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PAHO STUDY GROUP ON THE PREVENTION OF  
AEDES AEGYPTI-BORNE DISEASES

(Item 14.6 of the Agenda)



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REPORT OF THE PAHO STUDY GROUP ON THE  
PREVENTION OF AEDES AEGYPTI-BORNE DISEASES

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## I. INTRODUCTION

Aedes aegypti and disease agents that are transmitted by this mosquito continue to prevail in the Americas in 1970. The Pan American Health Organization and all its Members recognize that advances in the Twentieth Century have provided an adequate scientific knowledge to allow the hemispheric eradication of Aedes aegypti. The primary purpose of such action would be to prevent the continual occurrence or threat of epidemic yellow fever and dengue fever in urban populations. The delay in accomplishment of what appeared to be an attainable goal, namely, eradication of Aedes aegypti and the diseases it transmits, led the Directing Council of the Pan American Health Organization at its XIX Meeting, September-October 1969, to request the Director to review the current problems that are associated with this hemispheric program (Figure 1).

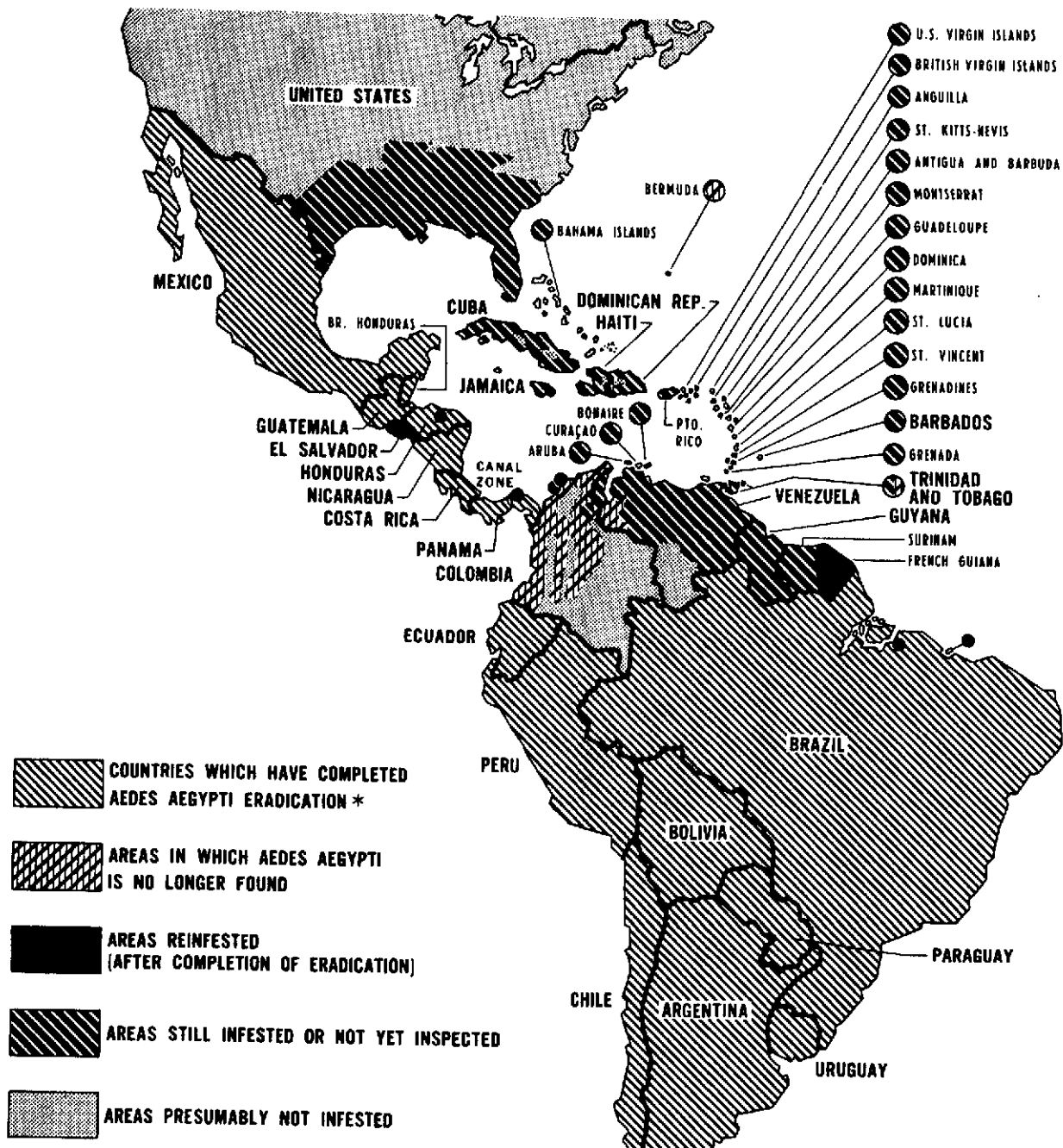
As the first step to meet the above request, the Director convened this Study Group to undertake a review of the problem and to report on the following specific aspects:

1. The extent and distribution of disease agents that may be transmitted by Aedes aegypti in the Americas.
2. The immediate and long-term consequences of the spread of such diseases.
3. The present strategy and scope of methods that are being or would be used to prevent and control Aedes aegypti-borne diseases.
4. The factors that may have limited the success of present programs and the promise offered by alternative approaches to the problem.
5. The identification of the procedures that are essential to or are alternative approaches in a program for the prevention and control of diseases transmitted by Aedes aegypti.
6. A plan for further in-depth study as to the costs and the benefits to be derived from alternative approaches to control, if they were utilized.

The following report summarizes the findings of the Study Group and its unusually competent panel of consultants and secretariat.

FIGURE 1

# STATUS OF THE AEDES AEGYPTI ERADICATION CAMPAIGN IN THE AMERICAS, DECEMBER 1969



\* ERADICATION CARRIED OUT ACCORDING TO THE STANDARDS ESTABLISHED BY THE PAN AMERICAN HEALTH ORGANIZATION



## II. DISTRIBUTION OF Aedes aegypti-BORNE DISEASES IN THE AMERICAS

### A. Jungle yellow fever

The first recognition that there was a cycle of yellow fever maintenance and transmission other than the accepted cycle between Aedes aegypti and man came in the 1930's. In the following several decades, Haemagogus mosquitoes and monkeys were demonstrated to sustain a "jungle cycle." Aedes leucocelaenus and Sabethini mosquitoes were implicated as secondary vectors. It was also demonstrated in laboratory studies, although not by isolation of virus from wild animals, that marsupials might participate in the vertebrate reservoir system.

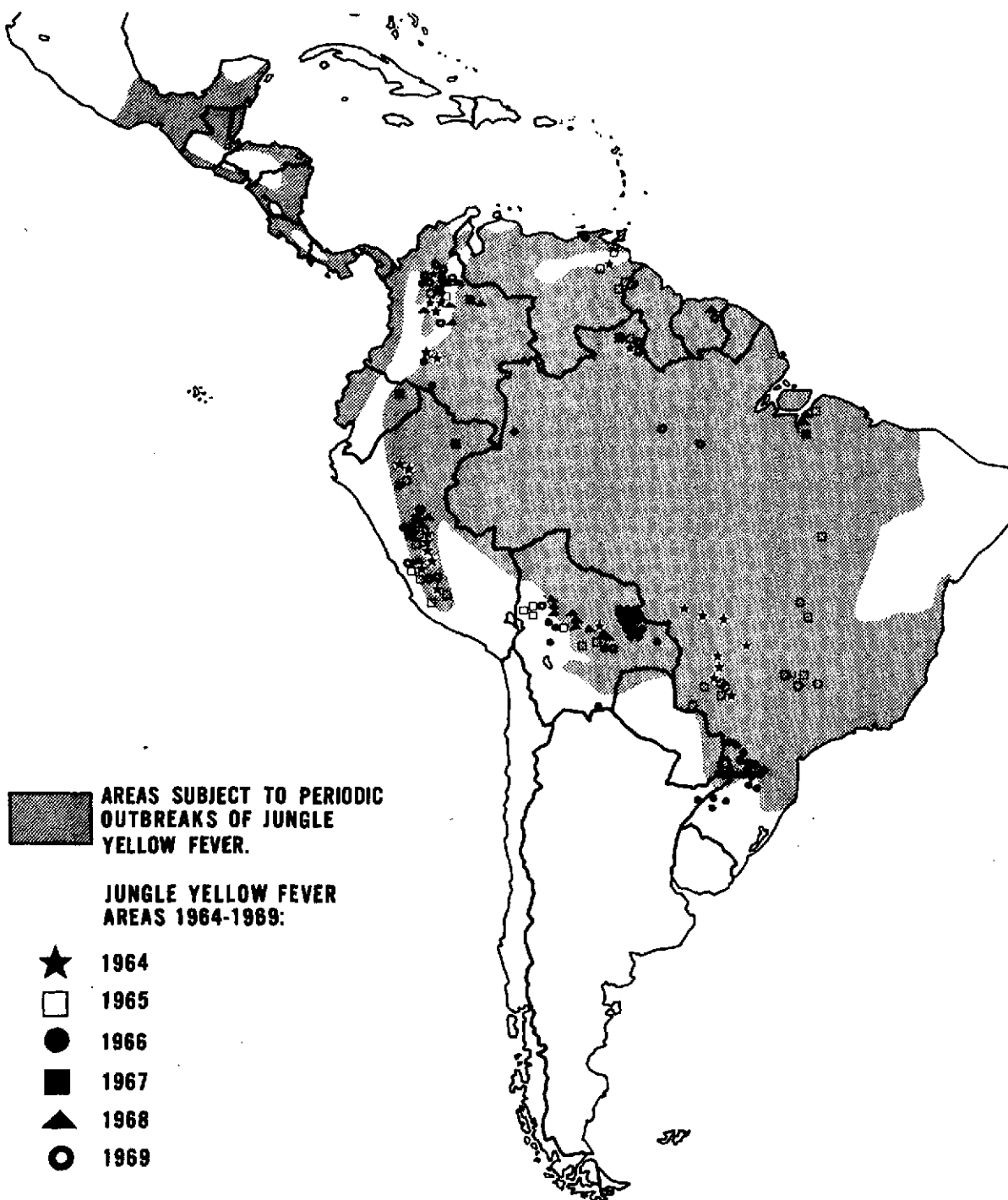
With the introduction of more adequate surveillance in jungle areas, helped by the use of the viscerotome in Bolivia, Brazil, Colombia, Ecuador, Peru, and Venezuela, a picture evolved of the total area involved in endemic transmission of yellow fever in the Western Hemisphere (Figure 2). The area is enormous, as it encompasses literally the entire Amazon drainage system (including the eastern parts of Colombia, Ecuador, and Peru, the Amazonian lowlands of Bolivia, and a part of Matto Grosso in Brazil) a small focus in the Ilheus region of Brazil, the Middle Magdalena Valley in Colombia, and the gallery forest areas of the Orinoco tributaries in Venezuela. The Darien lowlands of Panama, the hinterlands of French Guiana, Surinam and Guyana may also be suspected of harboring jungle yellow fever.

