Epidemiology and Control of Malaria in Suriname[1]

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Malaria is endemic in the interior of Suriname. However, epidemiologic data indicate that as of 1985 the only permanent malaria focus was located in an area along the Upper Marowijne River. The existence of this focal area can be accounted for partly by relatively high and stable numbers of the local malaria vector, Anopheles darlingi, *in the region and also by frequent travels of local inhabitants within the Upper Marowijne region. Government workers from this area appear to have played a significant role in spreading malaria to other parts of the country.*

Suriname can be divided into zones with different ecologic and malarial characteristics that correspond closely to the distribution pattern of the principal malaria vector, *Anopheles darlingi* Root. In the interior, within the primary rain forest area south of the limit of tidal influence (see Figure 1), *An. darlingi* occurs in stable populations throughout the year but exhibits regional differences with respect to abundance and seasonal fluctuations (*1*). *Plasmodium falciparum, P. vivax,* and possibly *P. malariae* are endemic in this area, despite attempts to control malaria since the 1950s through residual house spraying with DDT and treatment of positive cases.

North of the interior, where the rivers are influenced by tidal action, *An. darlingi* occurs in small numbers and unstable populations; here it has been collected on rare occasions in only a few localities. As previously noted by Rozendaal (*1*), this is probably due to the tidal action, which prevents development of suitable breeding habitats such as pools and other quiet places along the riverbanks. Breeding is therefore restricted mainly to submerged forested areas in the rainy season.

Within the partly cultivated coastlands, *An. darlingi* does not occur at all. Malaria disappeared from the coastlands in 1950–1960, following an eradication campaign based on DDT house spraying plus increased case detection and treatment. In this area, *P. vivax* was the predominant malaria species, but *P. falciparum* and *P. malariae* also occurred (*2, 3*). *Anopheles aquasalis* was generally considered to be the vector (*3, 4*).

In the savanna belt situated between the coastlands and the interior (see Figure 1) malaria transmission was less severe than in the interior but more intense than in the coastlands (*3, 5*). After malaria was eradicated from the coastlands, only small isolated outbreaks of the disease recurred in this savanna belt. Besides *An. darlingi*, a few other *Anopheles* species have also been considered incidental vectors in this region (*1, 6, 7*). However, conditions for malaria transmission appear unfavorable because of the unstable nature of vector populations

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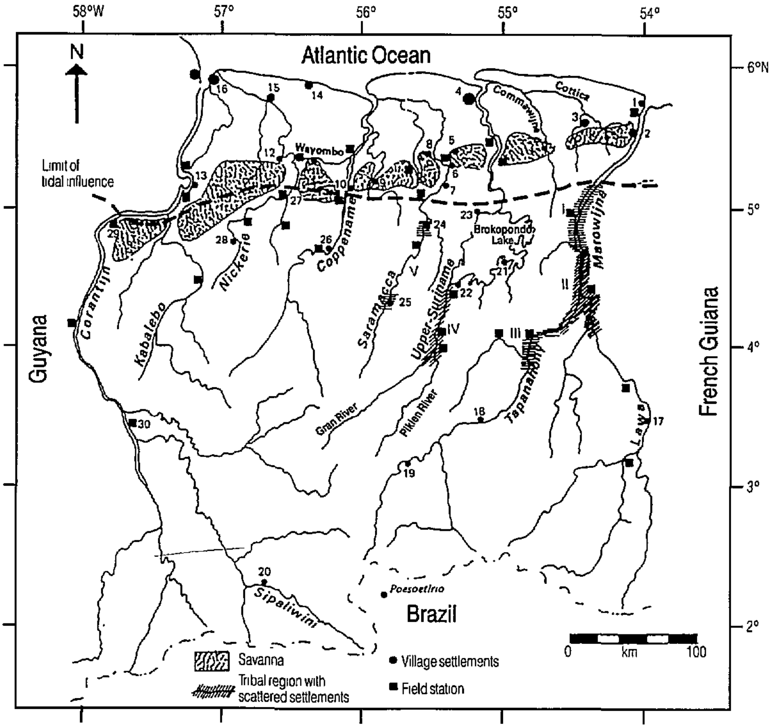
Figure 1. A map of Suriname showing inhabited centers and tribal areas cited in the text, the limits of tidal action, the savanna belt, and the observed intensity of malaria transmission and *Anopheles darlingi* infestation.



Legend

Bushnegro tribal regions: I. Paramaccan; II. Bilo-Djukan; III. Opo-Djukan; IV. Saramaccan; V. Matuay.

Settlements in tidal zone:

Name	Malaria transmission	*An. darlingi* infestation
1. Galibi	±	±
2. Albina	±	±
3. Moengo	±	±
4. Paramaribo	—	—
5. Matta	±	±
6. Pikien Saron	±	±
7. Kwakoegron	±	±
8. Bigi Poika	±	—
9. Tibitibrug	±	±
10. Witagron	±	—
11. Donderskamp	±	±
12. Tapoeripa	±	±
13. Apoera	?[a]	—
14. Coronie	—	—
15. Wageningen	—	—
16. New Nickerie	—	—

Villages, regions, and field stations in nontidal zone:

Name	Malaria transmission	*An. darlingi* infestation
17. Kawemhakan	++	++
18. Puleowime	++	++
19. Peleloe Tepoe	++	++
20. Kwamalasamoetoe	++	++
21. Lebidoti	(—)?[b]	—
22. Pikien Pada	(—)?[b]	—
23. Brownsweg	—	—
24. Njoen Jacobkondre	++	++
25. Poesoegroenoe	±	—
26. Raleigh Falls	±	++
27. Stondansi	±	++
28. Blanche Marie	—	++
29. Mataway	—	—
30. Amotopo	±	++
Upper Marowijne region	++	++
Upper Suriname River	±	±(+)[c]
Gran and Pikien rivers	+	++

Note: Malaria transmission: ++ moderate; + low, interrupted; ± incidental, normally without; — none.
An. darlingi infestation: ++ medium or high density; + very low density; ± collected once or twice over many years; — never collected.
[a]? = Uncertain whether local transmission occurs.
[b](—)? = Absence of local transmission likely but not 100% certain.
[c]±(+) = Usually ± but sometimes +.

and the small size and isolated nature of human settlements.

Although the interior in general has traditionally been considered a malaria-endemic area, the work reported here attempts to distinguish between interior areas with different epidemiologic characteristics. Such distinctions could provide a basis for rationalizing and focusing malaria control activities.

Because most malaria cases are known to originate in the region of the Marowijne River (see Figure 1), special attention has been paid to this region. It was expected that within the Marowijne region local malaria epidemiology would vary, since localized differences in the availability of *An. darlingi* breeding habitats were observed by Hudson (*8*) and Rozendaal (*9, 10*). Our aim was to reveal the existence of localities acting as a permanent reservoir from which other localities in the Marowijne region were periodically reinfected by people travelling within the region. If such focal areas actually existed, a more efficient application of control measures would be possible.

