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MALARIA IN SARAWAK AND BRUNEI*

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SYNOPSIS

A general malaria survey of Sarawak and Brunei, two of the territories of British Borneo, is described. Contrary to what was expected in view of the climate and the general conditions, the prevalence of malaria in Sarawak and Brunei proved, on the average, to be low. The coastal areas were found to be practically free from the disease, although epidemics have occurred there in recent years. Malaria was found to be endemic in the hilly and mountainous interior. In fact, topography proved to be an important factor in malaria prevalence, the spleen- and parasite-rates, generally speaking, being higher the more abrupt the country. Differences were also observed in the prevalence among the various racial groups, but these were considered to be due to different habits and customs rather than to race itself.

Entomological studies showed that *Anopheles leucosphyrus* Dönitz was the main malaria vector in the interior of Sarawak, *A. barbirostris* playing a secondary role. *A. leucosphyrus balabacensis* had already been recognized as the malaria vector in Brunei.

The favourable results of a first field trial of residual insecticides are mentioned and plans for a nation-wide malaria-control programme are briefly outlined.

The present paper summarizes the results of a general malaria survey of Sarawak and the neighbouring State of Brunei, two British territories on the north-west coast of the Island of Borneo. The survey was made to ascertain the extent of the malaria problem in both territories and it was part of the Sarawak Malaria Pilot Project's programme of work, which included also a first field trial of residual insecticides, the results of which are discussed in a separate paper.[a]

Little was known about the prevalence and distribution of malaria in Sarawak prior to the survey. It is true that records of malaria admissions from various hospitals in the country were available, but, with the exception of the northern part of Sarawak, the country had not been surveyed for malaria and it was felt that an appraisal of the malaria problem throughout the country was necessary. The survey of Sarawak met with the difficulties to be found in a country thinly inhabited, with very poor communications,

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[a] See page 673 of this number of the *Bulletin*.

with almost no roads, and where most of the villages have to be reached by canoe or on foot. In spite of these difficulties several hundred villages were visited and nearly 10 000 people were examined in a relatively short space of time. This was only possible thanks to the great help and co-operation of the local population and of all the Government officials concerned.

Sarawak stretches along the north-west coast of Borneo, forming a strip of land some 450 miles (720 km) in length, its depth varying from 40 to 120 miles (65-190 km) and having a total surface of some 47 000 square miles (122 000 km²). The country can be divided into alluvial coastal plains, hilly country, and finally, the mountainous areas of the interior. As will be shown later, the coastal plains have little importance from the malaria point of view; it is in the hilly country and in the mountains of the interior that endemic or hyperendemic malaria is to be found. The country is covered with dense forest, without grass land or open country, the clearings found in places being man-made. Sarawak, being almost on the Equator, has a uniform climate with a considerable amount of rainfall and a high relative humidity. The mean maximum-minimum temperature is around 80° F (27° C). Precipitation varies from about 100 inches (2540 mm) near the coast of the China Sea to some 200 inches (5080 mm) in the mountainous interior. Kuching, the capital of Sarawak, in the southern part of the country has an annual rainfall of 158 inches (4010 mm). Monthly variations are small, although the Kuching records show that the months with least rainfall are June, July, and August; precipitation increases in September to reach its maximum in January. In northern Sarawak monthly variations in rainfall are very small and there are areas where there is no definite pattern in the rainfall curve. Relative humidity is always high, the average monthly records at 8 a.m. in Kuching being always above 70%, readings below 60% at any time of the day being rare; similar results have been observed at the Malaria Project Station of Marudi in northern Sarawak. Thus, it can be said that climatic conditions are favourable for malaria transmission throughout the year.

The population of Sarawak, according to the 1947 census—the last available—is 546 385. The country is inhabited by a variety of racial and cultural groups, their distribution according to the 1947 census being as follows:[3]

Racial or cultural group	*Population*	*Percentage of total population*
Sea Dayak	190 326	34.8
Chinese	145 158	26.6
Malay	97 469	17.9
Land Dayak	42 195	7.7
Melanau	35 560	6.5
Other indigenous	29 867	5.5
Other non-indigenous Asian	5 119	0.9
European	691	0.1
	546 385	100.0

The Sea Dayak, or, as they call themselves, the Iban, are the predominant racial group in Sarawak and they are probably the most homogeneous of the indigenous groups. The name Sea Dayak probably originated when Europeans found them along the coast of Borneo engaged in their piratical expeditions, but it conveys the wrong impression of people living near the sea, when in fact they have always dwelt in the interior. The Chinese are numerically the second racial group but, from the point of view of trade and economic development, they are by far the most important group in Sarawak. The Chinese, like the Malays, are mostly found living near the coast and along the great rivers. Practically all the Land Dayak—another term coined by Europeans, to designate a group which was never found near the sea—live in the interior of the 1st Division in southern Sarawak. The Melanau are found in the coastal areas of the 3rd and 4th Divisions and, though some of them retain their pagan customs, most of them have become Mahommedans like the Malays. The Kayan and the Kenyah are found in the interior of the 3rd and 4th Divisions; other indigenous races are the Murut, the Bisaya, the Kelabit, and the nomadic Punan living in the north of Sarawak. The Malay language is used as the lingua franca of this racial mosaic and is understood throughout Sarawak.

The small State of Brunei is also on the north-west coast of Borneo and forms two enclaves in the Sarawak territory. Brunei has an area of 2226 square miles (5765 km^2) and a population of 40 657, according to the 1947 census. Climatic conditions are similar to those found in Sarawak ; the population is mostly Malay.

Topography and Malaria

The general results of the malaria survey of Sarawak and Brunei are presented in Table I. Most of the information was collected between July and December 1952, but a few records from 1953 have also been included. The data show that in most places comparatively low spleen- and parasite-rates were found. This is surprising for two territories situated almost on the Equator, and is contrary to what the climate and general conditions would suggest. Most of the people live in hypoendemic areas, that is in areas where the spleen-rate in children 2-9 years old is below 10%. The estimated population living in highly malarious or hyperendemic areas, where the spleen-rate in children 2-9 years of age is above 50%, is approximately 45 000, only 8% of the combined population of the two territories.

