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AEDES ALBOPICTUS IN THE AMERICAS

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SUMMARY

The recent finding of Aedes albopictus in seven states of the United States of America and three states of Brazil has raised considerable concern in view of the serious public health implications resulting from the introduction of an exotic and efficient vector of dengue and possibly of yellow fever in the Americas.

Aedes albopictus is primarily a forest species breeding in tree holes, bamboo stumps and leaf axils, but is also well adapted to such domestic containers as tires, tanks, drums and flower vases. Apparently the introduction into the United States of America was in tires transported in large cargo containers from Japan. This species feeds readily on man, other mammals and even birds. It is more cold hardy than Aedes aegypti, which may permit it to spread further north and south.

Aedes albopictus is an efficient vector of dengue in Asia and the Pacific and has been shown to transmit all four serotypes transovarially and transstadially. This, plus the high susceptibility, makes it likely that it could play an important role in the maintenance cycle of dengue viruses.

If Aedes albopictus is shown to be an effective experimental vector of yellow fever, it may provide the missing bridge for the transmission of yellow fever virus between the forest and urban environments.

This species has been found infected with Chikungunya virus and is experimentally susceptible to numerous other arboviruses.

The following are the major strategic approaches to control of Aedes albopictus in the Americas:

Collection and Dissemination of Information

- Information will be obtained and disseminated on the taxonomic features, keys of identification, biology, vector competence, insecticide susceptibility and distribution of Aedes albopictus.

Surveys and Surveillance

- PAHO will develop protocols for surveys and surveillance of Aedes albopictus, to be distributed and promoted in all the countries of the Region.
- A reporting system for Aedes aegypti and Aedes albopictus should be established.
- Priorities for surveys should be given to those countries with the most importation of used tires from the United States of America, Brazil and Asia.

- Rapid "spot" surveys should be done by international teams of PAHO and other entomologists in collaboration with national vector surveillance personnel.
- Continuous surveillance should be established in each country for early detection of introduction of Aedes albopictus.
- The importance of such artificial breeding habitats as tires, drums, tanks and flower vases, and such natural habitats as tree holes and leaf axils must be established.
- Susceptibility tests must be done in newly detected areas of infestation.

Surveillance for Aedes-Transmitted Disease

- Effective surveillance programs for dengue, dengue hemorrhagic fever and yellow fever should be implemented in selected countries.
- Laboratories must be upgraded and strengthened and personnel trained to ensure that each country has a minimum serologic diagnostic capability for dengue and yellow fever viruses.

Control Activities

Actions will be taken to prevent the further spread of Aedes albopictus and, where feasible, eliminate known infestations.

- Maximum use must be made of such proven Aedes aegypti control methodologies as source reduction, health education, supportive legislation, adulticiding and larviciding, and new strategies, as indicated by field trials and biological studies, must be formulated.
- The effectiveness of control methods must be monitored and evaluated to avoid wasteful or ineffective programs.

Yellow Fever Vaccination

- Immunization coverage with 17D vaccine against yellow fever should be increased to guard against the aggravated possibility of urbanization of yellow fever in the Americas by Aedes albopictus.

Training

- Training on all aspects of Aedes albopictus should be carried out at both the international and national level. This will include the taxonomic aspects, biology, ecology, survey and surveillance methods, vector competence, control strategies and insecticide susceptibility.

Research

Studies should be carried out on the following:

- Evaluation of the ability of Aedes albopictus to spread to new areas, including studies of flight range, diapause, competition with other species and passive spread by tires and other containers.
- Establishment of vectorial capacity of this species, including work on experimental transmission (both horizontal and vertical), extrinsic incubation, host preference, feeding behavior and life tables.
- Determination of the role of Aedes albopictus in dengue outbreaks in the Americas, especially in Brazil where it was present in areas with transmission.
- Formulation of new control strategies based on investigations of insecticide susceptibility, genetic plasticity, surveys of breeding habitats, and field trials of the treatment methods.

1. INTRODUCTION

The recent finding of Aedes albopictus in seven states of the United States of America and three states of Brazil has raised considerable concern in view of the serious public health implications resulting from the introduction of an exotic and efficient arbovirus vector in the Americas. The main concern relates to the potential threat of aggravation of the problem of dengue and yellow fever in endemic areas of the Americas and of California encephalitis in North America, as well as the possible extension of these arboviral diseases to new areas.

