MALARIA FIELD STUDIES IN A HIGH-INCIDENCE COASTAL AREA OF EL SALVADOR, C.A.[1,2,3]

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A three-year study of malaria incidence patterns has been carried out in a small high-incidence region of El Salvador with a population of about 6,000 permanent residents and 3,000 to 4,000 migrant workers. This article presents an overview of the findings of that study.

Introduction

Between 1968 and 1973 the Central America Research Station (CARS)[2] carried out a number of studies on malaria control measures in a limited but typical coastal area of El Salvador, Central America. During this time epidemiologic investigations were conducted to evaluate control measures and to determine the epidemiologic characteristics of malaria in an area of relatively high endemicity. The present article reports the epidemiologic findings for the years 1971 through 1973; during the two previous years, the area had been subject to a mass drug distribution program, the results of which will be reported elsewhere.

The Study Area

The study was limited to a small area, covering about 100 km^2, which is located on El Salvador's Pacific coastal plain about 20 km east of La Libertad (see Figure 1). The Government of El Salvador had previously designated this area "District 13" for purposes of prior malaria control activities.

Three rivers flow through this district and empty into the Pacific Ocean through a network of estuaries. The area is under intense cultivation, being heavily devoted to cotton and sugar cane crops and to beef and dairy cattle. The human population—concentrated in small settlements on marginal land, mainly along the roads—includes about 6,000 year-round residents and

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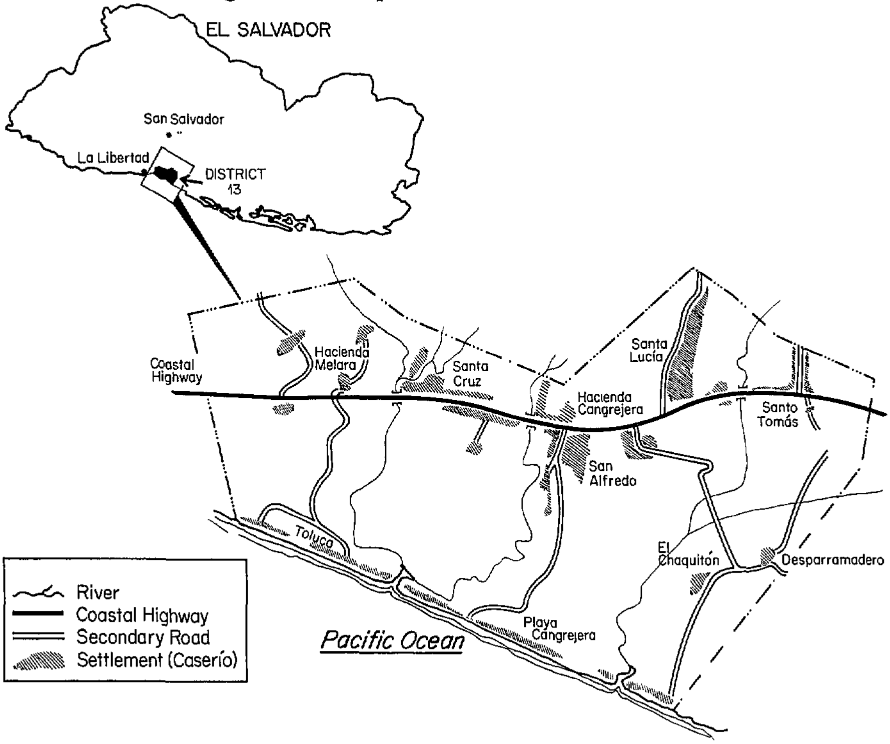
Figure 1. A map of El Salvador's District 13.



3,000 to 4,000 migrant workers. Most of the migrant workers and their families are in the area only during the harvest season (November through February), but fairly large numbers come for a brief time in early July to hand-weed cotton.

The climate in the study area is tropical, with marked rainy and dry seasons. The average annual rainfall from 1969 through 1973 was 1,610 mm (see Table 1). The rainy season begins gradually in April or May and tapers off in October; there is practically no rainfall from December through March.

Table 1. Rainfall by month in Santa Lucía, District 13, El Salvador, 1969-1973.

