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MALARIA EPIDEMIC IN HAITI FOLLOWING A HURRICANE

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On the night of October 3-4, 1963, a hurricane (Flora) swept across the southern peninsula of Haiti with devastating effect. In addition to the immediate damage caused by the storm, the area affected suffered a severe malaria epidemic which started approximately 2 to 3 months after the hurricane had passed. Since the epidemic occurred during the course of a malaria eradication program in which an extensive surveillance program was being carried out, an opportunity was provided to study its development closely. The following is a description of the outbreak, which is estimated to have caused some 75,000 cases of malaria.

Malaria in Haiti

Malaria in Haiti is mesoendemic and moderately unstable, with seasonal epidemic exacerbations showing a fairly close correlation with alterations in rainfall. Comparatively high blood slide positivity rates (31%) were seen in surveys of school children carried out in 1940-42 by Paul and Bellerive of the Rockefeller Foundation.[1] At that time 88% of the infections were caused by Plasmodium falciparum, 10% by P. malariae and 2% by P. vivax.

The principal vector is Anopheles albimanus, which is the main vector in the Caribbean and Central American region. A. albimanus is primarily a coastal mosquito, although it is readily found inland if conditions are suitable. It is largely non-domestic and zoophilic, but bites man and will enter houses. Reported sporozoite rates are low, below 0.6% according to MacDonald[2]. On the basis of epidemiological surveys, malaria transmission in Haiti is considered to be found mainly in areas under 500 meters altitude.

The rainy season in the area usually starts in late March or early April. The rainfall rises to a peak in May, with a secondary peak in August or September, and then begins to drop in October, November and December (Fig. 1). Although there is considerable fluctuation in rainfall from month to month and from season to season, some mosquito breeding continues, even during the driest seasons.

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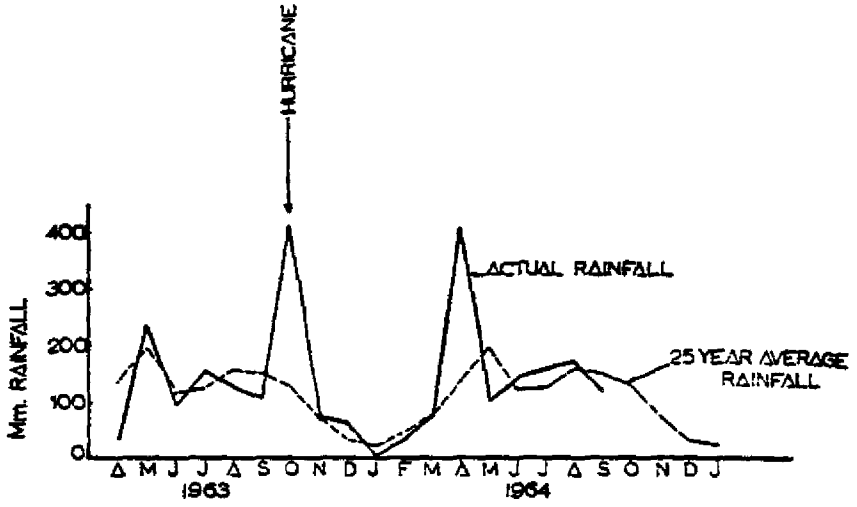

Figure 1. Monthly rainfall in millimeters, Petit-Goave, Haiti (in zone affected by hurricane).

A number of blood parasite surveys carried out in 1960 and 1961 in the area later affected by the hurricane showed parasite rates ranging from 17% to 32%. Annual parasitological surveys were started in January 1962 when the malaria eradication spraying program was initiated. Rates of 10% were seen in 1962 in index localities in the hurricane zone. By January 1963, the rate had dropped to 0.8% in the same area, but the rates in January 1964 had increased to 17%.

The Haiti Malaria Eradication Program

The malaria eradication program in Haiti was started in March 1961. The preparatory phase activities were carried out from May to December 1961 and the first cycle of spraying of houses with DDT at a dosage of 2 grams technical grade per square meter was started in January 1962. Spraying was limited to localities under 500 meters altitude and was carried out in six-month cycles. About 50% of the 4th cycle had been completed when the hurricane struck.

The surveillance program was started in June 1962, five months after initiation of the spraying operations. By October 1, 1963, some 100 voluntary collaborator posts were in operation in the area affected by the hurricane. These were being visited monthly by eight malaria service case finders, who also collected blood slides, primarily from fever cases, in localities along the route from one collaborator post to the next. Both collaborators and case finders in Haiti provide single doses of chloroquine to all fever cases from whom blood slides are obtained.

