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MALARIA TRANSMISSION IN THE TARAI, NAINI TAL DISTRICT, UTTAR PRADESH, INDIA

P. C. ISSARIS, M.D., M.P.H.[a]
S. N. RASTOGI, M.B.B.S., D.P.H.[b]
V. RAMAKRISHNA, B.Sc., M.A.[c]

WHO Malaria Control Demonstration Team,
Haldwani, Naini Tal District, Uttar Pradesh, India

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SYNOPSIS

A study of the problems of malaria transmission in the Tarai of Naini Tal District, Uttar Pradesh, India, has been made by a WHO Malaria Control Demonstration Team operating in the area between 1949 and 1952.

Earlier investigators of malaria transmission in the area had concluded that the fever season coincided with the pre-monsoon period; that *Anopheles minimus* was the chief vector; and that *A. fluviatilis* could be dismissed as a zoophilic non-vector.

As a result of the team's malariometric and entomological surveys, the following conclusions have been reached : malaria transmission takes place throughout the year; *A. minimus* is virtually non-existent and plays no part in transmission; *A. fluviatilis*, the primary vector, is responsible for transmission in the pre- and post-monsoon periods; *A. culicifacies*, the secondary vector, is responsible for transmission in the monsoon period (July-September).

The results of precipitin tests on *A. fluviatilis*—which gave a gross anthropophilic index of over 40%—indicate that the *A. fluviatilis* found in this region of India is a mixture of both anthropophilic and zoophilic races; further studies are required to substantiate this theory.

Physical Features of Naini Tal District

Bordering the foothills of the Himalayas throughout the length of Uttar Pradesh, India, are two long but narrow belts of soil with markedly different physical features. Immediately skirting the foothills is a waterless belt of porous soil, from 6 to 10 miles (10-16 km) wide, characterized by the presence of dense, tall forests as well as large rock formations, and with

[a] Team-leader
[b] Malariologist
[c] Entomologist

a ground slope of 70-80 feet per mile (13-15 metres per km). This belt is called the Bhabar and is almost always dry—because of the slope, which is apparent in the rapid current of the streams, and of the porous nature of the soil—except during the rains when it becomes converted into an overflowing watery area. Adjoining the Bhabar belt to the south is a wet belt of loamy, clay-like soil from 8 to 10 miles (13-16 km) wide, characterized by long grass reeds and less-dense forests, and devoid of any rock formations. This wet, swampy belt, which is called the Tarai, has a ground slope of 8-10 feet per mile (1.5-2 metres per km). Thus, the Tarai is almost a plain; and because of the flatness of the belt and the impervious nature of the soil, the subsoil water-level almost reaches ground surface, forming a large number of swamps, of sluggishly running, meandering streams, and of seepages in many places.

This article deals with observations made by the WHO Malaria Control Demonstration Team in the Tarai of Naini Tal District. This area, which is bounded by the Bhabar of Naini Tal District to the north, the cultivated plains of Rohil Khand to the south, the Kosi river to the west, and the Sarda river to the east, extends from latitude 28°51′N. to latitude 29°37′N. and from longitude 78°43′E. to longitude 80°5′E. A map of the area, showing the rivers, important centres, and communications is given in fig. 1.

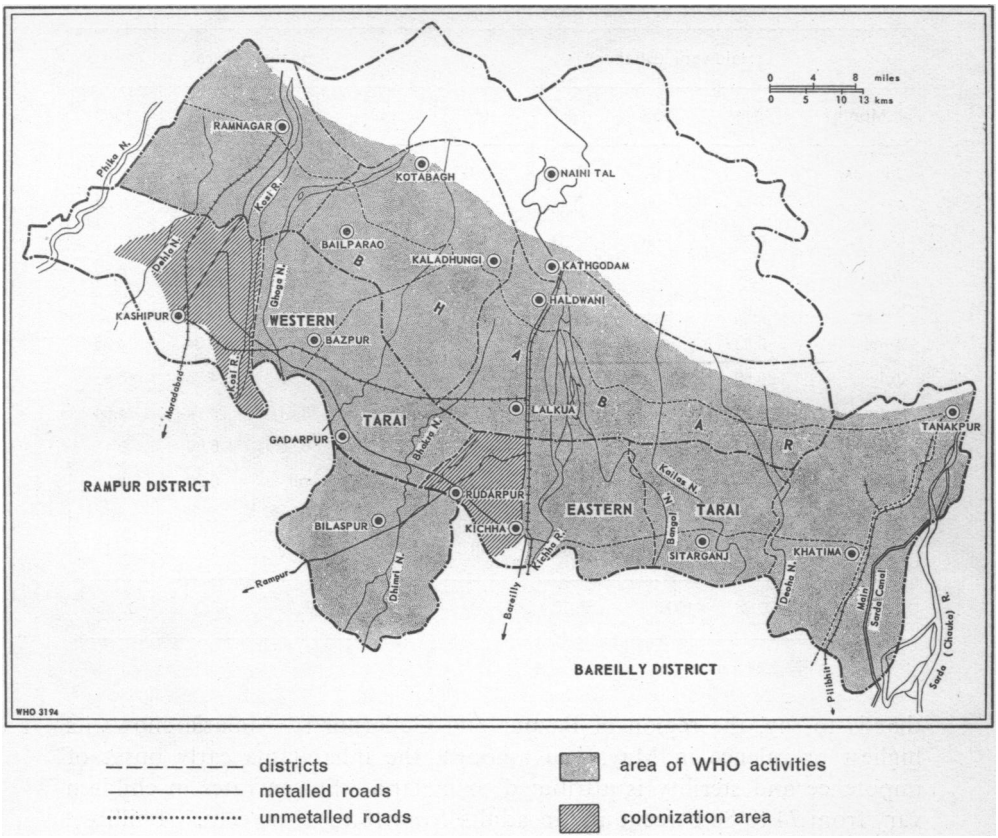
Climate

In the Tarai the climate differs from that of the adjoining plains chiefly in the variation of day and night temperatures. This variation, which is due to the nature of the soil, causes heavy sickness among the inhabitants of the tract at the beginning of the hot weather and towards the end of the rainy season. The excessive moisture, combined with the heat of the summer months, renders the climate distinctly enervating. The mean weekly maximum and minimum temperatures and relative humidity recorded at Bazpur, a typical Tarai centre, at 8 a.m., are 76°F (24°C), 60°F (16°C), and 70% respectively. May and June are the hottest, and January and February the coldest, months of the year.