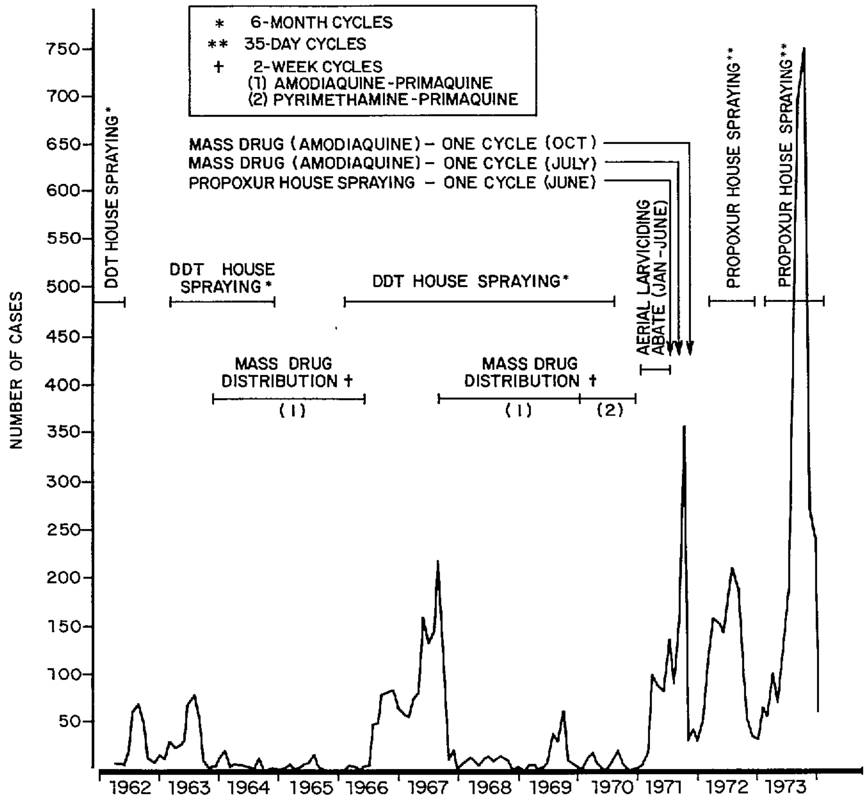
Month	Rainfall in mm				
	1969	1970	1971	1972	1973
January	?	25	8	0	0
February	?	0	0	0	0
March	?	0	0	0	0
April	102	0	0	10	135
May	156	226	73	139	97
June	240	264	274	282	421
July	260	304	258	85	176
August	241	200	282	200	307
September	424	292	473	325	211
October	380	246	267	221	219
November	25	5	59	49	41
December	0	42	0	4	0
Total	1,828	1,604	1,694	1,315	1,607

Overall average = 1,610 mm

Malaria History of the Area

The incidence of malaria in the study area from 1962 through 1973 is shown in Figure 2. The kinds and timing of malaria control methods used during this period are also indicated. Previous studies indicate that *Anopheles albimanus* is the principal (if not the only) vector of malaria in this part of Central America (*1, 2, 3*). A formal malaria eradication program began in El Salvador in 1956. Initially, this program concentrated on spraying house interiors

Figure 2. Antimalaria measures and malaria cases, by month, in District 13, El Salvador, 1962-1973.



with dieldrin or DDT every six months. However, widespread *A. albimanus* resistance to dieldrin was apparent by 1958, and beginning in August of that year DDT was used exclusively throughout the country. Soon after that, vector resistance to DDT was found to exist in many areas of the country; but because there appeared to be no suitable alternative, DDT spraying was continued. Beginning in 1963, spraying of areas with high malaria incidence, such as District 13, was supplemented with mass distribution of an amodiaquine-primaquine drug combination every two weeks. This drug distribution was discontinued in mid-1966 but began again a year later and continued through 1970. A combination of pyrimethamine and primaquine was used in District 13 during 1970, the final year of drug distribution.

During 1971, several control measures were adopted in the study area. These included aerial application of the larvicide Abate® during the dry season, two cycles of mass drug distribution with amodiaquine (July and September), and one application cycle of the residual insecticide propoxur—applied to the exterior walls of each house in the area.

Beginning in mid-March 1972 and continuing through December 1973, propoxur was applied as a residual insecticide to the interior walls of each house in the area on a five-week spraying cycle. The entomologic and epidemiologic evaluation of this insecticide usage in 1972 has been reported by Hobbs and Mason (*4*).

A significant factor affecting control of the malaria vector in this part of El Salvador is the widespread aerial spraying of insecticides for control of cotton pests. The impact of such spraying on vector populations has previously been reported by Hobbs (*5*).

