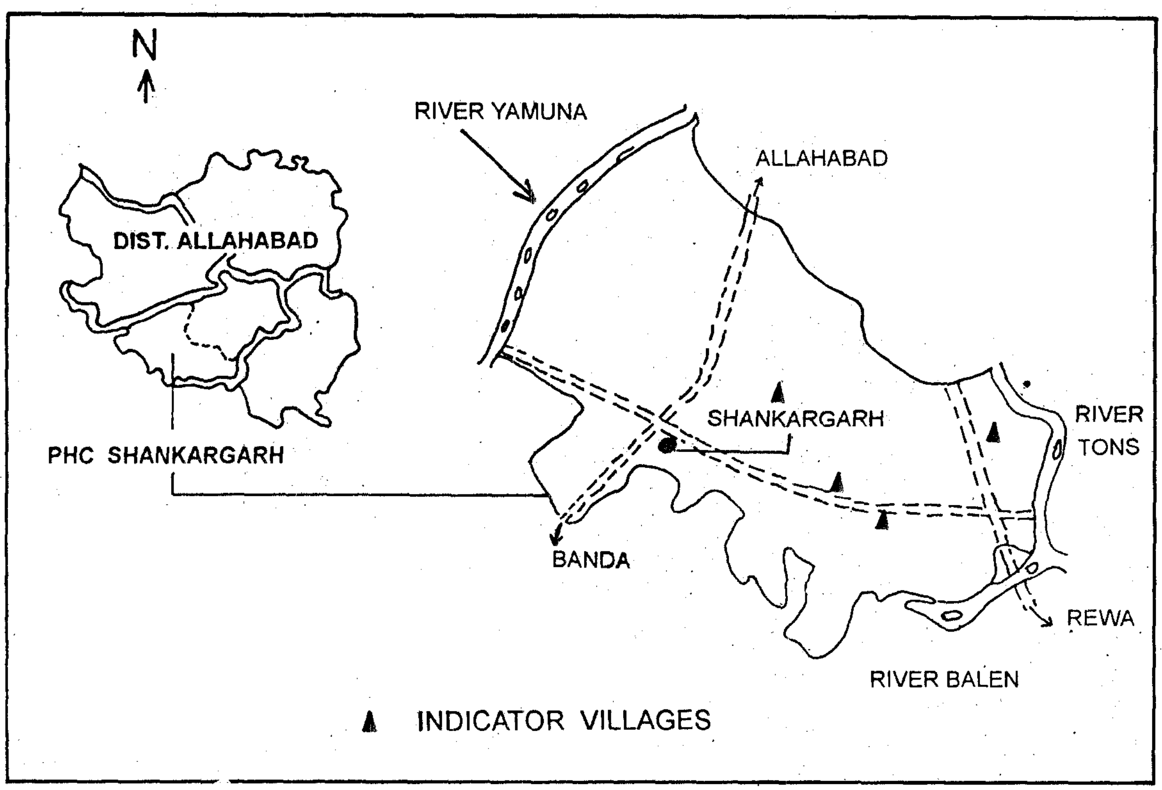

Fig. 1: Map showing the study area

quarries. The houses have mostly mud walls and thatched roofs. People are mostly from low socio-economic status and the literacy rate is only 29.5%[2]. Although farming supports major employment yet the mainstay of the economy of the area is quarring. Majority of labourers working in quarries are tribals and most of them stay in temporary hutments in the vicinity of the quarries.

Climate

Shankargarh has tropical climate which is characterized by a very hot summer season in the month of May and June. Spring starts from late February and continue up to early April. Southwest monsoon starts form late June. July, August, September and October are monsoon and post-monsoon months. Winter starts from November to mid-February with relatively low temperature and moderate humidity. The average temperature and relative humidity vary from 13.5°C in January to 42.4°C in May and from 24.1% in April to 83% in August respectively. The average annual rainfall is around 500 mm (Table 1).

MATERIALS AND METHODS

Indoor resting adult mosquitoes were collected fortnightly from two fixed and two random human dwellings and cattlesheds each in four indicator villages namely, Bhagdeva, Bemera, Bashera and Fultara using a torch and aspirator. Mosquitoes were collected in morning between 0600 and 0800 hrs

Table 1. Meteorological data of Shankargarh PHC of District Allahabad, U.P. (Averages from July 1987- June 1991)

Month	Av. temperature (°C)		Av. humidity (%)		Av. rainfall** (mm)
	Max.	Min.	Max.	Min.	
Jan	21.2	13.5	70.4	46.2	Nil
Feb	24.8	17.1	64.3	44.1	Nil
Mar	32.4	23.1	56.4	34.5	8.7
Apr	38.5	26.7	41.2	24.1	Nil
May	42.4	31.7	49.5	31.2	Nil
Jun*	39.4	29.7	66.7	50.9	77.0
Jul	34.9	27.4	80.2	62.5	194.9
Aug	34.4	28.8	83.0	63.7	209.8
Sep	33.9	28.1	82.2	62.9	84.2
Oct	32.4	24.8	68.6	45.2	Nil
Nov	27.4	21.3	65.8	41.9	Nil
Dec	22.3	15.7	71.5	52.2	2.9

*Average of three years (1988, 1989 and 1990); **Average from July 1988 to June 1991.

Table 2. Per cent composition of different anopheline species in stone quarry area of District Allahabad, U.P.

Species	No. collected	%
An. aconitus, Donitz, 1902	87	0.348
An. annularis, Vander Wulp, 1884	4262	17.035
An. barbirostris, Vander Wulp, 1884	22	0.088
An. culicifacies, Giles, 1901	9193	36.744
An. fluviatilis, James, 1902	32	0.128
An. nigerrimus, Giles, 1900	2	0.008
An. pallidus, Theobald, 1901	1102	4.405
An. splendidus, Koidzumi, 1920	5	0.019
An. stephensi, Liston, 1901	3	0.012
An. subpictus, Grassi, 1899	10,217	40.837
An. tessellatus, Theobald, 1901	38	0.152
An. turkhudi, Liston, 1901	1	0.004
An. vagus, Donitz, 1902	49	0.196
An. varuna, Iyengar, 1924	6	0.024
Total	25,019	100.000

throughout the study period from July 1991 to June 1992. The mosquitoes were brought to the laboratory, identified following Keys of Christophers[3], and Wattal and Kalra[4] and per man hour densities were worked out.

RESULTS AND DISCUSSION

During the study period a total of 25,019 anopheline mosquitoes representing 14 species namely, *Anopheles aconitus*, *An. annularis*, *An. barbirostris*, *An. culicifacies*, *An. fluviatilis*, *An. nigerrimus*, *An. pallidus*, *An. splendidus*, *An. stephensi*, *An. subpictus*, *An. tessellatus*, *An. turkhudi*, *An. vagus* and *An. varuna* were collected (Table 2). *An. annularis*, *An. culicifacies*, *An. pallidus* and *An. subpictus* were the major species whereas, remaining 10 species were present in very low man hour densities. Anopheline surveys have been carried out from different parts of the country, however, comprehensive surveys for any particular locality have been scanty[5]. This is the first ever report of anophelines from silica sand/hard stone quarry area. Earlier studies carried out by Barraud[6] and Puri[7] from United Provinces east region including Allahabad district revealed 13 anopheline species namely, *An. aconitus, An. annularis, An. culicifacies, An. fluviatilis, An. hyrcanus, An. minimus, An. pallidus, An. splendidus, An. stephensi, An. subpictus, An. tessellatus, An. turkhudi* and *An. vagus*. The non-availability of *An. minimus* in the present study might be because of extensive DDT spray whereas, availability of additional species namely, *An. varuna* could be the consequence of ecological changes in the area.

Man hour densities of all anopheline species in two different biotopes, i.e. cattlesheds (CS) and human dwellings (HD) are projected in Table 3. All anopheline species except *An. turkhudi* preferred cattlesheds than human dwellings throughout the year. However, during hot dry months (May-June) differences in the densities between human dwellings and cattlesheds was narrow which might be because of the availability of more favourable micro-climatic conditions for resting mosquitoes in human dwellings.

It is well-known that physiography and climate of a given area plays an important role in the seasonal prevalence of most of the mosquito species. In stone quarry area which is typified by innumerable quarry pits, the mosquito density was found very low in summer. However, in remaining parts of the year the mosquito density remained higher showing a minor peak in March (spring) and a major during September (monsoon/post-monsoon) (Table 3). This is in accordance with the previous findings in canal-irrigated area in Kheda district of Gujarat[8]. The higher densities recorded in present investigation might be because of canal seepages and availability of numerous breeding sites in form of quarry pits in the area.

In moderate temperature zone most of the anophelines occur throughout the year. However, a study carried out in the Thar Desert with extreme conditions of temperature, Bansal and Singh[9] reported *An. culicifacies* and *An. stephensi* throughout the year and other species namely, *An. annularis, An. subpictus, An. pulcherrimus* and *An. barbirostris* during monsoon and post-monsoon periods. In stone quarry area where, temperature and humidity varied from 13.5 to 42.4°C and 24.1 to 83%, *An. subpictus* was found abundant during August and September with a gradual decline till February followed by a minor peak in April. Likewise man hour densities of *An. annularis* started building up with the onset of winter in October, reaching a peak during mid-winter and then gradually decline till May in summer. *An. pallidus, An. fluviatilis, An. vagus* and *An. aconitus* were recorded during July to April, i.e. in monsoon/post-monsoon, winter and spring seasons. *An. barbirostris* and *An. splendidus* were collected only from October to January, i.e. during monsoon/post-monsoon and winter seasons. Similarly, *An. tessellatus* and *An. stephensi* were found only in winter and spring seasons. *An. nigerrimus* and *An. varuna* were recorded in December and January, i.e. during winter, while *An. turkhudi* was observed only in early April.

Table 3. Man hour densities of anopheline species in human dwellings (HD) and cattlesheds (CS) in stone quarry area of District Alahabad, U.P.

Species	Dwelling	1991						1992					
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
An. aconitus	HD	0	0	0.1	0.2	0.2	1.9	0	0.1	0	0	0	0
	CS	0	0	0	0.4	0.7	5.7	0.2	1.0	0.1	0	0	0
An. annularis	HD	6.2	5.7	7.0	9.7	8.5	4.1	4.1	2.5	3.6	1.4	0.1	0.7
	CS	19.4	15.1	19.9	64.2	99.7	101.9	37.0	46.2	42.9	22.0	4.1	6.6
An. barbirostris	HD	0	0	0	0	0	0	0	0	0	0	0	0
	CS	0	0	0	0.4	1.1	0.5	0.7	0	0	0	0	0
An. culicifacies	HD	15.4	23.5	85.9	68.6	12.4	9.9	7.7	8.4	10.1	18.2	6.6	8.5
	CS	32.5	60.5	155.0	156.1	100.1	85.2	70.9	57.0	84.2	54.7	7.6	9.9
An. fluviatilis	HD	0	0	0	0.1	0	0	0.1	0.1	0	0.1	0	0
	CS	0	0	0	0	0	0.2	0.6	2.0	0.4	0.2	0	0
An. nigerrimus	HD	0	0	0	0	0	0	0	0	0	0	0	0
	CS	0	0	0	0	0	0.1	0.1	0	0	0	0	0
An. pallidus	HD	0.6	0.1	2.6	4.9	2.7	4.2	0.5	0	0.1	0	0	0
	CS	1.6	0.6	3.6	16.7	42.0	53.1	2.9	0.6	0.4	0.2	0	0

contd...

