33 million inhabitants. With respect to the attack phase, the rates are 33.9 per cent and 30.1 per cent, respectively.

To a large extent, this rate corresponds to Brazil.

At the end of 1963, 27 per cent of the population lived in countries and territories in the preparatory phase. By comparison, this rate was 57 per cent in 1956.

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II. EPIDEMIOLOGY OF MALARIA ERADICATION IN CENTRAL AMERICA: A STUDY OF TECHNICAL PROBLEMS

R. W. Babione, M.D., M.P.H., F.A.P.H.A.

The title, "Epidemiology of Malaria Eradication," indicates an interest in the progress made by this ambitious campaign against one of the major communicable diseases of the world. To really understand what is happening in malaria eradication, one must abandon the global or hemispheric look and examine what has been going on in single countries or even within sectors of single countries. Malaria is actually a "place disease," but it has a wide and interesting variety of ecological habitats, varying with altitude, terrain, soil, climate, animal and plant life, as well as with living conditions and behavior. This is what makes it such a fascinating study for the epidemiologist.

As a model for what we would like to see everywhere, this paper will briefly glance at three malaria eradication programs of the Americas which have progressed more or less as planned toward a successful conclusion. It will then devote its attention to those programs which have encountered the most serious obstacles to success. These programs with problems are the most interesting, anyway. We shall note what progress has been made, where the standard program is failing, and why, and what is being or can be done to overcome the technical problems in these areas.

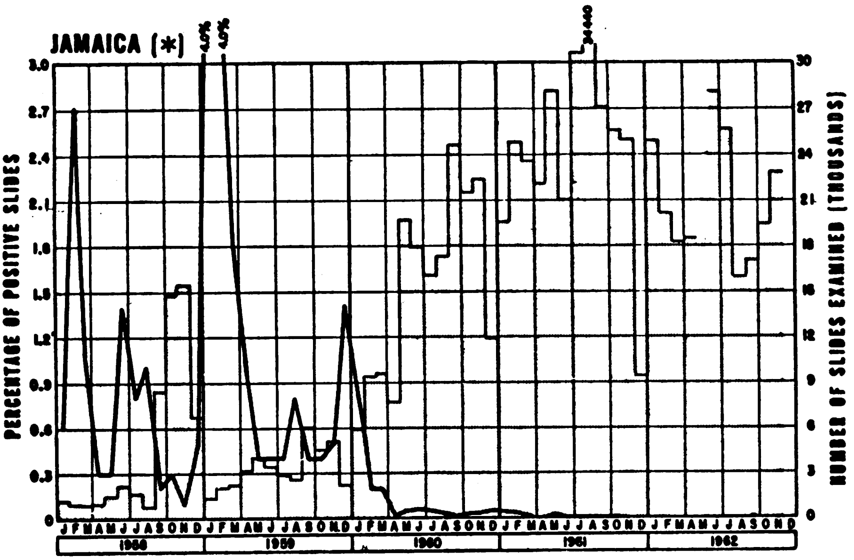
It will be shown that the most serious and complex problems are located along the Pacific Coast of Central America, and that they stem from characteristics of one vector, Anopheles albimanus, the only important American vector which shows high physiological resistance to both DDT and dieldrin.

Where Eradication Succeeded

In the programs of Jamaica, British Honduras, and Trinidad, we can see examples of the rapid and complete disappearance of malaria under residual house-spraying with DDT (see Figures 1-3). All three programs were started on dieldrin once a year, and all were changed promptly to DDT twice a year in 1959, when localized resistance to the former was discovered. No DDT resistance appeared in any of these countries. It should be noted that malaria control programs had been in effect for some years before they were converted to eradication by extending the residual spraying to every house in the malarious area. It should be noted, too, that some supplementary measure was used in each country to wipe out the final tiny smoldering embers of persistence of transmission. In Trinidad, this was monthly mass administration of chloroquine and primaquine in an area where A. (K) bellator was maintaining a low-level transmission by virtue of its habit of biting and resting mainly outside of houses. In Jamaica, the final small pocket was a community of fishermen whose work had them living in open, unsprayed caves during the week.

This human cause of persistence was overcome by intensified case finding, and radical treatment of cases and their contacts. In British Honduras, one final pocket of persistent transmission was found. It was due to a human factor, namely, rapid colonization of new land and building of many new houses which remained unprotected until the next six-month spray cycle. This problem was solved by assignment of a

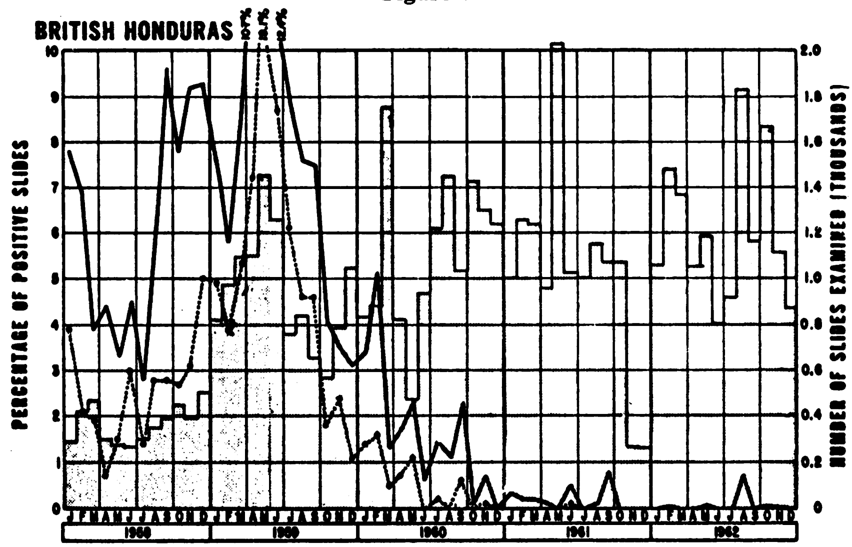
Figure 1



The malaria eradication campaign was begun in January, 1958, dieldrin being used in annual cycles. At the beginning of 1959 the vector A. albimanus was found to be resistant to the insecticide. Immediate plans were made to use DDT in six-monthly cycles. Between January and September, 1959, one part of the island was sprayed with dieldrin and the other with DDT. From October onwards only DDT was used. Most cases were due to P. falciparum, very few to P. malariae. Up to December, 1962, not a single autochthonous case has been identified.

