DRAINAGE AND LARVICIDING FOR CONTROL OF A MALARIA FOCUS IN HAITI

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INTRODUCTION. Malaria eradication programs have depended primarily on periodic applications of residual insecticides to walls of houses for interruption of transmission. The distribution of antimalarial drugs for treatment of cases or populations at risk has been virtually the only supplementary method of attack employed. Since 1961, various combinations of the measures have been used in Haiti.

Prior to development and world-wide usage of residual insecticides, source reduction and other anti-mosquito measures for control and prevention of malaria had been demonstrated in areas throughout the world. This paper describes the application of drainage and larvicidal activities for the control of malaria in a densely populated area of approximately 10,000 which experienced three epidemics and more than 1,500 cases of *P. falciparum* between February 1968 and April 1970.

DESCRIPTION OF FOCUS. Haiti began its malaria eradication program (SNEM) in 1961. About 75 percent of its population of some 4,500,000 live in areas classified as originally malarious. Program plans are developed for each of the 560 *Sections Rurales* (political subdivisions of the country). Malaria trends in some 8,000 localities in the Sections are periodically analysed for planning operations and evaluating attack measures. Malaria surveillance is by passive and active case detection. Passive case detection consists of the collection of blood slides from febrile people who visit one of some 5,300 voluntary collaborators. SNEM evaluators periodically visit all houses and collect slides from family members reporting fever within the past month in active case detection.

Prior to February 1968, only 14 cases of malaria were detected in 3 years from 15,572 blood slides collected from the population of 19,000 in Section Rurale 1 Varreux. In the succeeding 27 months, some 1,553 cases of *P. falciparum* occurred in the Section of which all but 10 were associated with three separate and distinct outbreaks as shown in Table 1 and Figure 1. The Section in which the outbreaks occurred contributed more than 15 percent of the total cases reported from the country as compared to less than 0.13 percent in similar time periods of before and after their occurrence (Table 2). The 1,308 cases in the second epidemic of 10 months' duration represented more than 50 percent of the total reported in the country.

Section Rurale 1 Varreux has 21 localities. Investigation of cases during the outbreaks by the SNEM Epidemiologist and Lobel (unpublished report) revealed that virtually all cases occurred in a population of about 10,000 from the three contiguous and congested localities of Chancerelles I, Cité Simone O. Duvalier, and Bourg Haitian II (Figure 2). The localities are on the coastal flood plain of the Caribbean Sea some 4 kilometers north of Port-au-Prince. Chancerelles I, and Cité Simone O. Duvalier are established communities of row type housing of cinder blocks with a population of about 7,000. Potable water is distributed to public watering points and to some houses. Community latrines and laundry

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TABLE 1.—Number of malaria slides examined with number and percent positive by time periods in Section Rurale 1 Varreux.

Time period	Months	Number slides examined	Number positive	Percent positive
Feb. 1968–May. 1968	4	8,444	152	1.80
June 1968–Oct. 1968	5	6,310	6	0.10
Nov. 1968–Aug. 1969	10	35,944	1,308	3.64
Sept. 1969–Nov. 1969	3	2,242	4	0.18
Dec. 1969–Apr. 1970	5	3,440	83	2.41
Total	27	56,380	1,553	2.75