Table 3. (*contd.*)

Species	Dwelling	1991						1992					
		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
An. splendidus	HD	0	0	0	0	0	0.1	0.1	0	0	0	0	0
	CS	0	0	0	0.1	0.1	0	0.1	0	0	0	0	0
An. stephensi	HD	0	0	0	0	0	0	0	0	0	0	0	0
	CS	0	0	0	0	0	0.2	0	0	0.1	0	0	0
An. subpictus	HD	24.7	213.4	188.7	37.4	6.6	2.6	1.4	1.2	2.5	10.2	6.9	13.9
	CS	51.7	296.0	249.4	59.1	31.2	12.7	7.0	3.1	2.4	14.9	8.0	31.9
An. tessellatus	HD	0	0	0	0	0.6	0	0.2	0	0	0	0	0
	CS	0	0	0	0	0.7	1.2	1.0	0.7	0	0.1	0	0
An. turkhudi	HD	0	0	0	0	0	0	0	0	0	0.1	0	0
	CS	0	0	0	0	0	0	0	0	0	0	0	0
An. vagus	HD	0.2	0.5	1.1	0.6	0	0	0	0	0	0	0	0
	CS	1.1	1.1	0.7	0.4	0	0.1	0	0	0.1	0	0	0
An. varuna	HD	0	0	0	0	0	0	0	0	0	0	0	0
	CS	0	0	0	0	0	0	0.7	0	0	0	0	0
Total	HD	47.2	243.2	285.5	121.6	31.1	22.9	14.2	12.1	16.4	30.1	13.6	23.1
	CS	106.4	373.4	428.6	297.5	275.9	261.2	121.4	110.7	130.6	92.2	19.7	48.4

An. culicifacies a well-known rural malaria vector was found abudant throughout the year except May and June, i.e. during extreme summer when densities declined drastically. The highest density was recorded in September during monsoon/post-monsoon season with another small spring peak in March. These observations coincide very well with the earlier findings of Yadav *et al.*[1] in which infant *P. falciparum* cases were recorded mostly during September to December suggesting active malaria transmission during this period. Further detailed studies on biology of vector species with special reference to transmission dynamics of malaria in stone quarry area is suggested.

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REFERENCES

1. Yadav, R.N., S.N. Tiwari, P.K. Tyagi, A.K. Kulshrestha and Anil Prakash (1993). Malaria in Shankargarh PHC, Allahabad district (U.P.): A clinical report. *Indian J. Malariol.*, **30**: 9-16.
2. Srivastava, R. (1990). *Socio-economic Evaluation of Integrated Strategy of the Vector Control of Malaria*, pt I. Community Response (Summary results, Shankargarh and Haldwani). Project report submitted by G.B. Pant Social Science Institute, Allahabad.
3. Christophers, S.R. (1933). *The Fauna of British India, including Ceylon and Burma.* v.4 (Today and Tomorrow's Printers and Publishers, New Delhi).
4. Wattal, B.L. and N.L. Kalra (1961). Regionwise pictorial key to the female Indian *Anopheles*. *Bull. Natl. Soc. Ind. Mal. Mosq. Dis.*, **9**: 115-121.
5. Rao, T. Ramachandra (1984). *The Anophelines of India*, Rev. ed. (Malaria Research Centre, ICMR, Delhi).
6. Barraud, P.J. (1933). Additional records of the distribution of anopheline mosquitoes in India (From January 1, 1931 to April 1933). *Rec. Mal. Surv. India,* **3**: 507-525.
7. Puri, I.M. (1948). The distribution of anopheline mosquitoes in India, Pakistan, Ceylon and Burma, pt V: Additional Re-cords, 1936-47. *Indian J. Malariol.*, **2**: 67-107.
8. Yadav, R.S., R.C. Sharma, R.M. Bhatt and V.P. Sharma (1989). Studies on the anopheline fauna of Kheda district and species specific breeding habitats. *Indian J. Malariol.*, **26**: 65-74.
9. Bansal, S.K. and Karam V. Singh (1993). Prevalence and seasonal distribution of anopheline fauna in District Bikaner (Rajasthan). *Indian J. Malariol.*, **30**: 119-125.

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Geographical Distribution and Dramatic Increases in Incidences of Malaria: Consequences of the Resettlement Scheme in Gambela, SW Ethiopia

MENGISTU WOUBE

The spatial distribution of malaria results from the interaction between vector, parasite, host, physical and human environments. This basic geographical approach provides an illustration of the geographical distribution of malaria in the world, particularly in the tropical regions. Due to the global climate change and population movements, it is predicted that malaria could have a greater impact on the non-immune or unprepared populations in the Northern Hemisphere in the coming decades. Presently, Sub-Saharan Africa (SSA) is the most adversely affected region in the world. Like any other SSA country, Ethiopia suffers from both epidemic (unstable) and endemic (stable) malaria in the high and lowland regions, respectively. Gambela is one of the areas with stable malaria in the humid tropical region of the country.

This study is based on observations, unpublished data, interviews and discussions with settlers and officials in Gambela. It is found that a degree of diverse malaria prevalence is associated with altitudinal, temperature and rainfall variations. Owing to the settlement and land-use changes, unexpected rainfall patterns, temperature increase, unstable political system and poverty, malaria has gone beyond its geographical limits. As a result, the number of malaria affected people has increased in the last 12 years. It is suggested that proper physical and social planning, understanding the geography, entomology, epidemiology, behaviour and life-cycle of malaria parasite, cooperation between the policy-makers, malaria specialists, neighbouring countries and international communities are urgent, if malaria has to be controlled and eradicated.

Keywords: Ethiopia, Geographical distribution, Malaria, Resettlement scheme

Geographic Laboratory, Uppsala University, S-752 36 Uppsala, Sweden.

INTRODUCTION

Malaria is a disease caused by a protozoan called *Plasmodium*. There are four species *P. falciparum*, *P. vivax*, *P. malariae* and *P. ovale*, which are referred to as malaria parasites or water-borne pathogens[1-3]. It is transmitted from a person suffering from malaria to another healthy person by the female mosquito of the genus *Anopheles*. There are about 60 vector mosquitoes in the world. May[4] divided these vectors in 10 major regions according to their distribution. These include: North America, Central and South America, Europe, North, East, Central and South Africa, the continent of Asia, Central, South and East Asia. Members of the *Anopheles gambiae* complex are the major vector of malaria in tropical Africa and Brazil. There are entomological, epidemiological, biotic, psychosocial, genetic, natural and geographical factors for the spatial distribution of malaria and its impact on various human activities.

However, due to physical and human geographical factors, malaria cases decreased and increased through time and space in most parts of the world[1]. Malaria and Africa are said to be almost synonymous; and it is also said to have originated from tropical Africa during Paleolithic and Mesolithic times. Through the effects of agricultural civilization, this disease diffused into the Indus Valley, Mesopotamia, southern China and the Nile Valley and then reached the Mediterranean, tropical and the temperate world[5]. The spread of malaria seems to follow the diffusion of human settlement from Africa (the origin of man) to the other parts of the world.

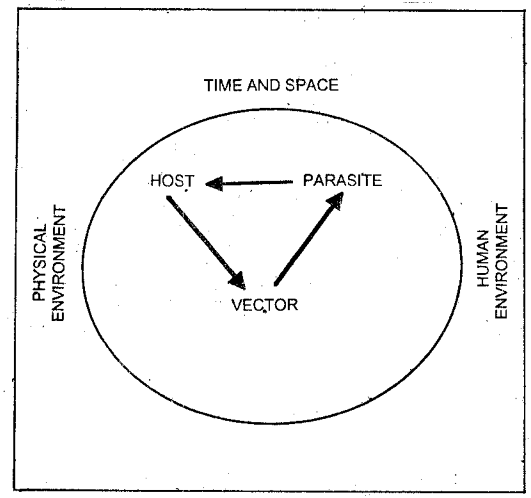

Fig. 1: The vicious cycle of malaria

It is often argued that malaria is a global, national, regional and local problem. It has no administrative boundary, but malaria existence and impact depends on environmental factors. Time and space play a very important role in the interaction between the three main malaria components (Fig. 1). It takes time and requires a conducive place for mosquitoes to lay eggs and pass the disease to another host. The parasite also requires time and space to complete the various stages of its life-cycle. The relationship between *Anopheles* (vector), *Plasmodium* (parasite), host (infected person), physical factors (altitude, land forms, temperature, surface water, vegetation and moisture) and human factors (settlement patterns, population movement, human behaviour, development planning and land-use change) are basic to understand the geography of malaria and control of the disease.

In absence of the host (humans), malaria transmission would not have developed. When a mosquito vector bites a person suffering from malaria for blood meal, the malaria parasite (*Plasmodium*) also enters mosquito's stomach with blood. These parasites then get lodged in the salivary gland of the mosquito and are transmitted to a healthy person with the next bite[6].

The geography of malaria

Most of the developed countries were also affected by malaria till it disappeared during the second half of the 19th century from western Europe and the beginning of the 1950s from eastern Europe[1,4] as a result of the eradication campaigns. The disappearance of the disease was mainly due to : (i) land-use changes through the draining of waterlogged areas and mosquito-breeding grounds; (ii) application of residual insecticides; (iii) combining anti-*Plasmodium* treatment with anti-mosquito campaign; and (iv) improvement of nutrition, housing, hygiene and clothing.

There were altogether 140 countries/areas where malaria was endemic in 1955[7], but the cases dropped from 280 million in the same year to 140 by 1963[8]. Although malaria was once thought to have been nearly controlled in most parts of the world in the 1950s, 270 million of the world's population (out of the 2000 million of those who were at risk) were already infected. 110 million clinical cases are reported annually, and about 1 to 2 million people die from malaria every year. Most of the increase in cases are from Africa (94 million clinical cases), southeast Asia (5 to 10 million), Central and South America (1 to 2 million) and Europe (about 5 million)[9]. In Sub-Saharan Africa (SSA) alone, where transmission is high, malaria kills a million people every year. Children below five and pregnant women have highest mortality. As Johnson[10] asserts, "never before in the field of human conflict with nature has a creature so small contributed to the misery of so many".

There are two malarious geographical zones: stable endemic in the lower altitude and epidemic outbreaks in the higher altitude. Africa is generally classified as the highest levels of endemicity in the world with holo-endemic regions. These malaria vulnerable zones were found up to 1000 m altitude with 2000 mm average rainfall/year, the minimum temperature required by *P. falciparum* is set from 19 to 20°C and savannah-forest vegetation. Below 1500 m altitude, 1000 mm rainfall/year and temperature below 19°C, stable endemic malaria decreases and the potential for epidemic outbreaks increases. The reason is that at lower temperature, parasite cycle requires longer duration for completion (the *P. falciparum* parasite may not complete its cycle). Although rainfall creates pools, streams, puddles etc. as the breeding sites but high rainfall washes them away. Unexpected seasonal rainfall and high temperature have brought epidemic malaria in high altitudinal zones of Africa, such as Kenya, Ethiopia, Zaire and Zambia[11]. Due to high temperature and rainfall, malaria increased by 501% in the previously malaria-free highland region in Rwanda in 1987[12]. This shows that climatic changes on the global level "is likely to modify malaria geography". The global increase of malaria transmission could lead to "high mortality and morbidity among the unprepared or non-immune population" in the northern Hemisphere[9].

In the low latitudinal areas in Africa (near the equator, approximately 10°N to 10°S), conditions are favourable for the mosquito breeding throughout the year. In the zones between 10 and 20°N and S with lower rainfall, malaria is more variable and unreliable both in amount and incidence. But between the equator and latitude 20°N and S, there is no clear natural break in transmission; and therefore, malaria can occur at any time of the year in endemic form. This complex system of environment varies from coastal swamps, lake shores, Islands, through various savannah habitat, permanent and temporary rivers, desert fringes and peri-urban centres. The land-use system also varies from pastoral-nomadic, slash- and burn-cultivation, fishing and modern farming. Such activities have brought deforestation, population mobility, settlement and resettlement schemes, poorly managed dams, utilisation of wells, piped water and year-round irrigation[13]. Large hydro-agricultural projects such as the Aswan Dam in Egypt, Lake Volta in Ghana and similar projects in the world are often blamed for upsurge in water-borne diseases. Although the highlands of Rwanda and Burundi ..... are said to be free from malaria, 21,000 people were affected (several hundreds died) in the latter country in 1991, due to the introduction of rice paddies in the highlands[10]. In Madagascar malaria broke out in the formerly eradicated area and killed 25,000 people within a few months in 1988[3].

As long as mobility exists (without proper protection), the highlanders can be exposed to malaria and transmit the disease to the previously malaria-free areas on their return to home bases. For example, seasonal labourers from Nigeria to the southern part of the country and to Ghana, pastoral-nomads to and from to Somalia, Sudan, Kenya and Ethiopia, population movement from the highlands of Rwanda and Burundi to the sisal-growing industry in Tanzania, the civil wars, trading movements and exchange of commodities between and within different environmental zones of Africa introduce fresh malaria infections. Migrant workers from Thailand to the Thai-Viet Nam border and to some villages in Burma and Viet Nam, and deforestation and resettlement in Brazil, increased malaria cases in 1990s. Areas which were free from malaria in 1960s in India, experienced malaria as the biggest health problem in the 1990s[3,10].