Because malaria transmission in the savanna region and several isolated settlements in the almost uninhabited western part of the interior occurred irregularly—at intervals of up to several years—it appeared that the parasites were being introduced from endemic parts of the interior. Annual reports of the Bureau of Public Health indicated that several such outbreaks were related to introduction of *P. falciparum* parasites into settlements in these areas by semi-immune carriers of the Djuka Tribe inhabiting the interior's most malarious Upper Marowijne region. Control of malaria in such receptive settlements might be possible if reintroduction of the parasites were prevented. For this reason, we have directed our attention to the role of people of Djuka origin and others as possible malaria carriers.

STUDY AREA AND PEOPLE

Climate

The climate of the interior is typical for a tropical rain forest area. In most years there is a major rainy season from April through August, a major dry season from September through November, a minor rainy season in December and January, and a minor dry season in February and March.

Key Locales and Their Inhabitants

Figure 1 delineates the most important malarious localities and tribal regions. Approximately 370,000 people live in Suriname, of which 320,000 live in Paramaribo, the capital, and in cultivated coastal areas. The remaining 50,000 live in the savanna belt and the interior. The savannas are mainly inhabited by Amerindians, while the interior is inhabited by some 30,000 descendants of Africans who call themselves Bushnegroes and about 2,000 Amerindians (see Figure 2).

Most of the Bushnegroes inhabit three distinct regions and are organized into several tribes. The Upper Marowijne region is inhabited by the Djuka Tribe and by the smaller Paramacca Tribe. As of 1982 this region had a population estimated at 8,301. The Upper Suriname region, inhabited by the Saramacca Tribe, had a population estimated at 16,413; and the Upper Saramacca region, inhabited by the Matuay Tribe, had a population estimated at 1,125.

The Djuka Tribe consists of two different subtribal groups, the Opos and the Bilos. The Opos live upstream of Granholo Falls along the Tapanahony River. The Bilos have ceremonial villages along the downstream part of the Tapanahony, but they live mainly in small camps on river islands situated close to their farm plots along the banks of

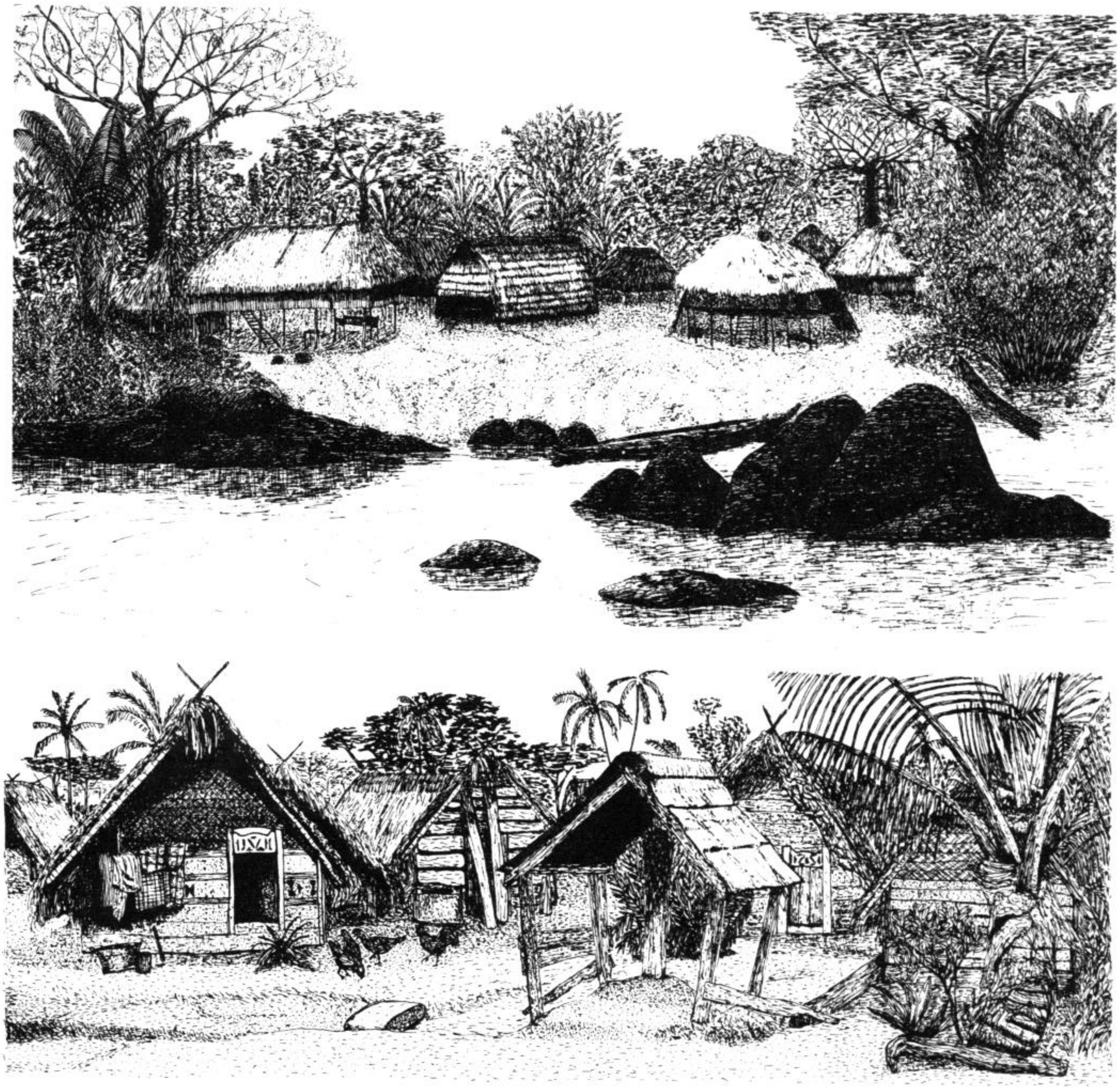


Figure 2. Line drawings by the author showing (top) a Bushnegro village along the Upper Suriname River and (bottom) an Amerindian village along the Litani River in southern Suriname.

the Marowijne and Lawa rivers (see Figure 1).

The Opos spend most of their time in their villages and often have their farm plots within walking distance in the forest. In contrast, the Bilos travel more frequently and over longer distances. They maintain social contacts by attending ceremonies and festivities in their villages and by visiting other camps, activities that often require many hours of travel by motorized dugout canoe.

Bushnegroes of the Saramacca Tribe live in villages near the Upper Suriname River and in permanent camps near their farm plots in the forest, all of which may be many hours' walking distance from the river.

People of the Matuay Tribe live permanently in some small villages that are within walking distance of their farm plots.

The Amerindians live in four isolated villages in southern Suriname. They maintain infrequent contacts with each other, as well as with Amerindian villages in Guyana, Brazil, and French Guiana, and sometimes travel to Suriname's coastal area.

Both *P. falciparum* and *P. vivax* infections occur among the Amerindians. However, *P. falciparum* is the only malaria parasite recorded among the Bushnegroes. This apparent absence of *P. vivax* may be accounted for by a certain degree of inherited immunity to this parasite among people of African descent (*11*).