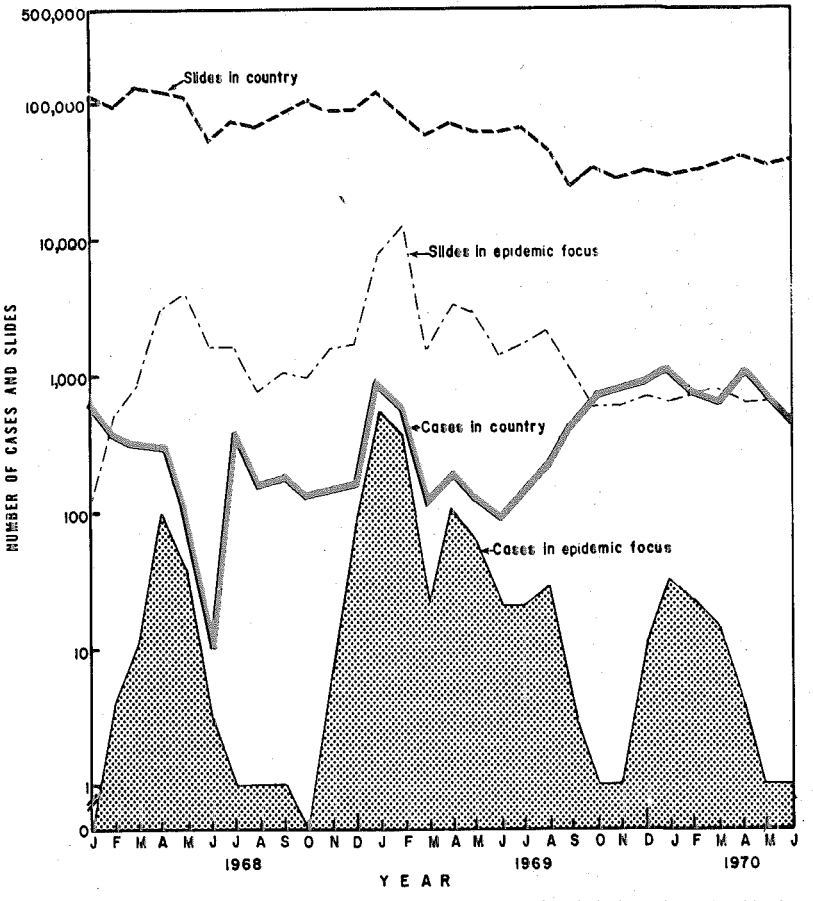

FIG. 1.—Number of blood slides examined and number of cases of malaria in Haiti and epidemic focus of sector 1-Varreux, by date of slide examination January 1968–June 1970.

TABLE 2.—History of malaria in epidemic focus and total country by 27-month time periods before, during and after the outbreaks.

Period	Number of months	Epidemic Focus			Total country		
		Slides	Positives	% Positive	Slides	Positives	% Positive
Nov. 1965–Jan. 1968	27	14,940	13	0.1	3,852,308	17,334	0.5
Feb. 1968–April 1970	27	56,380	1,553	2.8	1,879,789	10,395	0.6
May 1970–July 1972	27	11,335	35	0.3	663,453	27,530	4.1

facilities are centrally located. The third locality (Bourg Haitian II) is a "squatter" community which was established for the relocation of people from Port-au-Prince. Between December 1967 and January 1968, some 3,000 people constructed housing with material from their previous homes on the lowland between the sea and the railroad. Sometime previously, an all-weather road was constructed through the marsh to the sea for the development of wharf facilities. For ease of reference, the three adjacent localities will hereafter be referred to as Cité Simone O. Duvalier, or the malaria focus.

The elevation of Cité Simone O. Duvalier and environs ranges from about 2 to 10 feet above sea level. The salinity of the marshes that extend to the western edge of the populated area is affected by the 2-foot fluctuation in daily tides and seasonal rainfall. A limited drainage system had been constructed several years prior to the outbreaks to prevent flooding of the two original localities.

The average annual rainfall for the area during the past 25 years is 1,240 mm. The rainy season extends from late April to December with rainfall being more intense in the spring and fall than