Wars and conflicts have also been contributed to the spread of malaria due to the movement of troops from the malaria-free regions to the tropics and subtropical regions. In 1991 alone some 10,000 cases were diagnosed in Europe and 1000 in the United States. In 1992, 9000 cases were reported from Europe. In Italy, Britain and Netherlands alone, 2300 cases and 20 deaths were reported in the same year. The 2600 UN peace-keeping forces (2500 who contracted malaria) together with 3,60,000 Viet Nam refugees living in Thailand were expected to return with malaria and spread it to their respective countries or elsewhere[10].

Even though some malaria control and eradication programmes have been introduced, they lack maintenance, due to physical constraints, poor irrigation and dam projects, political instability, widespread poverty and drug resistance. Drug resistance means that the parasite develops resistance to quinine, chloroquine, tetracycline, amodiaquine, sulfadoxine, pyrimethamine and to other anti-malaria drugs[11,14]. Other alternate preventive methods are tried, but it is not cost-effective for many countries in the tropics and sub-tropics. In order to introduce effective anti-malaria drugs and control strategy, understanding the behaviour and the geography of the malaria vectors and parasites is necessary.

The main objective of this study is to answer: (i) why endemic and epidemic malaria has increased in the last 20 years in Ethiopia?, (ii) why malaria spreads beyond its geographical limit?, (iii) how does malaria aggravate the mortality and morbidity rates among the non-immune and immue population?, and (iv) whether or not the malaria incidence has brought a negative impact on the various developmental activities and the nation's health as a whole?.

Spatial distribution of malaria in Ethiopia

The spatial distribution, biology, behaviour and cycle of the malaria vectors and parasites lack geographical investigation. As Wondatir *et al.*[15] indicate "lack of adequate understanding of the epidemiology of malaria transmission has remained to be one of the major impediments to malaria control in Ethiopia". We argue that for a proper understanding of the spatial distribution and diffusion of malaria with causes and impacts of the disease requires detailed interdisciplinary researches at local, regional and national levels. Ethiopia with its diverse terrain, climatic and physiographic conditions and population movement, makes it an interesting country to test the applicability of various models of malaria geography, theories and hypotheses.

Malaria (*Woba* or *nidad* in Ethiopia) is one the most ancient diseases known to its people. Although the disease has been recoginsed for thousands of years, scientific description and treatment were obscured by many magical and symbolic .procedures. In 1930s and 40s, Covell[16] and Melville *et al.*[17], who contributed to the knowledge of epidemiology of malaria, recorded 42 anopheline species. This was latter supplemented by the National Malaria Control Programme. Accordingly, of all mosquitoes in the country about 60% were *Anopheles gambiae* s.l., 40% were *An. funestus* and *An. nili*, and 1% were other species[18]. The spatial distribution of these species varies with altitude, surface water, temperature and land forms (Table 1). Most of Ethiopian geography is conducive to malaria transmission and the country's landscape varies with associated complex social forms or ethnic groupings, population distribution and settlement patterns[10,19].

Ethiopia has five altitudinal seasons and three geo-climatic zones (Table 1 and Fig. 2). They are *kolla* or hot zone (46%), *wayna dega* or temperate zone (46%) and *dega* or malaria-free zone (8%)[20]. The altitude in the *kolla* is <1500 m above sea level (a.s.l). Mean annual temperature ranges between 20 to 30°C with 100 to 1500 mm rainfall and malaria incidence varies from moderately to highly endemic. The altitude of the *wayna dega* zone is 1500 to 2500 m a.s.l. and with an annual rainfall ranging from 400 to 2400 mm. Mean temperature is about 20°C and the malaria incidence varies from low endemicity to epidemic. At altitude above 2000 m above sea level climatic conditions are not favourable for mosquito breeding and survival. Some transmission takes place in the altitudes between 1600 and 2000 m and 20°C average temperature, but the disease is unstable and is seasonal[21].

This means that the malaria prevented the lowland region for thousands of years from being exploited by the highland farmers and government agencies.

Table 1. Environment-malaria relationship

Climatic zone	Altitude (m a.s.l.)	Mean annual temp. (°C)	Precipitation (mm)	Relative humidity %	Vegetation pattern	% population	Incidence of malaria
Dega	>2000	15	1000-3000	20-30	Forest-savannah	37	Malaria-free
Wayna dega	1500-2500	20	400-2400	30-40	Forest-savannah	45	Epidemic
Kolla	<1500	20-30	100-1200	60-70	Forest-savannah	18	Endemic

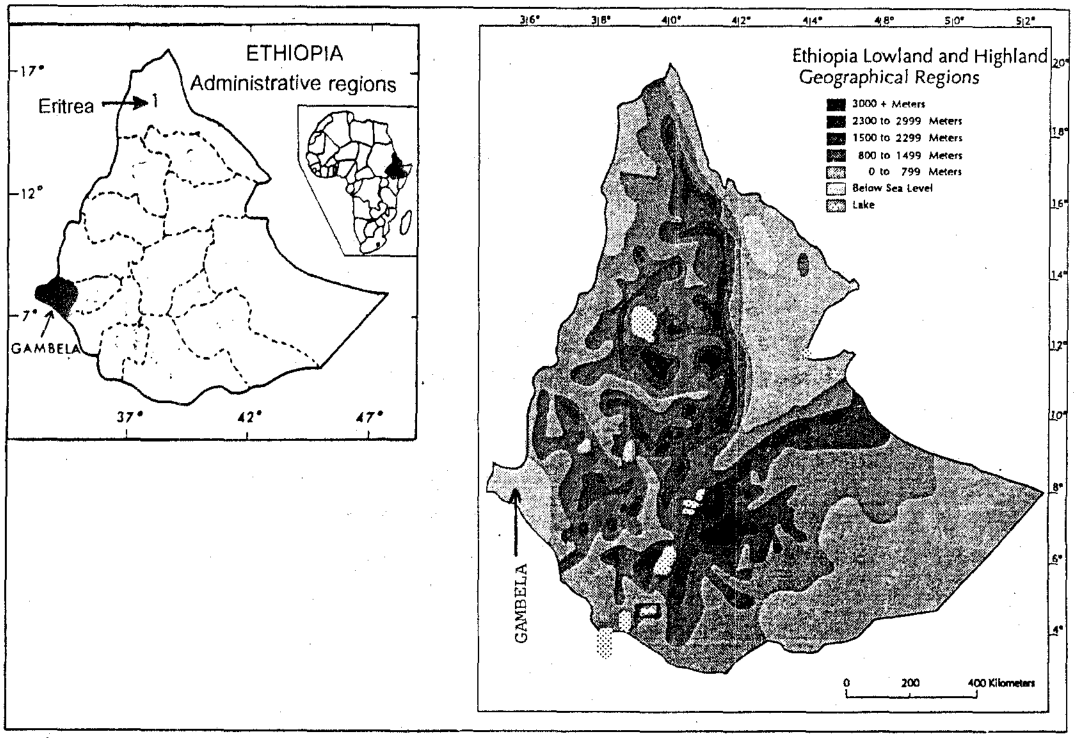

Fig. 2: Ethiopia: Lowland and highland geographical regions

Whereas, *wayna dega* has overpopulation, deforestation, severe soil erosion and famine[22-24]. As a result, without taking into account the issue of health in economic planning, large-scale farms and resettlement schemes were introduced since 1950s and especially since 80s in the previously avoided regions. If health aspects was given higher priority over others thousands of people from the *dega* and *wayna dega* regions wouldn't have moved involuntary to the malarious zones.

Epidemic or unstable malaria also occurs beyond its geographical limit (<1500 m a.s.l.) within the highlands of Ethiopia. In the 1800 m altitude in Dembia plain, north of lake Tana, Gondar region, for example, 7000 persons were killed by malaria in 1953. Although those who came from areas >2000 m altitude and visited Dembia plain became sick, when they returned to their native villages the disease was not transmitted to others, probably due to the absence of malaria vectors. Between March and October 1996, epidemic malaria killed more than 100 people and affected thousands particularly in Zengag Mariam, Layge Eyesus, Jejja Michael, Duge Abrham, Lemba Mariam, Jewana Michael, Jarjar

Michael and Wokerato Mariam. In the same year, epidemic malaria also occurred in Armacheho — western Gondar.

Moreover, the highest altitudinal limit of malaria transmission exceeded in the unusual malaria outbreak reported in 1958 (1800-2200 m altitude) at Debre Tabor (eastern Gondar), Bahar Dar (Gojam 1800 m above sea level), Zuquala plain and Lake Akaki (Shewa 1800-2000 m altitude), at altitude of 2150 m in the Awash River and the highway between Addis Ababa and Jima. Malaria also occurred at altitudes between 1400 and 2000 m, at the escarpment between Debre Sina (Shewa) and Adegrat (Tigray), at 1900 m altitude at Lake Haik (Wollo) and up to Mekele (Tigray) and other areas. Entomological investigation and blood examinations show, *An. gambiae* and *P. falciparum* to be the only vector and the dominant parasite, respectively, in all epidemic areas. The main reasons for the 1958 epidemic were the abnormal weather conditions. The average daytime temperature, rainfall and relative humidity were higher than in any previous years. Moreover, the disease was aggravated by shortage of food which resulted from crop failure, due to the 1957 drought. *P. falciparum* accounted for 71% of cases, *P. vivax* for 22%, *P. malariae* for 3% and multiple infections 4% in all the investigated areas[25].

Hospital records in 1957 showed that malaria killed more than 1,50,000 people out of the 3 million affected. This led to the establishment of Malaria Control Programme in 1959 as a joint effort between the Ethiopian Ministry of Health and the Point Four (US-Aid) by launching an intensive DDT spraying operation. In the 1960-70s, several thousand seasonal workers and pastoralists were affected in Awash and Didesa Valleys, Blue Nile, Baro-Akobo, Wabi-Shebele and Omo River basins, in the regions of Metema, Metekel, Arba Minch and southern part of Sidamo[18,21,25-27]. The above mentioned regions and areas are still covered with lots of vegetation (forest and woodland, scattered trees and tall grasses) big rivers and wild animals; human population is still low, and seems to be checked by endemic malaria and other tropical diseases.

During 1960s and 1970s, more than 80,000 agricultural labourers migrated during the peak harvesting season from the neighbouring highlands to savannah-forest vegetation zone (600-700 m altitude) in Metema and Setiti-Humera (Gondar)[28]. Even though the malaria problem was alleviated from 1960 to 70, it is still the most difficult epidemiological, pharmacological and immunological challenge as well as the major cause of mortality and morbidity in many parts of the country. Due to some irrigation schemes in the Awash Valley, seasonal movement of the pastoralists led to the spread of drug resistance in the areas bordering Somalia, Sudan and Kenya and natural environmental cycle of malaria got aggravated[26].

The natural vegetation of the lowland region has been disturbed because of free-grazing and unplanned settlement systems, the introduction of commercial farms and resettlement schemes mainly in the Awash Valley, Ogaden, Gambela and Metekel. More development projects were expanded in similar malarious regions, as indicated in the Ten Years Development Plan (1984-93). Without protective devices (e.g. bednets and window screens), projects such as water development and cotton plantations were also established in Arba-Minch and Kombolcha regions. As a result, physical and biological environments were changed; and workers who came from the malaria-free regions were badly affected[21].

In short, the massive population movement is one of the aggravating factors in malaria spread and was associated with 1950s commercial farms, 1970s state farms, establishment of the 1980s resettlement schemes and villagization. Since 1984 resettlement schemes, the number of malaria cases increased from 43, 545 between 1980 and 1984 to 235, 592 cases between 1985 and 1989[21]. Sivini[29] estimated that the resettlement schemes in whole Ethiopia led to more loss of human lives than those caused by 1972 and 1984-85 famine. Presently, the malaria cases are increasing and the breeding sites are also expanding in most parts of the country, particularly in Gambela and similar regions. On the other hand, DDT house-spraying campaign, which was used widely in the pre-1974 revolutionary period has not functioned properly throughout the 1970s, 80s and 90s. This coincided with: (a) political unrest in the country; (b) anti-western government policies; (c) lack of malaria-specialists and financial constraints; (d) forced and spontaneous population resettlements; and (e) land-use changes, especially following policy changes before and the post-1991 regional policies.