ANTIMALARIAL ACTIVITIES AND STUDY METHODS

Activities before 1982

Malaria control activities in this period consisted of procurement and examination of blood smears, treatment of positive cases, residual house spraying with DDT, and (from 1966 to 1973) distribution of table salt containing chloroquine or amodiaquine. These activities were carried out by the Anti-Malaria Campaign (AMC), a specialized unit of the Bureau of Public Health, which was based in Paramaribo.

For purposes of this campaign, the interior was divided into several attack-phase areas. A portion of the AMC's personnel were located in the interior and organized into mobile teams. These teams would return to Paramaribo after "expeditions" lasting two or three months.

Slides collected in the interior were sent to a laboratory in Paramaribo. Because several weeks or even months could elapse between smear collection and reporting of positive cases, it was often difficult to locate the people needing treatment. (Slides were mainly collected from fever cases at irregular intervals when the teams were out on "expeditions.") For this reason, presumptive treatment was provided to all people with fever or malaria-like symptoms.

Activities after 1982

Partly because of operational and logistic problems experienced by the AMC, it was decided in 1982 to put the Medical Mission (MM), a private primary health care organization, in charge of antimalaria activities in the interior. The mission, which had a coordination center in Paramaribo, subdivided the interior into several medical districts. Each of these medical districts had a center staffed by a physician and a nurse, and each was subdivided in turn into areas served by small dispensaries staffed by local health assistants.

Daily radio contact was maintained between each district center and the outposts. Boats, cars, and planes were used to provide supplies and maintain physical contact with the outposts, usually on a weekly basis.

The health assistants were responsible for monthly collection of thick blood smears from at least 10% of the population covered by each dispensary. These smears were separated into two groups, those collected by passive case detection work and those collected through active case detection measures. All the smears were sent for diagnosis as soon as possible to a malaria microscopist at the district medical center. The results were transmitted to the outposts by radio, and people yielding positive results were treated. Also, when any person complained of malaria symptoms or had a fever, a presumptive treatment was administered before the results of the blood smear examination were received.

Since these malaria control activities in the interior were seriously disturbed by political problems that began in 1986, the data available for analysis are primarily those from the years 1982–1985.

MALARIA INCIDENCE IN BUSHNEGRO TRIBAL AREAS, 1965–1985

To assess epidemiologic developments in the several Bushnegro tribal areas, AMC and MM data had to be combined. The medical districts of the MM differed from the operational areas of the AMC. Nevertheless, by merging several areas it was possible to obtain annual figures for the total numbers of slides examined, the total numbers found positive, and the estimated population sizes of the Djuka, Saramacca, and Matuay tribes in the 1965–1985 period. From these data the annual blood examination rate (ABER) was calculated in order to get an indication of the population coverage provided by the malaria control activities.

Differences between the Bilo and Opo divisions of the Djuka Tribe were studied using Medical Mission data from two medical districts, "Stoelmanseiland" (inhabited by the Bilos) and "Drietabiki" (inhabited by the Opos).

Malaria Transmission Foci in the Upper Marowijne Region

All villages, settlements, and camps in the Upper Marowijne area were mapped and divided into groups. This was done on a 1:40,000 scale map provided by the Aerial Survey Department in Paramaribo. All the camps were assigned names corresponding to those most commonly used by the local residents, and the clan and ceremonial village of each camp-owning family was recorded.

Coherent clusters of camps were grouped into camp regions considered epidemiologically homogeneous. Data were recorded for these camp regions to indicate (a) the extent to which camps were scattered about a region (done by taking the distance in meters between the two most widely separated camps and dividing by the number of camps in the region); (b) the size of the population (estimated by counting the total number of houses, because the number of people living in the camps was unknown and could not be readily determined by counting, since most residents were at work in the forest during the field team's daytime visits); and (c) the coverage provided by residual house spraying with DDT (since there were two spray cycles per year, the average coverage provided by each was calculated).

The camps and camp regions were introduced into the Medical Mission's case detection system by adding a special column on the thick smear form for recording the place where the subject stayed during the two weeks preceding onset of symptoms. If the blood sample turned out positive, this place was considered the place of infection. In some cases this might be wrong, but extensive case investigation of all positives would have been so time-consuming as to be impractical.

To compare coverage provided by the case detection system in different camp regions, the annual blood examination rate (ABER) was estimated. Since the precise population size of each region was unknown, the indicator used was the total number of slides examined per 100 houses, and the name of the indicator was changed to "camp annual blood examination rate" or CABER.

The annual parasite incidence (API) was estimated in a similar manner. That is, the indicator used was the total number of new positives per 100 houses (based on monthly data), and the name of the indicator was changed to "camp annual parasite incidence" or CAPI.

The ABER and API for the ceremonial villages were calculated using population data recorded by the Medical Mission for these villages in 1980.

The observed relationship between the number of camps belonging to one village and the size of that village, a relationship termed the "camp index" (see Table 3), was taken to indicate the tendency of those belonging to a certain ceremonial village to live in camps versus inside the village proper.

Data were also recorded regarding the DDT spray coverage provided and the percentage of houses that remained unsprayed due to refusals.

For practical reasons it was not possible to include the Paramacca tribal territory along the Upper Marowijne River (see Figure 1) in this study. Among other things, positive cases originating in this area often attended medical centers in the coastal area and did not appear in the Medical Mission's data.

Spread of Malaria from the Upper Marowijne Region

During 1982–1985, each locality with a malaria outbreak was investigated to determine who introduced the disease from the permanent focus, the Upper Marowijne Region, into that locality. Particular attention was given members of the Djuka Tribe residing in or near the affected locality, but other local people who had traveled to the Marowijne Region were also suspect.

During or shortly after the outbreak, the inhabitants were asked about their contacts with other malarious areas. All people with outside origins were also asked about their travels, and organizations or companies employing nonlocals in or near the site of the outbreak were investigated.

Another source of information was the AMC's case investigations. People returning from malarious regions to the coastal area were often checked for malaria parasites at the border town of Albina and also in Paramaribo. The AMC's reports on those people yielding positive results included information about the most likely place where infection was acquired (considered to be the place where the person stayed approximately two weeks before onset of symptoms), the person's birthplace, and the person's employer if any. These reports were reviewed to find people who were likely to have traveled from malarious regions to other parts of the interior for work or other reasons.

RESULTS

Malaria in the Tribal Areas Studied

Table 1 shows the number of people found infected with *P. falciparum* during the years 1965–1985, together with the ABER and API, in each of the three study areas.

The Upper Saramacca River area. Here the estimated tribal population declined from 3,600 in 1969 to 1,125 in 1982. A count taken in 1984 tallied only about 800 people, most of them old people and small children. Many teenagers and young adults had gone to Paramaribo.

Years of malaria transmission alternated with years of no transmission. An increase in the ABER after 1978 did not produce a decline in the apparent malaria incidence.