From the first studies of McArthur [2] in Borneo it became clear that endemic malaria was to be found only in the interior, and also that in a given area, such as the Tambunan Valley in North Borneo, where the original work of McArthur was carried out, malaria was more prevalent in localities near the hills than in comparatively flat land. Our observations, made throughout the five administrative Divisions of Sarawak and in the State

TABLE I. SPLEEN AND PARASITE SURVEYS AMONG THE GENERAL POPULATION AND THE CHILDREN 2-9 YEARS OLD IN SARAWAK AND BRUNEI

Date	Area	Racial group *	General population				Children 2-9 years old			
			number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)	number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)
		1st Division								
July 1952	Kuching municipal area	Ch & D	202[a]	1	—	—	—	—	—	—
April 1953	" " "	Ch	250	0.4	125	0	114	0	58	0
"	" " "	M	250	1.6	125	0	228	1.8	113	0
July 1952	Serian road	Ch	451[a]	2.0	—	—	—	—	—	—
"	Area south of Kuching	Ch	193[a]	3.1	—	—	—	—	—	—
"	" " " "	LD	264	5.7	—	—	—	—	—	—
May 1953	Lower Sarawak River	M	78	1.3	39	0	56	1.8	29	0
July 1952	Tai-i area	LD	864[a]	29.9	—	—	—	—	—	—
"	Upper Serian District	Ch	126	7.1	64	4.7	65	4.6	34	5.9
July-August 1952	" " "	LD	1088	44.6	550	28.6	692	41.5	338	30.7
	" " "	M	54	20.4	27	7.4	25	12	12	8.3
April 1953	Sadong River (Lower Serian District)	Ch	70	2.9	35	0	28	0	15	0
"		M	109	11.9	54	1.9	42	11.9	25	4
"	" " "	SD	64	0	32	0	47	0	26	0
August 1952	Bau District	Ch	100	6	48	4.2	59	5.1	30	6.7
"	" "	LD	188	48.4	97	19.6	114	42.1	60	18.3
"	" "	M	18	5.6	10	10	5	0	3	0
April 1953	Lundu District	Ch	87	9.2	43	4.7	26	0	12	0
"	" "	LD	132	47	68	25	77	45.4	39	33.3
"	" "	M	139	22.3	69	10.1	55	14.6	27	11.1
"	" "	SD	50	8	25	40	35	5.7	18	5.5
		2nd Division								
September 1952	Batang Lupar between Simanggang and Lubok Antu	SD	291	2.7	142	2.1	180	2.8	87	2.3
"	Batang Ai above Lubok Antu	SD	267	23.6	133	15	167	24	87	13.8
"	Batang Lemanak	SD	66	6.1	34	2.9	37	8.1	20	0
"	Area south of Sabu	SD	187	7.5	95	3.2	132	6.1	66	4.5
"	Simanggang (town)	Ch	50	6	25	8	32	3.1	15	0
"	" "	M	50	2	25	4	13	0	7	14.3
"	Sebuyau	Ch	44	2.3	22	0	8	0	3	0
"	"	M	52	0	26	0	20	0	10	0

*** The following abbreviations are used to designate the common racial groups:**

Bi — Bisaya
Ch — Chinese
Ka — Kayan
Ke — Kenyah
LD — Land Dayak
M — Malay
Mu — Murut
Nom. Pu — Nomadic Punan
Pu — Punan
SD — Sea Dayak

[a] Children 2-14 years old

TABLE I (continued)

Date	Area	Racial group *	General population				Children 2-9 years old			
			number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)	number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)
		2nd Division (continued)								
May 1953	Tanjong Bijar	SD	15	0	8	0	11	0	5	0
,,	Saratok District	Ch	89	0	45	0	30	0	15	0
,,	,, ,,	M	50	0	25	0	16	0	7	0
,,	,, ,,	SD	38	0	19	0	16	0	10	0
,,	Betong District	Ch	66	0	33	0	27	0	12	0
,,	,, ,,	M	50	6	25	0	35	5.7	17	0
,,	,, ,,	SD	266	5.3	132	5.3	152	5.9	81	4.9
		3rd Division								
October 1952	Sungei Kanowit	Ch	51	0	26	7.7	20	0	10	0
,,	,, ,,	M & SD	21	14.3	10	0	15	0	7	0
,,	,, ,,	SD	116	6.9	58	12.1	70	5.7	29	13.8
,,	Sungei Julan	SD	88	11.4	42	7.1	46	8.7	23	4.3
October 1952	Sungei Poi	SD	136	9.6	70	11.4	82	8.5	39	12.8
,,	Sungei Ngemah	SD	156	22.4	79	17.7	90	24.4	42	24.4
,,	Batang Rajang between S. Poi and S. Ngemah	SD	55	10.9	25	8	33	6.1	15	6.7
		4th Division								
March 1953	Marudi (Lower Baram)	Ch	25	16	13	0	15	6.7	9	0
,,	,,	M	36	5.6	18	0	21	0	9	0
November-December 1952	Baram River from above Marudi to Long Lama	Ch	30	13.3	15	20	9	11.1	5	20
		Ke	113	24.8	55	9.1	52	28.8	22	22.7
,,	,, ,, ,,	Ke & Ka	60	40	31	32.3	37	48.6	20	40
,,	,, ,, ,,	M	12	8.3	6	16.7	9	11.1	5	20
,,	Baram River between	Ch	41	29.3	20	10	14	0	6	0
,,	Long Laput and Long	Ka	204	36.8	103	33	126	41.3	66	31.8
,,	Akah	Ke	61	50.8	30	20	18	44.5	9	11.1
,,	,, ,, ,,	Pu	28	46.5	14	28.6	9	100	4	75
December 1952-February 1953 November 1953	Baram River above Long Akah	Ke	311	64	155	38.8	186	67.7	96	46.8
		Nom. Pu	127	11.8	64	6.2	23	26.1	11	18.2
March 1953	Tutoh River	Bi	16	43.7	8	37.6	12	33.3	6	16.7
,,	,, ,,	Ch	13	7.7	6	16.7	5	20	3	33.3
,,	,, ,,	Ka	38	23.7	19	5.3	23	8.7	13	7.7
,,	,, ,,	Ke	23	17.4	12	0	15	6.7	7	0
March-August 1953	Tinjar River	Ch	19	5.3	9	0	16	6.2	8	0
August 1953	,, ,,	Ke	198	34.4	102	14.7	82	31.7	43	23.2
	,, ,,	Pu	54	42.6	27	33.3	10	70	5	80

TABLE I (concluded)

