THE *AEDES AEGYPTI* ERADICATION PROGRAM OF THE U.S.*

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The early history of the New World is replete with references to scourges of yellow fever, or "Yellow Jack," as it was often called. Major epidemics continued to occur throughout the nineteenth century, striking settlements in all the vast region extending from Buenos Aires, Argentina, to Boston, Mass. Periodic outbreaks of yellow fever in the United States are often spoken of glibly now, but before methods of prevention were known, the very mention of the malady spread a terror unknown today (Williams, 1964).

Clarification of the epidemiology of yellow fever began in 1881 when Carlos J. Finlay advanced his theory that the disease is spread by the female *Aedes aegypti* mosquito. In 1900 Walter Reed and the Yellow Fever Commission proved this theory correct, and the following year William C. Gorgas initiated a specific campaign against *Ae. aegypti* in Havana, Cuba, to control an outbreak of yellow fever. Despite the early skepticism of many of his colleagues, Gorgas's anti-mosquito control program resulted in the eradication of yellow fever in the short space of 8 months. In 1904 he applied similar techniques in Panama which resulted in eliminating urban yellow fever from that country in 16 months. In the conduct of his work, he found that a few *Ae. aegypti* remained after cases had ceased to occur and he formulated his now-famous concept that there is a critical density, which he called the "yellow fever point," below which there are not sufficient mosquitoes to transmit the disease (Elton, 1952).

In the United States, campaigns against the vector mosquito quickly brought yellow fever under control. The last epidemic, in 1905, occurred at a much lower attack rate than had been seen in previous outbreaks, and before a quarter of the century had passed, the disease had entirely disappeared. The last known case—and it was believed to be introduced—was reported in 1924.

Freedom from this scourge was a boon to public health. Furthermore, it stimulated economic progress both directly and indirectly. For example, knowledge that yellow fever could be prevented resulted in negotiations with Panama for the construction of the Panama Canal—a project previously started by the French but abandoned because of the depredations of disease, particularly yellow fever and malaria. With yellow fever under control, work on the Panama Canal proceeded uninterrupted and this valuable route of travel and transportation was rapidly completed. Also, the country's business community was revived from the summer doldrums, a period of comparative inactivity when city people—all who were able—escaped the annual threat of yellow fever by spending the hot months in the country or the mountains.

By 1925, a number of Latin-American countries had apparently eradicated yellow fever with assistance from the Rockefeller Foundation. In 1926, however, there were sporadic outbreaks that coincided with a movement of nonimmune troops, but anti-mosquito measures prevented large-scale epidemics. During 1927 and early 1928 almost a year passed with no cases of yellow fever reported anywhere in the Americas (Soper, 1963).

But as Soper cautioned, success was not to come so easily. In 1928 yellow fever reappeared in Rio de Janiero, Brazil, after an absence of 20 years, and in 1929 there were outbreaks in several isolated towns in Colombia and Venezuela. The appearance of these and other outbreaks led to the discovery of the jungle cycle of yellow fever maintained in monkeys and mosquitoes other than *A. aegypti*. Although this discovery ruled out any possibility of eradi-

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cating yellow fever, it further strengthened the need for eradication of *Ae. aegypti* which provided the only means for spreading the disease to populated areas (Soper, 1963).

Experience gained in *Ae. aegypti* eradication in Rio de Janiero and other cities of Brazil clearly demonstrated that lasting success of an eradication program in any country would depend upon preventing reinfestation from neighboring countries. In recognition of the need for coordinated action, Bolivia proposed at the Pan American Sanitary Conference of 1943 that the countries of the Americas join in a concerted effort to eradicate *Ae. aegypti* from the entire Western Hemisphere. No action was taken at that time, but in 1947 the member countries of the Pan American Health Organization (PAHO) concurred in a resolution to this effect. Accordingly, 25 of 26 member-nations and territories of the League of American States initiated eradication programs and many of them have now achieved their goals. Figure 1 shows the progress that had been made in the hemisphere to the close of 1963 (WHO, 1964).