MATERIALS AND METHODS

This report is based on observations, interviews and discussions with 200 resettlers from Chebo, Perpengo, Ukuna Kigang, Uballa and Baro-Abol resettlement and settlement sites (40 persons from each resettlement site) and 40 members of indigenous populations (8 persons from each settlement site). Since this study is the part of on-going research on the issues of resettlement schemes and environment, information, observation and data was collected during field work (2 to 3 wks/yr) in 1986, 1989, 1991, 1994 and 1996. It is also based on unpublished data, collected from the various health stations and at the Gambela Hospital, through discussions on the causes and impact of malaria with 10 health officers and development workers (2 person from each site).

The geography of malaria in Gambela

Gambela is situated in the *kolla* zone (lowland region), covering 24,276 sq km and is located between 33° 00' and 35° 30'E and between 7° 00' and 8° 30'N of the Equator. It is located at the junction of the two geomorphological regions: the Ethiopian highlands and the south Sudanese plain. It can be divided into eastern [<7% of the total and surface of Gambela (1000 and 2000 m a.s.l.)], central (900 and 500 m a.s.l.) and western landscapes (500 and 300 m a.s.l.). The very flat and flooded topography of the extreme west is characterised as swampy area and the topography gradually slopes (Fig. 3). The present river network and drainage formation follows the eastwest faults system which is parallel although it is sometimes cut by faults. Gambela (hot humid-tropical zone) is characterised by high precipitation during the rainy seasons and by high evaporation losses during dry seasons.

Gambela covered by Guinea-Sudan forest, savannah grass types and sparsely settled by the indigenous population mainly Anuaks, Nuer and Majangir (<3 persons/sq km). The Anuaks do not

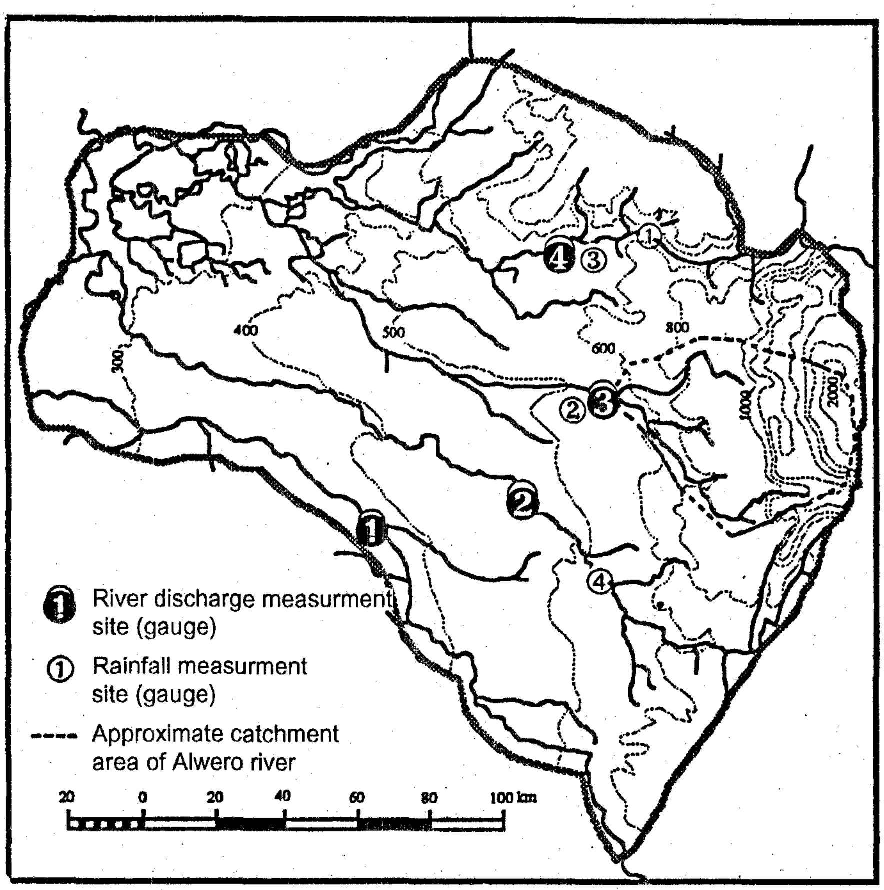

Fig. 3: Gambela Region: Altitudinal and hydrological features

raise cattle, but are engaged in slash-and-burn cultivation, simple hunting, fishing, collecting and gathering activities. The Nuer raise livestock and Majangir are engaged in farming and collecting wild honey. There were neither large farms nor clustered settlement patterns in the pre-1984 period. Following severe drought and famine that hit especially the northern part of Ethiopia, the previous government introduced a large-scale resettlement scheme in 1984 and moved more than 6,00,000 people and resettled them mainly in the malaria-prone and previously avoided lowland regions. Gambela received 25% of the total number of resettlers. Due to the civil war in southern Sudan, thousands of refugees were resettled in the south-western part of this region. As a result, 1996 population density reached about 8 persons/sq km. Although the majority of the resettlers went back to their original settlements, the 1994 population was higher by nearly 36% in comparison to the pre-1984 resettlement programme.

RESULTS AND DISCUSSION

The biogeographical nature of the region influences the vector species to be adapt to hot and humid climate with seasonal floods. Gambela is a year round or holo-endemic stable malaria transmission region[26,30]. The following inter-related physical and bioenvironmental factors account for the level of endemicity.

Altitude: The intensity and prevalence of malaria follow the altitudinal and geomorphological features. Topographic diversity of eastern landscape, such as hills and valleys is less conducive for larval development and has relatively low malaria endemicity. During heavy rains, most larvae are washed away. Since the topography would not allow the creation of stagnant water pools, the surface gets dry as soon as rainfall stops. This does not favour the development of mosquitoes which spread malaria. On the other hand, since most of the areas in the middle landscape are flat and wet for 5 to 6 months and dry for the rest of the year, rivers, streams, smaller ponds and swampy areas favour mosquito breeding resulting malaria throughout the year. The vast flat topography of the western landscape and extreme west is characterised as hot, marshy and swampy with lakes and flooded areas. This landscape is the most permanent malarious area in the region.

Hydro-physical characteristics in Gambela differ from other lowland regions, which are characterised as water collecting areas. Since Gambela is crossed by many rivers and streams, and as all rivers drain from the east to the west and some rivers in the lower altitudes are intersected by various small streams (Fig. 3), the vast area remains wet throughout the year. This is due to folding, faulting and uplifting processes, and all these create cut-off lakes and small streams, which are the arms of the main channel of big rivers. The geomorphology and flat topography of Gambela makes it favourable to the mosquito breeding through out the year. The Vertisols (heavy clay) have hard pan characteristics (fixed by iron-magnesium–Fe_2Mg properties) and maintain enough ponded water for sufficient periods of the year to permit mosquito larvae to complete their development. However, the prevalence of malaria varies from season-to-season.

Climate: The Gambela region is characterised as a hot humid tropical zone. Mean monthly, maximum and minimum temperature are 27, 30 and 25°C respectively. Mean annual evaporation is 1613 mm and most of the losses occur between December and April. Gambela is one of the highest precipitation areas in the lowland climatic zones of Ethiopia. This is mainly due to its geographical position, which is favourable for high temperature and precipitation. Due to dramatic latitudinal drop from the east and middle towards the west, the former receive more rain (mean annual precipitation is 1100 mm), have low temperature and lower evaporation; and the latter has a relatively low precipitation (mean annual precipitation is 800 to 900 mm), high temperature and high evapora-

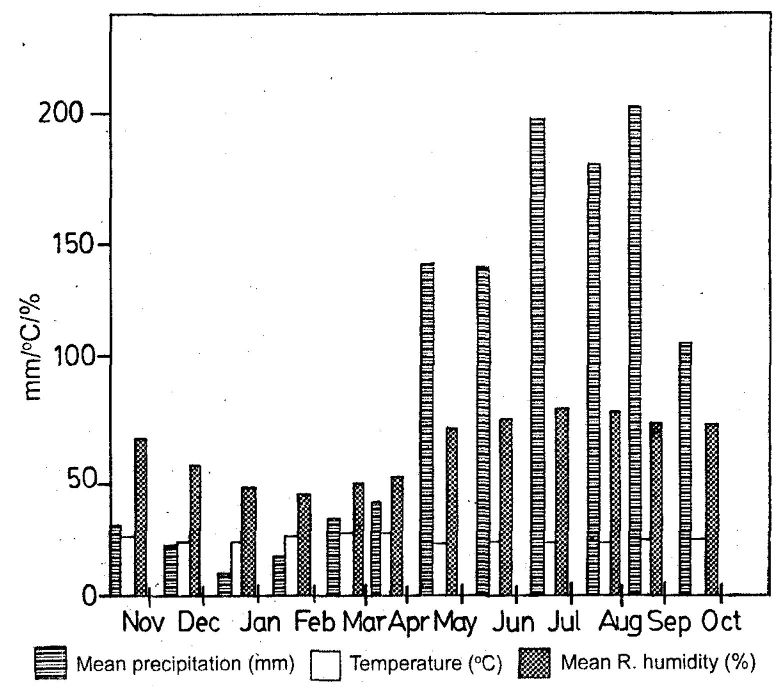

Fig. 4: Meteorological data on Gambela (November 1988 to October 1993)
Note: Dry and wet season last from November-April to May-October, respectively.

tion. As shown in Fig. 4, mean monthly precipitation varies from the wet season (142 mm in May to 203 mm in September) to dry season (8 mm in January to 36 mm in March). The relative humidity varies from 49-70% (March and May) to 72-78% (July-October). Although half of the year is dry, high temperature and the availability of surface water, such as streams, lakes, pools, marshes, ponds, swamps and irrigated surfaces allow the vector to transmit malaria throughout the year. Most larvae were found in shallow water bodies and at 27-28°C water temperature[31].

A high number of malaria cases is said to be associated with high rainfall but this is not always the case. The 1993 high rainfall, for example, did not produce much malaria, whereas the 1984-85 and 1988 low rainfall led to the most catastrophic malaria incidence. This means that the 1988 smooth rainfall was followed by the slow drought which created numerous breeding sites. The 1996 early and high rainfall have also produced as many malaria cases as the 1988 period. The malaria problem was aggravated by July-August 1996, flood from the Baro River that affected Itang and Jikaw, northwest of the region. As a result, thousands of people were left without shelter, food, clothing and were exposed to malaria at the time of the survey. When the temperature increased in September, the number of cases increased. This shows that the high malaria incidence is caused by mosquito, whose breeding depends on temperature and standing water rather than on high precipitation. Apart from the malaria conducive temperature in 1984-85, massive population that was non-immune resettled in the permanent malaria area during the peak malaria season. Krafsur[30] noted that there are two main peak seasons : (i) late in the dry season, breeding of *An. gambiae* occur in standing water of the rapidly drying swamps, isolated pools and pot-holes of small streams; and (ii) wet season breeding is confined to pools of standing water and the temporary flooded swamps adjacent to the river. The rising river levels, fluctuation of tributaries and rivers create mosquito breeding sites early in the wet season.

Vegetation: The increase and decrease of malaria is also associated with vegetation patterns. Plants are valuable source of natural chemical substances against insects and diseases. The diverse and dense savannah-forest vegetation in Gambela seems to be rich in natural anti-malaria plant species. According to indigenous population, trees like *Terminalia axiflora Engle* and *Diels* and *Azadirachta indica L.* have a chemical defensive system which is supposed to contain toxic substances which prevent flies and mosquitoes from entering the houses. They also believe that the milky juice of *Carica papaya L.* gives protection against malaria infection and other types of diseases[24]. Although the knowledge of the correct treatment for malaria is still lacking in Gambela, some indigenous anti-malaria herbs, such as *cinquefoil (Potentilla reptans)* in ancient Greek, *cinchona* bark in Italy in the 17th century, *quinine* (the bark of a tree), *qinghaosu* (in China and Viet Nam) and plant-based potions by Masai pastoralists in Kenya-Tanzania have been used in malaria treatment[6,10].

Due to absence of an improved land management system and the lack of understanding of the ethnomedical potential of these medicinal plants, the latter are declining in the study areas. The recent increase in malaria cases in the region seems to coincide with the post-resettlement and deforestation processes. Janssens and Wery[32] observed that the density of *An. gambiae* "in Guinea-Sudan increased with the degradation of the forest and is thus linked with human activities". As observed by the present author, the physiognomy and types of vegetation species in Gambela is classified as Guinea-Sudan vegetation and *An. gambiae* is the main vector in the region. It can be argued that the present land-use changes such as the destruction of the natural vegetation (which might act as anti-mosquito niches) and the introduction of new species seems to be one of the main causes for the epidemiological changes.