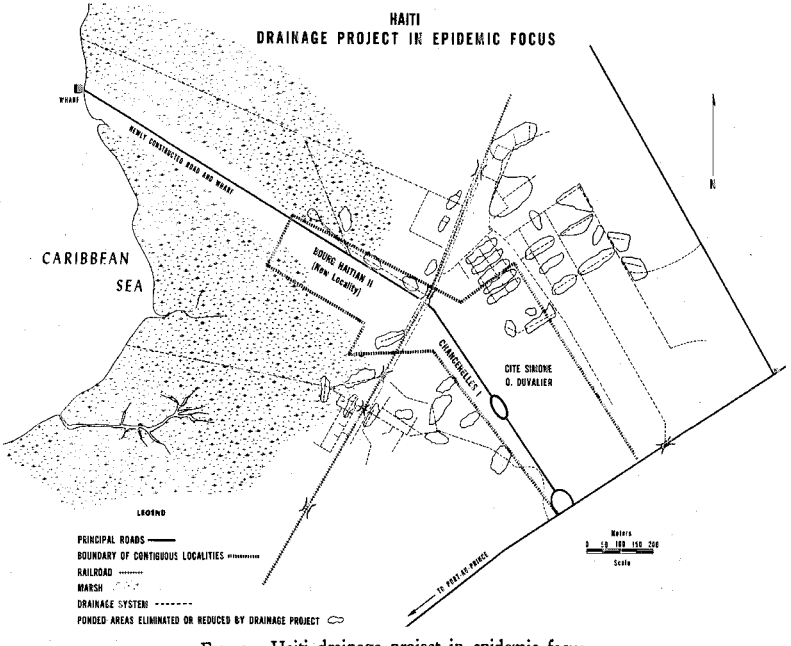

FIG. 2.—Haiti drainage project in epidemic focus.

during the summer months. In general, reduced rainfall during the summer months limits flooding and ponding of water to the spring and fall. Recorded rainfall in 1968 was slightly below the 25 year average while that of 1969 was some 20 percent higher than the average. Rainfall in 1970 was about normal and 1971 was somewhat above the average.

ATTACK MEASURES IN CITÉ SIMONE O. DUVALIER. Attack measures in Section Rurale 1 Varreux during the 3 years preceding the first outbreak consisted of brief periods of mass drug distribution (MDD) in the spring of 1966 and focal attacks in the fall of 1966 and again in January 1967. A focal attack is defined as the residual spraying of houses with DDT in the immediate vicinity of a case and radical treatment of positive cases and household members.

With the recognition of the first outbreak in early 1968, a focal attack with DDT was applied in April. In accordance with a subsequent revision in the plan of operations, MDD was initiated in the Section in July 1968 at 3-week intervals and walls of all houses were sprayed with DDT in the fall. Houses in Cité Simone O. Duvalier were resprayed during the second outbreak in early 1969 (focal attack). MDD in the focus was discontinued in February 1969 after 10 cycles because drug acceptance by the population had decreased to less than 40 percent. There was no increase in drug acceptance when 2 cycles of MDD were conducted in April following an increase in cases. Vector resistance to DDT was confirmed in early 1969. Neither residual insecticides nor mass drug distribution were used in the focus after February and May of 1969 respectively.

A single application of larvicides (144 gallons of a 2.5 percent suspension of DDT) was applied to mosquito-breeding habitats in September 1968. At that time, entomological inspections were intensified in the focus and man-biting collections of *A. albimanus* from dusk to one hour after sunset have been made continuously at selected locations in Cité Simone O. Duvalier. Densities are reported as number of bites per bait hour. The frequency of observations has been influenced by seasonal variations in rainfall, number of reported cases of malaria and trends in larval and adult densities.

Because of failure of MDD and residual house spraying to prevent or control the second epidemic, weekly larviciding with waste oil was begun in January 1969. By early summer the frequency of applications had been reduced to every 15 days. Larviciding was suspended between September and early November because of low mosquito adult and larval populations. Following resumption of larviciding in late November, breeding habitats have been treated semi-monthly with a solution of diesel oil (90 percent) and gasoline (10 percent). The gasoline was added to improve the spreading characteristics of the diesel oil.

During the peak of the second epidemic in early 1969, an inspection of the focus revealed numerous breeding habitats and showed that the drainage of the area had been seriously impeded by the construction of Bourg Haitian II and the road to the sea. The blockage of the natural drainage, and of the nominal drainage system previously referred to, resulted in the creation of extensive mosquito breeding areas. Cleaning of existing ditches and culverts was suggested, continuance of entomological inspections and larvicidal activities was encouraged and a drainage project to be constructed with hand labor and dynamite was proposed.