Data Collection Methods

During the three-year period of the study, information was collected from several sources. One such source was a passive case-detection system, which was operating for the entire period. This system enabled persons to report symptoms they considered indicative of malaria infection to an easily accessible post manned by a volunteer from the community—a "voluntary collaborator." Here a presumptive treatment with amodiaquine or chloroquine was available, and a blood film sample was obtained by finger puncture for later diagnosis. These blood films were picked up from each of the 14 posts in the area at least once a week and were brought to the CARS laboratory for staining and examination.

During 1972 a number of additional surveillance methods were employed. An active case search was made for persons with malaria symptoms; this entailed visiting each household in the study area every two weeks, obtaining blood film samples from consenting symptomatics, and offering presumptive treatment with amodiaquine or chloroquine. In addition, mass surveys were conducted in selected schools and communities. Slightly less than half of the cases detected were investigated in order to determine their origin and other background characteristics, and a number of family and neighborhood surveys were conducted around known cases. All persons encountered with fever during case detection and investigation activities were offered a presumptive antimalaria treatment.

During 1973 fewer mass surveys were conducted, and house-to-house visits for detection of active cases were done on a monthly schedule rather than a bi-weekly one. Case investigations were discontinued early in the year.

All blood films collected were stained and examined by CARS staff members. Slides were stained by a standard Giemsa method and 100 thick-film fields were examined to establish negativity. Parasite densities were determined routinely for all blood films positive for malaria. The densities were calculated using the ratio of parasites to white blood cells, based on an arbitrarily assigned WBC count of 6,500 per mm^3 of blood.

Along with the house-to-house case detection activity, a continuing census of the human population, both permanent and transient, was maintained. Information on malaria incidence during the years before 1970 was obtained from prior CARS studies and from El Salvador's National Anti-Malaria Service.

Daily weather information was collected by a Government meterological station in the area. Entomologic data were obtained by making weekly mosquito density measurements. This was done by collecting adult mosquitoes with human attractants and light traps, by collecting resting mosquitoes in houses and cattle stables, and by collecting larvae weekly at 18 breeding sites scattered throughout the study area.

Results

Malaria Incidence

Table 2 summarizes the data on *Plasmodium vivax* and *Plasmodium falciparum* cases detected in each of the three study years (1971-1973), showing the cases detected by the voluntary collaborator (VC)

Table 2. Malaria case detection, District 13, El Salvador, 1971-1973.

Year	Slides from voluntary collaborator posts				Slides from all sources*			
	Total slides collected	Slides positive for		Total positive slides	Total slides collected	Slides positive for		Total positive slides
		P. vivax	*P. falciparum*			*P. vivax*	*P. falciparum*	
1971	2,211	1,043	3	1,046	17,875	2,074	12	2,086
1972	2,984	1,106	233	1,339	19,680	2,132	533	2,665
1973	4,272	1,473	1,160	2,633	14,305	2,146	1,712	3,858

*Including voluntary collaborator posts.

posts alone and by all surveillance sources combined. It is apparent that there was a significant increase in the incidence of *P. falciparum* cases during the three-year period, while the annual incidence of *P. vivax* cases remained relatively stable. At the beginning, in 1971, there were hardly any *P. falciparum* infections in the study area. Only 12 cases were detected in 17,875 blood films collected from all sources, suggesting an absence of transmission of this species. At the same time, over 2,000 cases of *P. vivax* were diagnosed, which was roughly comparable to the number of cases diagnosed in each of the next two years.

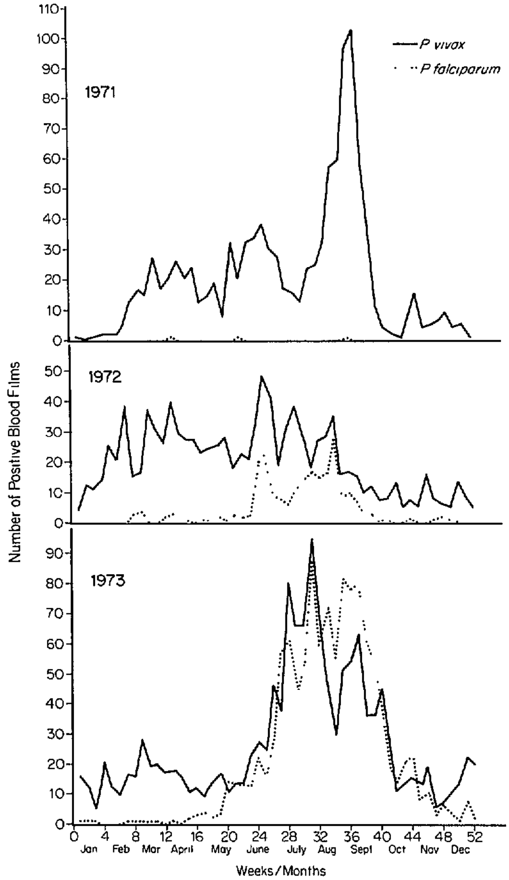
The relative efficiency of the VC posts, compared to the other surveillance methods, is shown by the data collected in 1972 (Table 3). Over half of the positive blood films were detected through the VC posts, although these posts contributed only about 15 per cent of the total number of blood films collected. Because these posts were operated in the same manner and number during the entire study period, year-to-year comparisons utilizing this source of data are probably of greater value than comparisons of data obtained by other means.