(See Figure 3 for symbols.)

Figure 2



The campaign began early in 1958, dieldrin being used in annual cycles. In 1959 evidence of insecticide resistance of the vector A. albimanus was discovered. From May onwards DDT was applied throughout the whole malarious area in six-monthly cycles. P. falciparum cases were much more frequent than P. vivax cases and there were a few cases of P. malariae up to June, 1960. In 1961 only two autochthonous cases were discovered, both in the same locality. In 1962 when all the country was in consolidation phase one imported case was found in March and again in May, and a small outbreak took place in a menonita colonization area (12 cases in August, 2 in September, 1 in October, and 3 in November) which was rapidly controlled.

(See Figure 3 for symbols.)

permanent sprayman to the locality. He sprayed every new house as soon as it was built, and new cases of malaria promptly ceased to appear. Two outbreaks have subsequently occurred in previously cleaned areas, due to imported cases among laborers coming for the sugar cane harvest from nearby parts of Mexico, but eradication was first achieved in British Honduras by residual spraying of DDT alone. The vector here and in Jamaica was A. albimanus.

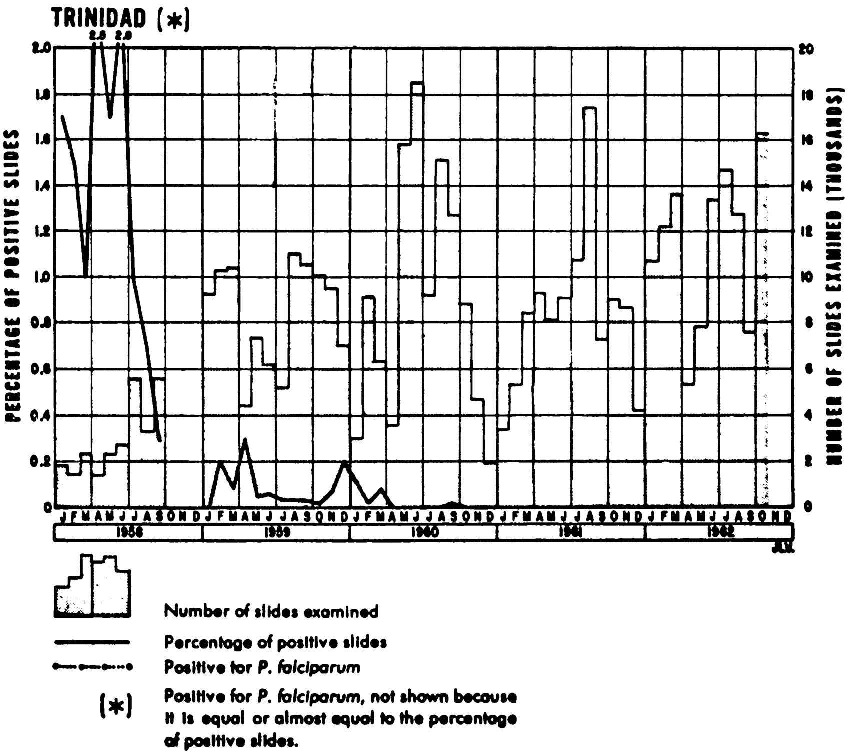
Other countries have had good or fair success, mainly depending upon adequate financial support and the quality of supervision, although some also have technical problems in limited areas.

Where Eradication Failed

In certain parts of five Central American countries (Panama excluded), despite rather well-conducted programs of DDT spraying for five years, malaria still persists at a discouraging high level. These areas will be the topic of this paper.

Table 1 shows the number of cases discovered during 1963, in six Central American countries and Mexico, arranged in order of their incidence. Also shown are population at risk, the number of cases per 1,000 population, and what is probably most significant, the population exposed to A. albimanus which are highly resistant to DDT. There is no other country in the Americas where malaria has persisted at such high levels after four or more years of well-administered residual spraying, as it has in parts of El Salvador, Guatemala, Nicaragua, and Honduras. The relative seriousness of the problem in these four countries can be seen in the total number of cases found during 1963, or equally in the incidence per