There have been repeated occasions in the past four decades when the virus moved out of suspected or known endemic foci to reinvade regions not known to be involved for considerable periods (Figure 2). Such movement of virus explains the epidemic which progressed from Panama to Mexico in the 1950's, the periodic epidemics which have swept through the more southern states of Brazil and into Paraguay and northern Argentina, and also those which have periodically involved northern Venezuela and Trinidad. The last known instance when a population center lay in the course of such movement and resulted in an Aedes aegypti-human cycle of transmission was in 1954 at Port of Spain, Trinidad.

There is evidence that epidemic movements have depended on the availability of susceptible monkey populations. The resident monkey population, particularly Alouatta, may be reduced to very low levels during these epidemic sweeps. Other monkey species are involved, and Cebus populations may suffer a low mortality. Periodic serological samplings of monkeys in a region provide data that allow an assessment of a given region's involvement in yellow fever virus activity. In addition, the information is of value to determine if the region is one of endemic persistence of virus, or will be subject to periodic epidemic invasion. In

FIGURE 2

# JUNGLE YELLOW FEVER IN THE AMERICAS



regions where vaccination has not been done, serological surveys of the human population can furnish similar information. In reality, such sampling, either of monkeys or of humans, has been very sporadic, and insufficient to provide the detailed data needed for a thorough assessment of the distribution of yellow fever.

There has been a very marked decline in the use of the viscerotome in recent years, and it is obvious that there is much less effective monitoring of jungle yellow fever occurrence than existed thirty years ago. The laboratories that are currently available for diagnostic studies (serology and viral isolations) in Argentina, Brazil, Colombia, Panama, Trinidad, and Venezuela have been responsible for the more recent yellow fever virus isolations, but these laboratories routinely receive specimens from only a fraction of the total territory involved. Human infections in most of the region are inefficiently monitored.

The diagnosis of yellow fever presents peculiar difficulties. Often cases do not exhibit the classical symptomatology, and even classical sporadic cases may not be recognized. Most cases go undiagnosed as they have a mild fever, no jaundice, and no distinctive signal features. Missed diagnosis can even occur during the course of an epidemic when the index of suspicion is high. Consequently, the existing figures on occurrence of yellow fever in humans represent a picture of gross underdetection.

If it is desired to develop and maintain an adequate assessment of the distribution of jungle yellow fever, a monitoring system would have to be established that is more extensive and precise than the current haphazard system. At the same time we know the areas where yellow fever was active in the period 1932-1958 and the distribution of proved human cases in the past six years (Figure 2). All findings would indicate that an extensive area of enzootic yellow fever persists today in South America and that, although it recedes and expands, it will continue to be an endemic area.

#### B. Dengue fever

The current status of the epidemiology of dengue fever in the Americas has been fully described in the report of 16 January 1970 from the Scientific Advisory Committee on Dengue entitled "Surveillance of Dengue in the Americas." In summary, epidemic dengue fever has occurred in the Greater and Lesser Antilles in 1968-1969. Dengue virus types 2 and 3 were present during 1968. Dengue type 2 was responsible for the intensive epidemic in Puerto Rico in 1969. An unidentified type or types of virus were active in Venezuela. There is evidence that dengue is endemic or is becoming endemic in Jamaica, Haiti, and Venezuela. The geographical patterns of occurrence in the several epidemics in the period 1963-1969 are presented in Figures 3-5.

Figure 3

OCCURRENCE OF DENGUE IN THE  
CARIBBEAN, 1963-1965

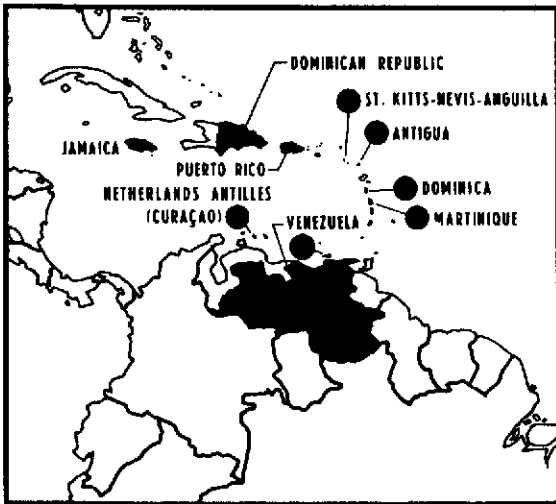


Figure 4

OCCURRENCE OF DENGUE IN THE  
CARIBBEAN, 1966-1967

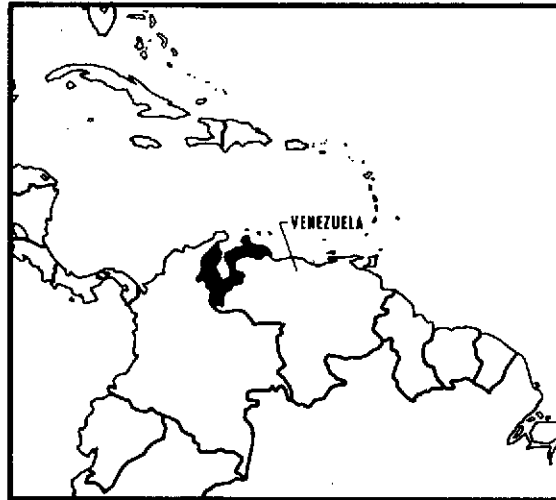


Figure 5

OCCURRENCE OF DENGUE IN THE  
CARIBBEAN, 1968-1969



In recent outbreaks in Asia, the spectrum of disease due to dengue has varied from undifferentiated mild febrile illness to the classical dengue fever syndrome. No cases of dengue hemorrhagic fever with or without shock syndrome have been reported from the Americas in spite of active surveillance in some areas.

Epidemic dengue and dengue-like disease occurred at irregular intervals in the pre-Aedes aegypti control era in an area that included much of the southeastern and Gulf coastal area of the United States of America, Mexico, Central America, and the northern part of South America. Eight major outbreaks have been recorded in this century. Serological surveys have revealed that dengue fever was active in earlier years in the Belem area of Brazil, and there are clinical reports of dengue-like illness in earlier years in more southern regions.

The continued presence of the vector in the Americas and the presence in the world of at least six viruses (dengue types 1, 2, 3, 4, yellow fever, and chikungunya) known to be transmitted by Aedes aegypti and to have major epidemic potential lead to the conclusion that the Americas remain at considerable risk.

Dengue fever, like yellow fever, has no reservoir in the temperate areas and must be reintroduced during the summer from a locality where transmission is active. Evidence recently obtained in Malaya may indicate there is a jungle dengue reservoir in monkeys.