Rainfall

During recent years the rainfall rate has slowly fallen, perhaps as a result of deforestation. The average annual rainfall for the whole of the Tarai tract is about 50 inches (1,250 mm). The monsoon usually breaks in the middle of June; highest precipitation is recorded in July and August; while in September it rains much less. The rest of the year is almost dry. The perennial breeding-places must obtain their water from the seepages; most of the other miscellaneous breeding-places have only a temporary existence.

FIG. 1. NAINI TAL DISTRICT AND BILASPUR TAHSIL, UTTAR PRADESH, INDIA



In contrast to the Tarai, in the Bhabar the rainfall is much greater—about 70 inches (1,800 mm)—while the monsoon breaks much earlier and lasts longer. The rainfall figures from Bazpur, a typical Tarai centre, and from Haldwani, a typical Bhabar centre, are shown in table I.

Previous Investigations into Malaria Transmission

The Tarai had until very recently been abandoned as uninhabitable because of the existence of hyperendemic malaria. The first investigations into malaria transmission in this area were carried out by Robertson,[10] Cameron,[1] Phillips,[8] and Clyde.[2] The first three investigators did not deal much with the entomological aspects beyond naming a few of the existing anopheline fauna. However, they stated that the fever season coincided with the pre-monsoon period. Robertson [10] writes of the Western Tarai,

TABLE I. MONTHLY RAINFALL, IN INCHES,* IN HALDWANI (BHABAR) AND BAZPUR (TARAI), 1949-52

	Haldwani (Bhabar)				Bazpur (Tarai)			
Months	1949	1950	1951	1952	1949	1950	1951	1952
January	nil	1.90	1.00	0.42	—	0.85	—	0.66
February	4.55	1.00	0.35	1.82	—	1.44	0.05	1.64
March	0.35	1.69	1.33	2.89	—	1.84	1.52	1.74
April	1.30	nil	nil	0.20	—	0.70	0.01	0.58
May	1.67	1.70	0.70	0.15	—	1.31	0.29	0.10
June	0.83	18.90	4.17	14.21	—	5.47	0.34	4.25
July	30.50	33.44	6.67	20.32	18.30	17.78	4.76	8.41
August	20.20	30.59	32.15	26.34	23.39	13.51	26.14	14.64
September	9.43	9.55	8.66	2.95	15.62	6.58	6.89	0.41
October	2.15	1.60	nil	3.14	—	nil	0.96	nil
November	nil	nil	1.10	nil	nil	nil	1.10	nil
December	nil	nil	nil	nil	nil	0.29	nil	nil
Total	70.98	100.37	56.13	72.44		49.77	42.06	32.43

* 1 inch = 2.54 cm

that is to say, the region of Bazpur and Gadarpur : " Malaria shows its highest prevalence in May, and amongst the inhabitants early onset of impotence and sterility is attributed to malaria. Spleen rates in children vary from 74 to 88 percent and in adults from 18 to 84 percent." Phillips,[8] who surveyed the Bhabar government estates, lists some of the anopheline species—including *Anopheles listoni* (now *A. fluviatilis*, *A. minimus*, and *A. varuna*) and *A. culicifacies*—and points out that, as the place is a death-trap, immigration into it should be stopped.

Clyde [2] gives details of investigations carried out over a period of nine years in the construction of the headworks of the Sarda Canal at Banbassa. An elaborate list of anopheline fauna and their breeding-places and the results of his dissections are given. His dissections were mostly negative except in the case of *A. minimus*, of which he dissected 110 and found a sporozoite-rate of 2.5%. Neither the months of infection nor other details are given.

In 1938-40, a team from the Malaria Institute of India worked in that section of the area now under discussion, which is situated in the Western Tarai, with their headquarters at Bazpur. Their findings were reported in the annual reports of the Malaria Institute of India for the years 1938,

1939, and 1940.[4, 5, 6] During the first year of their work they found two gut infections in the 1,817 specimens of *A. fluviatilis* dissected; all the other species, including *A. minimus*, were negative on dissection. In the second year, however, they found : " An infectivity rate of 18 per cent . . . [in *A. minimus*] during the height of the malaria season ".[5] Neither the numbers dissected, nor the months of infection, are given.

Their work was chiefly of interest because they carried out precipitin tests on the stomach contents of *A. fluviatilis* caught in this area and compared them with results from *A. fluviatilis* caught in the Wynaad area of South India, where another team was working at that time.

" The most interesting results were those obtained with *A. fluviatilis*, the percentage containing human blood in the U. P. Terai being 1.4 [350 blood-meals examined], as compared with 96.9 in the Wynaad Series [1,681 blood-meals examined]. The findings are in agreement with the results of dissections, and indicate that we are dealing with two entirely different biological races or species, although as yet no differences have been detected in the egg, larval or adult stages of specimens collected from the area under observation."[5]

They declared that *A. minimus* was the chief malaria-vector in the area and acquitted *A. fluviatilis* as being a zoophilic non-vector.

Investigations by the WHO Malaria Control Demonstration Team

It was with this background that the WHO Malaria Control Demonstration Team started work in May 1949.