Figure 3

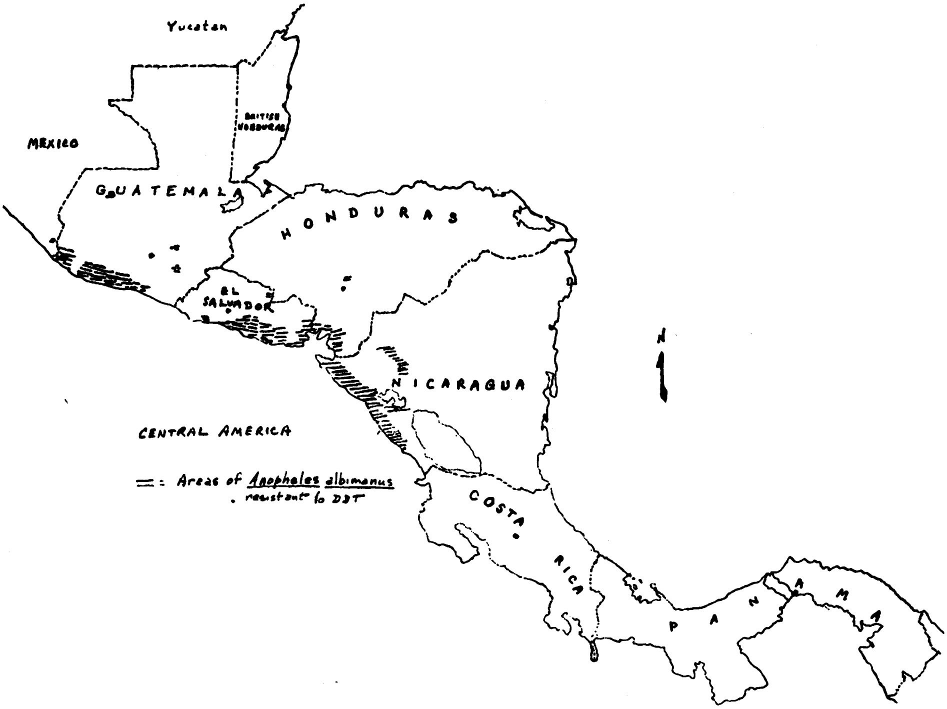


Full coverage began in January, 1958, dieldrin being used in annual cycles. A. albimanus found insecticide-resistant in 1958. Change on insecticide began in same year and from 1960 onwards only DDT was used in six-monthly cycles. In an area where the vector is Kerteszia bellator mass treatment was begun from June, 1959 onwards, the combination cloroquin-plasmochin being used every 30 days. From September, 1960, to December, 1962, there was not a single case except for one imported case from Africa in March, 1961. The figure does not give information on the last quarter of 1958 as it was not received.

Table 1—Malaria cases discovered in Central America during calendar year 1963

Country	Cases	Population in Malarious Area	Cases per 1,000 Pop.	Estimated Population in Areas of High DDT Resistance
El Salvador	17,846	1,641,000	10.9	450,000
Guatemala	15,116	1,912,000	7.9	350,000
Nicaragua	10,559	1,672,000	6.3	300,000
Honduras	7,077	1,873,000	3.8	100,000
Costa Rica	1,224	420,000	2.9	none
Panama	2,670	1,076,000	2.5	none
Mexico	16,741	20,901,000	0.8	one county only

Map 1



1,000 population. These two indexes show the same order of relative magnitude, since the four countries have nearly the same population exposed to malaria.

The most important of the several causes of persistence of transmission might be inferred from the last column of Table 1: the number of people exposed to malaria where the vector is highly resistant to DDT.

The geographical location of high levels of persisting malaria transmission and high DDT resistance are almost identical. Map 1 shows all of the areas in the Americas where A. albimanus has developed high resistance to DDT. These are also the areas of highest malaria transmission since the eradication program began to use DDT.

They are, with few exceptions, located in the low terrain on the Pacific slope of the Isthmus of Central America. Almost without exception, they are precisely the same areas where cotton cultivation is carried on intensively, or has been at some time recently. The reason for this co-extensive distribution is quickly apparent to a visitor in the Pacific coastal plain of these four countries. From the first of August to the end of February or even March, the cotton fields are sprayed at least once a week by aircraft using various insecticidal mixtures. DDT is one of the most common ingredients of the cocktail used. Not only is there tremendous selection pressure on the adult mosquitoes, both male and female, but the larvae also live in DDT-contaminated water. It is therefore not surprising that resistance to DDT is commonly seen at low or intermediate levels within a year or two of the breaking of new ground to

Table 2—Incidence of malaria in Guatemala, 1958-1963

Year	Slides Taken	Slides Positive	Per cent Positive
1958	62,119	12,219	20.65
1959	68,047	7,846	7.26
1960	129,742	3,387	2.61
1961	219,628	4,083	1.85
1962	323,313	5,996	1.85
1963	348,866	15,116	4.33

cotton cultivation (as occurred in the last few years in western Guatemala), and that the resistant mosquito population reaches progressively higher proportions as time goes on and the land is more completely devoted to cotton growing. On the other hand, A. albimanus has not become resistant in standard antimalaria campaigns, even after using DDT in houses for ten years or more (Costa Rica, for example), in the absence of agricultural use of DDT.

Resistance to DDT has appeared in A. albimanus in rice-growing areas in Nicaragua and Dominican Republic where aircraft dispersal of insecticidal cocktails is used, but it has not yet reached the high levels seen in cotton cultivation, probably because spraying is done less often and is much less extensive in its coverage.

Measuring Malaria

When malaria eradication programs started, there was no country-wide base line of incidence, and during the first four or five years of each program the case-finding network and diagnostic laboratory services were built up rapidly. The result of this lack of early information is inconsequential in programs that have gone well. By the time malaria was reduced to near zero, the case finding was nearly fully developed, and the absence of malaria could be adequately shown.

In the programs which have not gone well, case-finding activity has increased at a rate sometimes faster than the incidence of malaria has been reduced. In these situations, illustrated in Tables 2 and 3, the gross number of cases diagnosed may rise while the malaria in the country is in actual fact decreasing. To estimate the total impact of malaria in the presence of rapidly expanding case-finding activities, the percentage of slides positive, while also defective, is believed a better approximation to reality.

Table 4 shows that this method is not producing too favorable a picture of progress by a biased increase of sampling of the areas which respond well, or had little malaria to begin with. In Guatemala, the problem area of the

Table 3—Malaria cases in El Salvador, by years and method of discovery

	Active*			Passive†			Total		
Year	Slides	No. Pos.	% Pos.	Slides	No. Pos.	% Pos.	Slides	No. Pos.	% Pos.
1957	7,596	2,036	26.8	21,575	4,625	21.5	29,171	6,661	22.9
1958	23,766	2,936	12.3	27,839	6,415	23.0	51,615	9,351	18.1
1959	8,839	697	17.9	62,456	16,824	26.9	71,295	17,521	24.6
1960	7,019	304	4.3	68,362	9,708	15.8	75,381	10,012	13.6
1961	30,496	1,046	3.4	96,804	11,517	11.9	127,300	12,563	9.9
1962	41,397	724	1.7	152,672	14,709	9.6	194,069	15,438	8.0
1963	39,493	1,247	3.2	199,298	16,599	8.3	238,791	17,846	7.5

* Active search for cases. The service looks for fever cases in house-to-house visits.
† Passive search for cases. Sick people come to notification posts to receive medicine and give blood sample.