Examination of malaria incidence data from the VC posts, by week of blood film collection (Figure 3), indicates a somewhat similar seasonal pattern during the three years 1971-1973. There was usually a spring wave of *P. vivax* cases, followed by a short intense transmission season that started soon after the beginning of the rains in late May. The transmission season seems to have been characterized by an initial peak in late June, a second sharp peak in early August, and a rapid decline of cases in late August or early September. Because of the characteristic relapses of *P. vivax* infections, an indeterminate number of these case reports may have represented relapsing parasitemias rather than new cases, making a true assessment of seasonal transmission difficult.

Table 3. Results of various surveillance methods used in District 13, in terms of slides collected and malaria cases detected (1972).

Surveillance method	Slides collected		Positive slides		Slide positivity (%)
	No.	% of total collected	No.	% of total cases	
Voluntary collaborators	2,984	15.2	1,339	50.2	44.9
Active case searches	2,515	12.8	508	19.1	20.2
Mass surveys	8,279	42.1	288	10.8	3.5
Contact surveys	1,478	7.5	169	6.3	11.4
Follow-up of positive cases	4,424	22.5	361	13.5	8.2
Total	19,680	100	2,665	100	13.5

Figure 3. Blood films positive for *P. vivax* and *P. falciparum* obtained through voluntary collaborator posts in District 13, El Salvador, in 1971, 1972, and 1973.



The seasonal cycle of *P. falciparum* cases probably represents the actual seasonal pattern of malaria transmission better. Because of the paucity of cases in 1971, however, seasonal *P. falciparum* cycles were visible only in 1972 and 1973 (Figure 3). In both years, area-wide transmission began soon after the onset of the rainy season, and an initial peak number of cases occurred in the twenty-fifth week of 1972 and the twenty-fourth week of 1973. In 1972, after a subsequent decline in new cases, another peak was seen during the thirty-fourth week, followed by a rapid decline to an extremely low incidence for the remainder of the year. In 1973, however, the incidence continued to rise, with intermittent fluctuations, to a high on the thirty-first week. It then remained relatively high until the thirty-seventh week, at which time there was a sharp decline in cases, and few cases were seen after the forty-fourth week.

Figure 4 shows close 1973 correlations between the seasonal occurrence of *P. falciparum* cases, vector densities, and aerial application of agricultural insecticides in the area. Light trap captures indicate that *Anopheles albimanus* populations decreased to near zero levels shortly after the first two weeks of significant spraying activity, although rainfall continued at substantial levels, and a sharp decrease in cases followed two weeks later.

Figure 4. Correlations between cases of *P. falciparum* malaria, aerial insecticide spraying, *Anopheles albimanus* density, and rainfall in District 13, El Salvador (1973).

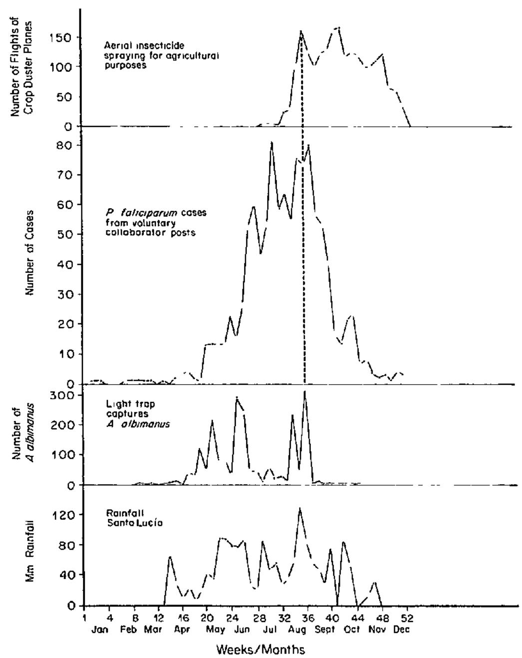


Table 4. Ages of positive subjects whose malaria cases were detected by the voluntary collaborator posts (1972-1973).