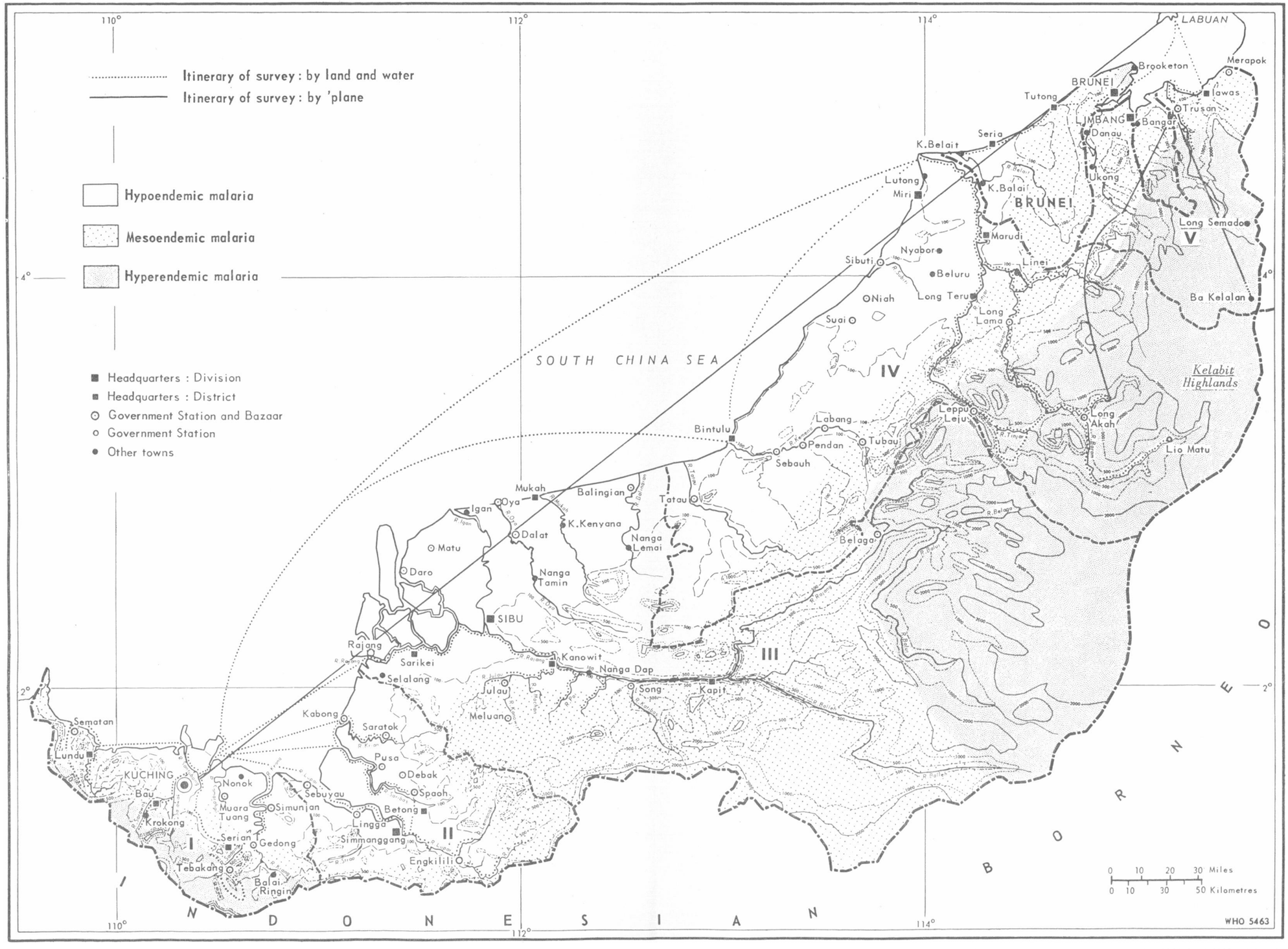
Date	Area	Racial group *	General population				Children 2-9 years old			
			number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)	number examined	spleen-rate (%)	number of blood examinations	parasite-rate (%)
		4th Division (continued)								
June 1953	Akah River	Ka	90	41.1	44	22.7	48	33.3	28	21.4
"	" "	Ke & Pu	30	60	14	42.9	12	75	7	42.8
March 1953	Bintulu River	Ch	46	2.2	23	0	34	2.9	17	0
"	" "	M	50	40	25	0	26	0	13	0
		5th Division								
November 1952	Trusan River	M	42	14.3	22	9.1	31	9.7	17	5.9
"	" "	Mu	153	38.6	74	25.6	66	36.4	38	26.3
"	Lawas River	Ch	50	2	25	4	37	2.7	19	5.3
"	" "	M	47	17	23	4.3	22	18.3	13	7.7
"	" "	M & Ch	24	8.3	11	0	15	0	6	0
"	Murut highlands	Mu	221	56.1	112	16.9	70	50	33	33.3
		Brunei								
December 1952	Brunei town	Ch	51	3.9	26	0	29	0	15	0
"	" "	M	170	3.5	85	0	110	1.8	54	0
"	Brunei River	M	60	30	30	6.7	32	34.4	15	13.3
"	Tutong road	M	122	30.3	61	8.2	82	25.6	40	5
"	Muara road	M	121	52	61	13.1	55	56.4	28	14.3

of Brunei, confirm McArthur's findings and stress the importance of topography when evaluating the malaria problem in Borneo.

The malaria map (Fig. 1) shows clearly the close relationship between malaria and topography. It has been prepared from the results presented in Table I, and to give an indication of the " reliability " of the map, the itinerary of the survey is shown on it. The 1st and 2nd Divisions were thoroughly examined and we are satisfied that sufficient information was collected in the 4th and 5th Divisions and in Brunei, but, as Fig. 1 shows, the 3rd Division, covering the large Rejang Valley, was only partly surveyed. There is a wide gap in the interior of the 3rd Division—an area very thinly inhabited, however—where our records are lacking and our estimates have to be accepted with due caution.

Hypoendemic malaria is found in areas below the 100-foot (30-m) level, the first contour line shown on the map. Mesoendemic malaria is found in higher country, and hyperendemic malaria is usually found in the

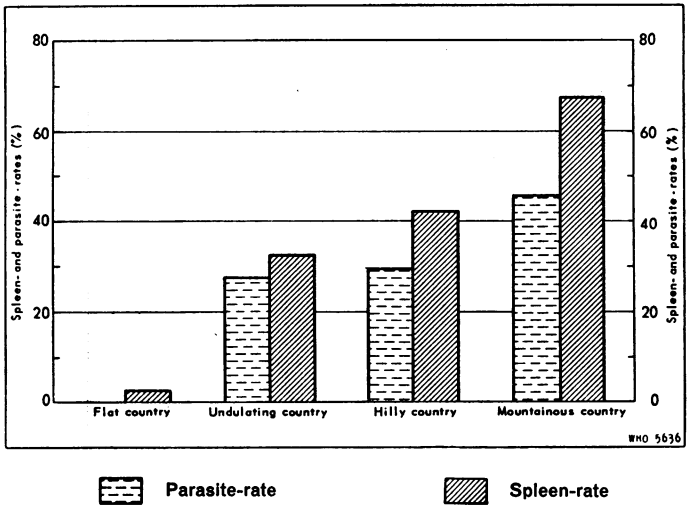
FIG. 1. MALARIA PREVALENCE IN SARAWAK AND BRUNEI, BASED ON RESULTS OF 1952-53 SURVEY