Table 4—Malaria in Guatemala, first 11 months of 1963, by type of area

Type of Area	Estimated Population	Slides Taken	% Notific.	Positive Slides	% Positive	Morbidity Rate/1,000
Coastal problem	231,930	112,739	48.6	8,321	7.38	35.9
Rest of attack	625,500*	64,900	10.4	2,921	4.50	4.7
Consolidation	1,056,000*	144,514	13.7	3,048	2.11	2.9

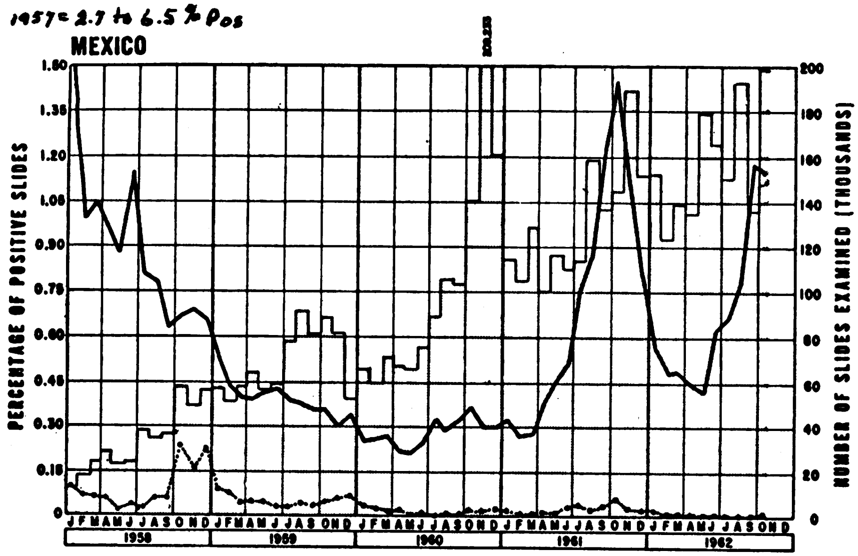
* "Average" population for the entire year; 355,000 were moved into consolidation in July, 1963, although much of this group actually had too much malaria to warrant the change.

Pacific Coast, which had the highest malaria incidence, received four or five times as intensive a case-finding activity as the rest of the malarious area during 1963. This usually happens in other countries as well.

Figures 4-9 can now be studied for a longitudinal view of what happened in each of the four countries by month, under the eradication program. The solid line represents the percentage of slides positive for all species, the dotted line the percentage positive for Plasmodium falciparum. The bar graph background represents the number of slides taken each month. It should be noted that the scale is not the same in the graphs of various countries, and rates for El Salvador and Nicaragua in the last half of 1962 are approximately equal.

In interpreting these graphs it also should be noted that the malaria situation has been subjected to a number of

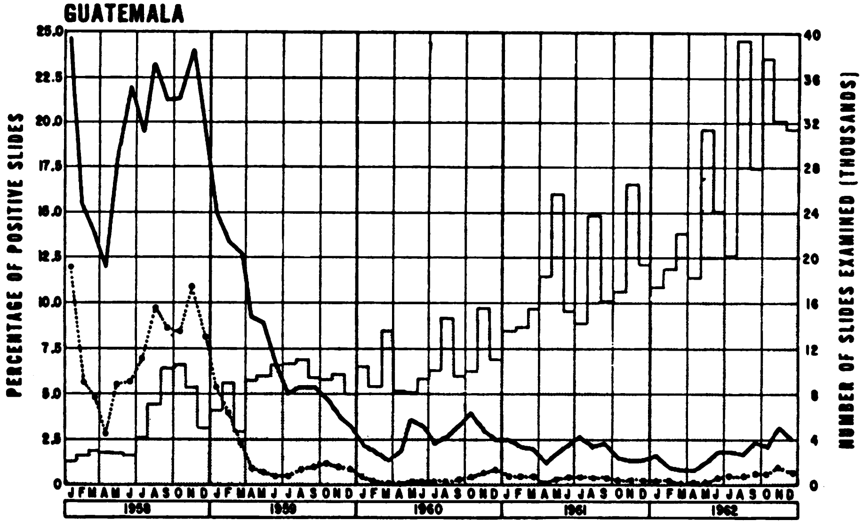
Figure 4



Full coverage began in January, 1957, dieldrin being used in annual cycles. In mid-1958 one of the vectors, A. pseudopunctipennis was found to be insecticide resistant. Almost complete shift to DDT in 1959. In 1961 suspension of spraying in 70 per cent of the originally malarious area. Transmission continues in problem areas where the attack is being intensified. The increase in cases from June, 1960, to this date is mainly due to case finding being carried on more intensively in problem areas than in the consolidation areas.