Age group (years)	1972			1973		
	Total slides collected	% Positive for:		Total slides collected	% Positive for:	
		P. vivax	*P. falciparum*		*P. vivax*	*P. falciparum*
0-4	299	43.8	5.0	452	45.1	17.0
5-14	1,057	47.5	6.8	1,446	49.1	26.4
15 +	1,628	29.1	9.0	2,374	23.5	29.5
Total	2,984	37.1	7.8	4,272	34.5	27.2

Similar patterns were also observed in the two previous years.

The age distribution of subjects with *P. vivax* and *P. falciparum* infections detected through the VC posts during 1972 and 1973 (Table 4) suggests minor differences in the distribution of these parasite species. The two younger age groups (0 to 4 and 5 to 14 years) showed higher positivity rates for *P. vivax*, but this situation was reversed with regard to *P. falciparum*—the two older groups (5 to 14 and 15 or above) showing the highest rates of positivity. These differences would be accentuated somewhat if attack rates were considered. Based on age information derived from the continuing population census, cases of *P. vivax* appeared to be about twice as common in the 5-14 age group as in the older and younger groups, and cases of *P. falciparum* seemed only about one-third as frequent in the 0-4 year group as in the older groups.

Little difference was observed in the positivity of blood films collected from males and females. However, population estimates indicate a higher attack rate for males than for females in 1973, with some 315 male cases per 1,000 population as compared to 261 female cases.

Origin of Cases

During 1972, a total of 1,285 known cases (814 *P. vivax* and 471 *P. falciparum*) were investigated to determine the extent to which cases were being imported into the area by migrant populations. Only 2.2 per cent of the cases could be confirmed as having been imported from outside the study area. These occurred primarily in migrants who became ill less than two weeks after they arrived; they included a number of *P. vivax* cases with attacks occurring during low transmission periods, probably representing relapses of infections acquired elsewhere.

About 74 per cent of the *P. vivax* cases and 69 per cent of the *P. falciparum* cases investigated occurred in subjects who had resided in the area for one year or more, and who had little or no opportunity for exposure outside the study area. However, fairly high proportions of cases (14 per cent of *P. vivax* and 19 per cent of *P. falciparum*) had resided in the area for three months or less when the infection became apparent. This finding suggests that in many cases the infection was acquired relatively soon after arrival; it is probably also related to the fact that the greatest influx of migrants coincided with the major transmission season.

Disabling Effects of Malaria

During the course of the case investigations, information was collected on the disabling effects of malaria infections in the area. The infected person was questioned concerning symptoms experienced and any disability (i.e., prevention of normal activity) resulting from the attack. The investigations were usually carried out three to four weeks after the attack was terminated with presumptive treatment, and the information derived from each case depended on the subject's recollection of events during this period. Since only 4 per cent of the subjects investigated claimed to be asymptomatic, it is assumed that the rest had received presumptive therapy. A tabulation of the symptoms recalled suggests that there was little difference between *P. vivax* and *P. falciparum* cases (Table 5). Higher proportions of *P. falciparum* patients reported "headache," "aches and pains," and "dizziness," which could suggest a higher proportion of *P. falciparum* cases with symptoms relating to the central nervous system. No deaths were reported in connection with any of the cases investigated.

Disability from malaria was determined by asking how many days the patient spent "in bed" during his attack. The term "in bed" was probably taken to mean inability to perform usual activities—work, school, or household duties—instead of being interpreted literally. Those who had experienced an attack of *P. falciparum* malaria reported spending an average of 2.9 days "in bed," while those with *P. vivax* cases reported an average of 2.4 days "in bed." Reported disability was somewhat greater among children four years of age or less, average days "in bed" being 3.6 for *P. falciparum* patients and 2.8 days for *P. vivax* patients.

Table 5. Symptoms reported by 1,232 symptomatic subjects with *P. vivax* and *P. falciparum* infections, District 13, El Salvador, 1972.

	% of cases[a]	
	P vivax	*P falciparum*
Asymptomatic cases	*4*	*4*
Symptomatic cases	*96*	*96*
Symptoms reported:		
Fever	93	94
Headache	80	85
Chills	70	64
"Aches and pains"	67	82
Anorexia	63	62
Sweating	43	50
Vomiting	37	34
Nausea	28	30
Dizzines	17	40
Diarrhea	8	6

[a]Italicized figures are % of total cases. Other figures are % of symptomatic cases.