An analysis of the parasite index for each month of the 1982–1985 period (see reference *12* for details) revealed that malaria was not endemic, as the Table 1 data might seem to suggest, but occurred in short-lived epidemics, probably after re-

Table 1. Results of malaria surveys (for *Plasmodium falciparum* only) in the interior of Suriname, 1965–1985.

	Area of Upper Suriname River			Area of Upper Marowijne River			Area of Upper Saramacca River		
Year	No. positive	ABER (%)[a]	API (%)[b]	No. positive	ABER (%)	API (%)	No. positive	ABER (%)	API (%)
1965	2,161	71.6	161.9	1,959	30.9	112.8	—	—	—
1966	1,315	62.1	97.8	1,524	30.7	87.8	—	—	—
1967	1,045	40.1	77.7	688	24.8	39.6	—	—	—
1968	1,172	63.2	87.2	334	24.4	19.2	—	—	—
1969	366	95.2	27.2	257	38.7	16.0	1	40.4	0.0
1970	355	96.4	26.2	511	29.9	31.6	0	44.7	0.0
1971	1,149	108.0	83.0	267	41.5	16.2	12	46.5	3.2
1972	320	114.2	22.6	39	43.7	2.3	13	71.1	3.4
1973	577	105.8	39.3	1,205	76.1	94.8	0	33.9	0.0
1974	3,231	133.9	219.8	467	203.1	36.7	60	32.7	15.3
1975	2,421	142.7	164.7	74	128.6	5.8	87	61.5	22.1
1976	31	175.7	2.1	271	131.0	21.3	—	—	—
1977	9	146.7	0.6	817	163.0	64.3	0	31.2	0.0
1978	2	137.0	0.1	765	101.5	53.9	0	27.5	0.0
1979	42	180.0	2.9	697	196.2	49.2	7	36.5	1.8
1980	2,817	210.9	162.0	1,150	186.1	92.2	10	70.2	7.5
1981	717	135.7	41.2	532	76.1	43.9	53	110.6	39.6
1982	97	132.9	5.9	1,680	132.6	202.4	64	87.6	56.9
1983	43	126.2	2.6	898	138.5	108.2	30	82.8	26.7
1984	30	122.2	1.8	2,331	195.9	280.1	40	144.4	35.6
1985	14	126.5	1.0	949	192.4	114.3	7	110.7	6.2

[a]ABER = annual blood examination rate (the number of smears examined per hundred residents).
[b]API = annual parasite incidence (the number of positives per hundred residents).

introduction of the parasite. During this period all positive cases originated in the downstream part of the Matuay tribal area, in and around the village of Njoen Jacobkondre. The upstream segment of the tribal area in and around the village of Poesoegroenoe remained free of malaria.

The Upper Suriname River area. In contrast to the other tribes, the Saramacca Tribe's population along the Upper Suriname River grew from an estimated 13,439 in 1965 to 14,700 in 1973 and 16,413 in 1982. From 1966 to 1973, medicated salt was provided for malaria control. This measure was discontinued in 1973 when the existence of chloroquine-resistant *P. falciparum* was first confirmed in Suriname. A major epidemic in 1974–1975 was attributed to introduction of chloroquine-resistant *P. falciparum* from the Marowijne region.

Except during the epidemic of 1974–1975 and a later epidemic in 1980–1981, the annual blood examination rate (ABER) tended to increase or remain steady, while the annual parasite index (API) tended to decline. All the positives recorded by the Medical Mission in 1982–1985 originated in the area of the Gran and Pikien rivers above the Upper Suriname, while the Suriname River area remained malaria-free. Of the malaria-positive subjects detected, 88.6% received radical treatment.

The Upper Marowijne River area. The size of the tribal population in this area declined from an estimated 17,358 in 1965 to 14,180 in 1978 and 8,301 in 1982. This was due to an exodus of young people, mainly men, to the coastal area.

Provision of medicated salt for malaria control began in 1967. This practice ended after 1973 because of chloroquine resistance, logistic problems, and poor acceptance of the bitter-tasting salt.

Case detection and treatment improved in 1982, and in 1982–1985 about 87% of all malaria-positive subjects were treated. Nevertheless, as indicated in Table 1, the API exhibited an upward trend.

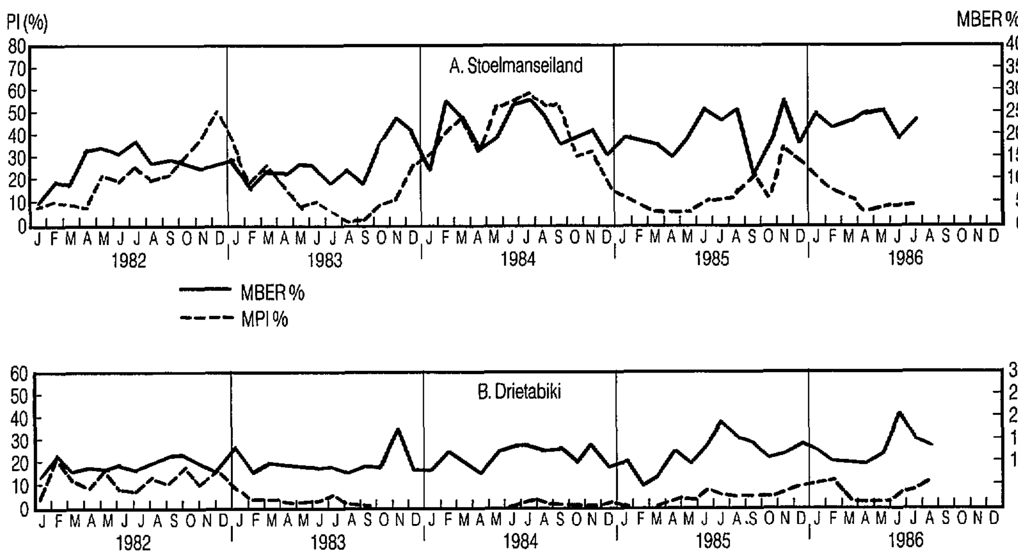
Malaria in the Medical Districts of Stoelmanseiland and Drietabiki

The charts in Figure 3 show the monthly blood examination rates and monthly parasite indexes for the medical districts of Stoelmanseiland and Drietabiki from January 1982 through July 1986. The former district contains the Bilo division of the Djuka Tribe, while the latter contains the ceremonial villages and most of the camps of that tribe's Opo division.

The differences observed between malaria patterns in the two districts were remarkable. In January 1983 the malaria incidence in Drietabiki dropped to a low level, where it remained until April 1985. The increase which began that month coincided with a small "gold rush" in a creek (Silacreek) that enters the Tapanahony River in the southern part of the Drietabiki District. All the malaria-positive people were gold miners or others living or working close to the mouth of the creek. The ceremonial villages and most of the camps of the Djuka Tribe's Opo division remained unaffected.