During June and July 1949, the first malariometric survey was carried out in the Bazpur-Gadarpur region, spleen examinations being made of the schoolchildren. Of the 516 children examined, 483 were found to have enlarged spleens—giving a spleen-rate of 94%—with an average enlargement of 2.7. Owing to technical difficulties, examination for parasites could not be undertaken at that time. Entomological observations were also carried out; it was found that of the vector species *A. minimus*, *A. fluviatilis*, and *A. culicifacies* collected, the number of specimens of *A. minimus* was strikingly insignificant when compared with the collections of the other two species.

Thus, the whole situation from the point of view of vectors appeared rather confused and a completely new series of investigations was required. Accordingly, a programme was planned to :

(1) find out whether *A. minimus* was present or absent, and to elucidate its role as a vector if present;

(2) discover the vector or vectors in the area, in the absence of *A. minimus*;

(3) establish the malaria transmission season by studying the infant parasite-rates and correlating them with the entomological findings.

TABLE II. WEEKLY ROUTINE COLLECTIONS OF VECTOR

(A) 1949—

Month	August				September				October					November				December					January			
Week ending	6	13	20	27	3	10	17	24	1	8	15	22	29	5	12	19	26	3	10	17	24	31	7	14	21	28
A. culicifacies	25	35	39	53	77	17	40	39	0	6	15	0	3	4	3	0	2	3	1	5	0	2	5	4	1	0
A. fluviatilis	3	0	2	6	4	1	4	14	0	37	38	26	6	33	10	27	32	20	23	5	13	19	8	11	13	0
A. minimus	3	1	0	0	2	0	1	1	0	4	5	1	0	0	1	1	1	3	1	0	0	0	0	0	0	0

(B) 1950—

Month	August				September					October				November				December					January			
Week ending	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	25	2	9	16	23	30	6	13	20	27
A. culicifacies	50	51	114	110	101	90	117	39	33	33	13	6	33	4	3	1	6	3	8	9	0	6	4	1	5	4
A. fluviatilis	5	17	9	19	51	43	32	17	38	70	37	18	57	85	44	64	67	103	83	55	55	28	30	36	46	36
A. minimus	0	0	0	1	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0

(C) 1951—

Month	August				September					October				November				December				
Week ending	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29
A. culicifacies	35	21	30	21	34	108	122	85	80	56	—	53	37	13	5	8	8	13	7	6	6	2
A. fluviatilis	7	1	2	2	4	4	26	29	26	62	—	97	97	85	79	102	87	68	54	68	64	41
A. minimus	0	0	0	0	0	0	0	0	0	0	—	0	0	0	0	0	0	0	0	0	0	0

SPECIES FROM UNSPRAYED CONTROL VILLAGES

1950

Month	February				March				April					May				June				July				
Week ending	4	11	18	25	4	11	18	25	1	8	15	22	29	6	13	20	27	3	10	17	24	1	8	15	22	29
A. culicifacies	0	2	0	0	0	0	0	0	2	0	1	0	5	1	5	9	32	19	46	7	15	17	18	2	36	40
A. fluviatilis	17	16	26	23	17	26	22	16	38	48	33	83	53	47	36	27	25	10	8	11	8	7	5	5	5	21
A. minimus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3

1951

Month	February				March					April				May				June					July			
Week ending	3	10	17	24	3	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28
A. culicifacies	1	2	0	0	0	0	2	0	8	4	2	4	7	9	6	5	18	11	16	29	20	20	17	23	37	33
A. fluviatilis	45	32	38	36	26	68	56	57	45	75	118	131	93	90	67	113	31	49	30	13	16	2	3	3	4	10
A. minimus	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

1952

Month	January		February			March		April		May			June			July		
Period ending	5	21	4	15	29	15	30	15	30	10	20	31	10	20	30	10	20	31
A. culicifacies	4	9	0	7	2	5	6	4	12	15	8	12	10	42	20	38	55	47
A. fluviatilis	35	51	35	37	34	66	73	49	53	31	6	15	2	0	2	5	5	3
A. minimus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Seasonal prevalence of vector species

Entomological observations during 1949-52 have shown that the following species of anopheles are prevalent in this area :

A. fluviatilis	*A. gigas*	*A. stephensi*
A. culicifacies	*A. hyrcanus*	*A. subpictus*
A. minimus	*A. karwari*	*A. umbrosus*
A. aconitus	*A. maculatus*	*A. varuna*
A. annularis	*A. pallidus*	*A. vagus*
A. barbirostris	*A. splendidus*	

Of these 17 species, only *A. fluviatilis*, *A. culicifacies*, and *A. minimus* are of any importance as malaria vectors in the area.

Weekly adult mosquito collections were made from selected catching-stations in unsprayed villages adjoining the demonstration area. The vectors collected are shown in table II and fig. 2.