C. Likelihood of occurrence of dengue hemorrhagic fever in the Americas

All available data from studies in Asia suggest that dengue hemorrhagic fever (with or without shock syndrome) occurs when two or more types of dengue viruses are continuously or simultaneously endemic. This situation now exists in the Caribbean, as dengue type 2 and 3 viruses were transmitted to man in the same area in 1968. We do not have sufficient information about the exact conditions of host and virus interaction to predict the occurrence of hemorrhagic fever. Based upon studies in Asia, it is clear that the syndrome may occur in both children and adults, although it has occurred predominantly in children. The intermittent disease experience in the Americas would suggest that, if dengue hemorrhagic fever develops, it may involve a broader age range than was observed in areas of Asia where dengue was highly endemic.

Dengue hemorrhagic fever may occur as sharp outbreaks accompanied by significant mortality. The short and fulminating course of this disease strongly resembles that of yellow fever. Epidemics in South-east Asia have produced near panic. Should this disease occur in the

Americas, a serious fear reaction can be expected. The occurrence in the Caribbean of a mysterious and fatal disease could produce a dampening effect on tourism and economic development that could last for years.

A serologic survey and case-finding technique that employs sentinel institutions was recommended to the Director of the Pan American Sanitary Bureau by the Scientific Advisory Committee on Dengue, and this could form the basis for a sound program of surveillance for dengue hemorrhagic fever. Such activities would serve the same purpose for yellow fever surveillance. The need for laboratory-supported epidemiological studies on a permanent basis cannot be over emphasized. The areas where hemorrhagic fever is most likely to occur and which therefore require first and constant attention are those where dengue fever is either endemic or repeatedly epidemic.

### III. STRATEGY FOR THE PREVENTION AND CONTROL OF Aedes aegypti-BORNE DISEASES

#### A. The present situation and its implications

The strategy and operation of campaigns for elimination of Aedes aegypti-borne diseases from the Western Hemisphere for the past quarter century were based on eradication of the mosquito from all infested areas and territories. The concept was first endorsed by the XI Pan American Sanitary Conference in Rio de Janeiro in 1942. In 1947, the Directing Council of the Pan American Health Organization entrusted the Pan American Sanitary Bureau with the solution of the urban yellow fever problem through the eradication of Aedes aegypti. This action was endorsed repeatedly by Member countries of the Organization in subsequent annual resolutions of the Council. The present strategy for Aedes aegypti eradication is presented in summarized form in the attached excerpts from the "Present Policy Guide for Aedes aegypti Eradication" (Appendix A).

Eradication of Aedes aegypti infestations was proven feasible and practical when eighteen countries and territories of the Americas achieved this goal. This attainment is a tribute to the interest, commitment, and economic sacrifice of the countries and reflects creditably on the advisory services of and assistance by the Pan American Health Organization. Thirteen of these countries are presently free of the mosquito, but five have been reinfested (Table 1).

On the other hand, Aedes aegypti has not been eradicated from 26 countries and territories, and, in some cases, there has not even been a significant reduction in the area of infestation and density of the mosquito population.

TABLE 1

COUNTRIES IN WHICH Aedes Aegypti HAS BEEN ERADICATED  
AND THOSE WITH RECENT REINFESTATIONS

Country	Eradication Confirmed	Reinfested
Bermuda	September 1953	-
Bolivia	September 1958	-
Brazil	September 1958	July 1967
British Honduras	September 1958	-
Ecuador	September 1958	-
Nicaragua	September 1958	-
Panama	September 1958	March 1969
Paraguay	September 1958	-
Peru	September 1958	-
Uruguay	September 1958	-
Canal Zone	September 1958	-
Guatemala	September 1959	-
Honduras	September 1959	March 1968
El Salvador	September 1960	June 1965
Chile	October 1961	-
Costa Rica	October 1961	-
Mexico	September 1963	Nine reinfestations since 1965, latest in October 1969
Argentina	October 1965	-

Eradication of the vector and the diseases it transmits is a multinational problem due mainly to the danger of reintroduction. Those countries that have eliminated Aedes aegypti, at considerable cost, have a vested interest in the remainder of the Region that is still infested. The present review indicates that despite the demonstrated feasibility of eradication of Aedes aegypti from the Hemisphere, this objective will not be achieved within a reasonable time unless every country can obtain the resources and ensure the administrative support that a successful program requires.

Eradication requires an effective administration and techniques that all too often are not available to many national health services. The investments already made by the nations of the Americas in the solution of the problem warrant the adoption by the Pan American Health Organization of whatever measures may be deemed necessary to support the permanent prevention of Aedes aegypti-transmitted diseases.

The main factors that have prevented the completion of national eradication programs appear to be financial restrictions, administrative rigidity, unsatisfactory labor relationships, sociocultural factors, insecticide resistance in the vector, and reinfestations.

Attention in the last few years has been focused on the failures and difficulties in accomplishing Aedes aegypti eradication from the Hemisphere rather than on the successful achievements. This attitude has stemmed from a number of factors, including 1) the reinfestation of countries that had achieved eradication and the difficulties of rapidly identifying and solving the problem; 2) limited progress in eradication in infested countries of the Continent (Guyana, Surinam, United States of America, and Venezuela) and in the numerous Caribbean Islands (Figure 1); 3) outbreaks of dengue in many of the above areas in 1963-64 and again in 1968-69; 4) the wide distribution of jungle yellow fever and the threat of reestablishing urban transmission which spreads readily from country to country; and 5) increased concern that dengue hemorrhagic fever may appear in dengue endemic areas of the Hemisphere.

The above problems have been recognized by the Governing Bodies of the Pan American Health Organization since 1958 and are reflected in their annual resolutions that have called for initiation, intensification, or acceleration of action by infested countries. Various working groups convened by the Organization have reviewed all aspects of these problems.

The duration of the threat is dependent upon future action by infested countries, and its potential magnitude will reflect the ability of reinfested countries to eradicate the mosquito. Therefore, until



such time as eradication may be achieved in the Hemisphere, it is essential that consideration be given to other procedures for control and prevention of Aedes aegypti-borne diseases.

Prior to initiation of the eradication program, it was assumed that urban outbreaks of yellow fever would not occur where the Aedes aegypti index was less than five per cent. The threshold index for prevention of dengue is not known, but it is postulated from data in Southeast Asia that an index below five per cent could sustain endemic urban dengue fever. Methodology is available to achieve vector densities below such levels. Such methods have rested primarily on the use of insecticides and secondarily on health education and source (breeding-place) reduction. Where the procedures are applied routinely in infested areas and infestation indices remain low, the threat of Aedes aegypti-borne diseases will remain low.

A major threat of disease transmission arises in those areas where reinfestations are not recognized and in infested regions where there is little or no control and a high index prevails. Implementation of current surveillance procedures to detect Aedes aegypti has been shown to be inadequate in some countries. The early detection of cases of disease spread by Aedes aegypti is generally by clinical and pathological recognition supported by serological methods and viral isolations. The use of viscerotomy is very limited today. Even assuming an adequacy of detection of introduced infections, an epidemic probably will develop because of delay between the time when diagnosis is established and initiation of anti-mosquito measures. An epidemic might be interrupted by the control program.

Surveillance would be more effective if primary emphasis were placed upon the detection and rapid eradication of Aedes aegypti. If one waits upon the detection of frank disease cases, with all of the limitations of diagnosis, there inevitably will be a delay in the control of disease transmission.

The continuity and efficiency of inspection of transport facilities and goods, via air, water, and land, leave much to be desired. There is reason to believe that the supervision of these activities, which present opportunities for mosquito invasion, is not too successful. To improve the program it is necessary to give special attention to inspection and control procedures. This should include the potential use of dichlorvos for disinsection of aircraft.

Possible consequences of the reinfestation of countries by the vector include the potential urbanization of yellow fever and the extension of dengue fever to areas that are not now affected. Other consequences are the serious effects of such events on the health, economy, and public reaction within the country. The possible appearance of hemorrhagic

dengue in this part of the world cannot be disregarded, and Aedes aegypti reinfestations should be considered in the light of this additional potential danger. Provided that an effective surveillance program is maintained in the countries which have eliminated Aedes aegypti, history demonstrates that reinfestations can be quickly controlled although there will be additional costs for the program.

B. Feasibility of various methods for eradication or control of Aedes aegypti

There has been considerable basic laboratory research to develop biological and genetical approaches to mosquito control. However, field evaluation of the findings have been very limited or nonexistent, particularly in the case of Aedes aegypti. There are insufficient data and experience to allow us to decide whether biologic or genetic approaches to control should be seriously considered as practical for either eradication or control of Aedes aegypti in the Americas in the next five to ten years. A WHO panel has recently summarized the knowledge and current potential of these approaches for the control of a number of mosquito species (WHO, Informal Consultations on Alternative Methods of Vector Control, Geneva, 1969). The present situation with reference to Aedes aegypti can be summarized as follows:

1. Biological control

A range of infectious agents, parasites and predators have been identified that can reduce the numbers of Aedes aegypti. These include: a) predators, notably Toxorynchites mosquitoes, that show promise of achieving control with continuous inundative releases; larvivorous fish are not well adapted for use against a mosquito that breeds in small and/or temporary containers; b) parasites, notably the mermithid nematodes and particularly Romanomermis; and c) infectious agents, including fungi, bacteria, viruses, and microsporidia.