In contrast, high rates of malaria were observed in the Stoelmanseiland District inhabited by the Djuka Tribe's Bilo divi-

Figure 3. Malaria case detection data from two medical districts inhabited by the Bilo and Opo divisions of the Djuka Tribe. The charts show monthly blood examination rates (MBER, solid lines) and monthly parasite incidences (MPI, broken lines) for the Bilo medical district of Stoelmanseiland (A) and the Opo medical district of Drietabiki (B).



sion. Fluctuations occurred, but the overall malaria incidence did not seem much affected by the improved case detection and treatment introduced in 1982.

Malaria Foci in the Upper Marowijne Region

Out of a total of 229 camps scattered over the Upper Marowijne and Lawa rivers, 216 could be grouped into clusters or "camp regions." This was possible because the inhabitable islands in the river were not distributed evenly over the river, and because every Djuka Tribe clan claimed its own part of the Marowijne and Lawa rivers for cultivation. Therefore, families belonging to the same clan often had their camps in the same part of the river.

Table 2 lists the different camp regions, showing certain general features of each region and its case detection data. One region, Gransanti, which was the least scattered, had the most positive cases and also yielded the highest "CAPI." Only at Gransanti, of all the camp regions, were positive cases found throughout the year. In all the other regions there were periods of at least two consecutive months when positives were not detected.

The coverage provided by house spraying with DDT was low and showed little variation among the camp regions. No relationship was observed between variations in malaria incidence and spray coverage.

Malaria in Ceremonial Villages of the Lower Tapanahony

Table 3 lists the ceremonial villages on the Lower Tapanahony River (just above the Upper Marowijne), showing various characteristics of those villages and case detection data.

The villages of Tabiki and Malobi had the most inhabitants, the largest numbers of positives, and the highest ABERs and APIs. Relative to their sizes, these villages also had the smallest number of camps (the lowest camp indexes). This is apparently because the Lower Tapanahony, site of the ceremonial villages, is used for cultivation by some Malobi and Tabiki residents. Accordingly, these people live permanently in their villages.

Despite their similar numbers of homes and inhabitants, Tabiki yielded nearly twice as many positives as Malobi. Moreover, positives were found in Tabiki in all months, while Malobi (like all the other study villages) had at least one two-month period when no positives were detected. The low degree of spray coverage provided in Tabiki could be partly explained by the relatively high percentage of people (over 50%) who refused to have their houses sprayed, the highest refusal percentage found in any ceremonial village. However, spray coverage in all the villages tended to be poor, and spray coverage variations between villages did not exhibit any relationship to variations in the API.

Malaria Dispersal to Nonendemic Locales

Investigation of outbreaks. In 1983, malaria outbreaks were recorded at the West Suriname localities shown in Table 4 (also see Figure 4). Besides the localities involved, the table lists the organizations whose agents were working at field stations in those localities and also shows the number of field agents who were of Djuka origin.

Regarding local residents, the inhabitants of the areas' Bushnegro and Amerindian villages said they never traveled to the Marowijne Region or any other region with endemic malaria. With only one exception, everyone said their travels

Table 2. Malaria case data and other information about camp regions within the area of the Upper Marowijne River (1985 data).

Region	No. of camps in region	No. of houses in region	Scatter factor[a]	Spray cover-age (%)	Smears exam-ined	CABER[b] (%)	No. of posi-tives	SPR[c] (%)	CAPI[d] (%)
Bergi	19	162	232	48	444	274	22	5.0	13.6
Gonsoetoe	12	71	433	44	55	77	0	0	0
Doetabikimoffo	18	138	200	49	210	152	19	9.0	13.8
Gakaba	16	151	250	54	310	205	14	4.5	9.3
Capasitabiki	7	63	286	64	171	271	23	13.5	36.5
Abetredjoeka	3	39	400	0	134	344	13	9.7	33.3
Aboenamimoffo	7	59	200	43	188	319	16	8.5	27.1
Stoelmanseiland	16	215	225	61	982	457	38	3.9	17.7
Gransanti	16	111	114	49	719	648	96	13.4	86.5
Loa	18	(—)[e]	244	(—)	37	(—)	2	5.4	(—)
Koffiekamisa	22	102	146	53	95	93	7	7.4	6.9
Goninimoffo	8	(—)	450	(—)	185	(—)	2	1.1	(—)
Goninikreek	11	57	1,273	86	149	261	3	2.0	5.3
Dagoede	35	172	149	58	89	52	8	9.0	4.7
Aboenamasoenga	8	56	875	51	12	21	1	8.3	1.8

[a]The "scatter factor" gives a rough measure of the degree to which camps were scattered within each camp region by taking the greatest distance (in meters) between the two most widely separated camps and dividing this by the number of camps within the region.
[b]CABER = camp annual blood examination rate, the number of slides examined annually per 100 houses within the camp region.
[c]SPR = smear positivity rate.
[d]CAPI = camp annual parasite incidence, the annual number of positives per 100 houses within the camp region.
[e](—) = no data available.

Table 3. Malaria case data and other information about ceremonial villages along the Lower Tapanahony River (1985 data).

Village	No. of inhabitants	No. of houses	No. of camps related to village	Camp index[a]	Spray coverage (%)	Houses occupied (%)	Smears examined	ABER[b] (%)	No. of positives	SPR[c] (%)	API[d] (%)
Poeloegoedoe	126	80	9	11	25	29	83	65.9	5	6.0	39.7
Tabiki	605	275	22	8	30	60	1,153	190.5	100	8.7	165.3
Benanoe	220	123	41	33	65	50	168	76.3	13	7.7	59.1
Wanfinga	166	93	29	31	34	48	124	74.7	8	6.5	48.2
Niki	89	39	7	18	0	26	75	84.3	3	4.0	33.7
Malobi	613	237	19	8	62	65	817	133.3	57	7.0	93.0
Vandaki	291	89	12	13	36	56	137	47.1	15	10.9	51.5
Clementi	305	157	22	14	60	37	28	9.2	2	7.1	6.6
Saje	218	93	12	13	67	45	22	10.1	0	0	0
Mpoesoe	212	100	15	15	38	21	15	7.1	1	6.7	4.7
Tjontjon	155	88	20	23	73	50	18	1.2	0	0	0
Powi	134	70	7	10	66	43	9	6.7	0	0	0
Karmel	111	39	0	0	74	57	4	3.6	1	25.0	9.0

[a]Camp index = the number of camps associated with each village per hundred houses in the village.
[b]ABER = annual blood examination rate (the number of smears examined per hundred residents).
[c]SPR = smear positivity rate.
[d]API = annual parasite incidence (the number of positives per hundred residents).

Table 4. Localities with malaria outbreaks in western Suriname in 1983, showing nearby government organization field stations and the government organization involved.