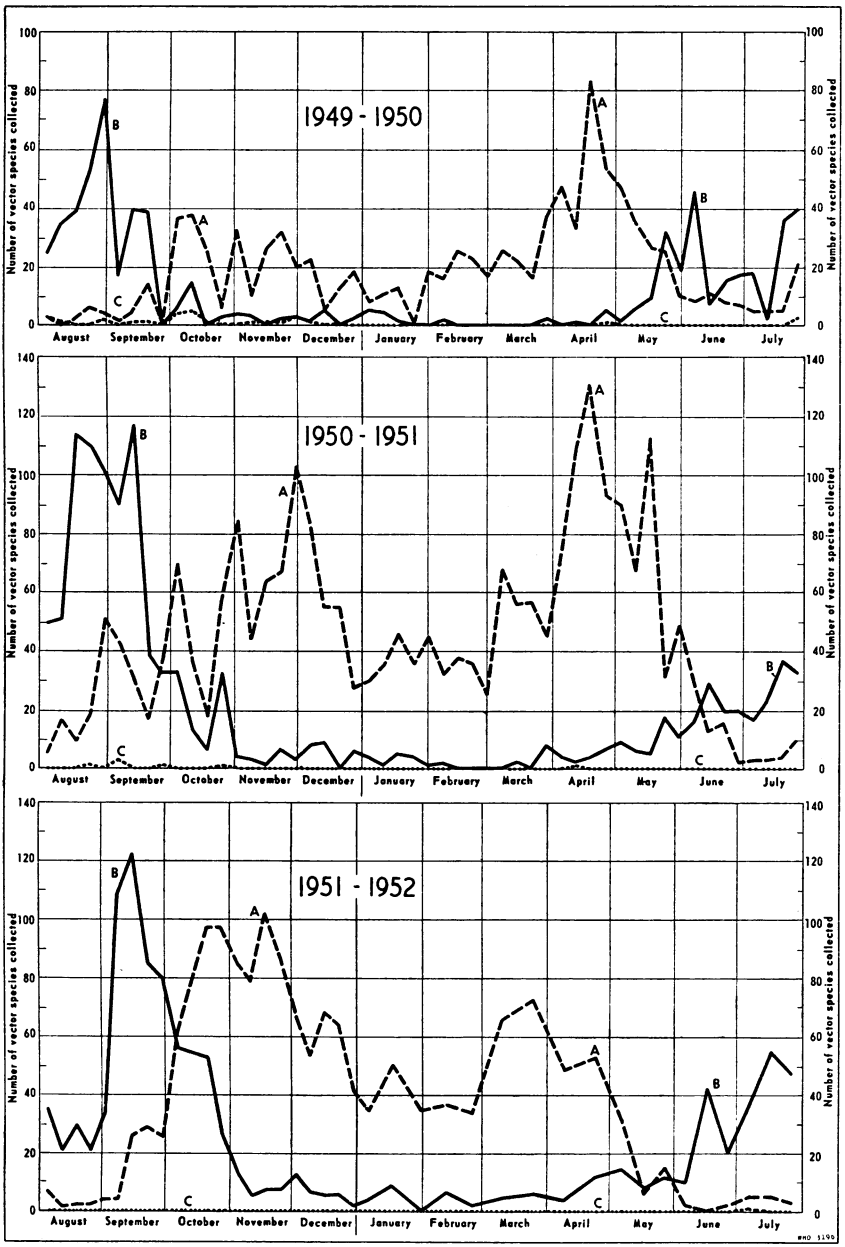
Some very interesting facts regarding the seasonal distribution of the vector species (*A. fluviatilis*, *A. culicifacies*, and *A. minimus*) emerge from a study of table II and fig. 2. It is clear that *A. minimus* is virtually absent, being caught only in small numbers and at long intervals; *A. culicifacies* is generally present during the months June-October; and *A. fluviatilis* is prevalent throughout the year but is collected in larger numbers during the months October-June.

A closer study of fig. 2 reveals that the number of *A. culicifacies* starts to rise during the middle of June or the beginning of July, depending on the date of onset of the monsoon, and reaches its maximum during August and the middle of September. The number of *A. fluviatilis* begins to rise in the later part of September, reaching its maximum in October-November and again in March, April, and May. It is obvious from the collections that the period of maximum prevalence of *A. culicifacies*—six to eight weeks—is relatively shorter than that of *A. fluviatilis*, which extends over more than six months.

Besides the routine collections mentioned above, extensive additional collections were made to see if *A. minimus* was present anywhere; all these collections revealed only a very insignificant number.

If all the collections of adult mosquitos made throughout the period of study are taken into consideration, it is found that *A. fluviatilis* is the most predominant species, forming over 66% of the vectors, and that *A. culicifacies* comes next in order, forming over 33% of the vectors, while *A. minimus* forms a very small minority, making up less than 0.5% of the collections.

FIG. 2. WEEKLY ROUTINE COLLECTIONS OF VECTOR SPECIES FROM UNSPRAYED CONTROL VILLAGES, 1949-52



A = *A. fluviatilis* B = *A. culicifacies* C = *A. minimus*

TABLE III. MONTHLY DISSECTIONS OF VECTOR

Month	1949–50									1950–51								
	A. culicifacies			*A. fluviatilis*			*A. minimus*			*A. culicifacies*			*A. fluviatilis*			*A. minimus*		
	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR
June	312	0	0	27	0	0	3	0	0	117	0	0	52	0	0	0	0	0
July	204	0	0	54	0	0	11	0	0	196	0	0	55	0	0	3	0	0
August . . .	139	0	0	16	0	0	4	0	0	443	1	0.23	106	0	0	0	0	0
September .	276	0	0	81	0	0	11	0	0	603	0	0	241	0	0	4	0	0
October . . .	59	0	0	213	0	0	15	0	0	67	0	0	181	0	0	1	0	0
November . .	12	0	0	123	0	0	5	0	0	28	0	0	425	0	0	1	0	0
December . .	9	0	0	44	0	0	2	0	0	27	0	0	535	0	0	0	0	0
January . . .	11	0	0	40	0	0	0	0	0	16	0	0	342	0	0	0	0	0
February . .	3	0	0	142	0	0	0	0	0	6	0	0	210	0	0	1	0	0
March	0	0	0	61	0	0	0	0	0	11	0	0	395	1	0.25	6	0	0
April	18	0	0	324	0	0	4	0	0	72	0	0	512	0	0	1	0	0
May	53	0	0	153	0	0	0	0	0	77	0	0	399	1	0.25	1	0	0
Total	1,096	0	0	1,278	0	0	55	0	0	1,663	1	0.06	3,453	2	0.06	18	0	0

ND = number dissected ; NS = number containing sporozoites ; SR = sporozoite-rate (%)

Dissections

During the whole period of the investigation, as many as possible of the vector species—i.e., *A. fluviatilis*, *A. culicifacies*, and *A. minimus*—collected from as many situations as possible were dissected. In the first few months both gut and glands were dissected, but later the gut dissections were abandoned to enable us to perform gland dissections on greater numbers and to discover the true vectors. Details of the numbers of vectors dissected monthly are shown in table III.