While agents have been identified that are pathogens of Aedes aegypti in the laboratory, there is little evidence that natural populations of Aedes aegypti are suppressed by such agents in Africa, Asia, or the Americas. However, the search for such evidence has been very limited. A procedure is established for the identification and laboratory evaluation of candidate agents at the WHO International Reference Center at Ohio State University. No single agent looks unusually promising for Aedes aegypti control or eradication, but it would be desirable for the Pan American Health Organization to support limited field trials in selected and limited areas of the Americas.

2. Genetical control

Certain genetical approaches have promised as adjuncts to our capacity to control or eradicate Aedes aegypti. None of them have been

evaluated in the field, and it is suspected that if they have any promise it will be to accelerate the final steps of an eradication campaign. They may be divided into the following three categories:

a) Chromosomal translocations

Workers at the Institute of Biology, University of Notre Dame, have a strain of Aedes aegypti with a chromosomal translocation which causes 80 per cent sterility and which is transmitted to surviving generations.

b) Sex ratio distorters

Strains of Aedes aegypti have been produced in the laboratory in which a meiotic drive mechanism ensures that 80 per cent or more of the progeny are males. Successful introduction of such a strain into a field population should cause a population decrease due to the scarcity of females.

c) Sterile male releases

Field trials with irradiated males have been limited and unpromising. Chemical sterilization still offers promise. Cytoplasmic incompatibility and hybrid sterility do not hold promise as a mechanism for Aedes aegypti control.

To summarize, the alternative or supplementary approaches to Aedes aegypti control or eradication by biological or genetical mechanisms continue to hold promise. However, developments have been slow, and there has been a lack of significant field evaluation. We will not know the feasibility or contribution of these approaches until well-organized field studies have been performed.

### 3. Chemical control

Resistance to insecticides by Aedes aegypti has become a serious problem. Strains that are both DDT-resistant and dieldrin-resistant are now widespread in the infested areas and are frequently responsible for reinfestations. It is important to know the exact levels of DDT-resistance as determined by standard tests in each infested area. It is also essential to know to what degree this resistance is interfering with the attainment of complete control in areas where DDT is still employed.

The continued use of DDT in the infested areas has led to two undesirable results, namely:

- a) It aggravates the problem by leaving surviving populations that are increasingly difficult to control; and,

b) its use in three-month cycles, as compared to the one-week cycle employed in the successful eradication operations with larvicidal oil, makes it easier for foci to escape undetected and untreated.

Moreover, there are now increased objections on the part of the public and some Governments to its continued application to the environment.

A number of organophosphorus (OP) insecticides are now available for larval and adult control. Of these, the most important are malathion, fenthion, dursban, and abate. One of their advantages is that little or no resistance has developed to them, so that their application will give complete control in every focus treated. Although laboratory studies indicate that Aedes aegypti develops only a mild tolerance to them, and that, only slowly, the possibility of the development of OP-resistance in the field remains unless the control operations are carried out thoroughly, extensively, and rapidly.

Malathion and abate are suitable for application indoors, but abate is at present too expensive for large-scale outdoor application. Fenthion and dursban are highly effective, but not as safe as the other two compounds. In assessing the increased costs involved in using these OP compounds, it is necessary to know the costs of the formulations and the timing of cycles that each compound requires.

None of the OP compounds mentioned have the great residual effect that DDT had before the onset of resistance. For this reason, certain nonchlorinated analogs of DDT recently developed at the CSIRO, Australia, are of great interest, because they are residual, safe and effective against DDT-resistant strains. Since they are biodegradable and promise to be inexpensive, their development is awaited with considerable interest.

#### 4. Vector surveillance

The Group felt that it would be desirable if the methods of reporting the presence of surviving populations of Aedes aegypti could be amplified in order to provide the information necessary to define precisely the relative status of Aedes aegypti in the Americas. The presence or absence of Aedes aegypti within countries, districts, and cities has usually been established, but fuller information is required. The data envisaged would include, for example, a quantitative and qualitative analysis of the main categories of larval habitats, their location (broadly speaking, whether indoors or outdoors), an estimate of the contribution each category makes to the adult Aedes aegypti population, and an estimate of the biting population.

Such data are considered necessary for a cost-benefit analysis of different methods of control, for a decision on the most suitable insecticide, and for evaluation of the progress of the control method which is chosen. The data would be essential for a balanced judgment on the potential value of control methods other than insecticides, such as the use of biological agents or genetical control methods.

The methods employed could well be reexamined, taking into account the experience of workers both in the Americas and elsewhere, and these methods should be applicable whether the objective is control, eradication, or surveillance of the mosquito.

### C. Vaccination of human populations

Active immunization against the two Aedes aegypti-borne diseases presents a remarkable contrast.

#### 1. Yellow fever

17D yellow fever vaccine is one of the most efficient and safe vaccines known. It produces serological conversions in nearly 100 per cent of the vaccinated persons and results in a long-lasting immunity. The precise duration of immunity is unknown but may extend for life. No case of yellow fever is known to have occurred in a properly vaccinated person more than seven days after vaccination. In recent years, serious reactions have been rare except in infants, and only one laboratory confirmed fatal postvaccinal encephalitis has been reported (in a three-year-old child). The use of jet-injector guns for vaccination greatly facilitates the use of 17D vaccine in mass campaigns. The vaccine is relatively thermolabile and should be maintained at  $-20^{\circ}\text{C}$ , and under refrigeration ( $+4^{\circ}\text{C}$ ) when transported. Once diluted, it should be used within a period not longer than one hour.

Three laboratories are producing 17D vaccine in the Americas. They are located in Rio de Janeiro (Brazil), Bogotá (Colombia), and Philadelphia (USA). The laboratory in Rio de Janeiro produces between 3 and 5 million doses yearly, the laboratory in Bogotá between 1.5 and 2 million doses, and the laboratory in the United States between 150,000 and 200,000 doses.

Countries in South America, especially Brazil, Colombia, and Venezuela, with populations who live in forested areas where the virus circulates periodically, have instituted vaccination programs covering much of the population at risk. No definite figures are available of the number of persons vaccinated in each country. It has been estimated, however, that a large proportion of the population at risk (as high as 80-90 per cent) has been immunized in each of the three countries mentioned above.

In view of the fact that Aedes aegypti has been eradicated from all cities and towns in South America with the exception of the north-eastern part of the Continent and Colombia, the urban populations are not regularly vaccinated.

Under the threat of epidemics, the vaccine is used in urban populations. No information is available regarding the proportion of an urban population that would need to be vaccinated to prevent an introduced virus from becoming established. The proportion of immunes required to bar virus spread would obviously depend on the presence, density, and distribution of the Aedes aegypti population.

## 2. Dengue fever

Vaccination cannot be counted on to play a significant role in current programs for the primary prevention of epidemics of dengue fever. It may play a modest role as a means of blunting the effect of a recognized or incipient epidemic in a nonendemic area in the Americas.

Four distinct dengue virus types are currently recognized, and they fail to cross-immunize for more than one to three months. Other variants may exist that are not protected against by these four types. Inactivated virus vaccine has little prospect of being effective, a situation similar to that found many years ago for inactivated yellow fever vaccines. Attenuated strains of two types of dengue fever have been tested experimentally, but only singly and not as a combined vaccine. One of these (type 1) appeared to give a detectable degree of short term protection when administered during a type 3 epidemic in Puerto Rico. This vaccine is still an experimental product made of infected suckling mouse brain. It has not been licensed for commercial production.

A similar vaccine, type 2, somewhat less attenuated, has also had some experimental trials in man, but it produced significant fever and rash in some persons.

Development of attenuated strains of the other two types has not been attempted.

If the sensitization hypothesis for the etiology of Southeast Asian dengue hemorrhagic fever is correct, it would have to be assumed that there would be an associated risk with use of any dengue vaccine in an area where any other type of dengue virus is or has been active in the recent past, or might be introduced in the near future. However, the degree of this risk, if any, is unknown, since it is postulated on hypothesis rather than experience. Expert opinions remain divided regarding the risk of using vaccine in such areas.

Studies have been made on purified fractions of dengue viruses as potential immunizing agents, but possible application of the findings will require further evaluation.

For these and other reasons that are not enumerated, effective control of dengue fever in the Americas by vaccination is not considered practical at the present time, nor to have great promise in the near future. Continued research, it is hoped, may improve the prospects.

#### D. Sociocultural factors

Several sociocultural factors bear on the problem of control or eradication of Aedes aegypti:

1. Weak motivation on the part of the general population and of the authorities to support Aedes aegypti eradication efforts may have been due in some cases, to the fact that the expression "eradication of Aedes aegypti" does not convey the proper priority to the program, since it does not place sufficient emphasis on the main objective, which is the prevention of urban yellow fever and dengue.