Contour lines are shown up to the 2000-foot (600-m) level.
The Roman numerals indicate the five administrative Divisions of Sarawak.

mountainous interior. It is only in the extreme south and in the northern part of Sarawak, and in Brunei, where the mountains come close to the sea, that highly endemic malaria is found relatively near the sea. It is the declivity of hills and mountains which makes an area malarious rather than its altitude above sea level. This is due to the habits of *Anopheles leucosphyrus*, which was first recognized by McArthur [2] as the main malaria vector in Borneo. *A. leucosphyrus balabacensis*, the vector responsible for malaria transmission in North Borneo, and *A. leucosphyrus* Dönitz, the carrier in Sarawak (D. H. Colless, unpublished report, 1953), usually breed in seepage water at the foot of hills and in temporary pools formed by mountain streams; the two types of *leucosphyrus* are not found breeding in the flat land or in the coastal areas.

FIG. 2. MALARIA PREVALENCE ALONG THE BARAM RIVER (4th DIVISION)



To give an idea of the distribution of malaria along the rivers of Sarawak, the spleen- and parasite-rates found along the River Baram in the 4th Division of Sarawak are shown graphically in Fig. 2 ; as can be seen, the further up-country one goes, the higher the malaria rates are.

Racial Groups and Malaria

Apart from the topography which gives the clue to the malaria prevalence in Sarawak and Brunei, racial groups are also of importance from the malaria point of view. Conditions in the interior of Sarawak have hardly changed in recent times and the mosaic of races of this primitive country

FIG. 3. LAND DAYAK WOMEN IN FESTIVAL DRESS, UPPER SERIAN DISTRICT (1st DIVISION)

The girls at the sides had enlarged spleens.

has been maintained up to the present day, each racial group keeping its customs and its way of life. There is much in common, however, between the various groups living in the interior. Dayak, Kayan, and Kenyah all have a semi-nomadic way of life, building the so-called " longhouses ", which have been defined as villages under a single roof, and making temporary shelters or farms on the slopes of the mountains where they plant their rice (see Fig. 3-5). Areas for cultivation are cleared by cutting and burning the forest. Since the land yields little under the very primitive methods used by the Dayak and related tribes, new patches of forest have to be cleared every year and new shelters are built in the clearings. Irri-

FIG. 4. FAMILY LIFE IN A KENYAH LONGHOUSE, UPPER BARAM (4th DIVISION)

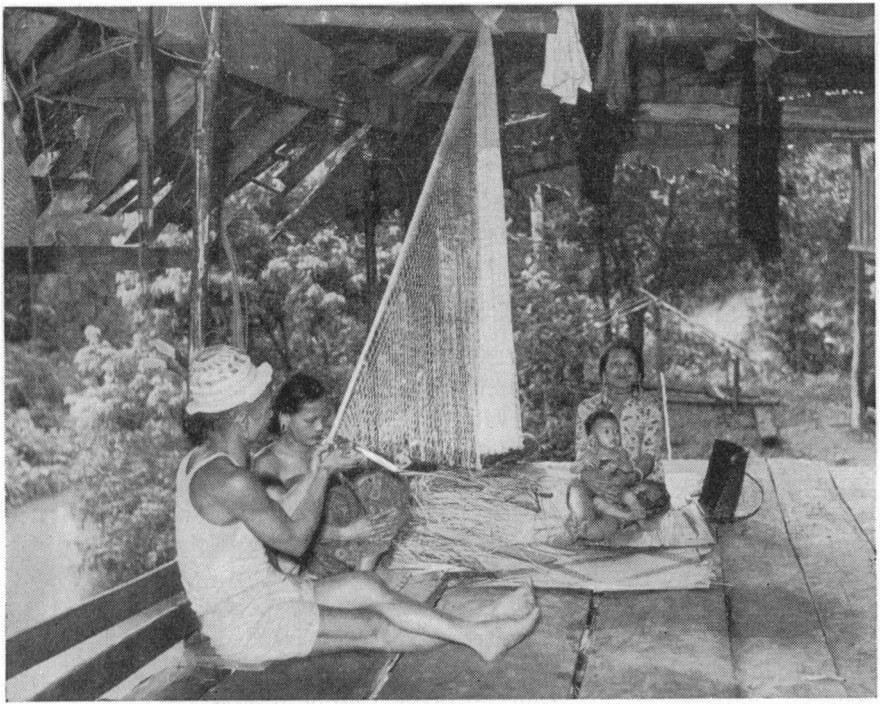


FIG. 5. A SEA DAYAK FARM, KANOWIT DISTRICT (3rd DIVISION)

gated rice-fields ploughed by water buffaloes, known throughout South-east Asia and even in North Borneo among the Murut and Dusun, are unknown among the Dayak, Kayan, and Kenyah groups, which form the bulk of the population in the interior of Sarawak and in large areas of Indonesian Borneo.

Our observations show that these racial groups suffer much more from malaria than do the Malays and the Chinese. The contrast between the Dayak and the Chinese is particularly interesting, since these groups are often found living in the same areas, but have widely different ways of life. We have calculated the average spleen- and parasite-rates (all ages) for the two groups in the rural areas of the 1st Division. The spleen- and parasite-rates for the Chinese were 6.5% and 3.7% respectively, and for the Land Dayak 44.7% and 27.0% respectively. The prevalence of malaria among the two groups is thus widely different, and this in spite of the fact that these total figures are based on observations made in the same areas. A clear-cut example of the difference between the Chinese and the Land Dayak as regards malaria is afforded by the results obtained in Tebedu, a small village in the Upper Serian District (1st Division). Spleen- and parasite-rates among 76 Chinese examined were 9.2% and 5.1% respectively and among 85 Land Dayak examined 63.5% and 30.9% respectively, and we would like to point out here that the Land Dayak longhouse was no more than 200 yards from the Chinese bazaar. Such a marked difference is due in our opinion to the habits and way of living rather than to race itself. We believe that the Dayak habit of living during several months in their small shelters or rice farms has a considerable bearing on malaria prevalence. People are less protected there against mosquitos than they are in the longhouses. Besides, domestic animals capable of deflecting anophelines from human beings are fewer than in longhouses and, assuming that breeding conditions were uniform, the number of anophelines per person would be higher in an isolated farm than in a longhouse containing several hundred people, a point that our observations in northern Sarawak have confirmed. If the agricultural activities have considerable importance, protection against mosquitos and prompt treatment against malaria must also have a definite bearing on malaria-rates. The Chinese living in the bazaars are probably less exposed than the Dayak and, being more conscious of the malaria danger, they protect themselves better; and we believe that the combined effect of all these factors produces the striking difference between the Chinese and Dayak groups.