Area Affected by the Hurricane

The cyclone crossed the mid-section of the southern peninsula of Haiti, directly affecting an area of some 2,200 square kilometers. This area is made

up of two coastal plains separated by a discontinuous chain of mountains in the interior, which reach an altitude of 1,200 meters. The main resourses of the region are coffee and sisal cultivation. Small scale farming of bananas, corn, millet, and red beans is carried on for family use. Some 520,000 persons live in the affected area. The region is densely populated, averaging some 250 persons per square kilometer. The highest densities are found on the coastal plains, where certain sections have more than 350 persons per square kilometer. The population is primarily rural. There are few urban centers and these contain only about 10% of the total population. Practically 100% of the population is of the Negro race.

The houses in the rural areas are of the type of construction commonly found in Haiti: walls made up of a base of woven wooden strips, covered with mud, and a thatch roof made of palm leaves or straw. The houses are quite small, approximately 9 feet by 19 feet, with the sprayable wall surfase averaging about 100 square meters. There is an average of 3.5 persons per house.

Description of the Hurricane

The hurricane was reported for the first time off the coast of Venezuela on September 30, 1963. The storm touched the southern peninsula of Haiti about 5:00 p.m. on October 3, and reached its maximum intensity in the interior about 8:00 p.m., with winds up to 250 kilometers per hour. It had completely passed over the peninsula by midnight that same night.

Flown over at low altitude, the area presented a picture of total destruction and desolation. Almost all the houses were completely demolished. The first estimate of actual damage, which could never be completely verified, was that there had been some 4,000 to 5,000 deaths. Some 200,000 persons were without any shelter and crops not yet harvested had been destroyed.

In addition to the actual damage from the winds, considerable damage was caused by floods following the storm. There were actually two distinct periods of heavy rainfall, one immediately related to the passage of the cyclone on October 3 and 4, and a second period on October 8, occasioned by the passage of the hurricane to the north of Haiti.

The second period of rainfall was less intense than the first, but because of the highly saturated condition of the soil from the first heavy rains, the second period of rains caused even heavier flooding. Many of the river courses had been blocked by fallen trees and impacted debris, mud and stones, causing diversion of the flood waters at many points. Although no observations were made on mosquito density by entomological personnel during October, it is assumed that the breeding subsequent to the hurricane must have reached an extremely high level. The temperature and humidity in the area for October and November were optimal for mosquito survival and reproduction (Table 1).

TABLE 1

Temperature and average relative humidity in Port-Au-Prince, Haiti, October-December 1963

Date	Temperature (°C)			Avg. relative humidity
	Avg.	Max.	Min.	
October 1963	27.6	31.8	25.4	73.9
November 1963	27.9	32.6	23.2	66.5
December 1963	27.8	32.5	23.1	65.4

Development of the Malaria Epidemic

The first indication of an unusual increase of malaria incidence in the affected area was a report by a voluntary collaborator post in mid-December of a sudden rise in the number of fever cases. By the end of December it was obvious that a full-blown epidemic was developing. From a total slide positivity rate of about 2% for the area in September 1963, the incidence rose to 12.1% by the end of December, to 22.2% by the end of January and to 25.6% by the end of February (Table 2).

TABLE 2

Malaria cases detected in area affected by hurricane by month of laboratory examination of blood slides

Date	Blood slides collected by				Totals		
	Voluntary collaborators		Malaria service case finders		No. collected	% pop. exam.	% pos.
	No.	% pos.	No.	% pos.			
June '62	361	3.3	1,010	2.4	1,371	0.3	2.6
July	365	1.6	1,075	3.5	1,440	0.3	3 1
Aug.	589	3.1	558	5.9	1,147	0 2	4.4
Sept.	742	1.5	716	3 6	1,458	0.3	2.5
Oct.	850	0.7	1,384	0.9	2,234	0.4	0.9
Nov.	681	2 8	890	1.2	1,571	0.3	1.9
Dec.	35	—	189	0.	224	0 04	0.
Jan. '63	257	2.3	1,894	0.9	2,151	0 4	1.0
Feb.	1,008	0.9	2,911	1.8	3,919	0.8	1.6
March	486	0.4	4,838	0.3	5,324	1.0	0 3
April	898	0.2	4,020	0.5	4,918	0.9	0.4
May	519	0.2	2,266	0.3	2,785	0.5	0.3
June	644	0.6	3,466	0.2	4,110	0 8	0.2
July	1,012	2.4	4,885	1.1	5,897	1.1	1.3
Aug.	1,024	5.0	4,176	1.6	5,200	1.0	2 3
Sept.	1,310	3.6	3,883	11.4	5,193	1.0	2.0
Oct.	724	2.2	1,840	11.5	2,564	0.5	1.7
Nov.	896	6.0	2,844	2.2	3,740	0.7	3.1
Dec.	1,524	19 8	2,338	7.1	3,862	0.7	12.1
Jan. '64	3,276	26.0	3,692	18 8	6,968	1 3	22.2
Feb.	3,805	37.8	5,699	17 3	9,504	1 8	25.6
March	3,829	20.4	5,659	15.4	9,488	1.8	17.3
April	4,487	14.9	7,851	5.4	12,338	2.4	8.8
May	1,993	12.1	8,564	2.9	10,557	2 0	4 6
June	1,100	11.8	6,991	5 9	8,091	1 6	6.7
July	1,875	13.8	7,510	9 5	9,385	1 8	10.4
	1,731	17.3	3,192	5.6	4,923	1.0	9.8
			1,254	4.9	5,232	1.0	9.4