SPECIES, SHOWING SPOROZOITE-RATES, 1949-53

Month	1951–52									1952–53								
	A. culicifacies			*A. fluviatilis*			*A. minimus*			*A. culicifacies*			*A. fluviatilis*			*A. minimus*		
	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR	ND	NS	SR
June	196	0	0	111	0	0	1	0	0	197	0	0	56	0	0	0	0	0
July.	277	0	0	64	0	0	0	0	0	570	1	0.18	41	0	0	0	0	0
August . . .	537	1	0.19	47	0	0	1	0	0	555	1	0.18	30	0	0	0	0	0
September .	581	0	0	159	0	0	1	0	0	555	1	0.18	104	0	0	0	0	0
October. . .	139	0	0	483	1	0.21	0	0	0	165	0	0	545	2	0.37	0	0	0
November. .	36	0	0	501	0	0	0	0	0	39	0	0	331	0	0	0	0	0
December. .	34	0	0	279	0	0	0	0	0									
January. . .	10	0	0	258	0	0	0	0	0									
February . .	12	0	0	248	0	0	0	0	0									
March. . . .	35	0	0	508	1	0.20	0	0	0									
April	48	0	0	455	1	0.22	0	0	0									
May.	93	0	0	133	0	0	0	0	0									
Total	998	1	0.05	3,246	3	0.09	3	0	0	2,081	3	0.14	1,107	2	0.18	0	0	0

A. culicifacies was found infected with sporozoites in the months of July, August, and September, and *A. fluviatilis* during the months of October, April, and May. Thus it is clear that *A. culicifacies* is responsible for transmission during the monsoon period, while *A. fluviatilis* is responsible for transmission during the pre-monsoon period and during a certain part of the post-monsoon period.

A. fluviatilis infectivity. The gross sporozoite-rate of *A. fluviatilis* for the years 1950-3 (7 positives out of 7,806 dissections) was 0.09%. However,

if the sporozoite-rates for this species are estimated seasonally—namely, for the pre-monsoon period (March, April, and May) and the post-monsoon period (October-November)—the sporozoite-rates given in table IV are obtained.

TABLE IV. SPOROZOITE-RATES OF ANOPHELES FLUVIATILIS, SHOWING SEASONAL VARIATIONS, 1951-2

Period of year	1951			1952		
	Number dissected	Number containing sporozoites	Sporozoite-rate (%)	Number dissected	Number containing sporozoites	Sporozoite-rate (%)
Pre-monsoon (March, April, and May)	1,306	2	0.15	1,096	2	0.18
Post-monsoon (October-November)	981	1	0.10	876	2	0.23
Total	2,287	3	0.13	1,972	4	0.20

The low sporozoite-rate in this species requires further study and suggests that this variety of *A. fluviatilis* may, perhaps, be different from the South Indian variety occurring in Wynaad, North Kanara, South Kanara, and East Central India, where rates of 5%-7% have been recorded (Covell & Harbhagwan,[3] Singh Jaswant & Jacob,[7] Ramakrishnan, Krishnan & Ramakrishna,[9] and Senior White [11]).

However, the sporozoite-rate of 0.09% observed in the Tarai compares perfectly with the sporozoite-rate of 0.11% recorded in the Deccan area and Nira Canal zones of Bombay State (Viswanathan [12]), and confirms the fact that although *A. fluviatilis* need not necessarily be as efficient a vector as in South India, it can nevertheless play an important role.

A. culicifacies infectivity. *A. culicifacies* was found infected with sporozoites in the months of July, August, and September. It showed a gross sporozoite-rate of 0.09% (5 positives out of 5,742 dissections). If the sporozoite-rate in this species is estimated solely for the monsoon period—when the species was found to be infective—the higher rate of 0.12% is obtained.

Thus *A. culicifacies* is shown to be responsible for malaria transmission during the monsoon period. This finding confirms the theory that *A. culicifacies* also plays an important role as a vector in areas between the foothills and the plains.

A. minimus. Only 76 specimens of *A. minimus* were dissected, with negative results during the whole period of our observations. The low numbers of the adult collections throughout the period, combined with

the negative results of the dissections, show that *A. minimus* is virtually absent and has no place in malaria transmission in the Tarai area.

Precipitin tests

As pointed out earlier in this article (page 315), the *A. fluviatilis* in this area was considered to be a zoophilic mosquito on the basis of the work carried out in 1938-40.[4, 5, 6] After that date, no further investigation of the feeding preferences of *A. fluviatilis* in this area was made until the WHO Malaria Control Demonstration Team started its operations. This team undertook a study of the feeding habits of *A. fluviatilis*; the stomach contents of recently fed specimens were collected on filter-papers which were sent to the Director of the Malaria Institute of India, who kindly had the precipitin tests performed at the Institute. The work carried out during 1949-52 revealed very surprising results. *A. fluviatilis* was found to have a gross anthropophilic index of 41.2% when the collections from houses, cattle-sheds, and outdoor resting-places were combined. Table V shows details of the collections and of the results obtained.