All the people living in the interior suffer more from malaria than the inhabitants of the coastal areas, but the prevalence of the disease is not uniform among the various groups. The Sea Dayak, or Iban, have in general lower spleen- and parasite-rates than the Land Dayak, the Kayan, or the Kenyah. This is particularly noticeable in the 2nd Division, the real Sea Dayak country. Although the general features of the interior of the

1st and 2nd Divisions are almost identical, and although the ways of life of the Sea Dayak and the Land Dayak are almost the same, the Sea Dayak appear to suffer much less from malaria than their neighbours, the Land Dayak. We have been unable to find a satisfactory explanation for this difference but, during the survey of the upper part of the 2nd Division, it was noticed that *A. leucosphyrus* was less abundant in the Sea Dayak longhouses than in the longhouses of the Land Dayak in the 1st Division, and it is possible that, in spite of a similar topography, the interior of the 2nd Division is less favourable for the breeding of *A. leucosphyrus* than the interior of the 1st Division. Soil formation may prove to be the real cause of the difference between the two neighbouring areas.

Other groups with comparatively high spleen- and parasite-rates are the Kayan, the Kenyah, and the Murut in northern Sarawak. Tables II and III show the distribution of malaria by age-groups among the Land Dayak in the interior of the 1st Division and in the Murut highlands in the 5th Division—two typical examples of high endemicity in Sarawak. As can be seen, the highest spleen- and parasite-rates among the Land Dayak are found in the age-group 5-9 years. In the case of the Murut, the highest spleen-rate is found in adolescents 10-14 years old. The highest parasite-

TABLE II. DISTRIBUTION OF MALARIA BY AGE-GROUPS AMONG THE LAND DAYAK, UPPER SERIAN DISTRICT (1st DIVISION)

		Age-group (years)					Total
		1	2-4	5-9	10-14	adults	
Number of spleens examined		—	327	364	358	37	1 086
Splenic enlargement	1	—	19	37	46	2	104
	2	—	62	136	116	2	316
	3	—	17	15	20	1	53
	4	—	1	1	1	0	3
	5	—	0	0	0	0	0
Total enlarged spleens		—	99	189	183	5	476
Spleen-rate (%)		—	30.3	51.9	47.5	13.5	43.8
Number of blood examinations		—	161	176	187	24	548
Parasites	V	—	10	6	5	0	21
	F	—	17	20	19	2	58
	M	—	19	29	21	4	73
	Mx	—	2	1	3	0	6
	G	—	17	14	10	1	42
Total parasites		—	48	56	48	6	158
Parasite-rate (%)		—	29.8	31.8	25.7	25	28.8

TABLE III. DISTRIBUTION OF MALARIA BY AGE-GROUPS IN THE MURUT HIGHLANDS (5th DIVISION)

		Age-group (years)					Total
		1	2-4	5-9	10-14	adults	
Number of spleens examined		8	31	39	11	132	221
Splenic enlargement	1	0	1	8	4	6	19
	2	0	11	9	4	47	71
	3	1	0	5	0	17	23
	4	0	0	1	0	8	9
	5	0	0	0	0	2	2
Total enlarged spleens		1	12	23	8	80	124
Spleen-rate (%)		25.0	38.7	59.0	72.7	60.6	56.1
Number of blood examinations		5	15	18	4	67	109
Parasites	V	0	1	1	0	1	3
	F	1	3	5	0	4	13
	M	0	1	0	1	0	2
	Mx	0	0	0	0	0	0
	G	1	1	3	0	1	6
Total parasites		1	5	6	1	5	18
Parasite-rate (%)		20.0	33.3	33.3	25.0	7.5	16.5

rate, however, is found in the age-groups 2-4 years and 5-9 years. Very similar results were found among the Kenyah and Kayan of the Upper Baram (4th Division) and have been discussed elsewhere.[a] It appears that in the endemic areas of Sarawak only a slight tolerance to malaria infection is developed in adolescents and adults, who show comparatively high spleen- and parasite-rates and who, in fact, suffer from overt attacks of malaria. In Tables II and III no distinction is made between males and females because no significant difference in malaria prevalence was found between the two sexes—a finding which applies to all the inhabitants in the interior of Sarawak. Such a difference would hardly be expected, since men and women are engaged in the same occupations: clearing the forest, planting and harvesting the rice, manning the canoes along the river, and building longhouses and rice farms.

A group numerically small but culturally important is the Kelabit, living in the highlands of the Upper Baram District near the Indonesian border. Though the Kelabit country was not visited by us, the area is shown on the malaria map (Fig. 1) as hyperendemic, since hyperendemic conditions were found in the neighbouring Murut highlands at approximately the same altitude (4000 feet (1220 m) above sea level). Mr. H. Brodie, Travelling

[a] See article on page 673 of this number of the *Bulletin*.

Superintendent, Sarawak Medical Department, found an average spleen-rate of 58% among 279 children, 1-10 years old, who were examined during his visit to the Kelabit highlands in 1954. We had found in 1952 a spleen-rate of 60% among a group of Kelabit travelling down-country. Thus the Murut and Kelabit highlands should be considered as hyperendemic and, since these are the highest inhabited areas in Sarawak, it is clear that altitude alone does not make any part of the country free from malaria.

The observations made on malaria prevalence among the Punan are of particular interest, owing to the nomadic habits of this group. They are hunters and food-gatherers, living deep in the forest in the remote interior of the 3rd and 4th Divisions, often going on their periodical wanderings to the Indonesian side of Borneo. Shy and elusive, the Punan seldom came in contact with Europeans and with the settled tribes of the interior until recent years. The Sarawak Government has arranged for periodical gatherings of these forest dwellers where they can trade and barter their forest produce under Government protection. The nomadic Punan mentioned in Table I (4th Division) were examined during these periodical meetings, and it will be observed that, in spite of their primitive habits and complete lack of protection against mosquitos, their spleen- and parasite-rates are lower than those of the Kayan and the Kenyah living in the same area. The settled Punan, building longhouses and planting rice in the Upper Baram and in the neighbouring Tinjar valley (mentioned also in Table I, 4th Division), have also higher spleen- and parasite-rates than their nomadic relatives, who seldom stay in one place for more than a few days or weeks.

There seem to be two possible explanations for the low malaria level of the nomadic Punan: (1) that they do not live long enough in one place to infect *Anopheles* mosquitos and set up malaria transmission, and (2) that the anopheline fauna in the virgin forest may be different from that in the areas where their settled neighbours live and where there is a good deal of secondary growth. We believe that the first explanation is the correct one and that the low spleen- and parasite-rates of the nomadic Punan are related to their nomadic habits.