By 1961 the United States was the only country on the mainland of the Americas with *Ae. aegypti* infestations that had not initiated an eradication program. That year we joined other member nations of PAHO in adopting a resolution that called for eradication of the species from the hemisphere within 5 years. The following year (1962) the Surgeon General of the Public Health Service, speaking at the Pan American Sanitary Conference, declared this country's intent to conduct an eradication program. In 1963, at the specific request of the late president, John F. Kennedy, funds were appropriated for the Public Health Service to develop and initiate an eradication plan. Thus, the program described here is an outgrowth of international commitments made over a period of about 15 years.

STATUS OF THE PROBLEM IN THE UNITED STATES. Although the United States had not initiated a formal *Ae. aegypti* eradication program during the years that yellow fever has been absent, cognizance has been taken of the potential problem. There has been a continuing awareness of the need to protect this country from accidental reintroduction of the yellow fever virus in man or the vector mosquito, and, at the same time, to protect our neighbors in the Americas from being reinfested with *Ae. aegypti* accidentally exported from this country. To provide protection against this two-way threat, the Division of Foreign Quarantine has enforced regulations requiring the vaccination of people traveling to and from endemic areas; has conducted physical examinations to detect cases among persons arriving from yellow fever areas; and has carried on an extensive entomological program to control *Ae. aegypti* at ports and dock sites in the yellow-fever-receptive area from Brownsville, Tex., through Georgetown, S. C. This continuing control program involves inspections and treatment and includes the disinsectization of aircraft traveling between endemic areas and this country (Hughes and Porter, 1958). During World War II and for a few years immediately following, a limited *Ae. aegypti* eradication program was carried on by the Public Health Service in conjunction with its program of Malaria Control in War Areas (MCWA).

Because of a revival of interest in yellow fever stimulated by a northward movement of jungle yellow fever from 1948 to 1957, the Communicable Disease Center (CDC), the successor to MCWA, initiated a program of surveillance and preparedness. All existing records on distribution of *Ae. aegypti* within the United States were analyzed and surveys were made to determine current distribution and densities of the vector (Hayes and Tinker, 1958; Tinker and Hayes, 1959; Tinker, 1963). Between 1957 and 1961, a pilot eradication project was carried out in Pensacola, Fla., a port city with moderate to heavy infestations, to study the eradication procedures that have been used in the Latin-American countries and to develop a practical methodology applicable to conditions in the United States (Morlan, 1962).