Soils: The deforestation process mainly occurs in the clay soil areas. Clay rich soils such as Nitosols, Pellic, Chromic and Gleyic Vertisols in Central Gambela are now under cultivation and are used for the resettlement scheme. Clay soils in Gambela are associated with water logging and seem favourable for the reproduction of various vectors of infectious diseases. According to the EVDSA[33], the Gambela soil types play an important role in being host to the various diseases that go through obligatory phases in the soil. Since the soil is always warm, the maturation period of the mosquito is about 20 days. The physical (hard pan) and chemical (iron-magnesium — Fe_2Mg) characteristics of the clay soils are capable of maintaining enough ponded water for sufficient periods of time to permit mosquito larvae to complete their development. The geomorphic aspects of Gambela, especially the soil characteristics, make the perpetuation of *An. gambiae* possible.

In short, the poor structure of soil is highly influenced by high residual clay which is aggravated by excessive and long periods of rainfall that produces long standing water bodies. As shown in Fig. 5, the Gleyic Vertisols — heavy to light clay or tropical black soils form a heaven for plant and animal species. Plants specially elephant grass (*Penisetum purpureum*) are evergreen, due to the availability of fresh water and sediment; and this ecosystem is powerful determinant of malaria. In our 1996 field work, the whole area was converted into a dam (Fig. 6). As a result, larvae producing sites are now expanding and the nearby settlers are exposed to more risk of malaria and other water-borne diseases. In our observation since then, the new dam seems to support the endemicity of more water-borne diseases in the region than it was in the pre-dam construction period.

Fig 5: The swampy area close to the Alwero River before construction of dam

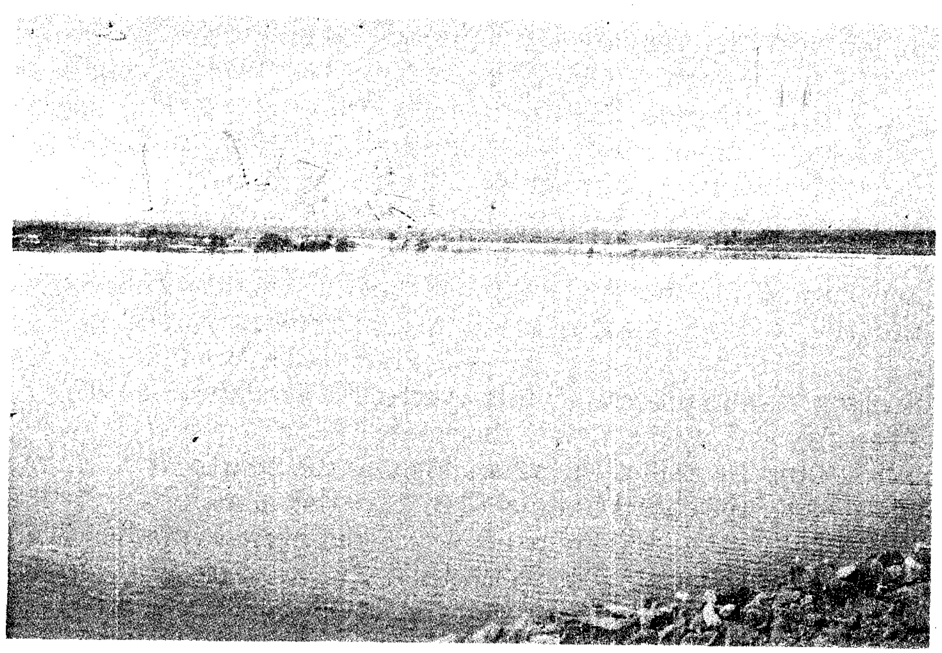

Fig. 6: The complete dam (completed in 1996)

Types of mosquito species: Even though six vector species are found in Gambela, *An. gambiae sol* (the most prevalent species), *An. funestus* and *An. nili* are the main malaria vectors in the region. As indicated in Table 2, 32% of the people examined were positive out of 7,66,998 blood examinations. *P. falciparum* predominated among all the investigated cases during 1986 to 1993. The low prevalence season occurs after the short rainy season (November-April) and the high prevalence during the high rainfall season (June-August) and again in September-November. During dry season, breeding occurred in standing residual waters of drying swampy areas, isolated pools, pot-holes along small streams, dams, irrigation sites and wells. *An. funestus* was active in the dry season,whereas *An. nili* was discovered in small stream early during dry and late in the wet season. It was also found that *An. funestus* bites more persons/day during the wet and dry seasons than the other malaria associated species[30,34]. Similarly, high intensity of *P. falciparum* occurs during the rainy season, whereas *P. vivax* and *P. malariae* affect people during the dry season[33]. Unlike Krafsur, Sehlu *et al.*[31] argued that *An. pharoensis* was as important as *An. gambiae* s.l., *An. funestus* was not common and the role of *An. nili* in transmission was negligible and became scanty. *P. falci-parum* predominated in all the investigated area during 1986 to 1993. In short, Gambela is characterised as a holo/hyper-endemic area of the world with stable malaria[15].

Population, land-use and settlement patterns: According to the indigenous population, malaria cases, before 1970s and 1980s, were not as alarming as in the post-resettlement pro-gramme because of: (i) absence of man-made malaria breeding sites (such as dams, deforestation, etc.); (ii) the population was isolated from other malaria-prone

Table 2. Prevalence of four *Plasmodium* species in Gambela (1986-93)

Year	No. Exam.	(+) ve	*Pf*	*Pv*	*Pm*	Mix
1986	22669	7543	–	–	–	–
1987	107835	51479	–	–	–	–
1988	1577134	71090	44352	27873	3	–
1989	202185	65489	58418	7589	82	–
1990	127296	30479	24099	6303	77	–
1991	12515	5148	4446	633	63	6
1992	20551	8286	6531	1670	76	9
1993	16813	7014	5291	1544	176	3

Source: Health Stations, Gambela; (–) denotes no data available.

people; (iii) traditional anti-malaria or malaria protection measures were widely practised; (iv) the population movement was confined within their own climatic region; (v) the non-immune highlanders, who migrated to Gambela, were very few and confined to the administrative centre; and (vi) they have had anti-malaria immunity system or haemoglobin. Armstrong (cited by Gebre-Mariam *et al.*[18]) observed that the indigenous population in Gambela have more resistance to the disease than the highlanders.

Between 1984 and 1994, 14,0000 ha of natural forest land was cleared for the establishment of resettlement schemes, state, resettlement and private mechanised farms. The forest was destroyed for firewood, construction purposes and growing food crops (e.g. maize — *Zea mays L.* and sorghum — *Sorghum sudanens*) to cash crops (e.g. cotton — *Grossypium* spp). They exerted pressure on soils as well. As a result, the above mentioned land-use activities have brought the loss of soil fertility and changed the map of the Gambela landscape and malaria geography. As Nega[35] pointed out as a consequence of the resettlement programme, the formerly endemic or "stable malaria situation was replaced by explosive epidemics". Following the introduction of agro-industrial development, settlement and resettlement schemes, expansion of urban and rural settlements and population explosion created change in the dynamics of transmission from seasonal to perennial.

Population movements have always aggravated malaria transmission. The malaria breeding sites are widely spread, new food systems are introduced and wide-spread migration and integration occur. About 98% of the respondents (indigenous people) did not consider the pre-resettlement malaria situation as a major problem in comparison to the resettlement periods. The indigenous people have a long-standing knowledge regarding malaria and therefore reduce their activities in the malaria-breeding sites during the peak season and use anti-mosquito herbs to avoid bites. They did not disturb the ecology by building roads, irrigation dams and clustered settlements, nor did they bring in sewage problems. Without considering local knowledge or introducing effective malaria control measures, the previous government resettled unprepared and non-immune highlanders in malaria-prone areas.

As a result, high malaria-related mortality and morbidity rates were reported during the first phase (1984-87) and the beginning of the second phase (1988-1990) of the resettlement schemes in Gambela. According to the respondents (the resettlers, health officers and development workers), the number of deaths were not registered, but it was estimated that 25% of them died in the first phase of the resettlement period. Resettlers did not get a chance to bury their own families and no religious services were performed. Rather, the local officials ordered the resettlers to bury hundreds of dead.

Apart from the resettlers, resettlement campaigners, military personnel and other staff were also affected by malaria.

At the time of the survey, 88% of the total respondents believed that they were suffering from malaria and 12% of other water-related diseases. Even though it is difficult to classify the type of diseases, the respondents complained of malaria symptoms, such as severe headaches, chills, sweating, pain in the back and extremities. From experience, about 91% of the respondents stated that they could tell when a person had malaria. They lost their mental and physical energy at the beginning of the rainy season when they require all their strength for preparing and planting crops. Very few people were found not sick during the course of the field work in 1986, and some of them who were interviewed earlier in 1986 have already died by 1989.

The main reasons for highest malaria cases detected during 1988-89 was: (i) population increased; (ii) the medical personnels in the various Health Station did not have incentive to provide proper medical care; (iii) the government was no longer allocating adequate financial assistance due to the war in north; (iv) shortage of foreign exchange to import anti-malaria drugs; and (v) there were very limited aid as the country was isolated by the western donors.

The establishment of large-scale mechanised farms and new settlement patterns led to deforestation, introduction of new plants (e.g. *Azadirachta indica L.*) and insecticides, which can change the behaviour of malaria associated mosquito species, aggravate the natural flooding system and other determinants of the micro-climate, e.g. soil moisture. When the food crops were no longer profitable, the land was converted to cash crop production like cotton (*Grossypium* spp). Although some resettlement farms were still used for maize or *Zea mays* (the major stable food crop in the region), its production has been declining by one-third in 1989 compared to the same period in 1988 and all these have brought deleterious effects on nutrition in the last eight years. In addition, maize production is neither sufficient nor has been the stable food for the highlanders who came from an area with a variety of food growing agricultural zones. The insufficient food created more malaria patients who were already weakened by high temperature, social injustice and general poverty. Due to employment opportunity, the mechanised farms in Gambela have attracted thousands of seasonal labourers from the highland region, but hundreds died of malaria, due to lack of proper housing and medical-care.

During 1990 and 1991, the number of reported malaria cases declined when some of the resettlers defected from the resettlement sites and others did not want to go to the Health Stations, because of the lack of trained personnels and medicine. Following government and political changes (since 1991) in the country, most of the resettlers abandoned the resettlement sites and quite a few Health Stations have not been functioning. Since the introduction of the 1992 federal type of regional state (*Kilil*), most of the budget is allocated to administrative activities and infrastructure development. The regional state has neither adequate capital nor encourages indigenous malaria knowledge. Those who were assigned to work in the Health Stations in Gambela, left the region in 1994. If adequate qualified medical personnels and facilities were available, the number of persons who were affected by malaria would have shown much higher figures than shown in Table 2.

The main reasons for increased malaria incidence and the impact of the disease can be summarized as resettlers arrived during the peak malaria season (June-September), the season with the highest relative humidity, a high amount of rainfall and flooding which creates many mosquito breeding sites. Since many people are settled on the flood-prone areas, and since trees are cleared and the land is flat, abnormal floods come to the farm land and resettlement sites. Stagnant water is a major problem during certain periods of the year. In addition, due to bad road conditions and increasing number of vehicles lot of puddles form all this favour intense vector breeding. Improvement of health care infrastructure, DDT spraying campaigns, drainage of mosquito breeding sites, biological control, such as the introduction of larvivorous fish and use of medicinal plants could all help to control the outbreaks of malaria.

The resettlers were physically weak and separated from their families (during the relocation process) and were relocated more than 800 km away from their original settlements. Lack of clean, sufficient and adequate drinking water, nutritious food, proper housing, clothing (rugged and dirty) and hygiene were widespread features in all resettlement sites.

Without entomological, long-term epidemiological and medico-geographical studies, DDT was used during the beginning of the resettlement schemes. Without nutritional improvement, resettlers, have been given malaria drugs, no serious investigation was conducted as to whether or not the types of drugs were effective, no medical facilities and qualified personnels were allocated. According to the information from the various Health Stations, *P. falciparum* is becoming progressively resistant to chloroquine a major drug for malaria treatment. Drug-resistant malaria was reported in different parts of the world[3,4], particularly in the border between Ethiopia, Sudan, Kenya and Uganda[14,15,36].