Locality	Field station: Name	Field station: Organization[a]	Numbers and ethnic origins of field assistants: Djuka	Others	Total
Raleigh Falls	Raleigh Falls	Stinasu	7	2	9
Witagron	Raleigh Falls	BWKW	7	4	11
Witagron	Raleigh Falls	LVT	2	3	5
Witagron	Witagron	BWKW	1	1	2
Tibitibrug	Goliath	LBB	39	30	69
Donderkamp }	{ Arrawarre	LBB	2	4	6
Tapoeripa }	{ Stondansie	WLA	10	1	11
Njoen Jacobkondre	Loksiehatie	GMD	14	14	28
Njoen Jacobkondre	Dramhoso	BWKW	6	4	10
Total			88	63	151

[a]Government organizations: Stinasu = Stichting Natuurbehoud Suriname (nature preservation); BWKW = Bureau voor Waterkrachtwerken and WLA = Waterloopkundige Afdeling (hydrologic studies); LVT = Luchtvaart Terreinen (airstrip service); LBB = Lands Bosbeheer (forestry service); GMD = Geologische Mijnbouwkundige Dienst (geologic and mining service).

were limited to the savannah and coastal regions. The lone exception, a man whose family and home were in Tapoeripa, said he was employed by a goldmining company on the Lawa River in Eastern Suriname and had stayed for a while with his family.

In or near these villages, however, were groups of nonlocal people—including a number of Bushnegroes of the Djuka Tribe—who traveled to their tribal area during certain holiday periods. A few of these people worked for private logging companies, but most of the Djukas were working for government organizations engaged in field research. Together with people from Paramaribo and other Bushnegro tribes, they staffed permanent field stations.

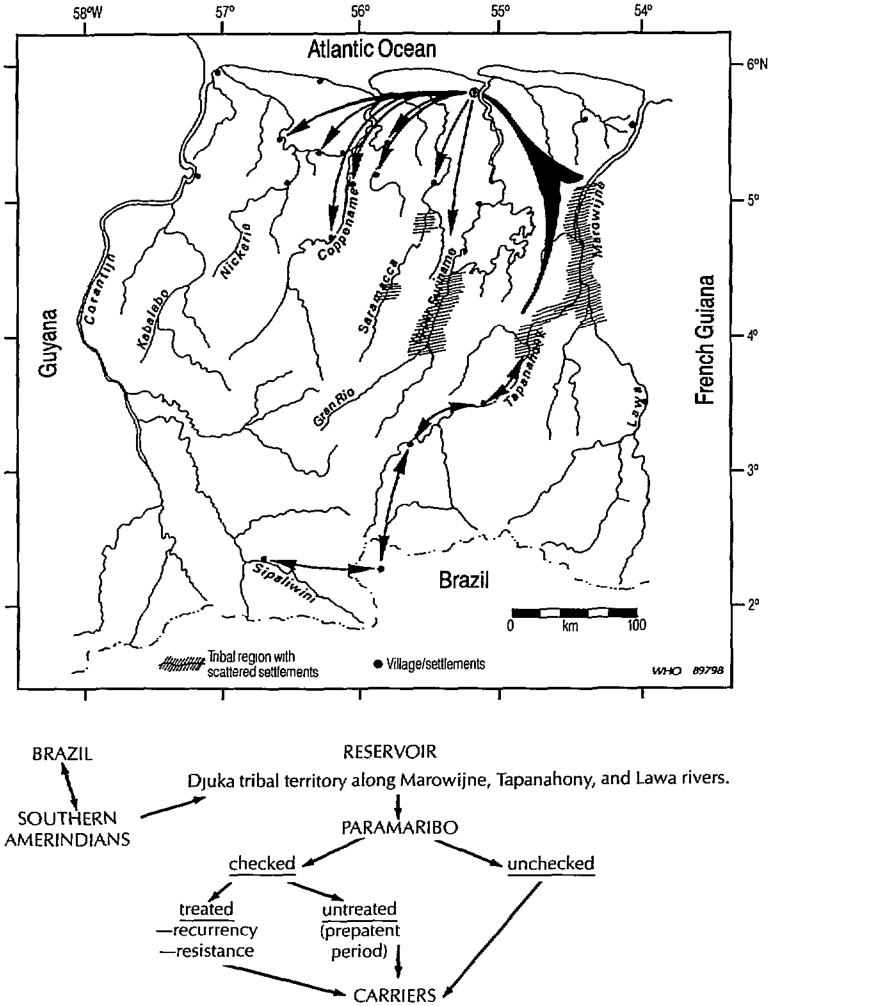
Direct evidence of the Djukas' role as carriers was hard to find. People with introduced cases were detected only at Raleigh Falls and at Dramoso (near Njoen Jacobkondre). One had been infected in the Marowijne Region focus, had subsequently been treated for malaria, and had suffered a relapse due to chloroquine resistance. The other had visited the Marowijne area four months earlier; however, when his case was detected he harbored only gametocytes and did not even know he had been infected.

Twenty-five of the 88 Djuka field assistants shown in Table 4 were asked how often they traveled to their tribal area. They could not provide exact information, since their frequency of travel was influenced by unpredictable events such as deaths. However, they usually went to their ceremonial villages to celebrate the New Year. Overall, it seems justified to estimate that these people averaged one trip to their tribal homeland per year. This is the same as the estimate made by administrative personnel in Paramaribo.

Government field activities. Table 5 lists all government organizations active in the interior as of 1983, together with the numbers of field personnel they employed at interior field posts by ethnic background. Figure 1 shows most of their permanent or semipermanent field stations. In all, the records show 842 active field personnel in the interior, 53.4% of Djuka origin. (The Saramacca Bushnegroes outnumbered the Djukas but were underrepresented in the government services.)

It was the custom of all government

Figure 4. A model showing the apparent pattern of malaria's spread from the endemic focal area in the Marowijne region to other receptive areas of Suriname. A transmission pathway to and from the Marowijne region and the Amerindian villages of southern Suriname and Brazil is also shown.



Governmental services with field teams in interior (hydrology, mineralogy, etc.), gold miners, woodcutters; in areas a, b, c, and d approx. 100 persons, 75% Djukas.

AREAS AT RISK

a) Saramacca River (300 people)—Njoen Jacobkondre; Loksie Hatie/Goenzie.
b) Tibiti Bridge (100 people + fishermen and woodcutters).
c) Coppename River (350 people)—Witagron; Raleigh Falls (tourists).
d) Nickerie River (50 people—hunters, fishermen, woodcutters).

organizations to rotate personnel from one field post to another, granting them a leave period in Paramaribo between their field assignments. Thus, Djuka personnel could be stationed anywhere in the interior. Conversely, personnel of non-Djuka origin who had been stationed in potentially malarious parts in the Marowijne region might also act as carriers of malaria parasites to other areas.

Table 5. Government organizations' field assistants, by ethnic origins (1983 data).

	Ethnic origins of field assistants				
Organization[a]	Djuka	Saramacca	Matuay	Other/ unspecified	Total
GMD	155	5	16	30	206
BWKW	58	25	19	10	112
Meteorologic Service	8	1	1	3	13
Stinasu	21	10	1	12	44
WLA	23	2	3	1	29
LVT	57	22	5	20	104
Subtotal	322	65	45	76	508
(%)	(63.4)	(12.8)	(8.6)	(15.0)	(100)
LBB[b]	128		206 (LBB non-Djuka)		334
Total	450		392 (total non-Djuka)		842
(%)	(53.4)	(46.6)			(100)

[a]For the titles and activities of the organizations listed, see Table 4, footnote a.
[b]The only ethnic distinction made for LBB (forestry service) field assistants was between Djuka and non-Djuka personnel.