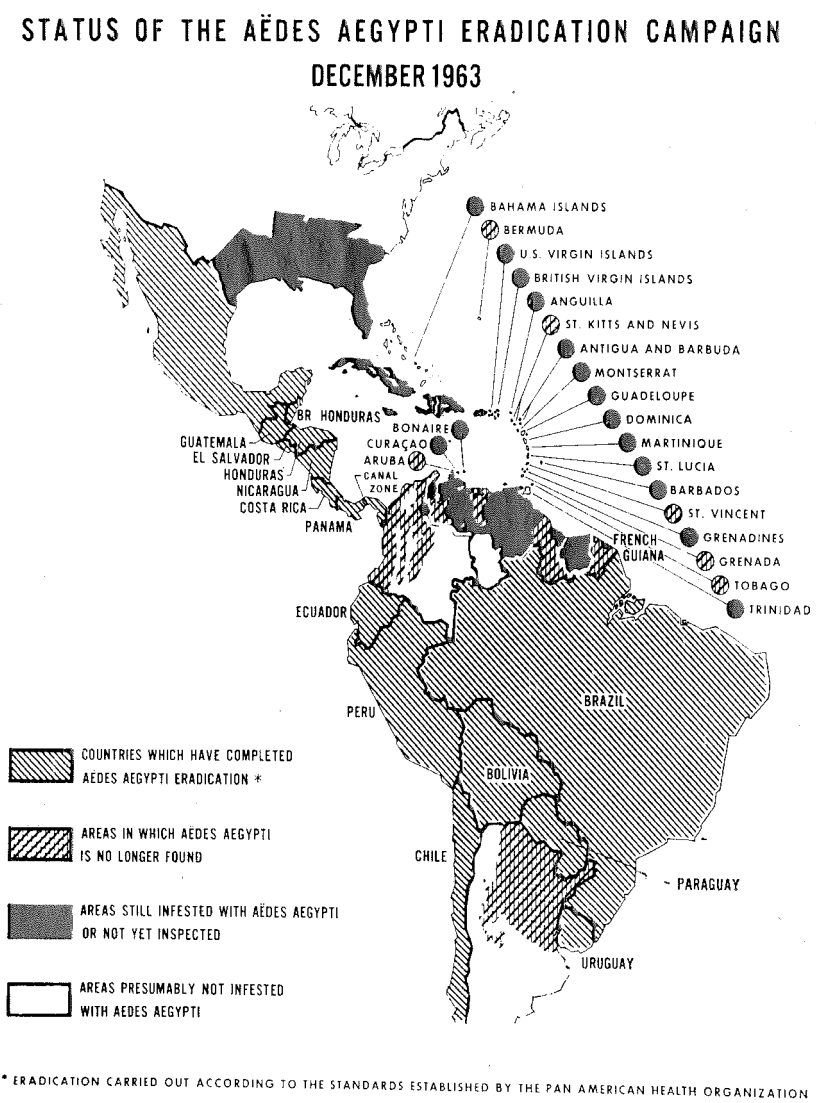

FIGURE 1

The CDC surveys were conducted in cooperation with state and local departments of health in 250 of 907 counties throughout the receptive area. Despite the recognized problem of evaluating negative data acquired in the survey procedures extensive information was obtained on the distribution and density of the mosquito. For example, all but 9 of 40 cities in the receptive area with populations over 50,000 were infested; in practically all instances, the small towns (populations less than 2,500) were free of the vector except in the southern part of Florida and in Puerto Rico and

the Virgin Islands; and throughout the area only isolated instances of rural infestations were found (Fig. 2). The results of these surveys, when compared with records of 1942–1945, showed a significant decrease in the area of infestation and the density of *Ae. aegypti* populations within the United States. In light of this new information, in 1960 the World Health Organization redefined the yellow-fever-receptive area in the United States, as shown in Figure 3.

As the survey results were studied and evaluated further, significant facts emerged. Some cities that remained infested throughout the 40's despite control during World War II, and some other infested cities not subjected to control measures, were alike free of *Ae. aegypti* in the recent surveys. Also, there had been a considerable decrease in *Ae. aegypti* density in rural areas. These findings suggested that other factors apart from control operations had acted to reduce the species below the level necessary for its perpetuation.

Among the identifiable factors that have placed heavy stress on the species during the past century, and especially during the last two decades, the following can be named:

1. DEVELOPMENT OF COMMUNITY AND INDIVIDUAL WATER SUPPLIES has eliminated the cistern and open well which were good sources of *Ae. aegypti.*

2. FIRE-PROTECTION FACILITIES, including installation of sprinkler systems and other changes in fire-protection procedures in warehouse and dock areas, have largely eliminated the fire barrel that had been a common source of *Ae. aegypti.*

3. DEVELOPMENT OF NEW INSECTICIDES, particularly the chlorinated hydrocarbon insecticides and their widespread use by agriculture and householders, has adversely affected the species.

4. IMPROVEMENTS IN COMMUNITY HEALTH AND SANITATION, especially in refuse collection and general sanitation in both urban and rural areas, have contributed to the reduction of breeding habitats.

5. HOUSING IMPROVEMENTS, slums clearance, and more effective land use appear to have adversely affected *Ae. aegypti.*

6. MODERNIZATION OF RAILROADS has eliminated the water tank and the old work train which were both prolific sources of *Ae. aegypti.*

7. THE TREND TO URBANIZATION, together with the economic improvement of rural families, seems to have lessened the problem in rural areas but may have added to it in urban areas.

8. METEOROLOGICAL FACTORS, such as the cycle of more severe winters in the yellow-fever-receptive area during the past two decades, and the pattern of rainfall in the Southwest, apparently have placed added stress on the survival of the species.