TABLE V. ANTHROPOPHILIC INDEX OF ANOPHELES FLUVIATILIS

Place of collection	Number collected	Number containing human blood	Anthropophilic index (%)
Cattle-sheds	134	38	28.4
Out of doors	38	17	44.7
Human dwellings	73	46	63.0
Total	245	101	41.2

The anthropophilic index of *A. fluviatilis* from human dwellings was over 60%, while that of those from cattle-sheds was only 28.4%. This suggests that some *A. fluviatilis* from human dwellings utilize cattle-sheds as their daytime resting-places after feeding on human beings. During the course of the observations, it was found that *A. fluviatilis* frequently rested out of doors; the anthropophilic index of the outdoor-resting *A. fluviatilis* was 44.7%, which was higher than that of those caught in cattle-sheds. It is difficult to compare the outdoor with the indoor collections, as well as to say what proportion of the *A. fluviatilis* population rests in outdoor shelters after feeding. The higher anthropophilic index of the outdoor resters suggests that the latter constitute a fair proportion of the human-biting *A. fluviatilis*, and that further studies of the behaviour as well as of the numbers of *A. fluviatilis* are warranted.

TABLE VI. INFANT PARASITE-RATES

Age-group (months)	Western Tarai (Bazpur and Gadarpur) and Bailparao															
	January ** (20 villages — 12–31 Jan.)								February ** (34 villages — 2–28 Feb.)							
	number examined	reaction							number examined	reaction						
		negative	positive *							negative	positive *					
			F	V	M	Mx	total				F	V	M	Mx	total	
							no.	%							no.	%
1	10	8	2	—	—	—	2	20	14	4	9	—	1	—	10	71
2	4	3	—	—	1	—	1	25	12	6	2	1	3	—	6	50
3	6	4	1	—	1	—	2	33	20	10	9	—	—	1	10	50
4	4	3	1	—	—	—	1	25	9	6	1	2	—	—	3	33
5	5	5	—	—	—	—	0	0	14	7	6	1	—	—	7	50
6	4	4	—	—	—	—	0	0	6	4	1	—	—	1	2	33
7	5	3	—	—	2	—	2	40	7	1	2	1	3	—	6	86
8	5	4	—	—	1	—	1	20	7	7	—	—	—	—	0	0
9	5	4	—	—	1	—	1	20	2	1	—	1	—	—	1	50
10	3	1	1	1	—	—	2	67	12	5	6	—	—	1	7	58
11	2	1	—	1	—	—	1	50	3	1	—	—	2	—	2	67
12	17	14	2	1	—	—	3	18	10	1	7	1	—	1	9	90
Total . .	70	54	7	3	6	—	16	23	116	53	43	7	9	4	63	54
Percentage of number examined . .		77	10	4	9	—		23		46	37	6	8	3		54

* F = *Plasmodium falciparum* infection ; V = *P. vivax* infection ; M = *P. malariae* infection ; Mx = mixed infection

IN THE WESTERN TARAI, 1950

Age-group (months)	Western Tarai (Bazpur and Gadarpur) and Bailparao															
	April ** (30 villages — 3–26 April)								June † (16 villages — 10–16 June)							
	number examined	reaction							number examined	reaction						
		negative	positive *							negative	positive *					
			F	V	M	Mx	total				F	V	M	Mx	total	
							no.	%							no.	%
1	11	10	1	—	—	—	1	9	1	1	—	—	—	—	0	0
2	15	13	2	—	—	—	2	13	1	1	—	—	—	—	0	0
3	11	9	1	1	—	—	2	18	1	—	1	—	—	—	1	100
4	10	9	—	1	—	—	1	10	4	1	1	1	1	—	3	75
5	15	12	2	1	—	—	3	20	4	3	1	—	—	—	1	25
6	13	8	3	1	1	—	5	38	6	3	2	1	—	—	3	50
7	8	6	1	1	—	—	2	25	3	1	1	1	—	—	2	67
8	7	6	1	—	—	—	1	14	1	1	—	—	—	—	0	0
9	2	2	—	—	—	—	0	0	2	1	—	—	—	—	1	50
10	3	2	1	—	—	—	1	33	4	—	2	1	1	—	4	100
11	11	8	2	1	—	—	3	27	3	3	—	—	—	—	0	0
12	10	6	1	3	—	—	4	40	4	2	—	1	—	1	2	50
Total . .	16	91	15	9	1	—	25	22	34	17	8	5	3	1	17	50
Percentage of number examined . .		78	13	8	1	—		22		50	23	15	9	3		50

** Observations carried out in Bazpur and Gadarpur
† Observations carried out in Bailparao

TABLE VII. INFANT PARASITE-RATES

Age-group (months)	Eastern Tarai (Sitarganj and Khatima)															
	February (31 villages — 20–25 Feb.)								March (101 villages — 9–24 March)							
	number examined	reaction							number examined	reaction						
		negative	positive *							negative	positive *					
			F	V	M	Mx	total no.	total %			F	V	M	Mx	total no.	total %
1	10	2	6	1	—	1	8	80	40	18	18	1	1	2	22	55
2	6	1	3	1	—	1	5	83	29	15	11	1	1	1	14	48
3	13	3	7	—	3	—	10	77	36	20	16	—	—	—	16	44
4	13	3	4	2	4	—	10	77	41	20	18	1	1	1	21	51
5	19	7	5	—	2	5	12	63	38	20	10	1	3	4	18	47
6	15	3	5	2	2	3	12	80	53	18	22	—	1	12	35	66
7	5	—	1	—	2	2	5	100	40	24	11	1	—	4	16	40
8	6	2	2	1	—	1	4	67	39	9	21	—	1	8	30	77
9	7	—	1	—	—	6	7	100	31	14	9	1	1	6	17	55
10	12	1	2	2	—	7	11	92	40	10	14	2	—	14	30	75
11	9	—	1	1	1	6	9	100	30	6	11	1	—	12	24	80
12	44	3	7	2	3	29	41	93	99	23	25	9	3	39	76	77
Total . .	159	25	44	12	17	61	134	84	516	197	186	18	12	103	319	62
Percentage of number examined . .		16	28	7	11	38		84		38	36	4	2	20		62

* F = *Plasmodium falciparum* infection ; V = *P. vivax* infection ; M = *P. malariae* infection ; Mx = mixed infection