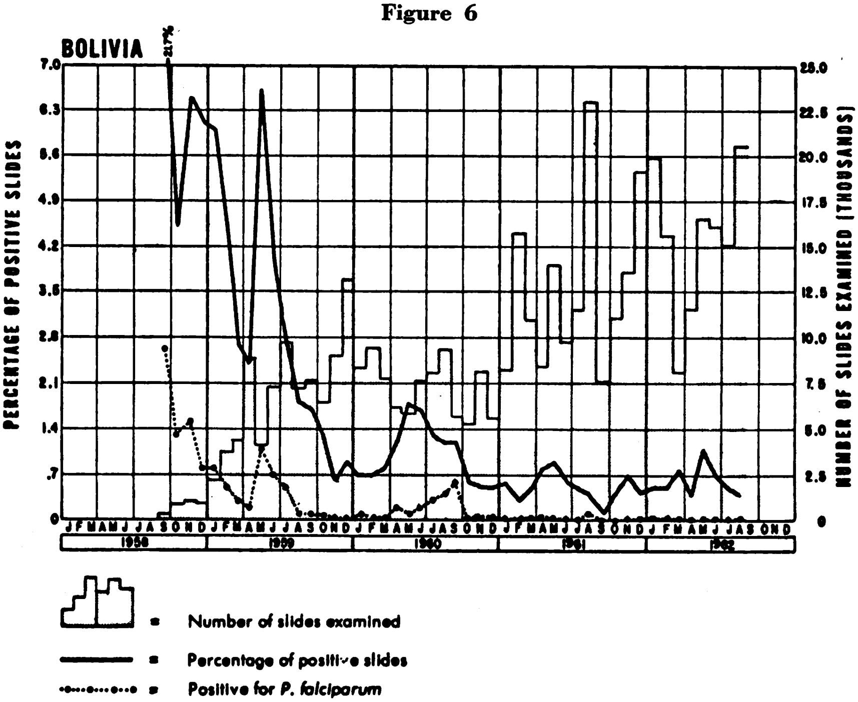
(Symbols for Figures 4-9 are carried under Figure 9.)

Figure 5



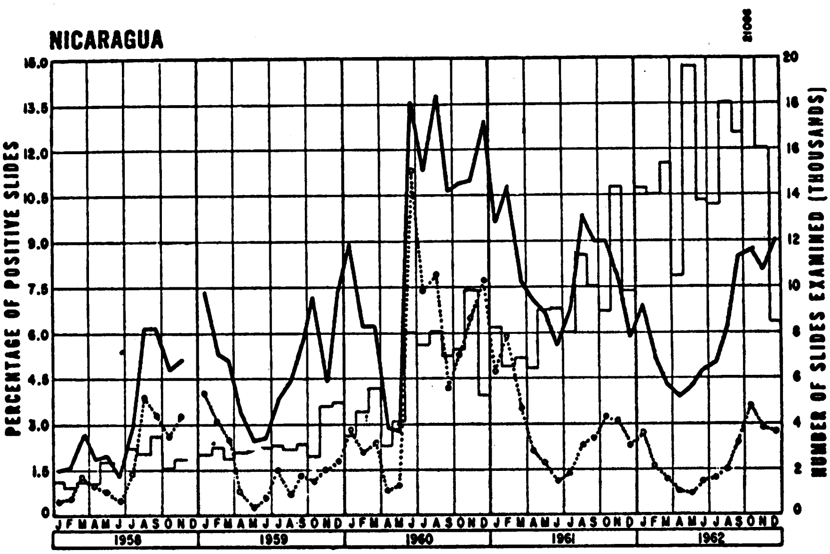
Full coverage began in August, 1956, dieldrin being used in annual cycles. A. albimanus resistance discovered in 1958. Insecticide changed to DDT in six-monthly cycles, from October of same year onwards. Rapid decline in number of cases observed. However, the vector was found to be resistant to DDT as well, in certain areas, and the opening up of new agricultural settlements without precautionary methods being taken caused serious epidemic outbreaks in 1960 and 1961. In some areas where the vector is resistant to both dieldrin and DDT, significant results have been obtained from antilarval methods.

Figure 6



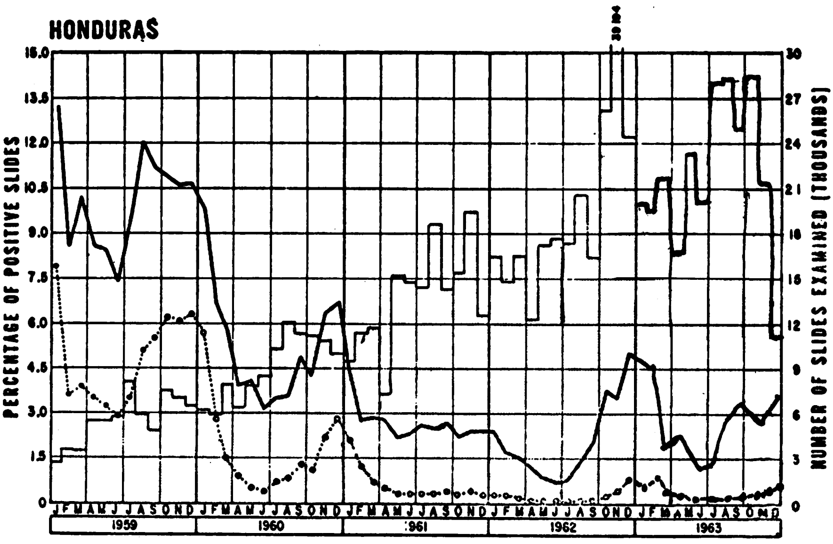
Full coverage began in December, 1958, mainly with DDT in six-monthly cycles. Dieldrin was used in annual cycles in areas that are difficult of access. Double resistance to insecticide has not been found in the main vectors, A. darlingi and A. pseudopunctipennis. DDT used alone from September, 1961, onwards. In 1961 and 1962, 70 per cent of the originally malarious area of the country spraying was suspended.

Figure 7



Full coverage began in November, 1958, DDT alone being used in six-monthly cycles. In 1959 A. albimanus found to be resistant not only to dieldrin (which was discovered in 1958) but, in certain areas, also to DDT. Serious epidemic outbreaks occurred in 1960 and in 1961, in part due to the construction of a highway which led to the formation of new breeding grounds in areas in which the vector was susceptible to DDT. In 1961 antilarval methods begun in some areas and trials made of malathion used intradomiciliary as a residual insecticide in others. Observation continues. In spite of the difficult situation in the problem areas, 70 per cent of the originally malarious area entered the consolidation phase during 1962. The program is facing financial difficulties.

Figure 8



Full coverage with DDT in six-monthly cycles began in July, 1959, with the discovery that A. albimanus was resistant to dieldrin. Subsequently, it was found to be resistant to DDT as well, in certain areas. During 1962 extensive areas entered the consolidation phase. The areas of agricultural development are facing the problem of immigration of infected workers from problem areas of the neighboring countries. A well-planned and excellently administered campaign. However, there is lack of funds for the program.