Following the partial cleaning of existing ditches in June 1969, the construction of the drainage system was again recommended in November by the engineer consultant of the Center for Disease Control (CDC). SNEM, with the assistance of the consultant, contracted for the temporary use of a government dragline which permitted the construction of ditches 9 feet wide and 6 feet deep with secondary ones of about 6 feet in width and depth. Between December 15, 1969 and February 3, 1970, some 28,191 cubic yards of earth were excavated by the

dragline in the construction of 16,484 lineal feet of ditches at a cost of $4,568.00. Lack of adequate mats for the dragline necessitated the manual digging of outfalls through the marsh to the sea (Figure 2).

The construction of laterals and outfalls by hand labor began in early December 1969 and, following a suspension of work for 4 months because of lack of funds, was completed in January 1971. During the peak of construction, 60 laborers were employed. Over 7,818 cubic yards of dirt were excavated of which approximately 900 was considered maintenance. Construction costs of $18,606.68 included $600.00 for purchase of shovels, picks and materials for construction of access bridges. Some 6 months after completion of the project, five laborers were employed for 4 months to clean the ditches.

DISCUSSION. More than 1,500 cases of *P. falciparum* malaria occurred during three outbreaks in a densely populated area of 10,000 in Haiti. Over their span of 27 months, the epidemics contributed more than 15 percent of the total cases reported in the country. The first outbreak of 152 cases in 4 months in early 1968 was preceded by the detection of only 14 sporadic infections in 3 years from the 19,000 people of the Section Rurale in which the focus is located. Since attack measures had been limited in scope and applied irregularly, the outbreak could not be attributed to operational failures.

In accordance with a revised plan of operations, mass drug administration (MDD) at 3-week intervals was begun in the Section of the focus in July 1968 and all houses were sprayed with DDT in the fall. The explosive nature of the second outbreak when cases increased progressively from 7 in November 1968 to 586 in January, 1969 focused attention on attack measures. The ineffectiveness of 10 cycles of MDD between July 1968 and February 1969 to prevent or control the second epidemic of 1,308 cases was attributed to the low rate of acceptance of anti-malaria drugs by the population. When MDD was subsequently applied as a focal attack in the spring and acceptance had not increased, the measure was discontinued. Failure of the house spraying cycle was believed initially due to its having been applied during the period of transmission and to the annual custom of repainting houses prior to the new year. Because of this, houses in the focus were resprayed in early 1969. With confirmation of vector resistance, the attack measure was discontinued.

Inspection of the focus during the peak of the second outbreak indicated that environmental changes converted the area from one of low receptivity to one of high transmission potential. Extensive permanent and temporary mosquito breeding habitats had been created by the construction in late 1967 of a road and housing for resettlement of people from Port-au-Prince which obstructed the drainage of the area. The failure of the attack measures to prevent or control the second outbreak prompted the initiation of routine larviciding in January 1969 and the eventual construction of the drainage system.

Attack measures, malaria cases by presumed month of infection (1 month prior to date of slide examination), monthly rainfall and average monthly adult vector densities for the 27-month epidemic and post epidemic periods are shown in Figure 3. In general, increases and decreases in malaria transmission in Haiti correspond to rainy and dry seasons respectively. It is probable that natural reductions in vector densities during the dry seasons accounted for the control of the first epidemic and contributed toward limiting the duration of the subsequent outbreaks. Nevertheless, it is concluded that the second epidemic was brought under control by larviciding. Further, it is concluded that the combined effects of drainage and larviciding resulted in the control of the third outbreak and the prevention of malaria in the focus in the succeeding 27 months while transmission in the country was rapidly increasing.

As noted earlier, entomological inspections in the focus were intensified in September 1968 just prior to the second outbreak. The monthly average of *A. albimanus* per bait-hour increased progressively from 6.0 in September to 53.7 in December. The maximum number recorded per bait-hour in a single collection was 131.0 in early December. Malaria cases increased from zero in October to 586 in January.