IN THE EASTERN TARAI, 1950

Age-group (months)	Eastern Tarai (Sitarganj and Khatima)							
	April (66 villages — 11–20 April)							
	number examined	reaction						
		negative	positive *					
			F	V	M	Mx	total	
							no.	%
1	32	18	7	1	4	2	14	44
2	24	18	4	—	2	—	6	25
3	32	15	11	1	1	4	17	53
4	34	27	5	—	1	1	7	21
5	31	24	5	—	1	1	7	23
6	33	23	7	1	1	1	10	30
7	30	18	4	2	3	3	12	40
8	29	20	3	2	—	4	9	31
9	35	16	7	3	4	5	19	54
10	58	22	15	6	2	13	36	62
11	37	16	5	6	3	7	21	57
12	58	20	9	4	2	23	38	66
Total . .	433	237	82	26	24	64	196	45
Percentage of number examined		55	19	6	5	15		45

The indices arrived at in our observations follow the pattern of those found by Senior White [11] in East Central India, which are shown in the following tabulation :

Place	*Anthropophilic index* (%)
Cattle-sheds	11.7
Out of doors	74.4
Human dwellings	56.8
Total	44.1

If we assume anthropophilism to be a characteristic of a particular race of *A. fluviatilis*—the theory put forward by previous workers—our findings suggest that the *A. fluviatilis* in the Tarai area is a mixture of both anthropophilic and zoophilic races, and that it is like neither the predominantly anthropophilic race of Wynaad nor the predominantly zoophilic race it was originally considered to be. The low anthropophilic index of the cattle-shed *A. fluviatilis* suggests the existence of a zoophilic race, while a fair proportion of the outdoor-resting *A. fluviatilis* appear to be of anthropophilic race. Further studies will have to be made to find out whether there are any morphological differences to support this theory of the existence of anthropophilic and zoophilic races.

Infant parasite-rates

Besides the routine malariometric survey comprising examination of the spleens and blood of school-age children in the different sectors of the area, a large number of blood-smears from infants aged from one to twelve months were collected and examined during the period of our work. This survey was undertaken to study the malaria-transmission period in the area, as well as to check the effect of the antimalarial operations. Complete details of the observations made are shown in tables VI, VII, and VIII.

Since this article deals with the transmission period in the area, we are presenting the details of observations carried out during the first year. The collections of infant blood-smears from both the Western and the Eastern Tarai were started in January 1950 and completed in April of the same year. In the following months, the collections were continued in certain sectors of the area, but the results are not presented, as the whole area was sprayed with DDT and the infant parasite-rates dropped practically to nil. However, in the figures for the Western Tarai for the month of June, the results of blood collections from infants in Bailparao—which at that time had not been sprayed and which, although falling administratively in the Bhabar, compares with Bazpur, Western Tarai, from the point of view of malariogenic and physical features—are given.

TABLE VIII. INFANT PARASITE-RATES IN THE RAMPUR AND BAREILLY DISTRICTS, 1950

Rampur and Bareilly districts (control area)

Age-group (months)	July (10 villages — 24–27 July)								August (16 villages — 3, 4, 7, and 22 August)							
	number examined	reaction							number examined	reaction						
		negative	positive *				total			negative	positive *				total	
			F	V	M	Mx	no.	%			F	V	M	Mx	no.	%
1	5	4	—	1	—	—	1	20	3	2	1	—	—	—	1	33
2	2	1	—	—	1	—	1	50	6	5	1	—	—	—	1	17
3	6	6	—	—	—	—	0	0	12	12	—	—	—	—	0	0
4	1	1	—	—	—	—	0	0	7	5	2	—	—	—	2	29
5	1	1	—	—	—	—	0	0	9	9	—	—	—	—	0	0
6	5	3	1	1	—	—	2	40	4	4	—	—	—	—	0	0
7	2	2	—	—	—	—	0	0	5	3	2	—	—	—	2	40
8	6	5	—	1	—	—	1	17	9	8	1	—	—	—	1	11
9	2	1	—	1	—	—	1	50	6	6	—	—	—	—	0	0
10	3	3	—	—	—	—	0	0	12	10	—	—	1	1	2	17
11	1	1	—	—	—	—	0	0	6	6	—	—	—	—	0	0
12	6	5	—	—	1	—	1	17	13	13	—	—	—	—	0	0
Total . .	40	33	1	4	2	—	7	18	92	83	7	—	1	1	9	10
Percentage of number examined . .		82	3	10	5	—		18		90	8	—	1	1		10

* F = *Plasmodium falciparum* infection ; V = *P. vivax* infection ; M = *P. malariae* infection ; Mx = mixed infection

The villagers in this area move to the hills during the summer and the monsoon months, so that the collections from this sector are not vrey high. However, out of the 34 collections made in June 1950 in Bailparao, 17 were positive, thus giving an infant parasite-rate of 50% and showing that malaria transmission takes place in this month and earlier, in May, also.

From table VI it can be seen that in the Western Tarai as well as in the Eastern Tarai (the Eastern Tarai was unsprayed at the time of our collections, whereas the Western Tarai was sprayed in June-July 1949), the infant parasite-rate is very high. In the Eastern Tarai an infant parasite-rate of 84%, 62%, and 45% in the months of February, March, and April, respectively, which included 32%-45% of mixed infections, was observed. Naturally these high rates, as well as the high percentage of mixed infections, show the magnitude of the malaria transmission during the course of the previous twelve months. In order to determine the trend of transmission in the different months, the parasite-rates of the infants who reacted positively were analysed by monthly age-groups; the figures obtained are shown in tables VI, VII, and VIII.