The sharp increase in malaria infections apparently occurred simultaneously in almost all parts of the area directly affected by the hurricane. Tabulation of the slide positivity rates by date of blood slide collection at voluntary collaborator posts indicated that the incidence already was rising sharply about 6 weeks after the hurricane, in the middle of November. The epidemic curve continued to maintain a high plateau, fluctuating between 21% and 31% during December, January and February.

The slide positivity dropped by the end of March to 9%. The affected zone was visited by entomological personnel at the end of November and in February, and it was reported that many of the possible breeding areas already were quite dry and very few A. albimanus larvae could be collected. This would seem to be consistent with the rainfall data for this period (Fig. 1). However, the incidence rose again in April to 12%, continued rising to 17% in May and was up to 19% in June and 27% by July (Fig. 2).

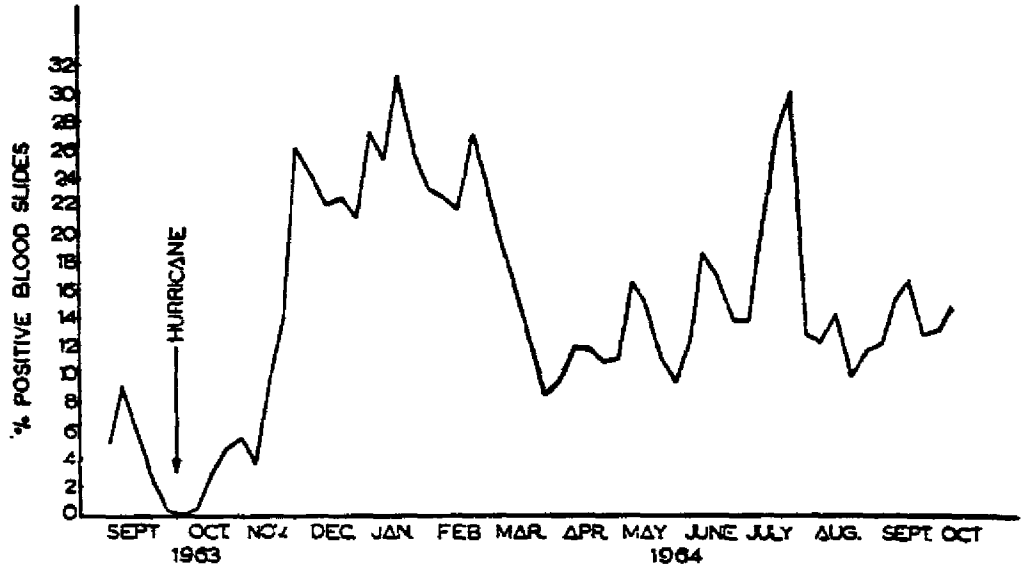

FIGURE 2. Percent of positive blood slides collected by voluntary collaborators, September 1963 & October 1964, by week of blood slide collection (zone affected by hurricane).

The parasite density was determined for all positive slides collected in the affected zone. The proportion of cases with "high" parasite density (more than 1,000 parasites per cubic millimeter of blood) rose from 56% in October 1963 to 77% in November 1963, dropped to 64% in March 1964 and rose to 84% in June 1964.

The outbreak was caused by Plasmodium falciparum (Table 3). Males and females were equally affected. Although the highest slide positivity rates were seen in infants and young children, the older age groups were also heavily affected, with rates in adults reaching 21% in January 1964 at the peak of the outbreak (Table 4).