Vector densities declined following introduction of routine larvicidal operations in January 1969 and, but for two exceptions, have been maintained at a relatively low level. The progressive increase from 1.5 mosquitoes per man-hour in March to 35.0 in May is attributed to excessive rainfall and reduction of larviciding cycles from 4 in March to 3 in April and 2 in May. The increase preceded an up-surge in transmission and resulted in a focal attack with MDD. The second significant increase occurred following the suspension of larvicidal operations when zero densities were recorded in July and August. Vector densities increased from 2.5 in September to 29.6 in October and

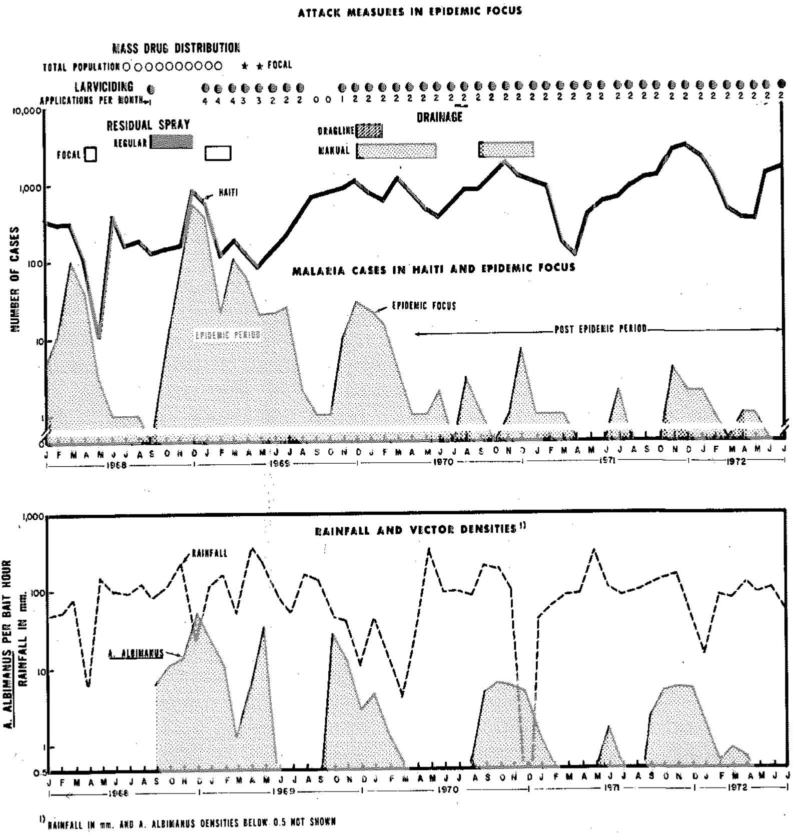

FIG. 3.—Attack measures applied in epidemic focus in relation to monthly cases by presumed date of infection, monthly rainfall and average number of *A. albimanus* collected per bait hour per month January 1968–June 1972.

precipitated the third outbreak. With resumption of routine larviciding in mid-November of 1969, vector populations have been maintained through 1972 at a relatively low level with only sporadic increases being associated with increased rainfall (Table 3).

The effectiveness of the drainage system in preventing or controlling malaria in the focus is difficult to evaluate because of the concurrent use of larvicides. Entomological observations, however, are indicative of its contributory effect. Following completion of the drainage project, vector densities have been maintained at a lower level than in 1969 with use of less than one-third the quantity of larvicide.

Obvious benefits of the drainage system included the permanent elimination of many temporary and semi-permanent mosquito breeding habitats; increased utilization of land for agricultural purposes; improved accessibility to breeding habitats, thereby facilitating larvicidal operations; and attainment of a degree of naturalistic and biological control resulting from variations in salinity in some of the breeding habitats and retention of permanent populations of larvivorous fish in others. A secondary benefit was the provision of a convenient source of water to the population for bathing and laundry purposes.

From the standpoint of eradication, transmission in the focus was not completely interrupted during the 27-month post epidemic period. Though none of the 35 cases were investigated, it is assumed that several were autocthonous.

TABLE 3.—Monthly average and range of *A. albimanus* collected per bait hour in Cité Simone O. Duvalier, 1969–1972.

	Number of *A. albimanus* per bait hour	
Year	Monthly average	Monthly range
1969	13.0	0.0–35.0
1970	2.5	0.2– 6.2
1971	1.9	0.2– 5.4
1972	1.5	0.2– 2.3

The three instances where 3 or more cases occurred in a single month can be associated with increases in rainfall and vector densities (figure 3). It is suggested that reduction of larvicidal cycles from 15 to 8 days during such periods may have completely interrupted transmission.