Before concluding the discussion on malaria prevalence among the various racial groups, a few words should be added about the Malays. In Sarawak they live on the coast and along the large rivers and suffer comparatively little from malaria. In the State of Brunei, however, relatively high spleen- and parasite-rates are found among the rural Malays, though Brunei Town is practically free from malaria. As pointed out before, the comparatively high incidence of malaria in the Brunei coastal areas is probably due to the proximity of the hills and mountains to the sea.

Regarding the distribution of malaria parasites in Sarawak and Brunei, the results summarized in Table IV show that the predominant species was *Plasmodium falciparum*, though *P. malariae* was the most abundant species in the Upper Serian District (1st Division of Sarawak) and in the Tinjar

TABLE IV. DISTRIBUTION OF MALARIA PARASITES IN SARAWAK AND BRUNEI

Date	Area	Racial group	Number of positive cases			Percentage distribution		
			P. vivax	*P. falciparum*	*P. malariae*	*P. vivax*	*P. falciparum*	*P. malariae*
July-August 1952	Upper Serian District, 1st Division	Land Dayak	26	60	74	16.2	37.5	46.3
August 1952	Bau District, 1st Division	" "	4	10	6	20.0	50.0	30.0
September 1952	Simanggang District, 2nd Division	Sea Dayak	4	13	12	13.8	44.8	41.4
October 1952	Kanonit District, 3rd Division	" "	13	17	8	34.2	44.7	21.1
November-December 1952	Baram River, 4th Division	Kayan & Kenyah	41	47	23	36.9	42.3	20.8
August 1953	Tinjar River, 4th Division	Kenyah & Punan	6	7	12	24.0	28.0	48.0
November 1952	Murut highlands and Trusan River, 5th Division	Murut	12	19	7	31.6	50.0	18.4
December 1952	Brunei	Malay & Chinese	2	9	4	13.4	60.0	26.6
Totals			108	182	146	25.0	41.5	33.5

Valley (4th Division). We do not know if this has a particular significance or if it is merely a matter of random distribution. What may be added here is that the areas where *P. malariae* was predominant were not areas of decreasing endemicity. On the contrary, subsequent observations showed that the malaria level was rising in the Tinjar Valley and possibly in the Upper Serian District.

Malaria Transmission

The entomological observations made in the interior of Sarawak have shown that *A. leucosphyrus* is the main malaria vector and that *A. barbirostris* plays a secondary role in malaria transmission. D. H. Colless, WHO Consultant, (unpublished report, 1953) showed that the vector in the Upper Baram in northern Sarawak was *A. leucosphyrus* Dönitz, 1901, and not *A. leucosphyrus balabacensis*, the proved vector in British North Borneo and Brunei. Taxonomic differences between the two types are very small and their bionomics do not differ much; nevertheless, their ability as vectors does not seem to be the same. Among 7568 *A. leucosphyrus* Dönitz dissected in the Upper Baram District in northern Sarawak we found a sporozoite-

rate of 0.40%, whereas the sporozoite-rate of *A. leucosphyrus balabacensis* found in North Borneo was 2.4% (McArthur [2]), and in the island of Labuan off the coast of Borneo, 1.6% (Colless [1]). How far this difference is due to the general conditions and how far to the vector itself, it is difficult to say, but the difference clearly exists and should be kept in mind always when comparing malaria in Sarawak with malaria in North Borneo.

Mosquito dissections were carried out at Marudi, in the Lower Baram, with a view to determining the possible malaria vector in a hypoendemic area. In all, 3195 *A. letifer*, 1013 *A. barbirostris*, and 250 other anophelines were dissected in a 15-month period, but the results were all negative and we were unable to solve the problem of the possible vector, if any, in a hypoendemic area such as the Lower Baram. It is worth recording here that *A. barbirostris*, which proved to be a secondary vector in the Upper Baram, in places where *A. leucosphyrus* was responsible for most of the malaria transmission, failed as a vector in the absence of *A. leucosphyrus*. Also, the curious finding of six gland infections among the *A. letifer* dissected in Marudi deserves mention. It was the opinion of P. G. Shute (personal communication, 1954), to whom the material was sent in consultation, that the parasites were probably sporozoites according to their morphology, but were not of human origin. This observation indicates the need to interpret always with caution the results of gland infections.

The infant parasite-rates found in the survey of Sarawak are summarized in Table V, and, as can be seen, they are remarkably low when compared with the results of the other spleen and parasite surveys. We do not think that the comparatively low sporozoite-rate alone can account for these very low infant parasite-rates. We have pointed out elsewhere[a] that the wide-

TABLE V. INFANT PARASITE-RATES IN SARAWAK

Date	Area	Racial group	Number of infants examined	Infant parasite-rate (%)
July-August 1952	Upper Serian District, 1st Division	Land Dayak	83	9.6
August 1952	Bau District, 1st Division	" "	17	11.8
September 1952	Simanggang District, 2nd Division	Sea Dayak, Chinese & Malay	68	0.0
October 1952	Kanowit District, 3rd Division	Sea Dayak	80	2.5
February 1953	Baram River, 4th Division	Kayan & Kenyah	99	16.1
August 1953	Tinjar River, 4th Division	Kenyah & Punan	26	7.7
November 1952	Murut highlands and Trusan River, 5th Division	Murut	34	5.9

[a] See article on page 673 of this number of the *Bulletin*.

TABLE VI. RELATIVE ABUNDANCE OF ANOPHELINES IN NIGHT HOUSE-CAPTURES IN BARAM DISTRICT (4th DIVISION)

Species	Locality	Number captured	Percentage distribution				
			20.00-22.00 hours	22.00-24.00 hours	00.00-02.00 hours	02.00-04.00 hours	04.00-06.00 hours
A. leucosphyrus	Leppu Leju	6 330	6.8	20.6	29.3	24.2	19.1
A. barbirostris	,, ,,	284	12.0	32.2	27.8	14.7	13.3
A. barbirostris	Marudi	947	27.1	21.6	19.3	16.3	15.7
A. letifer	,,	2 739	25.3	23.2	18.5	16.5	16.5

spread use of mosquito nets may effectively protect the infants, since *A. leucosphyrus* tends to visit the human dwellings late in the night.