TABLE 3

Distribution of Plasmodium species as based on positive blood slides, October 1963-May 1964

Species	No.	%
Plasmodium falciparum.....	6,184	98.5
Plasmodium malariae.....	59	1.0
Plasmodium vivax.....	26	0.4
Mixed.....	7	0.1
Total.....	6,276	100.0

TABLE 4

Blood slides collected by voluntary collaborators, by age group, October 1963-March 1964

Age (yrs)	Blood slides collected	Positive slides	Percent positive
Under 1.....	204	72	35.3
1-4.....	955	326	34.1
5-9.....	1,297	391	30.1
10-20.....	3,031	841	27.7
21 & over.....	6,247	1,094	17.5
Total.....	11,734	2,724	23.2

The most intensely affected area was along the northern coastal plain of the peninsula. The coastal sections showed higher rates than those in the interior and localities under 300 meters showed higher rates than localities at higher altitudes. At the height of the outbreak, malaria cases were detected in about 80% of localities sampled. Slide positivity rates for slides collected by voluntary collaborators reached 40-50% in some localities.

About one half of the 4th spraying cycle had been completed in most of the zone when the hurricane struck. Spraying operations had to be completely suspended in part of the area, since there was little left to spray, and were not resumed until January 6, 1964, when the regular 5th spraying cycle was

started in the rest of the country. In the intervening period, a quick reconnaissance to appraise the amount of house damage was carried out at the end of October, and a second more detailed geographic reconnaissance was accomplished in December. The first reconnaissance revealed that in the area affected by the hurricane about 68% of the houses had been destroyed, with the rest damaged to a greater or lesser degree. By the December reconnaissance some 80% of these houses had been rebuilt and repaired, and most of the rest were under construction. By the end of the 5th spraying cycle in April 1964, practically all the houses had been rebuilt or repaired.

The area of high slide positivity rates and rapidly increasing malaria incidence matches almost perfectly the area affected by the hurricane. However, it should be noted that some sections in the middle of the hurricane area, with a high percentage of house destruction, showed rather low parasite rates during the course of the epidemic. These are inland, mountainous sections, and are largely non-malarious areas.

The number of fever cases reporting to voluntary collaborator posts began to rise sharply in early December, reaching a peak in January and early February. At the height of the outbreak, the collaborators were collecting about 1,500 slides a week.

It is estimated that some 75,000 cases of malaria occurred in the hurricane zone between October 1963 and March 1964, based on an overall 25% slide positivity rate for fever cases, with an estimated 50% of the population affected with fever during the course of the epidemic.

Even though the epidemic developed rapidly, and probably affected most of the susceptible persons at risk in the area, there were no reports of undue or exceptional suffering or illness from the population or the civil authorities. A number of reports were received from medical practitioners of an increase in malaria cases in the area, but there was nothing to indicate that the epidemic had produced any alarming increase in the number of deaths or even in the amount of disability in the population. Mortality reporting is practically nonexistent in Haiti and no reliable information could be obtained from official sources.

Discussion

The rapid, simultaneous development of the malaria epidemic over practically all the area affected by the hurricane can be attributed to the following factors:

1. Continuing malaria transmission in the area before the hurricane and the presence of a considerable reservoir of gametocyte carriers at the time of maximum mosquito activity after the hurricane.

2. The great majority of the population without shelter or living in temporary shelters, with maximum exposure to biting activity of the mosquito vector.

3. Almost complete removal of insecticide coverage in houses.

4. An explosive increase in mosquito breeding, brought about by the heavy rainfall and extensive flooding.

5. Increased population movement in search of food, construction material, medical care, etc.

There had been an increase in malaria incidence in the affected zone in June, July and August, 1963, before the hurricane. Although there was an apparent drop in incidence in September, it is very likely that the number of fresh clinical cases was on the increase by October, when the hurricane struck. With a considerable number of gametocyte carriers available after the rains and flooding had stopped, when mosquito density was reaching its peak, and - with little or no protection from mosquitoes available, the first sharp rise in incidence could be expected about 6 to 8 weeks after the hurricane. This rise was seen, in fact, in the middle of November (Fig. 2).

It is unlikely that the epidemic could have developed as rapidly, and as simultaneously over such an extensive area, if malaria transmission had been interrupted before the hurricane occurred, during 3.5 cycles of house spraying with DDT. The explosive nature of the outbreak can best be explained by assuming that all the factors necessary to produce a malaria epidemic were combined at a time when the malaria incidence was already increasing in the area.