2. Resistance has developed to invasion of privacy during some spraying and vaccination programs. In addition to personal inconvenience, this may produce unforeseen and undesirable effects. A combination of education as to the need for spraying and vaccination, coupled with courtesy and consideration on the part of spray teams and vaccinators, overcomes much resistance.

3. Litter, the product of an affluent society, produces new and sometimes unexpected breeding places (e.g., discarded automobile tires). The litter problem is a part of a wider concern with environmental deterioration, and its solution will in major part depend on decisions made with respect to this larger problem. Individual and community motivation is badly needed to support community efforts at source reduction.

4. The population of some countries is increasingly concerned with and opposed to the use of insecticides.

5. Administrative-bureaucratic factors, such as overlapping jurisdictions, inter- and intra-agency competition and conflict, prestige, hierarchies within bureaucracies, and the like, may complicate the design and carrying out of the technologically most appropriate programs. It is increasingly apparent that one of the major barriers to

changing health behavior is rooted in the structural and value characteristics of administrative and professional systems. Medical systems urgently need behavioral science analysis comparable to that already done on target populations receiving new health services. Such research, of course, would normally not be restricted to Aedes aegypti programs.

#### IV. PLAN FOR THE ANALYSIS OF PROCEDURES FOR THE PREVENTION AND CONTROL OF AEDES AEGYPTI-BORNE DISEASES

The Group recognized during the course of this study that cost and benefit data were not available for many program activities. Such data are needed for proper evaluation of the feasibility and potential of alternative approaches to control.

A consideration of cost-benefit analyses of procedures for the prevention and control of diseases spread by Aedes aegypti must be related to the status of the vector control or eradication programs in the individual countries of the Americas. For example, preventive measures, and therefore cost requirements, will vary according to whether the countries a) have achieved eradication and/or have become reinfested; b) have programs in which the prospects of eradication in the immediate future are quite remote; or c) lack programs or have minimum programs in which little progress toward eradication has been made.

With reference to those countries that have achieved Aedes aegypti eradication, an estimate must be established of the costs of an effective surveillance system (vector inspection and control of foci), including emergency funds to combat extensive reinfestations. This implies that estimates will be made of the costs for an effective epidemiological surveillance if current services are not available within the countries.

For those countries still infested (b and c above), an objective evaluation of the programs should be made to determine if current procedures are adequate to prevent epidemics. If they are adequate, what are the projected costs and time required to achieve Aedes aegypti eradication under prevailing conditions? If current procedures are not adequate, realistic estimates should be made of the costs to reduce the vector population below the level at which an epidemic could occur and of the costs to achieve eradication within 4 to 6 years. In both cases the cost should be estimated for an adequate surveillance system to be maintained until the danger of reinfestations no longer exists.



Comparative data that will be required include annual costs of programs since their inception. In addition, estimates of the cost of combating epidemics of diseases and the economic impact that such epidemics would have in terms of medical care, quarantine embargoes, and tourism. Since the economic impact of an epidemic of yellow fever will differ significantly from that of a dengue epidemic, separate cost analyses should be made for the two infections.

Suggestions for elements that should be considered in making cost estimates, taking account of such factors as are mentioned above, are listed below as a guide and are not to be considered all-inclusive. While they are included as separate items, it is emphasized that the measures to prevent epidemics are not mutually exclusive. For example, the cost of preventing Aedes aegypti-borne yellow fever or dengue fever cannot be considered to be independent of the cost of maintaining an effective surveillance system, since both kinds of measures may be required.

It is appreciated that cost analysis studies must encompass a range of countries with different economies and monetary systems and this will be difficult. Some studies would best be done in selected situations that are representative of different ecological situations; other studies would best encompass evaluation of each country concerned with the problem of control of Aedes aegypti-borne diseases. Some recent estimates of the costs of programs are available (Appendices C - F), but the basis of these estimates and whether they are comparable cannot be stated.

The present Study Group did not include persons with expert knowledge of the technical approaches to a study of cost-benefit analysis. This is a highly specialized field, and the development of a detailed plan of cost-benefit analysis would require the collaboration of such persons with counterpart experts in the scientific fields concerned with the epidemiology of Aedes aegypti-borne diseases and control of the vector. However, the Group, based on its competencies in the last two fields, believes the following cost items deserve study and that comparative cost and benefit figures should be established.

The Group formed the opinion that many of the types of figures required should be part of the routine data collected by the Pan American Health Organization, and that this agency might consider developing its own staff to maintain an ongoing program of cost-benefit analysis in the countries of the Americas.

## 1. The control of epidemics

A cost analysis is required of the relative merits of establishing an international group of experts, supported by the Pan American Health Organization, who would be prepared to undertake control measures in any epidemic situation in the Americas versus leaving each country at risk to make its own arrangements. Studies are required in several different countries of the efficacy and cost of the following items:

- a) Ultra-low volume spraying: these should take into account the various insecticides, dosage rates, and frequency of application required in regions with different physical attributes.
- b) Aircraft: taking into account the availability of aircraft suitable for ULV application.
- c) Ground application of insecticides: taking into account misting and fogging techniques, larval control, and the availability of equipment.
- d) Insecticide stock-piles: taking into account both the quantities and types of compounds which might be held in stock.
- e) Vaccine: taking into account the quantity of 17D vaccine that should be held in stock and the duration of its potency on storage.

Taking into account all the measures required, estimates should be made of the costs of an emergency program in selected areas believed to be high-risk areas.

## 2. Preventive programs

There are several possible means of preventing Aedes aegypti-borne infections; their relative merits can be debated, but their relative costs have not been established. In a cost-benefit analysis, special attention might be drawn to the level of control that might be achieved by different techniques. In particular, the level of Aedes aegypti control may range from negligible control to complete eradication, and all levels less than eradication will involve permanent recurring control costs.

Alternative, but not mutually exclusive approaches, are as follows:

- a) Environmental control: taking account of such measures as campaigns for the manual elimination

of Aedes aegypti breeding sources and the elimination of household water tanks by the provision of an acceptable and potable piped water supply.

- b) Chemical control: taking account of the merits of alternative compounds, methods of application and of staff requirements.
- c) Supplementary or alternative methods: although genetical and biological control methods are still in the experimental stage, estimates of their relative costs and efficacy may be necessary at a future date.
- d) Vaccination: taking account of distribution and storage problems in different areas.

Account should be taken of the costs of monitoring the results of control using different methods.

### 3. Surveillance after Aedes aegypti eradication

A cost analysis is required of the measures necessary to prevent reintroduction of Aedes aegypti into areas that are free of the mosquito. The procedures requiring analysis are:

- a) The detection of reinfestations and elimination of the foci that are found.
- b) The prevention of reintroductions by the inspection and treatment of vehicles and goods that enter the free areas.
- c) The verification of a continued absence of Aedes aegypti by routine checks.

### 4. The advantages of preventing Aedes aegypti-borne diseases and the penalties of inaction

A comparative study should be made of the advantages to a country of preventing Aedes aegypti-borne diseases and of the penalties which might be suffered by not carrying out preventive measures. Such a study might be made by selecting specific countries with contrasting programs. Account should be taken both of epidemic and of endemic situations.

In addition to gathering data on mortality and morbidity, an analysis should include the effects of quarantine restrictions on the economy of the countries and take into account such sources of income as tourism and the import-export market.

5. The establishment and maintenance of a research program over the next ten years

Since there is a continued threat of Aedes aegypti-borne diseases in the Americas, there are many data which must be collected if we are to understand the dynamics of the infections and of their vector. In addition, there are some research projects which should be undertaken because of their direct relevance to the prevention and control of the infections. An analysis is therefore required of the cost of maintaining a research unit which would be responsible for such investigations.

The cost analysis could be based on the experience of the Pan American Health Organization and on that of existing research units in areas where Aedes aegypti occurs.

V. RECOMMENDATIONS

During the discussions of the Group, a number of suggestions and recommendations were made by the participants. Although the members were not asked for recommendations, they believed that certain items should be brought to the attention of the Organization.

1. The Pan American Health Organization should continue to stimulate and assist those countries that currently are not carrying out an eradication program to establish an adequate Aedes aegypti service.

Special attention should be given to the administration of such services.

The national services should be encouraged to develop and intensify community programs of source reduction including the extension of piped and potable water into individual dwellings.

2. The systems of surveillance in those countries which have already achieved eradication should be strengthened to prevent reintroduction of Aedes aegypti.

3. An appeal should be made to those countries that are still infested, and which are therefore likely to export Aedes aegypti, to have all routes of exit, such as maritime, fluvial and air ports, border towns, and other areas of contact, free of Aedes aegypti. Where there is extensive small boat traffic there should be insistence that all water containers are mosquito proofed.

Coordination of programs in neighboring countries, especially within the Caribbean Area, is considered absolutely necessary and may call for special regional agreements. The Pan American Health Organization should be prepared to offer immediate technical and financial assistance to manage emergency situations before spread to adjacent areas occurs. To meet such situations, the establishment of an Aedes aegypti Insurance Fund might be considered, along the lines of the pest control compact Document MS-36, The Council of State Governments, Chicago, Illinois, USA.