Due to limited area in resettlement sites disease spreads fast from one to another. High level of mobility occurs not only among farmers in the indigenous settlement and resettlement sites, but

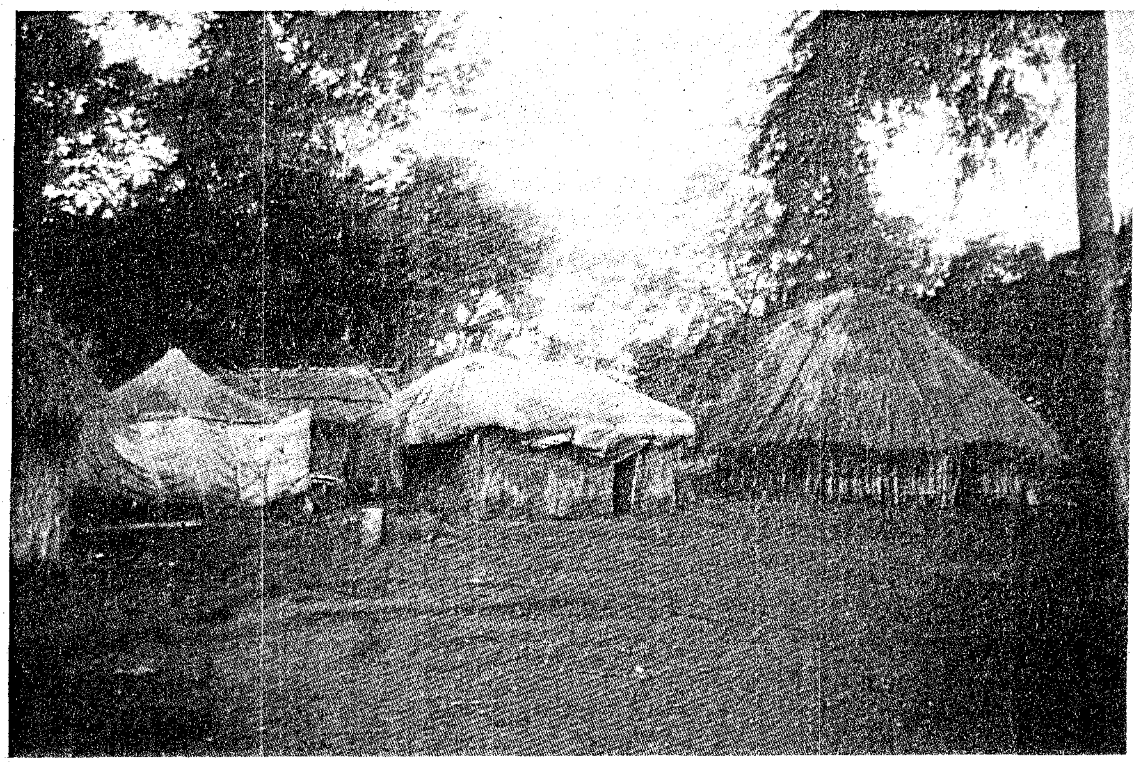

Fig. 7: Thatched roof Health Station at Perpengo resettlement sites

government employees, small business people and soldiers also move. The population in the towns has increased from < 7000 in 1983 to < 27,400 in 1994. Lack of garbage disposal and sewage treatment have created lots of mosquito breeding sites.

Resettlement Health Stations

There was one Hospital (at Gambela town), one Health Centre (at Itang) and ten Malaria Control Stations at various resettlement sites in Gambela in 1990. Except three Malaria Health Stations, the rest were not functional since 1991. These clinics lack infrastructure to perform simple microscopic tests on blood smears for malaria and thus their activities were limited to diagnosing fever clinically without microscopic examination and providing inadequate drugs to the suspected cases. There are no activities like monitoring of mosquito breeding sites, house spraying with insecticides, house-to-house survey, etc. Thatched roof clinics (Fig. 7) lack sanitation and light; and most of them could not protect medical equipment and medicines from rain, insects, rodents, etc. Although the thatched roofs were replaced by tin roofs in 1989, medical equipment, health service utilisation and accessibility were extremely poor at the time of the survey in 1996.

Mostly, these clinics were not open and the staff spend their time in the towns because of lack of medicines and incentives. Severe patients were often carried by relatives and friends and waited long hours in front of the clinics. Since most of them did not get assistance from the Health Stations, patients prefer to stay back home and die in peace. Many lives could be saved if the patients had accessibility to the Regional Hospital. The reasons for people not reaching Regional Hospital are: (i) in the pre-1991 period, resettlers were not allowed to move outside their resettlement sites; (ii) distance between the Regional Hospital and various resettlement sites varies from 10 to 100 km; (iii) friends and relatives had no physical strength to carry the patient to such a long distances; (iv) they had no money either to pay the medical or transport costs. In short, the Health Stations have failed in making people aware of the need to protect themselves and to come to the centre for early diagnosis and treatment and in providing medical facilities by trained personnels.

CONCLUSIONS

The geographical characteristics, such as altitude, topography, surface water, climate (the most important factor), population movement, land-use change, social and physical infrastructure are responsible for the rapid breeding of mosquitoes and the spread of other types of infectious diseases in Gambela. It can be concluded that there is no magic bullet for malaria control, it requires better understanding of the ecology, meteorology, demography, entomology, epidemiology and parasitology of the area. The resettlement programme ignored effective malaria control or eradication measures to avoid loss of human life. If the planners and policy-makers in Ethiopia understood the basic factors of malaria, consulted medical geographers, malariologists and entomologists before resettling people from the malaria-free highlands to malaria-prone areas the situation would have been entirely different. Through understanding local variations of environmental conditions such as climate, vegetation types, drainage, settlement locations and other environmental factors in relation to ill-health, vital information could be provided to the planners and decision-makers. These experts could have determined and assessed the disease potential at an early stage of resettlement.

Since the malaria parasite cycle has several stages, malaria vaccine remains a long-term hope. However, there is a need for substantial basic and clinical research before a true vaccine could be ready for use[37]. Till the dream of an effective vaccine is fulfilled, the following malaria control and eradication measures are vital.

Firstly, the geography of the disease should be understood before any development project is initiated. In order to understand the local variations of environmental conditions in relation to the spatial distribution of vectors, parasite, breeding sites and the number of infected persons, medical geographers and malaria specialists should provide vital information to the planners and policy-makers.

Secondly, the mud and thatched roof houses (which are not effective for the annual residual spraying method), nutrition, sanitation, water-supply and transport facilities must be improved. Mass education (traditional and scientific knowledge) on malaria, protection methods, chemotherapy are also vital. House-spraying, early diagnosis and prompt treatment of cases, selected control of transmission, regular reassessment of strategies are required.

Thirdly, biological and chemical methods such as introduction of larvivorous fish (e.g. *Gambusia*), sterilisation of male malaria vectors, effective treatment of malaria cases, chemical larviciding, environmental control through draining of water-logged areas and other breeding sites are necessary to control malaria. As reviewed by Jaenson[38], pyrethroids treated bednets (deltamethrin and lambdacyhalothrin) are considered as one of the most important strategies to control malaria transmission in the tropical environment. If nets are impregnated with permethrin every six months, millions could be protected from devastating malaria. However, these substances neither have detrimental effect on human beings nor have a propensity to accumulate in the animal food-chain.

Finally, it can be argued that development projects can do more harm than good (such as harming the physical environment, human and animal health, crops) and may involve high cost unless they are carefully planned and implemented. Through community participation, intersectoral, regional and international cooperation effective malaria control could be achieved.

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REFERENCES

1. Learmonth, A.T.A. (1977). Malaria. In *A World Geography of Human Diseases*. Ed. G.M. Howe (Academic press, London).
2. Lysenko, A.J.A. and A.E. Beljaev (1969). An analysis of the geographical distribution of *Plasmodium ovale*. *Bull. WHO*, **40**: 383-394.
3. Prothero, R.M. (1965). *Migrants and Malaria* (Longmans, Great Britain).
4. May, J.M. (1961). The Ecology of Malaria. In *Studies in Disease Ecology*. Ed. J.M. May (M/s. Hafner, New York).
5. Bruce-Chwatt, L.J. (1965). Paleogensis and paleoepidemiology of primate malaria. *Bull. WHO*, **32**(3): 363-387.
6. Colbourne, M. (1966). *Malaria in Africa* (Oxford University Press, London).
7. WHO (1994). *World Malaria Situation* (World Health Organisation, Geneva).

8. Spencers, J.E. and W.L. Thomas (1969). *Culutral Geography as an Evolutionary Int. to our Humanized Earth* (West Publishing Co., New York).

9. Martin, P.H. and M.G. Lefebvre (1995). Malaria and climate sensitivty of malaria potential transmission to climate. *AMBIO*, **XXIV**: 202-209.

10. Johnson, M. (1993). Malaria: It's back. *Time*, **141**(22): 46-52.

11. WHO (1992). World malaria situation in 1990. *Wkly Epidemiol. Rec.*, **67**: 161-168.

12. Loevinsohn, M.E. (1994). Climatic warming and increased malaria incidence in Rwanda. *Lancet*, **143**: 307-310.

13. Gwadz, R.W. (1991). *Malaria and Development in Africa* (American Association for the Advancement of Science, Washington D.C.): 99-103.

14. Anon. (1991). *Malaria and Development in Africa* (American Association for the Advancement of Science , Washington D.C.): 5-40.

15. Wondatir, Negatu, Petros Beyene, Lulu Mesfin, Adugna Nessibu, W. Robert and Dejene Tilahun (1994). Some aspects of malaria prevalence vector infectivity and DDT resistance studies in Gambela region, SW Ethiopia. *Ethiopian J. Hlth. Dev.*, **8**(1): 1-10.

16. Covell, G. (1957): Malaria in Ethiopia. *J. Trop. Med. Hyg.*, **60**: 7-16.

17. Melville, A.R., D.B. Wilson, J.P. Glasgow and K.S. Hocking (1945). Malaria in Abyssinia. *East African Med. J.*, **22**: 285-294.

18. Gebre-Mariam, Negussie, Abdulahi Yahaya and Mebrate Assefa (1988). Malaria. In *The Ecology of Health and Diseases in Ethiopia*. Eds. Z. Ahmed Zein and Helmut Kloos (M/s. Westview Press, Boulder, San Franscisco, Oxford):136-150.

19. Merid, Mekonnen (1958). *Malaria Epidemic, Belessa, Begemidir Province* (Unpublished).

20. WHO (1991). World malaria situation. 1889. *Wkly Epidemiol. Rec.*, **66**: 158-163.

21. Nega, Assefa (1991). Population Migration and Malaria Transmission in Ethiopia. In *Malaria and Development in Africa* (American Association for the Advancement of Science, Washington D.C.): 181-189.

22. Woube, Mengistu (1986). Problems of Land Reform Implementation in Rural Ethiopia: A case study of Dejenm and Wolmera districts (*Geografiska Regionstudier, 16*, Department of Human Geography, University of Uppsala, Motala Grafiska AB).

23. Woube, Mengistu (1987). The Geography of Hunger: Some aspects of the causes and impacts of hunger (*Research Report 95*, Department of Social and Economic Geography, University of Uppsala).

24. Woube, Mengistu (1995). Ethnobotany and the Economic role of the selected plant species in Gambela Ethiopia. *J. Ethiopian Stud.*, **18**: 1-26.

25. Fontaine, R.E., A.E. Najjar and J.J. Prince (1961): The 1958 malaria epidemic in Ethiopia. *American J. Trop. Med. Hyg.*, **10**: 795-803.

26. Kloos, H. (1990). Health aspects of resettlement in Ethiopia. *Soc. Sci. Med.*, **30**(6): 643-656.

27. Nega, Assefa (1989). Malaria in Ethiopia, its changing epidemiology and the potential role of alternative diagnosis and control methods — Master's Thesis (London School of Hygiene and Tropical Medicine, London, UK).

28. Mengesha, Berhanu and Abuhoy Mohamed (1978). *Kala-azar* among labour migrants in Metema-Humera region of Ethiopia. *Trop. Geog. Med.*, **30**: 199-206.

29. Siviní, G. (1986). *Faminine and the Resettlement Programme in Ethiopia* (Unpublished paper — University of Calabria).

30. Krafsur, E.S. (1971). Malaria transmission in Gambela, Illubabor Province. *Ethiopian Med. J.*, **2**: 75-94.

31. Sehlu, Fisehaye, Amenshewa Birknesh and Tarekegn Abose (1989). Seasonal prevalence and behavioural patterns of malaria vectors in Baro Abol, Gambela, SW Ethiopia. In *Proceedings of the 9th Annual Meeting of the Committee of Ehiopian Entomologists*: 97-118.