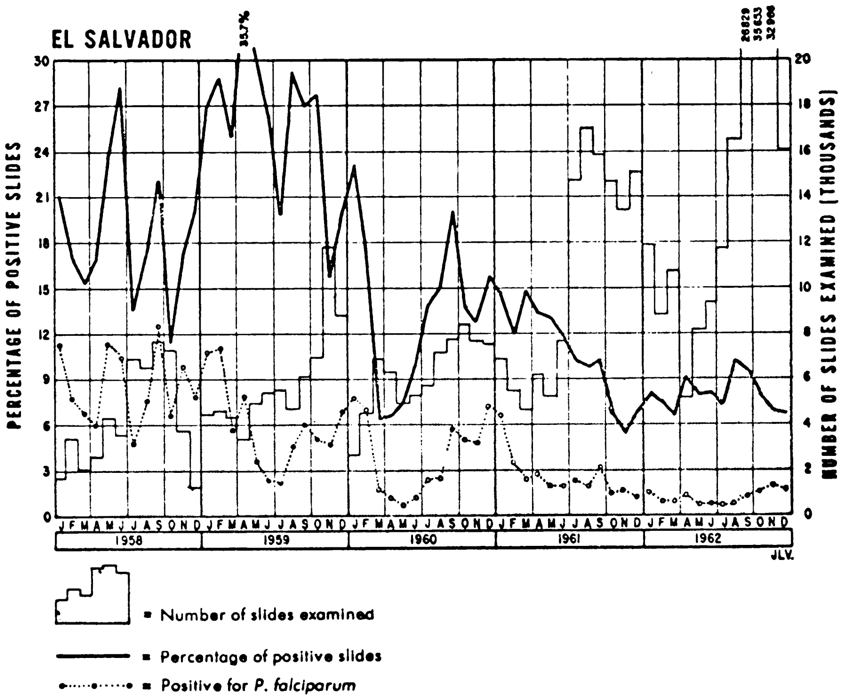
influences beside the effect of the malaria eradication program. For example, in all four countries there has been some increase in the average degree and/or extension of resistance of A. albimanus to DDT, primarily in the coastal area, and frequently a large increase in population living in these areas, all of which tends to increase malaria.

In El Salvador, this change has been least marked because resistance was widely dispersed and of rather high degree initially, and it has been increasing relatively slowly in both area and degree. This is because cotton cultivation was widely developed before the eradication program started. Nevertheless, even in El Salvador, the initial response to the change of the program to DDT, which really was not fully applied until August, 1959, was rather good. The response to malaria eradication was generally satisfactory outside the cotton growing areas, except for a small coastal sector where cotton has not arrived and the vector is still susceptible. Here irritability of the vector, poor housing, frequent alteration of sprayed surfaces, and outdoor living were found by Rachou, et al.,* to be factors in maintaining transmission. Migration also plays a role.

In Nicaragua, malaria cases increased

* Rachou, R. G.; Schinazi, L. A.; and Moura-Lima, M. M. Preliminary Note on the Epidemiological Studies Made in El Salvador to Determine the Cause of the Failure of Residual Spraying to Interrupt the Transmission of Malaria. WHO/MAL/392 (Apr. 30), 1963.

Figure 9



Full coverage with dieldrin and DDT began in July, 1956. In 1958 A. albimanus found to be resistant to dieldrin. From August, 1958, onwards only DDT was used. Subsequently DDT resistance was also found in some coastal areas. A recent evaluation showed that the area of stable malaria is the coastal zone with an altitude under 300 meters where vector resistance to insecticide is most pronounced. In this area special studies are being carried out to determine the cause of the persistence of transmission through pilot programs of larviciding and mass drug administration to the population.

Table 5—Increases of malaria in problem areas of Guatemala between 1962 and 1963

Sec.	Dept.	County	1962 Slides	1962 Pos.	1962 % Pos.	1963 Slides	1963 Pos.	1963 % Pos.	% Increase No. Cases	% Increase % Pos.
A	Escuintla	S. Jose and Masagua	5,073	405	8.0	4,740	444	9.4	10	17
		La Democr. and La Gomar	3,761	434	11.5	4,758	714	15.0	65	30
		S. Ana Mixt. (N. Con)	80,096	1,448	1.8	62,751	2,300	3.7	59	102
		Tiquisate	6,867	398	5.8	9,641	1,935	20.1	385	246
	Suchitep.	Mazatenango, Cuyot.	2,446	149	6.6	3,585	715	20.0	380	202
	Retalhuleu	S. Andrs. V. S., Retalhuleu, Champ.	4,623	418	9.0	7,221	1,639	22.7	292	152
	S. Marcos	Ocós	840	32	3.8	2,100	728	34.6	2,170	812
		Tiquisate to Ocós Subtotal	14,776	997	6.8	22,547	5,017	22.3	403	230
B	Jutiapa	Moyuta	16,076	350	2.2	19,147	301	1.6	−14	−27
C	Baja Verapaz	Cahabón, Carchá Panzós	13,615	795	5.8	11,828	722	6.1	− 9	4

A. Coastal area with resistance to DDT, and with cotton cultivation.
B. Coastal area without resistance, and without cotton cultivation. Colonization problem.
C. Baja Verapaz, interior area, without resistance. Colonization problem.
Note: Santa Ana Mixtán (Nueva Concepción) shows an enormous amount of slide taking and many positive slides, but a low percentage of slide positivity in 1962-1963. This is the result of an intensive program of case finding and radical treatment in a part of 1962 and 1963, both of which contributed to a true reduction of as well as an abnormally low slide of positivity rate. A lesser program of case finding and radical treatment was carried on in Jutiapa in both years.

sharply in May, 1960, with the discovery of an intense focal outbreak of man-made malaria, the result of a road-building project in a resistant area. This was largely controlled, but rates remained high in 1961 and 1962, due to a greatly intensified case-finding activity in the highest transmission centers on the Pacific Coast.