Investigation of cases detected in Albina and Paramaribo. Table 6 shows data obtained by reviewing AMC investigations of malaria cases detected in Albina and Paramaribo in 1982–1985. In most years (1982, 1984, and 1985) the bulk of the cases appeared to have originated in the Upper Marowijne region. An exception was 1983 because that year saw important malaria outbreaks in Western Suriname.

A considerable share of the investigated cases occurred in people who were working for government organizations and were likely to travel to other parts of the interior or the savanna. Of those government workers and others who contracted malaria in the Upper Marowijne region and whose ethnic background was known, almost all were members of the Djuka Tribe.

DISCUSSION AND CONCLUSIONS

The Upper Saramacca Region

The Upper Saramacca region can be separated into two geographically and epidemiologically distinct areas, one encompassing a group of villages near Poesoegroenoe and the other including another group of villages near Njoen Jacobkondre. The first group of villages remained free of malaria in 1982–1985 while the second suffered several malaria outbreaks. This history agrees with Rozendaal's observations that *An. darlingi* is scarce or lacking near Poesoegroenoe but occurs in notable and relatively stable numbers near Njoen Jacobkondre (*1*).

The Upper Suriname Region

No data are available on the abundance of *An. darlingi* in the territory of the Opo-Djukas, which was in the Drietabiki Medical District, but a number of factors could account for the comparatively low levels of malaria transmission in this area. To begin with, most of the Opo-Djukas lived in their ceremonial villages, which were clustered together and had good access to the medical district's dispensaries and health center. Hence, there is good reason to suppose that the case detection and treatment system's effec-

Table 6. Information obtained on cases detected in Albina and Paramaribo that were investigated by the AMC (1982–1985 data).

			Infections probably originating from:						
			Marowijne region				Other areas		
			Total positives				Total positives		
Year	Cases investi-gated	Positive government employees	No.	(%)	No. of Djukas	No. of government employees	No.	(%)	No. of government employees
1982	194	98	148	(76.3)	—[a]	82	46	(23.7)	16
1983	201	52	95	(47.3)	—	25	106	(52.7)	27
1984	416	48	397	(95.4)	357	46	19	(4.6)	2
1985	139	20	128	(92.1)	110	18	11	(7.9)	2

[a] — = data not recorded.

tiveness was greater there than in the Bilo-Djuka territory in the Upper Marowijne region.

Schaapveld (*13*) concluded that the Medical Mission increased the efficiency of malaria control activities in the interior but could not prove those activities produced better results. However, reduced malaria incidence in the Upper Suriname region after 1982 and in the Drietabiki Medical District after 1983 suggests the Medical Mission's improved malaria control activities met with some success.

Generally, in areas with a low vector capacity, case detection and treatment can be expected to have an important impact on malaria incidence (*14*). In the case at hand, Rozendaal (*1, 9*) discerned two entomologically different subregions within the territory of the Saramacca Tribe in the Upper Suriname region. These subregions included (1) the villages along the Gran and Pikien rivers, where relatively stable *An. darlingi* populations were found, and (2) downstream from these rivers' confluence, the villages along the Upper Suriname River, where *An. darlingi* had been collected only incidentally and in very low numbers. This difference between the two areas (together with the other circumstances cited above that tended to work against malaria) accounts well for the observation that within the territory malaria transmission only occurred along the Gran and Pikien rivers.

The Marowijne Region

Overall, the reported data indicate that at least through 1985 the Djuka tribal territory in the Upper Marowijne region, an area within the Stoelmanseiland Medical District, was the only permanent focus of *P. falciparum* transmission in Suriname. This finding can be attributed to several circumstances, including: (1) higher vector densities in the Djuka territory than in other parts of Suriname (*1, 9*); (2) the extensive travels of the Djukas, who spread malaria parasites to virtually all localities within their tribal territory as well as to many other places; and (3) the vastness of the Djuka territory. In addition, the Djuka population's low density and high mobility tended to work against control measures such as DDT residual house spraying or treatment of positives, rendering them relatively ineffective.

Within the affected area, *An. darlingi* apparently occurred at sufficient densities throughout 1985 to maintain malaria transmission in both the Gransanti camp region (see Table 2) and the village of Tabiki (see Table 3). An additional important factor seems to have been the density and size of the human population. Specifically, the Djuka population is dispersed in small clusters over a large area, which results in a very low overall population density. As may be seen in Tables 2 and 3, as of 1985 some of these population clusters had a higher number of inhabitants and a higher population density than others. Tabiki had about the highest figures in the village category, while Gransanti had the highest density of any camp region.

In order to confirm these localities' role as permanent malaria foci, continued studies over a longer period are needed. It is also important that the basis for comparing the different camp regions be improved through increased case detection in the more remote areas, since the extreme remoteness of some camp regions may have reduced the level of blood smear collection and case detection.

Malaria Control Strategies in Suriname

Nonendemic areas. Obviously, preventing dispersal of malaria parasites from the Marowijne region to other potentially malarious areas would tend to reduce malaria in the latter areas.

Figure 4 illustrates the spread of malaria from its focus in the Marowijne region to other areas, including the spread of both *P. vivax* and *P. falciparum* malaria to and from Amerindian villages in southern Suriname.

Since the carriers in most cases are working for government or private organizations, it should be possible to register them and to have them checked in Paramaribo upon their return from the Marowijne region. However, checking of carriers does not guarantee elimination of carriers—because chronic infections with low parasitemia, examination of blood during the prepatent period, and drug resistance all afford circumstances in which positive cases may be missed. Therefore, special attention should be given to the teams of government service workers in the field. In some cases, appropriate measures could be organized by the Medical Mission's health assistants.

Informing carriers and the inhabitants of malaria-receptive villages about how malaria spreads is also of considerable importance in obtaining the cooperation of the people involved. In isolated places with resident village health workers, it might be advisable to require that all visitors have their blood checked and receive a presumptive treatment before they spend a night there. The author found (unpublished data) that this method successfully prevented introduction of malaria parasites for up to two years in two Amerindian villages of southern Suriname. (Prior to introduction of this measure, these villages were cleared of malaria parasites by administering mass drug prophylaxis for three months—*15*).

In the Upper Suriname and Upper Saramacca regions, it would seem sufficient to rely on the case detection and treatment measures carried out by the Medical Mission since 1982. However, more attention needs to be paid to the Gran and Pikien river areas and to the villages near Njoen Jacobkondre.

Past epidemics have shown that the vector capacity is not always very low in the Upper Suriname region, and it is likely that another epidemic will occur if malaria parasites become available. Under such circumstances, additional vector control measures could be considered for short periods of time. To help prevent such an occurrence, elimination of a possible parasite reservoir along the Gran and Pikien rivers and prevention of the parasites' reintroduction must continue to receive high priority. In addition, the Medical Mission's standard case detection activities in Njoen Jacobkondre along the Upper Saramacca River should be supplemented by monthly blood examinations of the few Djukas who work and live in that area.