The survey data also showed that *Ae. aegypti,* which is a semi-tropical mosquito, exhibits a pattern of reproduction and proliferation that varies from a relatively constant rate in Puerto Rico, the Virgin Islands, and southern Florida to a seasonal rate in the more northerly portions of its range. This distribution is shown in Figure 4, where Zone A represents the area of continuous breeding and Zones B, C, and D indicate the areas of seasonal breeding and the sporadic, discontinuous infestations recorded in the surveys of 1956 to 1962. While it is impossible to assess the relative significance of the factors producing this picture of interrupted distribution, their value is recognized nonetheless.

PLAN OF OPERATION. During the early stages of program planning, the Malaria Control in War Areas program was looked to as a prototype. In that program, conducted during the 1940's by the Public Health Service in cooperation with State and local health departments, the Federal government provided all materiel and manpower and pursued operations in very close collaboration with the States. Although individual communities in the operational areas realized definite benefits, the primary purpose of the program was national safety and national manpower conservation. In the *Ae. aegypti* eradication effort, too, the primary interests are national and international, although again

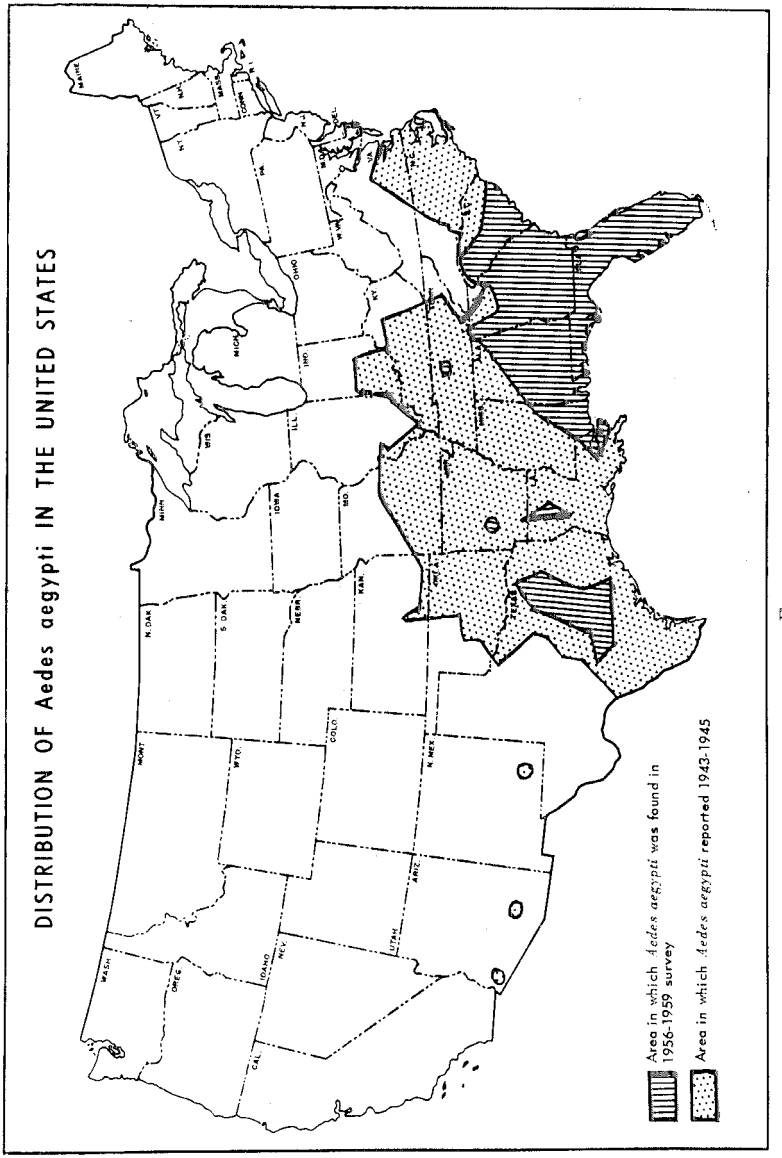
DISTRIBUTION OF Aedes aegypti IN THE UNITED STATES
Area in which Aedes aegypti was found in 1956-1959 survey
Area in which Aedes aegypti reported 1943-1945
WASH
OREG
CAL
IDAHO
NEV
MONT
WYO
COLO
UTAH
ARIZ
N. MEX
N. DAK
S. DAK
NEBR
KAN
MINN
IOWA
MO
OKLA
TEXAS
ARK
LA
WIS
ILL
MICH
IND
OHIO
KY
TENN
MISS
ALA
GA
FLA
S.C.
N.C.
VA
W. VA
PA
N.Y.
MAINE
VT
N.H.
MASS
R.I.
CONN