In Honduras, malaria transmission was rapidly interrupted in 90 per cent of the population. The rise seen in the last quarter of 1962 and first quarter of 1963 occurred mainly in two counties where resistance to DDT and vector density were both very high at that time.

In Guatemala, the effects of DDT resistance are most clearly seen. There was very little DDT resistance in the country in 1959 and 1960. The initial response to DDT spraying was very promising. The only important persistence of malaria in 1960, 1961, and 1962 was limited to one small section of the coast in an area of rapid colonization. But in 1963, the total amount of malaria, as well as the malaria rate, jumped alarmingly (see Table 2). Table 5, Section A, shows the differences between 1962 and 1963 in the present "problem area" of the coastal plain; i.e., its western two-thirds up to the Mexican border. The increases of 400 per cent in cases or 230 per cent in slide positivity rate are seen in exactly the counties where DDT resistance appeared for the first time in 1963, or where it rose from previously low levels to high ones. This change followed the introduction of large-scale cultivation of cotton for the first time in these areas a year or two before. Laborers in the cotton fields carried a great deal of malaria from this source to many clean areas of the country.

It can be seen that in Section B, the eastern part of the same coastal plain where there is no resistance, there was no increase in malaria, but actually a decrease in the same period. In San Jose and Masagua counties, where resistance was only partial and not greatly changed in this period, the increase was very small. In the interior, in Baja Verapaz, there was essentially no change.

What Can Be Done to Solve the Problem

Field trials of malathion and fenthion as substitutes for DDT were started in March, 1959, in El Salvador. While killing more DDT-resistant mosquitoes initially than DDT, their duration of effect was much less and on sorptive surfaces, such as mud walls, it was too little to be considered practical. Studies were continued and a formal Insecticide Testing Team was organized in 1960. Several new insecticides kill DDT-resistant mosquitoes very well, but none has been found with ability to last long enough on mud walls to make it practical. Methods for using larvicides also were field-tested by this team.

All of the factors in persistence of transmission under various conditions were carefully analyzed by the Epidemiology Study Team under Rachou. On this and other evidence, it was concluded that DDT continues to exert a restraining effect, even in resistant areas, by virtue of several factors:

1. Resistance to DDT is not complete in most areas where it is found. Up to 70 per cent or more of the A. albimanus are still susceptible in "resistant areas" and house spraying alone rarely increases the percentage of resistance. Resistance tends to fall in the transmission season; i.e. when the rainy season arrives and high densities of moquitoes appear.

2. The excito-repellency effect of DDT on A. albimanus has been found to be high in most of the resistant populations encountered. This has three possible beneficial results: DDT has been shown to reduce the number of vectors entering a house; to increase the percentages of those that leave the house without biting; and to cause them to give up their normal resting place inside the house if they do feed in it. These effects of DDT tend to lower the number of contacts of the vector with man and, although helping the mosquito to escape the toxic effects of the sprayed walls, the insect is more exposed to predators and adverse climatic conditions after feeding. In any event, malaria transmission was halted in Greece and parts of India, in spite of the appearance of DDT resistance in the vector.

For these reasons, although recognized to be insufficient to stop all transmission in certain high transmission areas, use of DDT was continued even in the presence of resistance (and irritability), first because it was believed to be reducing the size of the problem area (marginal areas with intermediate levels of resistance and of transmission potential were believed to be controlled by it); and, second, because by reducing the potential of transmission in the hard core of the problem area, it would reduce the extent and time that supplementary and more expensive attack measures would have to be applied.

While these studies were going on, field trials were being carried out with several supplementary or alternative attack methods:

Larviciding

Larviciding with chlorthion or fenthion was rapidly effective in two small problem areas of Guatemala where breeding was limited in extent. It has been recommended for additional use in similar conditions. It eradicated the DDT-resistant vector in the first two places it was tried, and the vector has not returned. Unfortunately, there are not many areas in rural America where this method is economically practicable. When tried in flat terrain with ground pool breeding, it has failed.

Larviciding was also tried, using Paris green, to protect the city of Managua, Nicaragua. It was only partially effective and had to be supplemented by mass drug treatment. Larviciding was effective in halting all transmission in Guayaquil, Ecuador. Oil was used for two and a half years, followed by one year of fenthion.

Use of Malathion Where Walls Were Suitably Nonsorptive

Malathion was tried in the worst problem areas of the Nicaraguan coastal plain where a moderate or a high percentage of wood houses seemed to give some hope of success. It was used in four-month cycles, and proved to be about as effective as DDT, plus intensive case-finding and radical treatment, had been before. But with only 37 per cent to 75 per cent of the houses of wood, it was found insufficient by itself in these high transmission centers. It is now being supplemented with mass drug treatment in foci of persistent transmission. Malathion failed after four to six weeks in a small trial in El Salvador where all the houses were of mud. It is presently being used in most of the problem areas of Honduras, but regularly only since the end of April, 1964. It is anticipated that some supplementary mass drug treatment will have to be used in the localities with highest transmission. Malathion has been most effective in Estelí, a town of 13,000 population in Nicaragua, where almost all houses are of wood. Transmission is low enough so that radical treatment of cases should stop it altogether.