The Upper Marowijne region. Elimination of the focus along the Marowijne River is the best way to prevent malaria transmission in other areas. Therefore, the malaria programs of both Suriname and French Guiana should give this region priority.

Cooperation between the two countries in their border area is essential. In Suriname, the Upper Marowijne region is the only area where effective vector control methods must be an integral part of antimalarial activities. It will be hard to improve the region's standard case detection and treatment system, and even if that system were improved it seems likely that additional control measures would be needed.

The existence of focal areas of transmission in the Marowijne region greatly improves the prospects for sharply reducing malaria. It would be affordable to perform frequent and intense active case detection in this region followed by immediate treatment of positive cases. Also, if other suitable vector control methods do not become available, one could try through health education to convince local residents of their need to cooperate with spray teams so as to obtain adequate house-spraying coverage. In addition, future research should give priority to studying the focal areas involved.

Vector control methods. Residual house spraying with DDT has been an important component of antimalarial activities in the Suriname area since the 1950s. In this connection, Rozendaal et al. (*16*) have shown this method, correctly applied, to be very effective at killing mosquitos entering houses in Suriname. The fact that the method has produced no visible successes can be attributed to the generally low degree of spray coverage attained. In the regions of the Marowijne and Suriname rivers, the level of coverage was generally on the order of 50% or lower, due mainly to poor cooperation by the local population for reasons explained by Barnes and Jenkins (*17*). In addition, the author observed that houses listed as sprayed were often only partly sprayed by the spray teams, who did not want to remove all the objects covering the house walls.

Coverages of almost 100% were only obtained in the interior along the Upper Saramacca River and in the southern Amerindian villages. However, regular malaria outbreaks at Njoen Jacobkondre on the Upper Saramacca suggest that DDT house spraying alone cannot prevent malaria transmission even when house spraying is reasonably thorough. Also, as previously noted by Rozendaal et al. (*16*), application of DDT to the Amerindian houses does not make much sense, since the houses are open structures (often lacking walls) that allow irritated mosquitoes to escape before they pick up a lethal dose.

Rozendaal et al. (*18*) also considered impregnating locally used mosquito nets with a pyrethroid insecticide to provide a potentially more acceptable vector control method. However, it appeared that the Bushnegro population's custom of washing these nets weekly would reduce the residual life of the insecticide to less than a month.

Another possible method that might be more compatible with local customs would be to cover the eave openings and other wall openings in the Bushnegro houses with strips of insecticide-impregnated wide-mesh netting (*19, 20*). This might succeed in preventing many mosquitoes from entering the house and in killing many that do enter. A prime advantage of this method would be its ease of application. However, it would be necessary to determine whether it would be effective under prevailing Suriname conditions.

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REFERENCES

1. Rozendaal JA. Observations on the distribution of anophelines in Suriname with particular reference to *Anopheles darlingi*. *Mem Inst Oswaldo Cruz.* 1990;85(2):221–34.
2. Flu PC. *Rapport omtrent malaria onderzoek in de binnenlanden van Suriname.* The Hague: Algemene handelsdrukkery; 1912.

3. Van der Kuyp E. Contribution to the study of malarial epidemiology in Suriname. *Mededelingen koninklyk vereenigd indisch instituut Amsterdam.* 1950; Vol. 89 (Afdeling Tropische Hygiene, Vol. 18); pp. 1–146.
4. Bonne C, Bonne-Wepster J. Mosquitoes of Suriname. *Mededelingen koninklyk vereenigd indisch instituut Amsterdam.* 1925; Vol. 21 (Afdeling Tropische Hygiene, Vol. 13); pp. 1–588.
5. Van der Kaay HJ. Malaria in Suriname: a sero-epidemiological study. *Acta Leidensia.* 1976;43:1–91.
6. Geyskes DC. Notes on the neotropical Anophelinae in Moengo, Suriname. *Mosq News.* 1946;6:113–18.
7. Panday RS. *Anopheles nuneztovari* and malaria transmission in Suriname. *Mosq News.* 1977;37:728–37.
8. Hudson JE. *Anopheles darlingi* Root (Diptera: Culicidae) in the Suriname rain forest. *Bull Entomol Res.* 1984;74:129–42.
9. Rozendaal JA. Observations on the biology and behaviour of anophelines in the Suriname rain forest with special reference to *Anopheles darlingi* Root. *Cah ORSTOM Sr Entomol Med Parasitol.* 1987;25:33–43.
10. Rozendaal JA. The relation between seasonal fluctuations in malaria transmission, breeding habitats of *Anopheles darlingi,* river height, and rainfall in the rainforest of Suriname. *Med Vet Entomol.* 1991;4 (In press).
11. Bruce-Chwatt LJ. *Essential malariology* (2nd ed.). London: Heinemann; 1986.
12. Rozendaal JA. *Epidemiology and control of malaria in Suriname with special reference to* Anopheles darlingi [Doctoral thesis]. Leiden, Netherlands: State University of Leiden; 1990.
13. Schaapveld K. *Integration of antimalarial activities into basic health services in Suriname* [Thesis]. Leiden; 1984.
14. MacDonald G. *The epidemiology and control of malaria.* London: Oxford University Press; 1957.
15. Schaapveld K. A malaria control trial at Peleloe Tepoe, Suriname. *Suriname Med Bull.* 1984;7:1–49.
16. Rozendaal JA, Van Hoof JPM, Voorham J, Oostburg BFJ. Behavioral responses of *anopheles darlingi* in Suriname to DDT residues on housewalls. *J Am Mosq Control Assoc.* 1989;5:339–50.
17. Barnes ST, Jenkins CD. Changing personal and social behavior: experiences of health workers in a tribal society. *Soc Sci Med.* 1972;6:1–15.
18. Rozendaal JA, Voorham J, Van Hoof JPM, Oostburg BFJ. Efficacy of mosquito nets treated with permethrin in Suriname. *Med Vet Entomol.* 1989;3:353–65.
19. Lines JD, Myamba J, Curtis CF. Experiment hut trials of permethrin-impregnated mosquito nets and eave curtains against malaria vectors in Tanzania. *Med Vet Entomol.* 1987;1:37–51.
20. Majori G, Sabatinelli G, Coluzzi M. Efficacy of permethrin-impregnated curtains for malaria vector control. *Med Vet Entomol.* 1987;1:185–92.
21. Bruyning CFA. Some observations on the distribution of *Anopheles darlingi* Root in the savanna region of Suriname. *Doc Med Geogr Trop.* 1952;4:171–74.
22. Molineaux L, Gramiccia G. *The Garki Project: research on the epidemiology and control of malaria in the Sudan savanna of West Africa.* Geneva: World Health Organization; 1980.
23. Stage HH, Geijskes DC. Observations on mosquito and malaria control in the Caribbean area: part I, Suriname. *Mosq News.* 1946;6:177–80.
24. Van Thiel PH. Malaria problems arising from the construction of a reservoir in the interior of Suriname. *Trop Geogr Med.* 1962;14:259–78.

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