If in both the Western and Eastern Tarai the figures for the groups of babies aged from one to six months, considered separately for January, February, and March, are examined, a very clear indication is given of the extent of the transmission which occurred in the period October 1949 to March 1950. The infants giving positive reactions in these groups form 38% of the total number of positive reactors. A number of these positive reactions must be due to transmission occurring in the post-monsoon period, namely, October, November, and December. On the other hand, considering the number of infants aged one and two months found positive, it can be concluded that during January and February, the coldest months of the winter, malaria transmission appears to be active. This observation of active transmission in the months of January and February is not corroborated by the entomological findings, as during these months no infective species was found. It must be mentioned here that, for the months of January, February, and March, 12 out of the 42 infants in the one-month age-group who reacted positively were from one to ten days old, and 11 were from 11 to 20 days old; thus a total of 23 out of the 42 positive reactions were obtained from infants not more than 20 days old. The finding of positive reactions in infants aged from one to ten days can be attributed to congenital transmission, since the minimum period of incubation in malaria is longer than ten days. However, even if we venture to assume that a proportion of the positive reactions in infants aged from 11 to 20 days is due to congenital causes, the remainder of the positive reactions obtained can be explained only by the fact that a certain amount of transmission by the mosquito is taking place during the months of January, February, and March.

The infant parasite-rates of 62% and 45% observed in the months of March and April, respectively, in the Eastern Tarai, and of 22% and 50% observed in April and June, respectively, in the Western Tarai, combined with the positive findings in *A. fluviatilis* during the months of March, April, and May, indicate that malaria transmission definitely occurs during the pre-monsoon period.

With regard to the monsoon period, the results of the blood-smears taken in July and August 1950 from infants in Rampur and Bareilly districts —the control area—show that the gross infant-parasite-rates were 17.5% and 10% in the two months, respectively; from the blood-smear results, the distribution of the parasite-rate by monthly age-group was also assessed. These data, combined with the finding of positive *A. culicifacies* during July and August, prove that transmission occurs also during the months of the monsoon. The number of blood-smears collected from infants in the Rampur-Bareilly control area during July and August was only 132, which is not significant when the fact that these two districts are densely populated is taken into consideration. However, it was not possible to collect a larger number of blood-smears owing to the non-co-operation of the villagers. The low infant-parasite-rate in these areas may be due also to the fact that these areas have slightly different malariogenic and physical features from the other areas where examinations were made.

TABLE IX. MALARIA TRANSMISSION IN THE TARAI, NAINI TAL DISTRICT

Period of year	Infant parasite-rate	Vector species	Malaria transmission
Pre-monsoon (March, April, May, and June)	very high	*A. fluviatilis*	definitely occurs
Monsoon (July, August, and September)	high	*A. culicifacies*	definitely occurs
October-November	very high	*A. fluviatilis*	definitely occurs
December, January, and February	fairly high	probably *A. fluviatilis*	results of analysis of infant parasite-rates by monthly age-groups indicate that some transmission occurs even in these months

This study has revealed the fact that malaria transmission occurs throughout the year, with some seasonal variations in intensity. The pattern of malaria transmission in the Tarai, Naini Tal District, is shown schematically in table IX.

Conclusions

1. Considering together the results of parasite studies made on infants and the entomological findings, we can with certainly say that in the Tarai, Naini Tal District, malaria transmission occurs in the pre-monsoon months (March, April, and May), during the monsoon period (July, August, and September), and also during the post-monsoon period (October and November). Although the entomological findings do not by themselves show that transmission occurs during the months of December, January, and February, analysis of the infant parasite-rates proves that a certain amount of transmission occurs during these months also.

2. The vector species in this area are *A. fluviatilis* and *A. culicifacies.*

3. *A. minimus* is virtually absent.

4. *A. culicifacies* is responsible for transmission during July, August, and September.

5. *A. fluviatilis* is responsible for transmission during the rest of the period, namely, October to June.

6. It appears that the transmission started by *A. fluviatilis* during the pre-monsoon period is continued by *A. culicifacies* during the monsoon period, and that *A. fluviatilis* plays a further important role during the post-monsoon period and after.

7. *A. fluviatilis* in this area is no longer zoophilic but has an anthropophilic index of over 40%.

RÉSUMÉ

La région de Terai, dans le district de Naini Tal, en bordure de l'Himalaya, était considérée, tout récemment encore, comme inhabitable en raison de son climat insalubre et du paludisme hyperendémique qui y régnait. D'après des observations faites par divers auteurs au cours des 50 dernières années, la saison d'infection paludique précédait la mousson, l'intensité maximum étant en mai. Les indices spléniques étaient de 74-88% chez les petits enfants et de 18-84% chez les adultes. *Anopheles minimus* avait été reconnu comme vecteur principal et *A. fluviatilis* comme une espèce zoophile, non vectrice.

Une équipe de démonstration de lutte antipaludique de l'OMS commença son travail dans cette région en mai 1949. Les premières investigations ayant donné des résultats différents de ceux qui étaient connus, des recherches systématiques furent entreprises. Elles montrèrent que, parmi les 17 espèces d'anophèles présentes dans la zone étudiée, seules *A. fluviatilis*, *A. culicifacies* et *A. minimus* jouent un rôle comme vectrices. *A. fluviatilis* représente 66% des anophèles vecteurs, *A. culicifacies* 33% et *A. minimus* 0,5%.

Les recherches entomologiques ainsi que les indices parasitaires établis sur les jeunes enfants permettent d'affirmer que, dans la région de Terai, la transmission du paludisme a lieu de mars à novembre. Les indices parasitaires indiquent, à défaut de preuve entomologique, que la transmission se poursuit, dans une certaine mesure, durant les mois de

décembre à février. *A. culicifacies* est l'espèce active durant la mousson (juillet à septembre), *A. fluviatilis* avant et après la mousson. *A. fluviatilis* n'a pas, dans cette région, un caractère exclusivement zoophile; l'espèce présente un indice d'anthropophilie de 40%.

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