Mass Drug Distribution

Mass drug distribution using a combined tablet of 150 mg of chloroquine and 15 mg of primaquine was field tested in one of the worst problem areas of El Salvador in 1961 and 1962. It is given once every two weeks, in a dose of four tablets for a large adult (over 60 kg), three for a small adult, and children proportionately less. It has been very effective as a supplementary measure to DDT spraying in El Salvador (total 120,000 persons) and Costa Rica (12,000 persons), where 80 per cent to 90 per cent of the population in the treatment area received treatment. It reduced but often failed to halt transmission in Mexico, Guatemala, and Nicaragua where acceptance of the drug dropped to 70 per cent or less. As a supplement to larviciding, it required 33 cycles (a year and three months) to halt tranmission along the shore of Lake Managua where acceptance was from 72 per cent to 78 per cent during the last half of this long period. When used alone, mass drug distribution failed in several localities in Nicaragua, due to poor acceptance and high mosquito density, and has been supplemented or replaced by larviciding in these localities. Two trials have been made of the same dose given weekly for 10 or 11 weeks in small intense foci of transmission in El Salvador (1,600 population) and Honduras (7,000 population). With acceptance of up to 99 per cent, the measure was highly effective in cleaning up these foci.

Mass drug distribution on two-week cycles is presently the most widely applicable and certainly the most rapidly effective supplementary measure available for overcoming technical problems in malaria eradication campaigns. It requires about five times as much personnel as residual spraying of houses twice a year, and far more intensive supervision and health education. It is a difficult measure to apply well over a long period. Up to the present, drug resistance has not appeared and a constant watch is maintained against this eventuality.

A method of adding chloroquine to dietary salt was tried in the Amazon Valley, and the interior of British Guiana. It has very limited applicability and its record has not been good. It was an excellent success in two sectors of British Guiana (28,000 population) and failed in a third (9,000 population), as well as in most of the Amazon Valley. Causes of failure were insufficient intake, poor administration, and especially the development of chloroquine resistance.

Conclusion

DDT used as a residual spray inside of houses has been very effective in halting transmission of malaria in most of the area where it has been properly applied. The most serious single obstacle to its success has been a physiological resistance of the vector. So far, this has been found to be a problem in the Americas only with A. albimanus and only in the Pacific coastal plain of four Central American countries (since 1963, in a small neighboring section of Mexico as well). DDT resistance is found in most localities where cotton is grown on a large scale and very rarely elsewhere. Dieldrin resistance of a very high order always is found with it, preventing a change to that insecticide.

Excito-repellency of DDT is a problem in some areas of susceptible vectors, and other (contributing) factors include poor housing, alteration of walls after spraying, outdoor biting, migration, and the like.

Although not sufficient to halt all transmission, residual spraying with DDT is believed to be worth continuing, even in problem areas for reasons given. It can be supplemented (under certain conditions replaced) by one or more of the following measures:

(a) A change of insecticide. Intensive search for a new one goes on, but so far malathion is the only fully tested, practical, and available one that is effective against the doubly resistant strain of A. albimanus. Unfortunately, it lasts too short a time on sorptive surfaces, especially certain mud walls, to be widely used in Central America.

(b) Larviciding or permanent source reduction, where mosquito-breeding areas are limited and human population density is high, may be less expensive and more effective than other measures. It has been used effectively in a few places.

(c) Mass drug administration is effective when properly carried out, not only in overcoming problems of insecticide resistance, but also those of excito-repellency of DDT, outdoor biting, lack of housing, movement of people, and the like. It is neither possible nor necessary to obtain 100 per cent coverage. Except for short periods in the presence of an epidemic, even 90 per cent acceptance over a long period is difficult to obtain. Acceptances below 80 per cent are not successful in most situations where the measure will be used, but lower acceptance may succeed if the transmission potential is not high. The frequency of administration and the percentage of population which must be treated, as well as the time that treatment must be carried out, to a great extent all depend upon the level of transmission which has to be overcome. The percentage of persons treated, and the percentage who miss all their treatments regularly, will affect the time that a course must run. No rule for predicting the length of a program is known, but theoretically eight doses should be given to all potentially infected persons after the last infectious mosquito bite occurs in P. vivax infections. Twelve to 14 cycles have been effective.

Drug resistance to chloroquine has appeared in P. falciparum in several places in South America, but not as yet in Central America. The services have been alerted to watch for it, since it would destroy the present hope of success with the chloroquine-primaquine combination, if it should become established.

Methods already exist for overcoming the obstacles facing malaria eradication in the problem areas of Central America. They are more costly, and require more trained and reliable personnel for their proper execution than the standard method of house spraying.

They must be intelligently selected for each situation. It is believed that with these measures malaria can be eradicated, even in the problem areas. It is the lack of resources to apply the available supplementary methods properly which is delaying eradication of this disease in Central America today.

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III. THE ROLE OF SURVEILLANCE IN A MALARIA ERADICATION PROGRAM

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THE Expert Committee on Malaria of the World Health Organization in its Seventh Report defined surveillance with reference to malaria eradication as "that part of a malaria eradication program designed to discover evidence of any continuation of transmission, to establish its nature and causes, to eliminate residual foci, to prevent or cure such residual or imported malaria infections in man as would delay the ending of transmission or threaten its resumption in a given area, and, finally, to substantiate the fact that eradication has been achieved."

This definition clearly places total responsibility on the surveillance mechanisms for providing the quantity and quality of data, and for the consolidation and evaluation of these data necessary to guide the various attack measures utilized. It is intended here to discuss the surveillance mechanism in present malaria eradication programs, based upon experiences of the Communicable Disease Center in disease surveillance programs.

The Communicable Disease Center of the United States Public Health Service has been engaged in disease surveillance in the United States since 1947. It is particularly interesting in that these efforts were initially directed toward the problem of malaria in 13 southern states where, in the mid-1930's, the disease had been shown to be firmly established. Since 1947, surveillance activities have increased in scope and presently include such diseases as poliomyelitis, hepatitis, diphtheria, measles, tetanus, anthrax, infectious encephalitis, salmonellosis, rabies, psittacosis, and brucellosis. During this period, various surveillance methods have been utilized and evaluated, and substantial experience has accumulated. Based upon this experience, the surveillance operation seems logically divided into three distinct phases. The first of these is the collection of data. The second is the process of analysis and interpretation of the data. The third includes the action taken as the result of the analyzed data, together with appropriate dissemination of the analyzed data. Surveillance then implies action, and is not