4. A permanent stock of at least 3 million doses of 17D vaccine should be kept at the disposal of the Pan American Health Organization for the control of possible urban outbreaks of yellow fever or emergency jungle yellow fever situations. A study should be done to evaluate whether potency will be retained on storage at -70°C.

5. A research program should be developed which will include a coordinated study of problems related to the control and eradication of Aedes aegypti-borne diseases. Advantage should be taken of the accumulated experience of the Pan American Health Organization with its Jamaica Insecticide Test Unit, INCAP, CEPANZO, and the Foot-and-Mouth Disease Center.

The following types of activities should be considered, among others:

- a) Evaluation of promising new insecticides and of alternative genetical and biological methods for controlling the vector by their early assessment in the field. This will require the Pan American Health Organization to develop close relationships with the research laboratories and assist in the arrangement for the field tests. The Caribbean Islands will be well suited for such studies.
- b) Intensified evaluation of the insecticides in use by means of frequent periodic testing of insecticide susceptibility by the standardized WHO method and assessment of the results achieved in the field. Continued support and expansion of the Jamaica Insecticide Test Unit could cover this point, taking account of the need for spot-checks on the effectiveness of insecticide treatment to be made twenty-four hours after the application.
- c) Monitoring of the changing distribution and abundance of Aedes aegypti.

- d) Continuing surveillance of jungle yellow fever in primate hosts and vectors, and of dengue in urban and rural communities.
- e) Analysis of conditions which might predispose communities in different areas to endemic and epidemic disease.
- f) Development of dengue virus vaccines and field evaluation of their efficacy.
- g) Improvement of the stability of yellow fever vaccine and development of simplified methods for its administration under varied field conditions.
- h) Evaluation of environmental sanitation activities (source reduction) on both house infestation indices and adult mosquito densities.
- i) Field studies to determine the efficacy of ULV dispersal of insecticides by aircraft as a means of reducing adult mosquito populations and of preventing or aborting an epidemic.
- j) Activities directed towards the epidemiological and ecological analysis of specific difficult situations.

6. Analysis of the sociocultural factors involved in vector control and in other activities related to this problem should be undertaken with the participation of behavioral scientists, who should be assigned, where appropriate, to Aedes aegypti field studies. Research is also needed on means of improving communications within the campaign services, and between control operators, the scientific workers, and the administrators at high levels of government.

7. The cost-benefit study, for which an outline is presented in Section IV of this report, is considered of great importance for rational decisions on the future strategy for the control of Aedes aegypti-borne diseases, and every effort should be made to carry it out.

### 13.2.1 Preparatory

The following activities are carried out in this stage, although not necessarily in this order: preparation of the plan of operations; setting up of offices and establishment of the administrative system; recruitment and training of personnel; purchase of supplies and equipment; geographical reconnaissance of the area to be covered, including preparation of maps, numbering of blocks, and, if necessary, the numbering of houses; and the preparation of work itineraries.

A start will also be made on activities designed to inform and motivate the population about the program and to enlist the cooperation of the community in eradicating the mosquito.

The duration of the preparatory stage will, of course, vary, depending on the extent of the infested area and the scope of the program. Generally speaking, this stage should be completed in three to five months, but in some instances a longer period will be necessary. In any event, this period should not exceed one year.

### 13.2.2 Attack

Once the preparatory stage is completed, eradication operations proper will be begun throughout the area it is planned to cover. These operations should be carried out along the lines set forth in the manual of technical and administrative standards for Aedes aegypti eradication campaigns prepared by PAHO.

Aedes aegypti eradication by means of residual-action insecticides comprises basically the following operations:

- a) Initial survey to ascertain the presence and the exact distribution of the mosquito in each locality;
- b) Treatment of the localities found to be positive;
- c) Verification (post-treatment inspection) of treated localities to evaluate the results of treatment; each verification will be followed by a new treatment of the areas found to be still infested, until eradication of the mosquito is achieved.

It is recommended that the methods laid down in the above-mentioned manual be applied in these operations.

Essential factors in the attack stage are correct coverage of each locality, strict compliance with work itineraries, punctual maintenance of

treatment and verification cycles, and efficient field operations. This can only be achieved as a result of the appropriate orientation, coordination, and supervision of the activities of all personnel.

To facilitate the attainment of this aim, the field personnel should be organized into teams composed of five workers, or six as a maximum, with a team leader. For every five team leaders there will be a supervisor who will be responsible for the general supervision of the work of the five teams. At a third level of supervision, every 25 teams will have an inspector who will be responsible for the orientation, coordination, and general supervision of the work of the teams.

The treatment-verification cycles adopted will depend on the duration of the residual action of the insecticide used by the program.

It is considered that, in normal conditions, a cycle of three months for DDT or dieldrin and two months for some organophosphorous insecticides will be adequate. Nevertheless, it should be borne in mind that only a careful evaluation of the results obtained in the early months of work, supported by laboratory observations on the duration of the residual action of the insecticide, can tell whether the cycle adopted by the campaign is adequate or whether it needs to be adjusted to special conditions existing in the area.

Furthermore, the results obtained with insecticide applications must be continuously and carefully evaluated in order to promptly discover any defect interfering with the eradication of the mosquito.

It is strongly recommended that if the infestation index in a locality is not drastically reduced through the application of insecticide, as is to be expected, a careful and complete investigation should be made, before normal operations are continued, to determine and eliminate the causes of the failure of the treatment. If this is not done, the campaign may suffer severe setbacks and financial losses which would have been avoided.

The duration of the attack stage coincides in practice with the duration of the eradication of the mosquito, since this stage is to be considered completed only when all the localities in the area covered have had at least one negative verification, and the Aedes aegypti problem in that area is reduced to the sporadic occurrence of small isolated foci of the mosquito.

Regarding time, the duration of the attack stage varies considerably, since it obviously depends on a whole cluster of factors. However, in normal circumstances, this stage should be completed in from one to three years, according to the size of the area covered, and its degree of infestation.



### 13.2.3 Consolidation

In this stage the foci of Aedes aegypti that have survived the attack operations will be eliminated.

In order to find these foci, the verification cycle employed in the attack stage will be continued in all the initially positive localities considered negative. These inspections will serve a dual purpose: to confirm the absence of the mosquito in those localities and to prevent reinfestations.

It is recommended that, in addition to the search for larvae, the presence of adults of Aedes aegypti should be investigated in the course of the verification of certain localities in which the conditions make for the existence of hidden breeding places, in order to discover any possible hidden foci of the mosquito.

The consolidation stage is to be considered completed when all localities in the initially positive area are negative by the last verification.

### 13.2.4 Maintenance

In this stage the inspection will be continued in the initially positive area until it can all be declared free of the mosquito, in accordance with the criteria for eradication established by PAHO.

During this stage a specific vigilance service will have to be organized.

## 14. Insecticides for the eradication of the mosquito

In some areas of the Americas, Aedes aegypti is still susceptible to DDT or to dieldrin, and the eradication of the vector in these areas should be based on the use of those insecticides. However, these products can no longer be used in most of the areas still infested in the Hemisphere owing to resistance of the mosquito.

For such areas some new insecticides are available, which have been used for several years now, with good results, against strains of Aedes aegypti resistant to the chlorinated insecticides. Among those new products, special mention must be made of the organophosphorous compounds Abate, fenthion and malathion.

Abate is a highly effective, persistent, and safe insecticide. Its application in drinking water in slow release formulations has been approved by the WHO Expert Committee on the Safe Use of Pesticides in Public Health (WHO Technical Report Series No. 356, 1966). Fenthion and malathion have been shown to be effective and safe products for "perifocal" use and for application to nonpotable water.

Fenthion, when employed in association with Abate by the "perifocal" method, is effective in work cycles of up to two months. Malathion with Abate used in the same way is equally effective, but in this case the treatment-verification cycle should not exceed one month, because the residual action of malathion in the containers does not last longer than that. The recommendation at present is that the eradication of the vector in areas where DDT and dieldrin resistance has been confirmed be based on the use of the above-mentioned organophosphorous insecticides, preferably the association of Abate with fenthion.

It is, however, obvious that only insecticides to which the local Aedes aegypti is susceptible should be used by the campaign. Thus, before initiating operations in any area, it will be advisable to test the susceptibility of the Aedes aegypti strains in the area in order to select the appropriate insecticides. Furthermore, once eradication work is begun, the campaign should continue to test the susceptibility of those strains regularly so that the insecticides being used can be promptly replaced, if it should become necessary.

In this regard it should be mentioned that WHO has undertaken a long-term program whose main purpose is to obtain new insecticides to solve the problems of resistance. More than 40 manufacturing companies provide this program, which was begun in 1960, with recently developed compounds; so far, approximately 1,500 compounds have been examined and new chemicals are being received at the rate of 200 per annum. All these compounds are systematically evaluated by a group of ten laboratories and four WHO field test units, where the new products are subjected to the necessary tests to determine their insecticide properties, toxicological characteristics, and suitability for practical use. Among the compounds currently under study, are some (in addition to the phosphorous compounds already mentioned) which appear to be suitable for Aedes aegypti eradication.