FIGURE 2

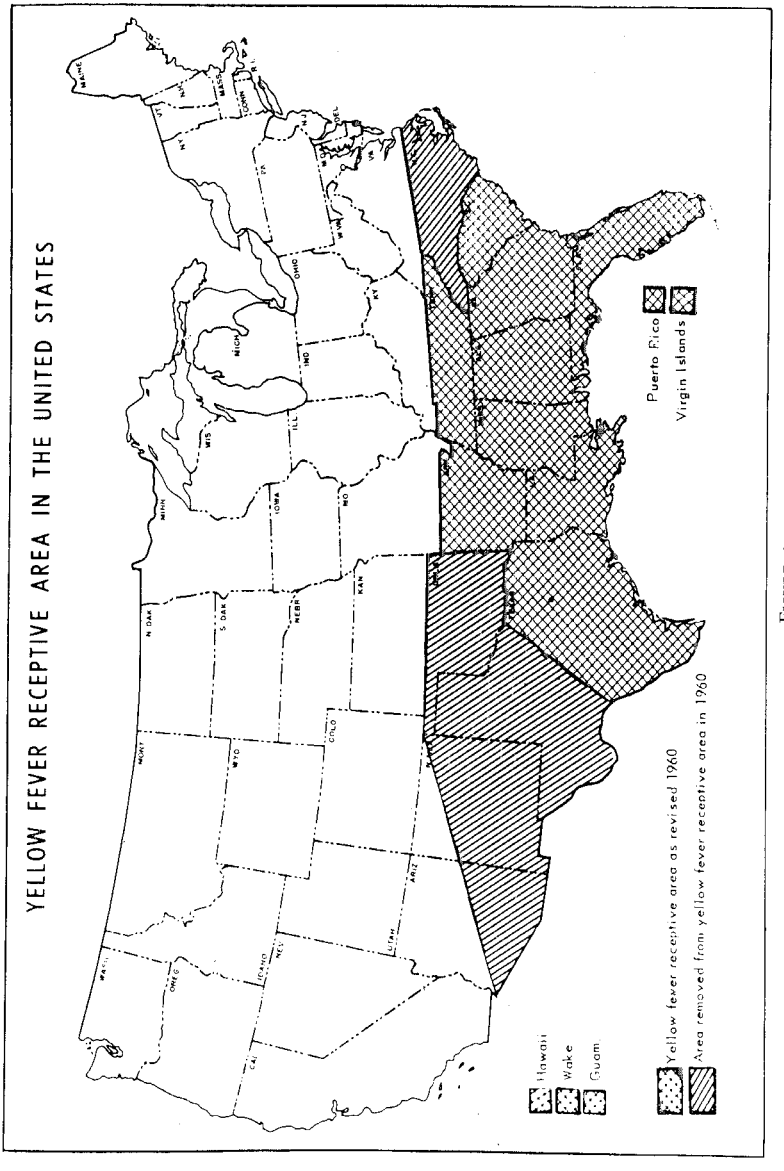
YELLOW FEVER RECEPTIVE AREA IN THE UNITED STATES
Puerto Rico
Virgin Islands
Hawaii
Wake
Guam
Yellow fever receptive area as revised 1960
Area removed from yellow fever receptive area in 1960