Characteristics of Parasitemias

By definition, those persons whom the normal passive and active case-detection systems found positive for malaria were symptomatic. During 1972, a number of surveys carried out among special groups, such as schoolchildren and members of specific communities, found that between 3 and 10 per cent of the population exhibited asymptomatic *P. vivax* parasitemias. While some of these may have been early infections which subsequently produced symptoms, many undoubtedly represented asymptomatic attacks tolerated by the patient, with low parasitemias which continued for indeterminate periods. Asymptomatic *P. falciparum* parasitemias, except for post-treatment gametocytemias, were seen much less frequently.

Of the blood films from *P. falciparum* cases detected by the voluntary collaborators in 1972, 83 per cent were found to have trophozoites only, 12 per cent exhibited both trophozoites and gametocytes, and 5 per cent showed gametocytes only. When all sources of blood films are considered, gametocytes were observed in 54 per cent of the positive samples; but a progressive decrease was seen among older age groups, the percentage of positive samples ranging from 67 per cent in the 0-4 year age group to 49 per cent in those 15 years of age and above. The results for 1973 were essentially the same. A similar age trend was observed with respect to gametocyte densities, higher average densities being found in the younger age groups.

In general, the average parasite densities found in blood films collected at the VC posts were slightly lower among older age groups (Table 6). This was seen more consistently with regard to *P. vivax* infections, but even with this species the differences could not be considered great. Nor was there any appreciable difference between the parasite densities found in blood films from male and female subjects. However, as might be expected, there was a direct correlation between parasite densities and the degree of disability (symptoms and "in bed" time) reported by the patients.

One change observed among all age groups and those infected with each parasite species was a pronounced increase in the parasite densities noted in 1973 as compared to 1972. In 1972 the average *P. falciparum* density was 5,004 per mm^3, while in 1973 it was 6,588 per mm^3. Similarly, for *P. vivax* the 1972 average was 3,989 per mm^3, compared to 5,018 in 1973.

Table 6. Average parasite densities, by age group, among cases detected by the voluntary collaborator posts (1972-1973).

Age group (years)	Parasites per mm^3 of blood*			
	P. vivax		*P. falciparum*	
	1972	1973	1972	1973
0-4	5,055	5,820	6,608	7,250
5-9	4,578	5,341	4,250	8,170
10-14	4,020	5,211	4,715	8,018
15 +	3,275	4,384	5,089	5,705
Total (all ages)	3,989	5,018	5,004	6,588

*Calculated using the ratio of parasites to white blood cells, assigning an arbitrary WBC count of 6,500 per mm^3.

Availability of Antimalarial Drugs

As previously noted, presumptive treatment was offered to each person found with symptoms in the course of the surveillance activities. Additional sources of treatment were also available in the study area. An estimated 5,000 to 10,000 chloroquine tablets were sold each year during the period in question, and some 500 injections of chloroquine were given through about 38 private shops. Antimalaria treatment was also administered by some of the farm managers to workers requesting treatment for malaria symptoms.

Discussion

Although similar patterns of malaria incidence could be seen in each of the three study years, there were notable differences. The reasons for these differences are undoubtedly multiple, relating to variations in climatic conditions, to various control and treatment measures used in the area during these and previous years, and to differences in surveillance methods.

The low levels of *P. falciparum* cases observed in 1971 and 1972 (Table 2) were probably related to the mass distribution of antimalaria drugs on a continuing fortnightly schedule for the preceding two years, during which time only rare cases of *P. falciparum* were detected. Because of the curative effect these drugs have on *P. falciparum* malaria, this species often disappears from areas given such treatment and may return only slowly if importation of cases from neighboring areas is infrequent. Moreover, the chances for importing this species from nearby areas were undoubtedly reduced because presumptive treatment of symptomatics was available throughout the entire coastal region of El Salvador, and also because *P. falciparum* tends to produce an attack sufficient to stimulate the patient to seek treatment.

On the other hand, the relapsing tendency of *P. vivax* infections, plus the probability that neither presumptive treatment nor the drugs administered in mass treatment campaigns would cure such infections, contributed to the presence of a *P. vivax* reservoir at the beginning of the transmission season. This, in turn, made it possible to have a reasonably "normal" transmission rate despite widespread prior drug use. It should be pointed out that a suppressive drug was distributed to the entire accepting population on two occasions during 1971 (July and October). While this alone would probably not have eliminated *P. falciparum* for the entire year, it could well have contributed to a continued low level of transmission.