Therefore, it is believed that the resistance of the vector to insecticides will not prevent the success of the eradication campaigns provided they are appropriately carried out and the eradication of the mosquito is completed in a reasonable period of time.

#### 15. Methods for combating the vector

Aedes aegypti eradication is based essentially on the use of insecticides, supplemented by the destruction, removal, or protection of containers of the kind preferred by the mosquito.

The elimination of the largest number possible of such potential breeding places should begin in the preparatory stage, and continue throughout the campaign to the vigilance stage. Through its health education program and other promotional activities, the campaign should

make sure that, in addition to its own personnel, personnel of the public health services and other official agencies, as well as the community in general, participate in this effort.

There is no need to emphasize the importance of eliminating potential breeding places. Suffice it to consider the time and money the campaign will save by the removal and adequate disposal of all the useless containers capable of breeding Aedes aegypti that are usually found in large numbers in courtyards and gardens, in vacant lots, and in certain commercial and industrial establishments.

However, experience to date has shown that the campaign must consider health education and environmental sanitation only as complementary measures. These measures make the field operations easier, and help to shorten the duration of the campaign, but the eradication of the mosquito must still be based chiefly on the adequate use of insecticides.

The method first used in Aedes aegypti eradication consisted basically in the application of a mixture of oil as larvicide in all containers found breeding the mosquito. Aedes aegypti was eradicated from Bolivia and from most of the territory of Brazil by that process, known at present as the traditional (or classical) method. Although very effective when correctly applied, the process is costly because the use of a larvicide without residual action requires a weekly cycle of work to detect the foci of the mosquito and eliminate them before the adults emerge. This method may still be indicated in special circumstances, but it is not recommended as routine for the eradication of the vector.

Since residual-action insecticides began to be employed against Aedes aegypti, the campaigns for the eradication of the mosquito have used the following methods:

- a) Intradomiciliary method - It consists essentially in the spraying of the inside walls of the houses, supplemented by the treatment of the most important containers found in the premises. The spraying is basically the same as the one used in the malaria eradication campaigns. The treatment of the containers is done following the same technique used in the perifocal method (which will be described below). The insecticide concentration in the pump, and the length of the treatment-verification cycle will vary with the efficiency of the insecticide used, and the duration of its residual action.
- b) Perifocal method - This method consists basically in the treatment of all containers of the type preferred by

Aedes aegypti, whether they have water or not. Such treatment comprises the spraying of the walls of the container both externally and internally so that they are completely covered with a thin film of insecticide. In addition, the spraying should extend to cover with the same film of insecticide the surface of the water, if there is any in the container, as well as any wall close by the container up to two feet on each side and above it. In this method also, the concentration of the insecticide in the sprayer, and the working cycle to be adopted, will depend upon the product used by the campaign.

- c) Focal method - This process is based on the use of the insecticide, solely as larvicide. The product is put in all containers capable of breeding Aedes aegypti, whether or not they have water. The amount of insecticide to be poured into each container and the working cycle will depend on the size of the container and the efficacy and the duration of the residual action of the product. This method was employed in some areas in the early days with DDT. But, since it takes only limited advantage of the residual action of the insecticide, it was soon abandoned. Its use at present is not recommended for the same reason, except in special circumstances, such as in the event the campaign is forced to use a product with only larvicidal action.

Of the three methods, the intradomiciliary obviously gives the insecticide more chance to act against the mosquito, whether it is in the larval stage in the containers or as an imago either in the containers or on the walls. When correctly applied in the areas where Aedes aegypti normally rests inside the houses, the method is highly effective. However, it is too expensive and usually very difficult to apply in commercial and residential areas. Consequently, although its use may be indicated in special circumstances it is not recommended as a routine method for eradicating the vector. The method recommended for that purpose is the perifocal. In spite of using less insecticide in more limited areas, this method gets almost as much yield from the product as the intradomiciliary method. This is because the perifocal method applies the insecticide at precisely the points where the mosquito, by biological demand, is forced to enter in contact with the product, that is to say, in the breeding places and their surroundings. For this reason, the perifocal method, specially when the eradication campaign is combined with a program of environmental sanitation, is easier to apply and much more economical than the intradomiciliary, yet there is no great difference between the efficacy of the two methods.

#### 16. Criteria of eradication

On the basis of the experience gained by the countries of the Americas in the struggle against Aedes aegypti, the Pan American Sanitary Bureau has

established the requirements to be met before the Governing Bodies of the Organization can accept the declaration of eradication of the vector in a country.

These requirements which may be found in the Guide for the Reports of the Aedes aegypti Eradication Campaign in the Americas (PAHO Miscellaneous Publication No. 49, 1960) are briefly as follows:

- a) All areas of the country with ecological conditions favorable to Aedes aegypti must be inspected, and all localities that are found infested with Aedes aegypti in this inspection should be worked until the eradication of the vector is completed.
- b) Generally, eradication of the mosquito will be considered achieved in a locality when, in a period of one year after the last application of insecticide, three consecutive verifications have negative results. In special cases two additional negative verifications within the period of a year will be necessary, the first upon eighteen months and the second upon twenty-four months after the last treatment.
- c) In small rural localities, generally the mosquito will be considered eradicated upon one negative verification six months after the last treatment. In special circumstances a second negative verification will be required within at least eighteen months after the first negative verification.
- d) Through periodic reports, the Government should supply to the Bureau the data necessary to the evaluation of the field work. These reports also constitute the basis for the Bureau's report on the continental program. Data on this program are published monthly in the Bulletin and are included in the Annual Report of the Director and in the documents concerning the program presented to the Governing Bodies of the Organization.
- e) The final verification to prove eradication of the vector should be made with the collaboration of technical personnel of the Bureau.

In addition to the criteria mentioned above, in order for a country to be considered free of Aedes aegypti by the Governing Bodies of the Organization it must also satisfy certain requirements regarding colonies of

the mosquito. These requirements, established by the XVII Pan American Sanitary Conference (Washington, D. C., 1966) in its Resolution XX are in brief the following:

- a) To eliminate all colonies of Aedes aegypti that exist in areas in its territory in which the ecological conditions are favorable to the vector;
- b) Not to permit the existence of any colony of the mosquito except in recognized scientific centers situated in areas that are ecologically unfavorable to the vector;
- c) To ensure that colonies of the vector existing in those unfavorable areas are permanently maintained in such a way as not to allow the country to be reinfested by Aedes aegypti from those colonies.

#### 17. Vigilance service

Vigilance to prevent reinfestation should be initiated as soon as Aedes aegypti eradication is completed, and should be continued without interruption for as long as there are infested areas in the Americas.

It is unnecessary to emphasize the risk of reinfestation being run by countries which are not maintaining adequate vigilance services in their territories, especially those which, because of their geographical situation and ease of communications, are more exposed to the sources of reinfestation in the Hemisphere. Nor is there any need to insist on the advisability of all areas free of the mosquito in the Americas maintaining an efficient vigilance service.

This service should be aimed at preventing the importation of the mosquito and at discovering and promptly eliminating any reinfestation which it has not been possible to prevent.

For the achievement of these objectives the following measures are recommended:

##### 17.1 Preventive measures

These measures should include:

- a) Control of air traffic, to ensure compliance by the airlines with the provisions of the international sanitary regulations dealing with disinsection of aircrafts;

- b) Control of sea and river transport. To ensure that small craft coming from abroad keep their water containers mosquito-proof. To inspect large vessels coming from infested areas, particular attention being paid to those parts of the vessels where Aedes aegypti may breed;
- c) Control of land transport. It is essential to control railroads and other forms of land transport coming from infested countries. Where necessary, they must be disinfected and all containers capable of transporting eggs of the mosquito must be treated. Special attention should be paid to used tires regardless of their mode of entry, and those arriving from infested areas shall be appropriately treated.

#### 17.2 Measures for discovering reinfestations

These shall vary from country to country depending on whether the country free of Aedes aegypti is adjacent to countries also negative or adjoin countries still infested.

In the first instance, the following is recommended:

- a) Vigilance at all international ports and airports, and all frontier posts served by international communication systems;
- b) Make this vigilance at a six-monthly cycle, inspecting at least ten per cent of the houses existing in the above-mentioned localities.

In the second instance the following is recommended:

- a) To survey periodically the localities in which the ecological conditions are favorable to the vector, inspecting at least ten per cent of the existing houses;
- b) To inspect at a six-monthly cycle ten per cent of the existing houses in the localities most exposed to reinfestation that are not an international port or airport, or a frontier post on the border with an infested country;
- c) To inspect at a three-monthly cycle at least 33 per cent of the houses in the international ports and airports as well as in the frontier posts situated on the border with an infested country.