32. Janssens, P. and M. Wery (1987). Malaria in Africa South of the Sahara. *Ann. Trop. Med. Parasitol.*, **81**(5): 487-498.

33. EVDSA (1988). *Master Plan of the Integrated Utilisation of the Water and Land Resources of the Gambela Plain*, v. 1 and 2-6 (Ethiopian Valley Development Studies Authority, Gambela).

34. Krafsur, E.S. (1970). *Anopheles nili* as vector of malaria in a low-land region of Ethiopia. *Bull. WHO*, **42**: 466-471.

35. Nega, Assefa (1993). Malaria. In *The Ecology of Health and Diseases in Ethiopia.* Eds. Z. Ahmed Zein and K. Helmut (M/s. Westview Press, Boulder, San Francisco, Oxford): 342-352.

36. El-Gadal, A.A. (1991). The experience of the Blune Nile health project in the control of malaria and other water-associated diseases. In *Malaria and Development in Africa* (American Association for the Advancement of Science, Washington D.C.): 51-58.

37. Bjorkman, A. (1994). *Malaria Vaccine Research — Still a Long Way to Go.* Ed. Y. Hofvander. *Nytton U-Landshalsovard.* **2**: 17-19.

38. Jaenson, Thomas G.T. (1994). The role of insecticide treated bednets in malaria control. Ed. Y. Hofvander. *Nytton U-Landshalsovard*, **2**: 23-26.

SHORT NOTES

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An Epidemiological and Entomological Investigation on Malaria Outbreak at Tamulpur PHC, Assam

N.G. DAS, I. BARUAH, S. KAMAL, P.K. SARKAR, S.C. DAS and K. SANTHANAM

Keywords: Assam, Entomological and epidemiological study, Malaria outbreak

Northeast India is well-known for endemicity of malaria. In spite of control measures adopted by National Malaria Eradication Programme (NMEP), the incidence of malaria is increasing day-by-day. This may be due to chloroquine resistant strains of *Plasmodium falciparum*, difficult terrains, favourable climatic conditions for mosquito breeding, high man-vector contact and low socio-economic status. Chloroquine resistance of *P. falciparum* have been reported earlier from Assam, Arunachal Pradesh, Meghalaya and Nagaland by several workers[1-4]. Moreover, recent studies carried out by Jana-Kara *et al.*[5] and Prakash *et al.*[6] found *P. falciparum* as the most dominant species of malarial parasites in Assam. In India, about two million cases of malaria are being reported every year by the NMEP. *P. falciparum* contributes about 35 per

Defence Research Laboratory, Post Bag No. 2, Tezpur-784 001, India.

cent of total malaria in the country. It is worth mentioning that northeastern region contributes about one-eighth of the entire *Plasmodium falciparum* load of the country.

Anopheles dirus and *An. minimus* are the efficient malaria vectors of northeastern region. *An. minimus*, which seems to have either disappeared or scarce in this region due to constant insecticidal spray, rapid urbanization, deforestation etc., has been reported from several states of northeastern region and re-established its role in malaria transmission[5-11].

During April-June, 1995, there was a malaria outbreak in Goalpara, Nalbari and Sonitpur districts of Assam which resulted in heavy casualities. This laboratory undertook an investigation covering epidemiological and entomological aspects of malaria in four worst affected villages under Tamulpur PHC in Nalbari district of Assam.

Tamulpur PHC under Nalbari district lies on northwest part of Assam, sharing an international border with Bhutan. Tamulpur PHC comprises many villages dominated by local Bodos, Assamese and some migrated population from Nepal. It is a low-lying area and the paddy cultivation is the main occupation of the villagers. Houses are made up of thatched roofs and walls of split bamboos with mud-plaster. The area is intersected with *katcha nallahs*, streams with aquatic vegetations, ditches, ponds and paddy fields which provide ideal breeding habitats for mosquitoes. The worst malaria affected villages namely, Baitamari, Sontola, Sorubelbari and Kalbari under Tamulpur PHC were selected for the present study.

Blood slides were collected from the fever cases of all the four villages. They were stained and examined under microscope in the field laboratory for rapid detection of malarial parasites and early treatment. Epidemiological parameters, such as SPR, SfR, *Pf*%, age and sexwise distribution of malaria infection were calculated and analysed.

Adult mosquitoes were collected from the human dwellings and cattlesheds from 1800 to 0600 hrs with the help of 6 volt battery operated CDC miniature light traps (Communicable Disease Centre, USA). Simultaneously, two hourly collection of mosquitoes were done from dusk-to-dawn to determine the peak biting hour of the vector species. Resting collection of mosquitoes was also made in human huts from 0500 to 0700 hrs with the help of aspirator tubes. The collected mosquitoes were identified in the field camp using standard keys. Man-hour and per trap night (PTN) density were calculated for important malaria vectors. Alive female *Anopheles* species were dissected to determine their parity status by counting the number of dilatations in the overioles and to detect sporozoite infection in the salivary glands.

In epidemiological study, a total of 250 blood slides were collected from the fever cases out of the total study popula-

Table 1: Malaria incidence in villages under Tamulpur PHC

Villages	BSC/E*	Malaria cases among age groups (yrs)						(+)ve	*Pf*	SPR	SfR	*Pf* %
		<10	11-20	21-30	31-40	41-50	>51					
Baitamari	100	25	9	16	2	6	1	59	55	59.0	55.0	93.2
Sontola	75	21	14	8	6	1	–	50	50	66.7	66.7	100.0
Sorubelbari	44	23	3	5	2	1	–	34	30	77.3	68.2	88.2
Kalbari	31	6	4	3	1	–	1	15	13	48.4	41.9	86.7
Total	250	75	30	32	11	8	2	158	148	63.2	59.2	93.7

*Blood slides collected and examined; Population = 2834.

Table 2. Mosquito species encountered during epidemic at Tamulpur PHC

Species	No. collected		Total
	Human dwelling	Cattleshed	
Anopheles annularis	20 (6.68)	175 (10.94)	195 (10.26)
An. barbirostris	5 (1.67)	61 (8.81)	66 (3.47)
An. crawfordi	10 (3.33)	87 (5.44)	97 (5.11)
An. culicifacies	3 (1.00)	106 (6.63)	109 (5.74)
An. kochi	13 (4.33)	35 (2.19)	48 (2.53)
An. minimus	8 (2.67)	97 (6.06)	105 (5.53)
An. philippinensis	1 (0.33)	6 (0.38)	7 (0.37)
An. subpictus	7 (2.33)	46 (2.88)	53 (2.79)
An. vagus	60 (20.00)	281 (17.57)	341 (17.95)
Cx. bitaeniorhynchus	6 (2.00)	101 (6.31)	107 (5.63)
Cx. gelidus	3 (1.00)	15 (0.94)	18 (0.95)
Cx. malayi	51 (17.00)	884 (55.25)	935 (49.21)
Cx. quinquefasciatus	81 (27.00)	1(0.06)	82 (4.32)
Cx. vishnui group	216 (72.00)	3675 (229.69)	3891 (204.79)
Aedes (B) lineatopennis	13 (4.33)	100 (6.25)	113 (5.95)
Ae. (m) scatophagoides	–	2 (0.13)	2 (0.11)
Armigeres subalbatus	4 (1.33)	25 (1.56)	29 (1.53)
Mansonia indiana	–	4 (0.25)	4 (0.21)
Ma. uniformis	–	6 (0.38)	6 (0.32
Total	501 (167.00)	5707 (356.69)	6208 (326.74)

Figures in parentheses indicate per trap night collection.

tion of about 2834. Of these, 158 blood slides were found positive for malaria indicating 63.2 per cent positivity rate. *Plasmodium falciparum* was the most dominant species which formed 93.7 per cent and *P. vivax* contributed 6.3 per cent of the total cases (Table 1). Similarly, high incidence of *P. falciparum* was reported earlier from different geographical areas of Assam by several investigators[5-7]. Analysis of data revealed a little difference in the incidence of malaria among male and female population indicating slide positivity rate of 59.8 and 66.4% respectively which is in confirmity with the earlier findings of Dutta and Bhattacharyya[12]. Among the four villages, the highest slide positivity rate (SPR) was recorded in Sorubelbari (77.3) followed by Sontola (66.7), Baitamari (59.0) and Kalbari (48.4). Cent per cent *P. falciparum* cases were recorded in Sontola, while 93.2, 88.2 and 86.7% in Baitamari, Sorubelbari and Kalbari respectively.

Maximum number of positive cases of malaria was recorded in the age group of 1-10 yrs and minimum in the age group of 51 yrs and above (Table 1). Dutta and Rajvir[13] also reported high incidence of malaria among children up to the age of 14 yrs in north Indian districts.

Altogether 6,208 mosquitoes belonging to 19 species under 5 genera namely, *Anopheles* (9), *Aedes* (2), *Armigeres* (1), *Culex* (5) and *Mansonia* (2) were collected from human dwellings and cattlesheds in 19 trap nights (Table 2). The major species encountered were *Culex vishnui* group (3891), *Cx. malayi* (935), *Anopheles vagus* (341), *An. annularis* (195), *Cx. bitaeniorhynchus* (107) and *An. minimus* (105). Anophelines formed 16.45 per cent of the total collections. Per trap night density of anophelines in human dwelling and cattleshed were 42.33 and 55.88 respectively. Among anophelines, *An. vagus* was the dominant species (33.4%) followed by *An. annularis* (19.10%), *An. culicifacies* (10.68%) and *An. minimus* (10.28%) (Table 3). Per trap night collection of known malaria vectors namely, *An. annularis*, *An. culicifacies* and *An. minimus* were relatively high in cattlesheds than in human dwellings. Similar observations were made from the other parts of northeastern region[14,15]. These species were found to rest indoor with a man hour density of 1.53, 0.83 and 0.57 respectively.

The study on the biting activity of malaria vectors revealed that *An. minimus* starts biting from 2200 hrs and continued up to 0400 hrs with a peak between midnight and 0200 hrs (Fig. 1). In contrast, Bhatnagar *et al.*[7] found peak biting of *An. minimus* in the first part of night during dry season and late part of night in the wet season in foothills of Nagaland. Similarly, high density of *An. minimus* was observed from 2000 to 0400 hrs with a peak between midnight and 0200 hrs in Tuichang[9] and between 2200 and 2400 hrs in Tlabong[16] in south Mizoram during wet season. In confirmation of earlier observations of Bhatt *et al.*[17] the present study also revealed that *An.*

Table 3. Composition of anopheline species and their indoor resting density under Tamulpur PHC

Species	No. collected	% collection	Resting collection (30 man hrs)	PMHD
Anopheles annularis	195	19.10	46	1.53
An. barbirostris	66	6.45	–	–
An. crawfordi	97	9.50	–	–
An. culicifacies	109	10.68	25	0.83
An. kochi	48	4.70	–	–
An. minimus	105	10.28	17	0.57
An. philippinensis	7	0.69	8	0.27
An. subpictus	53	5.19	21	0.70
An. vagus	341	33.40	147	4.90
Total	1021		264	8.80

PMHD — Per man hour density.