As has been noted above, the great majority of the rural houses were destroyed by the storm. Most of those that remained standing were without roofs, and practically all the houses, with or without roofs, were thoroughly drenched by the heavy rains that followed the storm. It can be assumed that there was almost complete removal of any insecticidal coverage that had been present before the hurricane. No appreciable difference in malaria incidence was seen between localities sprayed during the first 3 months of the 4th cycle, before the hurricane, and those that had not yet been sprayed when the hurricane struck.

No direct correlation was seen in the different sections in the affected zone between the amount of house destruction and the level of total slide positivity parasite rates over the six-month period after the hurricane. It is assumed that the difference in rates is an expression of the differing "malariousness" of each area rather than a direct result of the amount of house destruction. Also, it was noted that the percentage of house destruction was not necessarily a reliable index of insecticide coverage, since practically all of the houses left standing were damaged to some degree, and most of the insecticide was later removed by rains, repairs or replastering.

The 5th cycle of spraying in the affected zone, which started in January 1964, was accelerated so that the area could be covered in 4 months, by the end of April 1964 when the next transmission season was due to start. In addition, mop-up brigades covered the area again in April, to spray any new or repaired houses missed by the regular brigades.

The rainfall in the area in April was particularly heavy, and totalled as much as was recorded during October 1963, when the hurricane had struck (Fig. 1). The malaria incidence in the area had dropped during February and March and it was hoped that the fresh insecticide coverage would provide the protection needed to prevent any further increase. However, the rates began to rise in May and June and by July had reached a slide positivity of 30% for slides collected by voluntary collaborators (Fig. 2).

In addition to an increase in percent of positivity for slides collected by both voluntary collaborators and case finders, the absolute number of cases also rose (Fig. 3). The proportion of positive slides with high parasite density began to rise again in April, after having dropped from a peak in December. Also, the percent of "positive" localities and the percent of collaborator posts detecting malaria cases began to show an increase in July. From all indications, there was a true increase in malaria in the area, evidently as a direct result of the heavy rains in April.

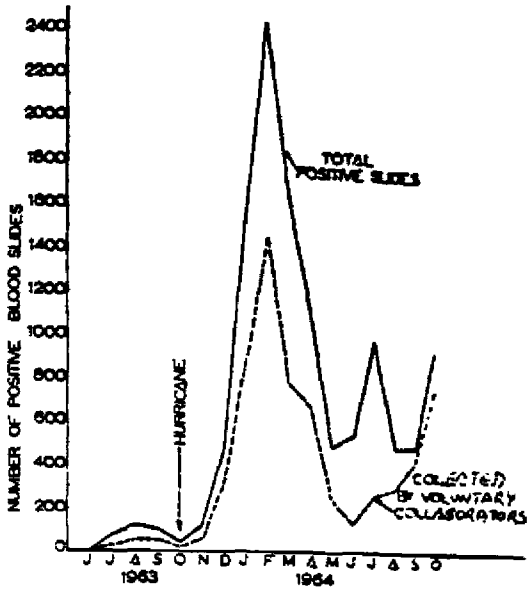

Figure 3. Malaria cases detected (positive blood slides) in zone affected by the hurricane, from June 1963 through October 1964, by month of laboratory examination.

It was assumed initially that one of the main factors in the development of the epidemic was the loss of insecticide coverage caused by the house damage and heavy rains during and after the hurricane. In view of the increase in malaria transmission after the spring rains, in spite of fairly adequate spray coverage, it would appear that this factor may have less importance than previously estimated.

Recent studies on the behavior of A. albimanus in Haiti indicate that most of the biting activity takes place in the early evening, when the great majority of the rural population can be found outside of their houses. Only a small proportion of the mosquitoes come inside of the houses to bite or rest.

Even though the vector is susceptible to DDT and bioassays on sprayed wall surfaces indicate satisfactory mortality up to 6 months, it is likely that most of the malaria transmission in Haiti is extra-domiciliary and that DDT house spraying alone may not be sufficient to interrupt transmission in highly malarious areas. Additional studies are now being carried out to clarify these questions.

Summary

An epidemic of malaria following the passage of a hurricane over Haiti October 3-4, 1963, is described. The epidemic started about 6 to 8 weeks after the hurricane and is estimated to have produced some 75,000 cases of malaria in a 3- to 4-month period. It is assumed that the rapid, simultaneous development of the epidemic over practically the entire affected area was facilitated by the presence of a considerable reservoir of gametocyte carriers, and the massive increase in mosquito breeding brought about by the heavy rains and flooding. The effect of DDT insecticide spraying in houses on malaria transmission in Haiti is still under investigation.

Any gains made by 2 years of DDT spraying have been completely wiped out by the epidemic and the malaria eradication program can be assumed to be starting over again in the affected area.

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