Whether or not the continuing low incidence of *P. falciparum* cases during 1972 was due to a further residual effect of prior drug usage is unclear. A total of 533 cases were detected by all surveillance sources, but only 233 of these were found by the voluntary collaborator posts. The reported number of *P. vivax* cases remained about the same as in the previous year. It would seem logical that the buildup of *P. falciparum* transmission levels might well have been slow, particularly with the constant availability of early treatment through the active and passive case detection systems. Moreover, 1972 was a year of comparatively low rainfall, and even the expected peaks of *P. vivax* cases during the usual season of high transmission were considerably depressed (see Figure 3). A somewhat earlier initiation of aerial insecticide spraying for agricultural purposes in 1972 may also have resulted in a reduction of malaria cases as compared to more normal years.

The significant increase of *P. falciparum* cases in 1973 suggests a return to "normal" transmission levels. There had been no mass distribution of drugs in the study area during the previous year, nor was there any in 1973. Another factor which may have increased transmission during 1973 was the apparent emergence of vector resistance to propoxur, which was used as a residual spray in all of the area's houses during 1972 and 1973. Such resistance, which had been noted in 1972 (*4*), appeared to intensify during 1973.

Cases of *P. vivax* occurred throughout the area at virtually all times of the year, regardless of the presence or absence of significant vector populations. A close analysis of these cases (*6*) has suggested that a large majority of the cases occurring during "non-transmission" seasons may have been relapses of infections acquired during the high-transmission season the previous year. Relapses cannot be differentiated from primary attacks, either clinically or parasitologically; however, an indeterminate proportion of cases occurring at any time during the year are undoubtedly relapses. For this reason, under normal circumstances *P. falciparum* may provide a more accurate estimate of actual transmission patterns. While foci of *P. falciparum* cases were also seen occasionally during seasons when vector populations were generally low, these outbreaks were usually localized and could be related to focal vector breeding at sites where water had collected during the dry season.

The relationship of the heavy use of aerially sprayed agricultural insecticides to the reduction of vector populations and malaria cases was evident during the three years of observations. The effect of such insecticide use on vector populations in this area has been reported previously (*5*), and the resulting decrease in malaria transmission—as shown by the subsequent rapid decrease in cases—is striking. There is little doubt that the use of agricultural insecticides in this area provides an effective method of malaria control during the spraying season. However, there is also a well-grounded suspicion that the use of agricultural insecticides has contributed significantly to the development of vector resistance to those compounds used specifically for vector control (*7*). Thorough testing of *A. albimanus* mosquitoes from the study area has shown high levels of resistance to all classes of insecticides used for residual house spraying, and the ineffectiveness of the carbamate propoxur in the study area during 1972 and 1973 has been well-demonstrated by the high malaria transmission rates.

The studies of parasite densities yielded several interesting findings, especially with regard to the decrease of those densities among older age groups. Macdonald (*8*) has pointed out the relationship of gametocyte and total parasite densities to length of residence in areas of intense malaria transmission, and has interpreted the reduction in parasite densities with age as a reflection of acquired immunity. The decreases seen in hyperendemic situations are generally more pronounced than those seen in the present study. However, this may well be due to the greater frequency of infections in hyperendemic situations, leading to production of higher levels of acquired immunity and lower parasitemias than would be seen among comparable age groups in an area of moderate endemicity such as the one involved here.

Another factor which may have served to diminish the differences observed in the present study could be the usual source of blood films—many of which were collected by passive and active case-detection systems from persons with actual symptoms. It is generally thought that compared to non-immune subjects, persons with partial immunity tolerate higher asexual parasite densities prior to a symptomatic attack. In such semi-immunes, one would expect to see higher asexual parasitemias at the time of sampling (i.e., at the appearance of first symptoms) than would be seen in non-immunes. This circumstance would have little effect on gametocyte densities, however, and indeed the present study did find *P. falciparum* gametocyte occurrence and density to vary more with the subjects' age than did the occurrence and density of asexual parasites.

The reasons for the increased *P. falciparum* and *P. vivax* densities on positive 1973 blood films—as compared to those collected the previous year—are not apparent. The overall results do indicate a large increase in *P. falciparum* cases in 1973, which might explain the increased densities of this parasite species. Since the incidence of *P. falciparum* had been relatively low for the previous three or four years, 1973 could almost be considered an epidemic situation involving a high number of non-immunes. In this regard, the highest rates of increase in *P. falciparum* parasite densities were seen in the 5 to 9 and the 10 to 14 age groups. On the other hand, the 1973 increase in the number of *P. vivax* cases was relatively small, and would not appear to explain the observed increase in *P. vivax* parasite densities.