STATUS OF Aedes Aegypti ERADICATION BY COUNTRY AND  
OTHER POLITICAL UNITS IN THE AMERICAS  
DECEMBER, 1969

COUNTRY OR OTHER POLITICAL UNIT	A R E A (I N K M S <sup>2</sup> )			PRESENT STATUS	ACTIVITY IN PROGRESS
	T O T A L	AREA ASSUMED INITIALLY INFESTED	PERCENTAGE OF TOTAL		
Argentina	4,024,458	1,000,000	24.8	Eradication completed	Surveillance
Barbados	430	171	39.8	Infested	Program in operation
Bolivia	1,098,581	100,000	9.1	Eradication completed	Surveillance
Brazil	8,511,965	5,358,822	63.0	Reinfested	Program in operation
Colombia	1,138,338	280,000	24.6	Infested	Program in operation
Costa Rica	50,700	20,000	39.4	Eradication completed	Surveillance
Cuba	114,524	100,000	87.3	Infested	Program in operation
Chile	756,945	100,000	13.2	Eradication completed	Surveillance
Ecuador	283,561	69,454	24.5	Eradication completed	Surveillance
El Salvador	21,393	18,675	87.3	Reinfested	Limited program
United States of America	9,359,781	1,536,819	16.4	Infested	Program suspended
Guatemala	108,889	36,423	33.4	Eradication completed	Surveillance
Guyana	214,969	4,662	2.2	Infested	Program in operation
Haiti	27,750	27,750	100.0	Infested	Program suspended
Honduras	112,088	69,929	62.4	Reinfested	Limited program
Jamaica	11,424	11,424	100.0	Infested	Program in organizational phase
Mexico	1,972,546	1,000,000	50.7	Reinfested	Program in operation
Nicaragua	130,000	65,263	50.2	Eradication completed	Surveillance
Panama	75,650	56,246	74.3	Reinfested	Program in operation
Paraguay	406,752	200,000	49.2	Eradication complete	Surveillance
Peru	1,285,215	638,000	49.6	Eradication complete	Surveillance
Dominican Republic	48,734	42,020	86.2	Infested	Program suspended
Trinidad & Tobago	5,128	3,108	60.6	Infested	Program in operation
Uruguay	186,926	186,926	100.0	Eradication completed	Surveillance
Venezuela	912,050	710,000	77.8	Infested	Limited program

Cont.



STATUS OF AEDES AEGYPTI ERADICATION BY COUNTRY AND  
OTHER POLITICAL UNITS IN THE AMERICAS  
DECEMBER, 1969 (Continued)

COUNTRY OR OTHER POLITICAL UNIT	A R E A (I N K M S <sup>2</sup> )			PRESENT STATUS	ACTIVITY IN PROGRESS
	T O T A L	AREA ASSUMED INITIALLY INFESTED	PERCENTAGE OF TOTAL		
Antigua (Barbuda y Redonda)	442	442	100.0	Infested	Program in prelimi- naries of operation
Aruba	190	174	91.6	Infested	Program in prelimi- naries of operation
Bahamas	11,405	11,405	100.0	Infested	Limited program
Bermuda	53	53	100.0	Eradication completed	No information
Bonaire	281	246	87.5	Infested	Program in prelimi- naries of operation
British Honduras	22,965	22,965	100.0	Eradication completed	Surveillance
Canal Zone	1,432	1,432	100.0	Eradication completed	Surveillance
Cayman Islands	259	259	100.0	Infested	Program in operation at Cayman Brac
Curaçao	472	448	94.9	Infested	Program in prelimi- naries of operation
Dominica	789	789	100.0	Infested	No activities
French Guiana	91,000	91,000	100.0	Infested	Program in operation
Grenada- Grenadines (Carriacou, Little Martinique, & Union)	344	344	100.0	Infested	Program in prelimi- naries of operation
Guadeloupe (part of St. Maarten)	1,779	1,619	91.0	Infested	Program in operation
Martinique	1,102	1,000	90.7	Infested	Program in operation
Montserrat	98	83	84.7	Infested	Program in prelimi- naries of operation
Puerto Rico	8,897	8,897	100.0	Infested	Program suspended
Saba, St. Eustatius (part of St. Maarten)	67	67	100.0	Infested	Program in prelimi- naries of operation
St. Kitts-Nevis & Anguilla	357	357	100.0	Infested	No activities
St. Lucia	616	259	42.0	Infested	Program in operation
St. Vincent	388	332	85.6	Infested	Program in organizational phase
Surinam	142,822	48,000	33.6	Infested	Program in operation
Turks & Caicos Islands	430	430	100.0	Infested	No activities
Virgin Islands (UK)	153	153	100.0	Infested	No activities
Virgin Islands (US)	344	344	100.0	Infested	Program suspended

## APPENDIX D

DATA BASED ON THE TOTAL COST OF THE AEDES AEGYPTI ERADICATION  
IN SOME COUNTRIES OF THE AMERICAS<sup>1</sup>

Country	Year	Currency	Cost
Argentina	1955 - 1963	Argentinian Peso	55,886,576
Colombia	1950 - 1966	Colombian Peso	5,437,538
Chile	1960 - 1961	Escudo	25,000
Mexico	1958 - 1963	Mexican Peso	44,207,000
Peru	1940 - 1954	Sol	5,250,000
Uruguay	1948 - 1958	Uruguayan Peso	430,000

<sup>1</sup>Source: Data presented by each country at the Conference on Aedes aegypti Eradication in the Americas, 1967.

## APPENDIX E

DATA BASED ON THE AMOUNT EXPENDED BY THE AEDES AEGYPTI ERADICATION  
CAMPAIGN IN 1969 AND FIGURES FOR THE 1970 BUDGET OF SOME  
COUNTRIES AND TERRITORIES IN THE AMERICAS<sup>1</sup>

Country	Expended in 1969	Budget for 1970
Brazil	345,000	644,000
Colombia	53,521	72,394
El Salvador	61,291	62,160
Grenada	1,000	30,000
Guyana	100,000	120,000
Honduras	54,291	83,080
Martinica	3,000	261,000
Mexico	179,813	72,000
Panama	65,133	100,602
Santa Lucia	36,000	47,000
Surinam	202,503	236,096
Trinidad	119,000	123,000
Venezuela	<u>765,618</u>	<u>742,824</u>
Total	<u>1,986,170</u>	<u>2,594,156</u>

<sup>1</sup>Source: Data received by cable from each country or territory.

## APPENDIX F

ESTIMATED COST OF THE Aedes Aegypti ERADICATION CAMPAIGN IN THE  
COUNTRIES AND TERRITORIES STILL INFESTED OR REINFESTED IN THE AMERICAS  
(FEBRUARY 1970)<sup>1</sup>

Country or Territory	Estimated number of houses	Probable duration of the campaign	Cost in US\$ estimated by <u>Aedes aegypti</u> Working Group in 1967	Updated estimate in 1970, in US\$
Antigua	14,000	3 years	176,000	176,000
Netherlands Antilles	52,000	3 "	542,000	542,000
Bahamas	29,000	3 "	358,000	358,000
Barbados	52,000	3 "	499,000	499,000
Brazil	180,000	2 "	-	2,500,000
Colombia	41,000	2 "	39,000	200,000
Cuba	2,330,000	4 "	27,400,000	27,400,000
Dominica	14,000	3 "	176,000	176,000
El Salvador	220,000	4 "	2,100,000	2,100,000
United States of America (2)	14,496,100	5 "	-	250,000,000
Grenada	22,000	3 "	290,000	290,000
Guadalupe	66,000	3 "	764,000	764,000
French Guiana	8,000	3 "	117,000	117,000
Guyana	135,000	4 "	1,220,000	1,220,000
Haiti	689,000	4 "	1,682,000	6,000,000
Honduras	60,000	2 "	-	600,000
Cayman Islands	500	2 "	-	10,000
British Virgin Islands	3,000	3 "	46,000	46,000
Jamaica	512,000	4 "	3,849,000	4,800,000
Martinique	67,000	3 "	764,000	764,000
Mexico	(3)	2 "	-	500,000
Montserrat	3,000	3 "	46,000	46,000
Panama	16,000	2 "	-	600,000
Dominican Republic	740,000	4 "	5,886,000	8,000,000
St. Kitts, Nieves and Anguilla	13,000	3 "	176,000	176,000
St. Vincent	19,000	3 "	261,000	261,000
St. Lucia	21,000	3 "	285,000	285,000
Surinam	70,000	3 "	859,000	859,000
Trinidad	50,000	2 "	161,000	400,000
Turks and Caicos	3,000	3 "	46,000	46,000
Venezuela	1,768,000	6 "	31,496,000	17,000,000 (4)
TOTAL:			79,218,000	326,735,000

Observations:

1. Total cost, including cost of equipment, vehicles, materials, insecticides, etcetera. Not including PASB/WHO budgetary allocations, amounting to US\$491,637 in 1970 for this Hemisphere.
2. Including Puerto Rico and US Virgin Islands.
3. Not possible to estimate.
4. Information received from one of the Study Group Members.