CONCLUSION. Three outbreaks of *P. falciparum* malaria with more than 1,500 cases were experienced by the Haiti malaria eradication program in a densely populated focus of 10,000 people in 27 months. The focus contributed more than 15 percent of the total cases reported in the country in contrast to less than 0.13 percent in similar time periods of before and after the outbreaks. It is concluded that the outbreaks resulted from environmental and ecological changes brought about by the construction of a road and resettlement housing which obstructed the natural drainage of the area and created extensive mosquito breeding habitats.

Malaria transmission in Haiti is marked by seasonal trends with periods of high and low prevalence associated with rainfall. It is likely that natural reductions in vector populations during the dry seasons contributed to limiting the duration of three epidemics and probably accounts for the control of the first outbreak. Larviciding contributed to the control of the second epidemic. The third epidemic followed the suspension of larviciding which permitted a buildup of vector densities. Its control, and the prevention of malaria during 27 months following the outbreaks while malaria transmission in the country was increasing, is attributed to the combined effects of the drainage project and of the program of larviciding.

House spraying with residual insecticides is the method of choice for eradicating or controlling malaria. In areas of continuing transmission, mass drug distribution is a useful supplementary attack measure. Combined measures of attack failed to prevent or control the second outbreak and were discontinued because of vector resistance and low rate of drug acceptance by the population. The ex-

perience in Haiti, and reports of persistent transmission in other countries despite the repeated application of residual insecticides, reconfirm needs for continuous evaluation of attack measures. Complexities of factors contributing to persistent transmission requires the utilization of multi-professional disciplines for investigation of causes of persistent transmission and evaluation of attack measures. It is suggested that the extent of reported problems throughout the world warrants a reappraisal of the role of entomology by eradication programs.

Prior to the development of the residual insecticides, the effectiveness of "classical" methods of source reduction and anti-mosquito measures for control of malaria had been widely demonstrated in many areas of the world. Because of their effectiveness, it is concluded that increased attention should be given by malaria eradication programs to their use as supplementary or alternative attack measures in areas of persistent transmission.

ACKNOWLEDGMENT. The assistance of John Sexton, Dr. F. Milor, M. L. Silva, Dr. I. Pons and Mr. J. S. Karam who supervised and evaluated much of the field operations is gratefully acknowledged and appreciated.

NEW DISTRIBUTION RECORDS FOR SNOWPOOL *AEDES* MOSQUITOES IN THE MOUNTAINS OF ARIZONA AND NEW MEXICO

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For several years we have been investigating the distribution of the snowpool *Aedes* mosquitoes in the mountains of western North America. These species with the exception of *Aedes* (*Aedes*) *cinereus* Meigen belong to the subgenus *Ochlerotatus* and are single brooded species found at higher elevations in the mountains and mountain valleys of the western United States. Due to their univoltine habits and over-wintering in an egg stage with an obligatory diapause they are believed to have evolved in arctic or cold temperate regions. They were apparently pushed southward into the western United States during Pleistocene glaciation and were left restricted to the colder mountainous regions when temperatures warmed after the glaciers receded northward. Certain species, such as *Aedes cataphylla* Dyar, *Aedes fitchii* (Felt and Young) and *Aedes increpitus* Dyar which often occur at lower elevations in mountain valleys may still be in the process of extending their ranges.

Although there are over twenty snowpool *Aedes* species known to occur in western North America, only four of these species have been reported as occurring in Arizona and New Mexico. *Aedes cataphylla* and *Aedes fitchii* were reported from northern Arizona by Richards, Nielsen and Rees (1956). *Aedes fitchii* also has been reported from New Mexico (Wolff, 1970). *Aedes increpitus* was reported from New Mexico by Theobald (1903) who described it as a new species *Grabhamia vittata*. *Aedes pullatus* (Coq.) was recorded for New Mexico by Miller, Doll and Wheeler (1964).

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