Table VI shows the distribution of anophelines in night house-captures made at two-hourly intervals; the results are based on monthly captures made over a period of 15 months in Leppu Leju, in the Upper Baram District, and in Marudi in the Lower Baram. The mosquitos were caught resting on the walls before or after feeding. *A. leucosphyrus* was clearly much more abundant between midnight and 2 a.m. than earlier in the night and, in fact, hardly any specimen of *A. leucosphyrus* could be found in our catching-stations before 8 p.m. The other two species, *A. barbirostris* and *A. letifer*, tended to visit the houses earlier than *A. leucosphyrus*, though it was interesting to find in the case of *A. barbirostris* caught in both the Upper and the Lower Baram that the locality had some influence on the relative abundance of this anopheline in night house-captures.

A summary, based on the series of night house-captures discussed above, of the distribution of anophelines at different levels is presented in Table VII. When considering the results it must be kept in mind that we are referring to the height above the floor, which in Sarawak is usually several feet above the ground, the houses being built on poles. The results shown in Table VII indicate that a considerable number of anophelines is captured above 5 feet (1.5 m), and this points to the necessity of applying insecticides high up on the walls in residual-spraying operations.

Rainfall in the Baram District is evenly distributed throughout the year with very little difference from month to month. It was found, however, that the density of all the mosquitos in the area followed the small variations in the rainfall curve. The population of *A. leucosphyrus*, *A. barbirostris*, and *A. letifer* seems to increase when the rainfall increases, and this applies also to the culicine species of the area. The results of mosquito dissections made in the Upper Baram District have been discussed elswhere,[a] but it may be said here that, as judged by the sporozoite-rate, transmission seems to be

[a] See article on page 673 of this number of the *Bulletin*.

TABLE VII. DISTRIBUTION OF RESTING ANOPHELINES AT DIFFERENT LEVELS IN NIGHT HOUSE-CAPTURES IN BARAM DISTRICT (4th DIVISION)

Species	Locality	Number captured	Percentage distribution		
			up to 3 feet	3-5 feet	above 5 feet
A. leucosphyrus	Leppu Leju	6 330	48.2	32.8	19.0
A. barbirostris	,, ,,	284	53.7	29.8	16.5
A. barbirostris	Marudi	947	48.8	36.8	14.4
A. letifer	,,	2 739	37.5	38.2	24.3

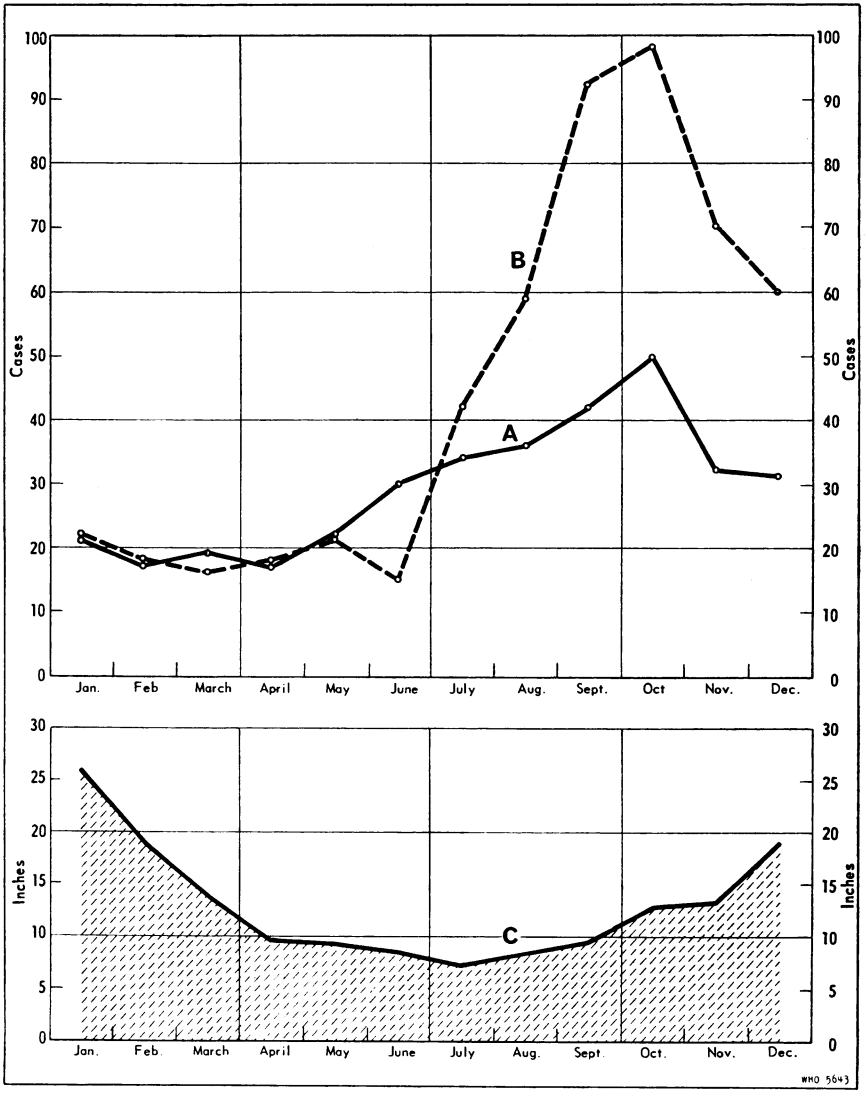
higher from January to June than from July to December, and that the results of the periodical spleen and parasite surveys indicate also that there was more malaria transmission in the first half than in the second half of the year. This, however, does not seem to be related either to the amount of rainfall or to the size of the vector populations.

In the southern part of Sarawak no information was collected by the Malaria Pilot Project on seasonal fluctuations of malaria transmission, but the records of malaria admissions to the Kuching hospital—a reliable and large sample—show a very definite trend in the curve of malaria cases. Kuching has a definite annual cycle in rainfall and we believe it is worth summarizing here the monthly cases of malaria in the Kuching hospital from 1945 to 1952 and the Kuching rainfall, based on records from 1876 to 1952.

	J	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
Kuching rainfall (inches)	26.2	19.3	14.0	9.7	9.3	8.7	7.3	8.5	9.7	12.9	13.5	19.0
Laboratory malaria cases	21	17	19	17	22	30	34	36	42	50	32	31
Clinical malaria cases	22	18	16	18	21	15	42	59	92	98	70	60

As can be seen, both laboratory and clinical malaria cases increased during the comparatively dry part of the year, reaching a peak in October. The results are shown graphically in Fig. 6, and there can be no doubt that in the 1st Division seasonal variations in malaria transmission occur. On the north coast of Java (W. J. Stoker, personal communication, 1955) a similar rainfall curve is found, together with a similar curve of malaria incidence. The vector there is *A. sundaicus*, and it may be thought that the malaria cases in the Kuching hospital are also due to this vector. We do not think, however, that this is so. The *sundaicus* areas in the 1st Division are very thinly inhabited and according to our records there is at present practically no malaria. Furthermore, the Chinese, who form the bulk of the Kuching malaria cases, are hardly found in *sundaicus* areas. They live mostly in

FIG 6. KUCHING RAINFALL AND MALARIA ADMISSIONS TO KUCHING HOSPITAL



A = laboratory malaria cases B = clinical malaria cases C = Kuching rainfal

localities where the vector would be *A. leucosphyrus*, and we think it likely that *A. leucosphyrus* was responsible for most of the malaria cases in the Kuching hospital.