FIGURE 3

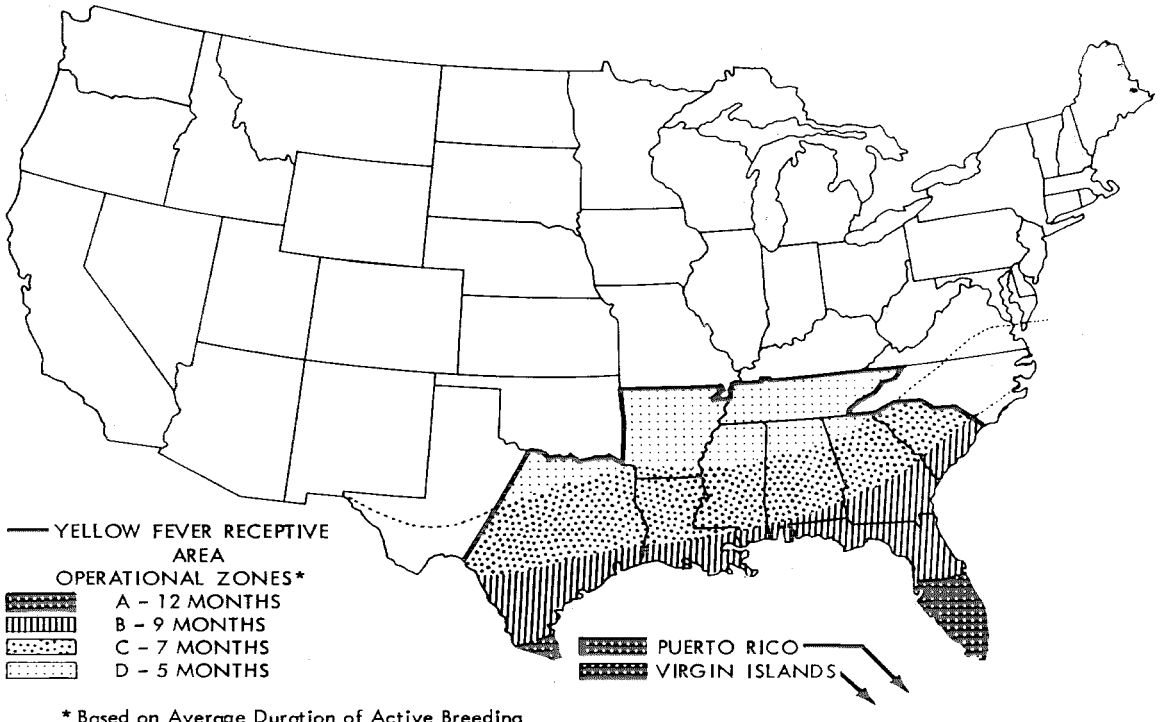
Operational Zones for Aedes aegypti Eradication
YELLOW FEVER RECEPTIVE AREA
OPERATIONAL ZONES*
A – 12 MONTHS
B – 9 MONTHS
C – 7 MONTHS
D – 5 MONTHS
PUERTO RICO
VIRGIN ISLANDS
* Based on Average Duration of Active Breeding

FIGURE 4

individual communities are expected to realize considerable benefits. Because of the parallel in purpose and benefits, on this eradication program as on the MCWA program, operations were to be performed through the mechanism of Federal employees working in the cooperating States.

However, differences in the ecology of the target vector in the two programs dictated a need for a different operational approach. The malaria mosquito breeds primarily in permanent bodies of fresh water so the MCWA operations were pursued largely in outlying and rural areas. In contrast, *Ae. aegypti* breeds in artificial containers in or adjacent to man's dwellings, and its survival relates very closely to the customs and mores of the people. Operations will be carried on primarily in the cities, and it is of paramount importance that the program be conducted after a plan that will assure the cooperation and support of the public and the responsible health agencies.