It is apparent that the passive detection of cases by the voluntary collaborator posts has served well in developing basic epidemiologic information about this area. The other surveillance methods and the case investigation led to discovery of many additional cases and contributed additional information about asymptomatic cases, case origins, and disability due to malaria; but they contributed little of the information needed for a basic understanding of transmission patterns. The studies conducted in 1972, including various surveillance methods, indicated that the voluntary collaborator posts detected approximately one-half of the malaria cases found. Thus, one would consider the total number of cases in a given area to be at least twice as high as those reported by the passive detection system alone.

For many years this system of passive case detection has performed well in El Salvador and other countries in assessing the progress of malaria eradication and control programs. Its single outstanding fault has been its usual inability to provide information on a timely basis. Because of delays in collecting slides from the posts and returning them to a central laboratory for staining and examination, and because of frequent further delays in examining slides and reporting results, the information provided is frequently one or two months old. While this system still yields adequate retrospective information, it does not permit timely control programs directed at current transmission problems. In the future, if there are no effective or economically feasible broad coverage programs—using such methods as residual insecticide applications or mass chemotherapy—there may be a greater need to rely on focal control activities based on current information about disease incidence. But unless the usual time-lag involved in operating this passive detection system is materially reduced, the system will not be adequate for this purpose.

Perhaps just as important as the surveillance function of the voluntary collaborator post is its role as a treatment facility. The usual early presumptive treatment that it makes available to the population has done much to reduce disability and eliminate mortality from malaria in this area. The part played by this early and easily available treatment in reducing transmission is highly speculative, but it seems certain that it does make an important contribution.

The fact that 83 per cent of the *P. falciparum* cases detected at the VC posts were found to exhibit only asexual parasites suggests that early case detection and treatment, at least within the first eight days of detectable parasitemia, is the rule. It was assumed that in many of these cases treatment was early enough to abort the infection prior to the formation of gametocytes, as is usually the case if a 4-aminoquinoline drug such as chloroquine is administered during the first six or seven days of patent parasitemia. Examination of many of these cases two to three weeks after treatment showed this to be the case in some, while others exhibited gametocytes, indicating that treatment had been too late to abort gametocyte production. Treatment of *P. vivax* infections with a 4-aminoquinoline usually eliminates infectivity within 48 hours of treatment. The addition of small quantities of primaquine to the presumptive treatment regimen might be worth considering as a way of achieving the same purpose with *P. falciparum*.

The future prospects for control of malaria transmission in this typical coastal area of El Salvador do not appear to be bright. The failure of low-cost mass coverage programs of interior house spraying appears inevitable, because of vector resistance to insecticides and incompatible vector behavior patterns. This situation coincides with the current era of reduced support for malaria programs—a circumstance that would appear to preclude introduction of high-cost measures such as universal drug distribution for indefinite periods.

Effective and affordable control programs, which would accept tolerable levels of transmission, could be based on intimate knowledge of the epidemiologic factors involved in an area similar to that described in the present study. Obviously control procedures would not be needed throughout the entire year. Vector populations are generally low and focalized during the dry season, and during the season of agricultural insecticide spraying there is enough control of vector populations to reduce malaria cases to low levels. Thus, control measures would be needed principally during the early months of the wet season. The application of measures could be localized in accordance with needs, involving such steps as drug distribution to high-risk groups or vector control in high-risk areas, as determined by current surveillance information. In this regard, the continuation of an effective and well-supported voluntary collaborator system—both for surveillance and for prompt presumptive treatment of cases—would constitute an irreducible minimum activity for keeping malaria morbidity and mortality in such endemic areas within reasonable limits.

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SUMMARY

A three-year investigation was made of the incidence patterns and characteristics of malaria in a small high-incidence coastal area of El Salvador with a resident population of about 6,000 persons and a migrant population of 3,000 to 4,000 others. It found a significant increase in the incidence of *Plasmodium falciparum* cases during the three-year period, combined with relative stability in the annual number of *Plasmodium vivax* cases.

A close correlation was observed between the seasonal occurrence of *P. falciparum* cases in 1973 and vector densities, and between vector densities and aerial application of agricultural insecticides. Cases of *P. vivax* appeared about twice as common in the 5 to 14 year age group as in older or younger groups, and cases of *P. falciparum* seemed only about one-third as frequent in the 0 to 4 year group as in older groups. The attack rate in 1973 was somewhat higher in males than in females. There appeared to be a decrease in parasite densities with age, as well as a direct correlation between parasite densities and the degree of disability (symptoms and "in bed" time) reported by patients.

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