Malaria Control

The first experiment in malaria control by residual spraying in the interior of Sarawak was carried out in the Baram District in northern Sarawak. The observations made from November 1952 through January 1955 have been discussed elsewhere,[a] but it may be said here that the results obtained are considered satisfactory, since a high degree of malaria control was achieved, and, with a few exceptions, malaria transmission was interrupted. The difficulties encountered were due mostly to the habits of the local population, semi-nomads, living often in temporary shelters, rather than to the vector, *A. leucosphyrus* Dönitz, which, in spite of its elusive reputation, was found resting indoors on the walls. In view of the encouraging results obtained in this first experiment, the Sarawak Government has voted ample funds for a five-year nation-wide campaign of residual spraying with insecticides. Funds have also been allocated in Brunei to start a malaria-control programme throughout the State.

Two insecticides were used in the Baram experiment—BHC and DDT—and it was found that the former, requiring four sprayings per year, was not suitable for a country with such poor communications as Sarawak. The cost of DDT-spraying operations in the Baram pilot scheme was comparatively high: US$ 0.45 per person protected per year. This was due to the great difficulties of communication in the area and to the need for spraying twice a year and for protecting the longhouses and the temporary rice farms. An insecticide of more lasting effect than DDT would have clear advantages in Sarawak and a field trial of dieldrin is now in progress in the interior of the 1st Division. If a single spraying of this insecticide proves to be sufficient, the cost of spraying operations will be much reduced. Transport expenses will be lower in other parts of Sarawak than in the Baram District, where the difficulties of transport are extreme.

Any method based on larval control is considered impracticable in Sarawak. It would be difficult to carry out effective larval-control measures around the villages in the interior, and it would be practically impossible to carry them out around each isolated farm or shelter built each year in the clearings made for planting the rice. For this reason we believe that the naturalistic control method proposed by McArthur,[2] though perhaps feasible in certain areas of North Borneo with a settled population, is completely impracticable among the Dayak and related groups living in the interior of Sarawak.

The nation-wide programme envisaged by the Sarawak Government raises the question of which areas can be considered as malarious and which not. In general, in an equatorial country, it is difficult to draw a line between non-malarious areas, that is areas without transmission, and

[a] See article on page 673 of this number of the *Bulletin*.

malarious areas in which transmission takes place. In the case of Sarawak we believe that there is malaria transmission in the hyperendemic and mesoendemic areas, but it is more difficult to say what happens in the hypoendemic areas. We are satisfied that only in a few places, such as the Kuching municipal area, is there no malaria transmission, and think that in most areas with very low spleen- and parasite-rates there is probably malaria transmission. Even in coastal areas where there is practically no malaria at present, epidemics may occur and, in fact, have occurred in recent times. We can say, therefore, that with a few exceptions, such as Kuching and possibly Brunei Town, and a few other urban areas, the whole of Sarawak and Brunei should be considered as potentially malarious, and, in a programme based on a nation-wide scale, control measures for the whole country should be devised.

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RÉSUMÉ

Une enquête sur l'endémie paludéenne a été effectuée sous les auspices de l'OMS en 1952. La population de Sarawak appartient à divers groupes raciaux et culturels dont les principaux sont les Dayaks de la mer, les Chinois, les Malais, les Dayaks des terres et les Melanau. Les Dayaks de la mer, qui en fait vivent à l'intérieur des terres, représentent le groupe le plus nombreux (34,8 % du total) et le plus homogène; les Chinois forment le second groupe, du point de vue numérique (26,6 %), mais le plus important sur le plan économique. Comme les Malais, ils vivent surtout le long des côtes et sur les bords des grandes rivières. Brunéi, enclave dans le territoire de Sarawak, a quelque 40 000 habitants, la plupart Malais, les conditions climatiques sont celles de Sarawak.

Il existe une relation étroite entre la fréquence du paludisme et la topographie de Sarawak. Le paludisme est hypoendémique dans les terres basses, jusqu'à 30 m d'altitude; il est mésoendémique dans les terres plus accidentées et hyperendémique dans les régions montagneuses de l'intérieur. Ce n'est qu'à l'extrême sud et dans le nord de Sarawak, où les montagnes sont proches de la mer, que l'on rencontre le paludisme près du littoral. Ce sont les déclivités des collines et des montagnes plutôt que l'altitude qui déterminent l'endémie paludéenne. Il faut en chercher la cause dans les mœurs d'*Anopheles leucosphyrus*, principal vecteur du paludisme à Bornéo, qui gîte dans les eaux d'infiltration au pied des collines et dans les mares temporaires formées par les eaux de ruissellement.

D'autre part, l'intensité de l'endémie paludéenne varie aussi selon le groupe racial. Ainsi, par exemple, les Dayaks, Kayan et Kenyah souffrent du paludisme plus que les

Chinois et les Malais. Le contraste entre Dayaks et Chinois est particulièrement frappant dans les régions où habitent ces deux groupes, qui ont des genres de vie très différents. Dans la même région, les indices splénique et parasitaire étaient de 6,5% et 3,7% respectivement chez les Chinois et de 44,7% et 27,0% chez les Dayaks des terres. Ces différences semblent être dues à des habitudes de vie plutôt qu'à un facteur racial proprement dit. Les Dayaks, semi-nomades, vivent pendant plusieurs mois de l'année dans les huttes qu'ils construisent dans leurs rizières où ils sont moins protégés des piqûres que dans leurs « maisons communes »; dans ces dernières, les chances de piqûres sont réparties entre les centaines de personnes qui y habitent. Les Chinois, sédentaires en revanche, installés dans les bazars, sont moins exposés que les Dayaks et, mieux avertis des dangers des piqûres, s'efforcent de les éviter.

La lutte entreprise dès 1952 a donné des résultats qui ont engagé le Gouvernement de Sarawak à établir un plan quinquennal de lutte antipaludique. A Brunéi, des fonds ont été alloués pour une campagne antipaludique.

Les difficultés rencontrées dans l'application de mesures de lutte tenaient plus au genre de vie des habitants qu'aux mœurs du moustique, qui, contrairement à ce que l'on croyait, se repose sur les parois à l'intérieur des habitations et peut y être atteint par les pulvérisations d'insecticides à effet rémanent.

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