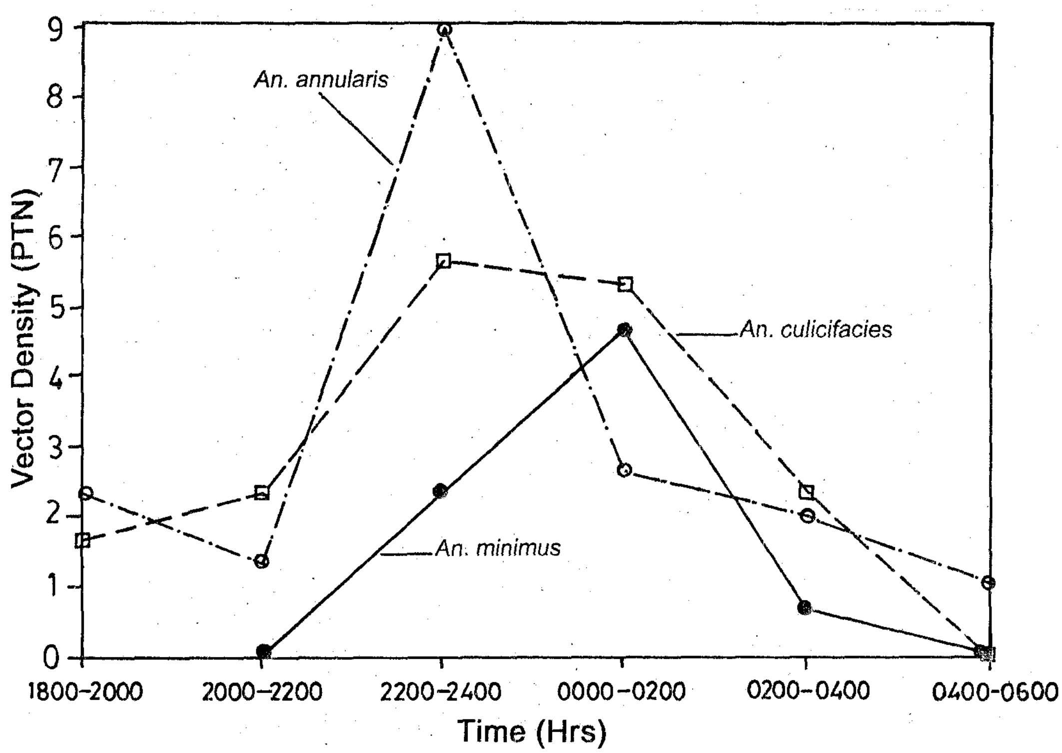

Fig. 1: Biting rhythm of malaria vectors at Tamulpur

annularis and *An. culicifacies* bites throughout the night with a peak biting activity between 2200 and 0200 hrs. A total of 98 *An. culicifacies*, 91 *An. minimus* and 41 *An. annularis* were dissected but none was found positive for sporozoites in the salivary glands. High parity rate of *An. minimus* (73%), *An. culicifacies* (70%) and *An. annularis* (65%) indicate their potentiality as vector(s) in the present epidemic. Prakash *et al.*[6] confirmed the role of *An. minimus* as a vector during the same epidemic at Tamulpur.

Profuse breeding of *An. culicifacies* and *An. minimus* was found in the grassy margins of slow flowing *katcha nallahs*, streams and paddy fields. Das *et al.*[16] reported the breeding of *An. minimus* from streams/rivers in Mizoram. Vas Dev[18] also observed the breeding of *An. minimus* in streams/streamlets with grassy margins and paddy fields, while *An. culicifacies* only in paddy fields in Sonapur, Assam.

An. minimus and *An. culicifacies* were found susceptible to 4% DDT as cent per cent mortality was observed within two hours of holding (recovery) period. In case of *An. annularis*, 82% mortality was recorded after 24 h of recovery period which required further verification for its resistant status. However, resistance of this species to 4% DDT had been already reported from Tezpur[19].

High parasitic load in the community, high density and long survival of vector(s) may be responsible for the present outbreak of malaria at Tamulpur. Unlike other parts of the country, the major malaria vectors are still susceptible to 4% DDT in Assam. Thus, reasonable coverage and methodical spray of insecticides coupled with the reduction of parasitic load in the community may be effective in controlling malaria in this region.

REFERENCES

1. Barkakaty, B.N. and M.V.V.L. Narasimham (1992). A longitudinal study to monitor chloroquine resistance of *P. falciparum* malaria in Bokajan and Manja PHC area of Karbi Anglong district, Assam. *Indian J. Malariol.*, **29:** 173-183.
2. Satyanarayana, S., S.K. Sharma, P.K. Chelleng, P. Dutta, L.P. Dutta and R.N.S. Yadav (1991). Chloroquine-resistant *P. falciparum* malaria in Arunachal Pradesh. *Indian J. Malariol.*, **28:** 137-140.
3. Barkakaty, B.N., P.C. Kalita, Silpi Das and A.C. Talukdar (1984). Chloroquine resistant *P. falciparum* malaria in Assam and Meghalaya. *Indian. J. Malariol.*, **21:** 55-66.
4. Das, Silpi, R.G. Roy and S. Pattanayak (1979). A note on chloroquine resistance test on *P. falciparum* in Nagaland. *Indian J. Med. Res.*, **70**(Suppl.): 30-33.
5. Jana-Kara, B.R., Wajihullah, B. Shahi, Vas Dev, C.F. Curtis and V.P. Sharma (1995). Deltamethrin impregenated bednets against *Anopheles minimus* transmitted malaria in Assam, India. *J. Trop. Med. Hyg.*, **98:** 73-83.
6. Prakash, A., R.K. Mahapatra and V.K. Srivastava (1996). Vector incrimination in Tamulpur Primary Health Centre, District Nalbari, Lower Assam during malaria outbreak 1995. *Indian J. Med. Res.*, **103**(2): 146-149.
7. Bhatnagar, V.N., S.R. Dwivedi, B.G. Misra and M. Das (1982). Detection and incrimination of *Anopheles minimus*, Theobald

1901 as malaria vector in the foothill area of Nagaland, India. *Indian J. Malariol.*, **29**: 129-133.

8. Kareem, M.A., Y.K. Singh, V.N. Bhatnagar and M.A. Das (1983). A preliminary report on entomological studies under PfCP in Zone-I. *J. Com. Dis.*, **15**: 207-208.
9. Das, S.C. and I. Baruah (1985). Incrimination of *Anopheles minimus*, Theobald and *Anopheles balabacensis balabacensis* Baisas (*An. dirus*) as malaria vectors in Mizoram. *Indian J. Malariol.*, **22**: 53-55.
10. Dutta, B. and B.D. Baruah (1987). Incrimination of *Anopheles minimus*, Theobald, as vector of malaria in Arunachal Pradesh. *Indian J. Malariol.*, **24**: 159-162.
11. Wajihullah, B. Jana-Kara and V.P. Sharma (1992). *Anopheles minimus* in Assam. *Curr. Sci.*, **63**: 7-9.
12. Dutta, P. and D.R. Bhattacharyya (1990). Malaria survey in some parts of Namsang circle of Tirap district, Arunachal Pradesh. *J. Com. Dis.*, **22**: 92-97.
13. Dutta, P.K. and B. Rajvir (1991). An epidemiological study in north Indian district. *J. Com. Dis.*, **23**(1): 29-33.
14. Das, S.C., P.K. Sarkar, N.G. Das, S. Hazarika and P.R. Malhotra (1984). Note on the collection of mosquitoes from animal sheds and human habitations in Assam. *Geobios New Reprints*, **3**(2): 142-144.
15. Das, S.C., M. Bhuyan, I. Baruah and P.K. Talukdar (1991). Mosquito survey in Tripura. *Indian J. Malariol.*, **28**(2): 129-134.
16. Das, S.C., M. Bhuyan and I. Baruah (1990). Active malaria transmission in south Mizoram. *Indian J. Malariol.*, **27**(2): 111-117.
17. Bhatt, R.M., R.C. Sharma, V.K. Kohli, A.S. Gautam and D.K. Gupta (1991). Biting rhythm of malaria vector *Anopheles culicifacies* in Kheda district, Gujarat. *Indian J. Malariol.*, **28**(2): 91-97.
18. Vas Dev (1994). Breeding habitats of *Anopheles* mosquitoes in Assam. *Indian J. Malariol.*, **31**(1): 31-34.
19. Das, N.G., I. Baruah, P.R. Malhotra, S.C. Das and C.K. Krishnan (1987). Susceptibility of some *Anopheles* mosquitoes to DDT and Dieldrin in Tezpur (Assam). *Indian J. Pub. Hlth.*, **31**(4): 221-224.

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Incrimination of Malaria Vector on Ayodhya Hills, India

K.K. CHATTERJEE and A.K. HATI

Keywords: *Anopheles*, Sporozoite rate, Vector

Ayodhya-Bagmundi range of hills, situated in the extreme west of Purulia district, West Bengal, India is highly endemic for Malaria. Average altitude of this hill area is 2200 ft from the mean sea level, mostly covered by dense and moderate forests with some isolated villages inhabited by tribals. Out of total *Plasmodium vivax* and *P. falciparum* cases reported from whole Purulia district during last ten years, Ayodhya hills alone contributed 12.6 and 73.0% respectively. A total of 20,565 malaria cases were reported from Ayodhya hills during 1983-1994, of which 33.10, 64.88 and 2.02% were *P. vivax*, *P. falciparum* and mixed infection respectively indicating predominance of *P. falciparum*.

No natural infection with *Plasmodium* sporozoites and oocysts was obtained in any *Anopheles* species from this area[1]. To search out the anopheline vector responsible for the transmission of malaria in the present study area, indoor-resting mosquitoes were collected from human habitations, cattlesheds and mixed dwellings and outdoor-resting mosquitoes were collected from bushes during 1993-1994 (two years) employing a total of 242 man-hour following standard methodology[2].

Department of Medical Entomology, School of Tropical Medicine, Calcutta-700 073, India.

A total of 15,230 mosquitoes of 11 species were collected from the study area. Of the total mosquitoes collected, 4913 (32.26%) were *Anopheles*. Among the total anophelines 320 (6.51%) were collected from outdoor-resting places and 4593 (93.5%) from indoors. Anophelines comprised seven species namely, *An. subpictus* (1737), *An. vagus* (1375), *An. annularis* (601), *An. barbirostris* (503), *An. culicifacies* (467), *An. nigerimus* (123) and *An. aconitus* (107). Both *An. annularis* and *An. culicifacies* are the established vector of malaria in India[3]. *An. annularis* and *An. culicifacies* occupied the third (12.23%) and fifth (9.5%) position in terms of prevalence among the anophelines in the present study area. Average per man-hour densities (indoor + outdoors) of *An. annularis* and *An. culicifacies* were 2.48 and 1.93 respectively. Densities of both *An. annularis* and *An. culicifacies* were significantly higher ($p < 0.05$) in the rainy season than those in the winter and summer.

Salivary glands as well as guts of 84 wild caught *An. culicifacies* and 105 *An. annularis* were dissected out and examined to detect natural infection with sporozoites or oocysts of any species of *Plasmodium*. No natural infection was detected in dissected *An. annularis* population but two specimens of *An. culicifacies* were found naturally infected with *Plasmodium*, one with sporozoites and the other with oocysts. The natural infection rate was calculated to be 2.38%. Sporozoite and oocyst rate was 1.2% separately. The natural infection was ascertained to be of *P. falciparum* by ELISA test.

So *An. culicifacies* has been incriminated as the vector of malaria for the first time on the Ayodhya hills of Purulia distsrict, West Bengal, India. Freshwater pools, streams and small rain water collections (during monsoon) were found to be the breeding ground of *An. culicifacies* in the study area. Further studies are necessary to specify the sibling species of *An. culicifacies* from Ayodhya hills, India.

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REFERENCES

1. Rao, T. Ramachandra (1984). *The Anophelines of India*. Rev. ed. (Malaria Research Centre, ICMR, Delhi).
2. WHO (1964). Expert Committee on Malaria. *Tech. Rep. Ser.* No. 272.
3. Sharma, V.P. (1996). Re-emergence of malaria in India. *Indian J. Med. Res.*, **103**: 26-45.

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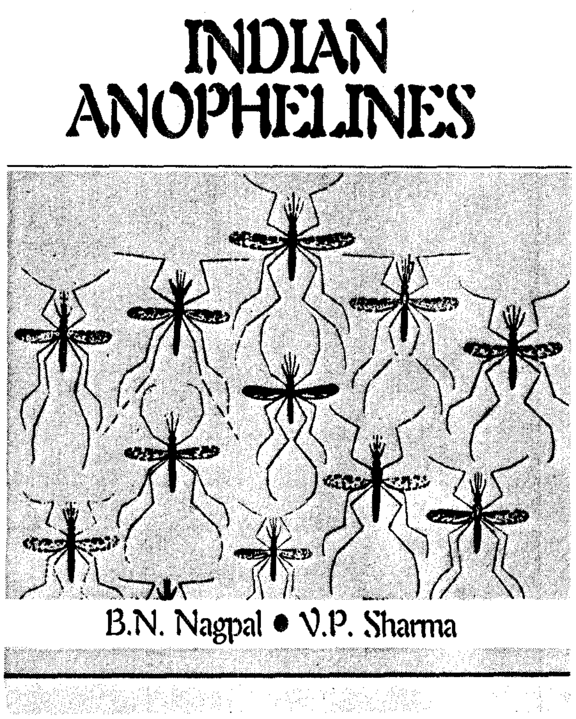

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