Under the plan initially developed, the program was to be initiated simultaneously throughout all of the yellow-fever-receptive area. Operations were to be guided by experience gained on the Pensacola project, i.e., heavy reliance on inspections, insecticidal treatment, reinspections and retreatment as needed until criteria for eradication are met. These criteria are to be consistent with those established by PASB but with modifications to suit conditions in the United States. Planned procedures included initial inspections to determine areas of infestation; an intensive educational and informational program to elicit the support and cooperation of the public; premises inspections and spraying with DDT, followed by reinspections and respraying as needed; surveillance and inspections in the States bordering the infested areas; and because of the possibility that *Ae. aegypti* might develop resistance to DDT (resistance has already been reported in the species in Puerto Rico and the Virgin Islands), continuing studies to provide alternate control methods—for example, by substitution of other insecticides, or by use of chemo- and radiological sterilants or other biological control techniques. Under this plan the estimated cost of the proposed 5-year program, based on manpower and equipment projections for the Pensacola study, approximated 100-million dollars.

The magnitude of these estimated figures led to a reappraisal and revamping of the plan of operation. The revised plan is designed to effect significant reductions in appropriated funds through attainment of maximum cooperation from every source with a vested interest in the various aspects of the control program. At present, efforts are being made to secure the assistance and cooperation of the State and local health departments in the States affected, the U. S. Department of Defense, local civic groups, and every other agency, official or voluntary, with related objectives or operations.

To provide incentive, create interest, and encourage initiative and cooperation at the State and local levels, and at the same time to eliminate duplications of effort, the program will be conducted through contractual arrangements with the State health departments. This will assure complete integration of operations into ongoing vector-control and environmental-sanitation programs. Further, it will permit the employment of local personnel as inspectors and spraymen but with Federal funds paying the costs.

Under the terms of the contracts, Public Health Service will assign Federal personnel to State and local health departments as needed to coordinate and supervise the program in conjunction with and under State and local policies; develop the methods of operations and prepare operational manuals; provide training for inspectors and spraymen; furnish materiel and supplies; conduct necessary studies; and maintain surveillance in the States bordering the infested areas.

Operations will emphasize mosquito source reduction supplemented by insecticidal treatment of infestations and will involve premises sanitation, community

clean-up campaigns, and various related sanitation activities to eliminate *Ae. aegypti*. As a rule, insecticides will be applied only to actual infestations and immediately-adjacent areas with a high potential for breeding. These selective applications will be made with hand-compression or power sprayers, and care will be taken to avoid possible contamination of food products and water. As inspections are made, the sanitary condition in each block will be appraised and recorded and the owners of premises will be notified of adverse conditions to be corrected. Data on all socioeconomic and environmental factors favoring the production of domestic mosquitoes will be used to develop an effective source-reduction program in collaboration with local departments of health.

Endorsement of all phases of the program by local and State representatives, other public officials, civic leaders, and the people will be encouraged. To create the atmosphere of understanding essential to achieving this objective, a strong public information program employing modern methods and procedures will be conducted.

Three million dollars was appropriated by Congress for activation of the program in FY 1964. Since funds are not adequate to activate operations throughout the yellow-fever-receptive area simultaneously, initial efforts will be concentrated in the heavily infested urban centers of Zone A, the zone of continuous breeding and heaviest infestations. This includes the principal cities and towns of Puerto Rico, the Virgin Islands, southern Florida, and portions of Texas. Contracts have been negotiated with the health departments of these States and territories, and operations are scheduled to begin April 15.

Beginning in July 1964, an experimental program will be undertaken in Louisiana to evaluate the effectiveness of source-reduction measures accompanied by only limited insecticidal treatment of heavy infestations by a mobile crew. Also, extensive surveys will be conducted during the summer of 1946 throughout the yellow-fever-receptive area to provide more precise information on the distribution and density of *Ae. aegypti*. Results of the Louisiana study and of the surveys, together with an evaluation of the initial operations, will permit early appraisal of the program and allow necessary changes to be made in the operational plan.

As resources become available, the program will be expanded to embrace the entire receptive area. It is expected that the effects of this concerted drive will result in the eventual eradication of the species. In addition, many ancillary benefits will be derived from the program. Other domestic mosquitoes that can serve as disease vectors or pests will be controlled and the breeding places of rodents, flies, and other vermin will be eliminated. There is good cause to believe that this cooperative plan of operation will lead to a strengthening of State and local vector-control and sanitation programs throughout the yellow-fever-receptive area.

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