2. DISTRIBUTION AND ECOLOGY

Aedes albopictus has a wide distribution in Asia and the Pacific, ranging from temperate regions to the tropics. Although isolated introductions were discovered in the continental United States as early as 1946, it was not until August 1985 that it was found to be established in the state of Texas, and since then in the states of Louisiana, Tennessee, Mississippi, Alabama, Georgia and Florida. In Brazil, since June 1986 this species has been found in the states of Espirito Santo, Minas Gerais and Rio de Janeiro. This wide distribution suggests that the initial introduction occurred some years ago.

There is evidence that the introduction of Aedes albopictus to the United States was in tires transported in large cargo containers from Japan.

Aedes albopictus is primarily a forest species that has become adapted to the urban environment. It breeds in tree holes, bamboo stumps and leaf axils in the forest and in flower vases, tanks, drums, tires and other artificial containers in cities and towns. Whereas Aedes aegypti is largely (but not entirely) restricted to breeding in artificial containers in and around human dwellings in urban environments, Aedes albopictus utilizes similar sites but is also adapted to rural environments and a wider range of breeding habitats. Individual females lay their eggs--a few at a time--in several containers, which may contribute to rapid local spread of the species. It is also readily transported over larger distances by man, as eggs, larvae, or adults. It prefers to feed on man, but will readily feed on other mammals and sometimes on birds. Autogeny (production of viable eggs without a blood meal) has been reported in the Houston strain. Moreover, unlike Aedes aegypti it is a cold-adapted species throughout its range in northern Asia, females undergoing ovarian diapause and surviving in hibernation. The Houston strain has been shown to undergo similar diapause.

Further introduction of Aedes albopictus to other countries in the Americas seems to be imminent and may have already occurred. The support for this assertion is as follows. Firstly, the conditions that contribute to the spread of Aedes albopictus are probably the same as for Aedes aegypti. Among these are the rapid expansion of international and domestic air and overland traffic, and the lack of adequate entomological surveillance. Secondly, the environmental conditions in extensive areas of the Americas are suitable for its breeding habits. Aedes albopictus can utilize the same type of artificial containers that serve as breeding sites for Aedes aegypti in domestic and peridomestic habitats, such as flower vases, bowls, bottles, and tanks.

3. PUBLIC HEALTH IMPORTANCE

The two most important diseases of the Americas that could potentially be transmitted by Aedes albopictus are dengue and yellow fever. Up until now, the mosquito Aedes aegypti has been the only vector implicated in the urban transmission of these two diseases. Undoubtedly, the sharp increase of dengue activity observed in the past 20-25 years is greatly due to the increase and dissemination of Aedes aegypti populations. After initial success in the campaigns for eradication of this mosquito in the '50s and '60s, by 1986 all but five countries had become reinfested. Unfortunately, despite the existence of political mandates adopted by the American countries to eradicate Aedes aegypti, a constellation of financial, political, administrative, socioeconomic and technical problems has decreased the effectiveness of vector control programs in the Region. The rapid growth and urbanization of human populations in tropical areas and increased travel and commerce between countries have also contributed to the proliferation of this mosquito.

3.1 Dengue

Dengue fever is an urban mosquito-borne disease of man which has afflicted many millions of persons over the last two centuries. Dengue viruses are group B arboviruses that belong to the Flaviviridae family. The four serotypes of dengue virus--DEN-1, DEN-2, DEN-3 and DEN-4--are antigenically very close to each other, but they are different enough to induce only partial cross-protection after infection by one of them.

Classic dengue fever has an abrupt onset with presence of high fever, severe headache, retroorbital pain, muscle and joint pains and rash. Skin hemorrhages such as a positive tourniquet test and or petechiae are not uncommon. The fever lasts for about five days and rarely more than seven. Infants and young children may have an undifferentiated febrile disease with maculopapular rash.

Dengue hemorrhagic fever (DHF) is an acute febrile illness characterized clinically by hemorrhagic manifestations which may be accompanied by a shock syndrome (DSS). Moderate to marked thrombocytopenia with concurrent hemoconcentration is a distinctive laboratory finding.

Dengue hemorrhagic fever is an increasing public health problem in most of the countries of tropical areas of the Western Pacific and South-east Asian Regions. This disease is among the ten leading causes of hospitalization and death in children in at least eight tropical Asian countries. The seriousness of the problem is further illustrated by the fact that since 1956 over 650,000 patients have been hospitalized and almost 17,000 deaths have been reported.

In the Americas, epidemics of dengue-like illness have been recorded in the Caribbean since 1927. The first dengue virus to be isolated in the Americas was serotype 2, from a sporadic case in Trinidad in 1952.

Clearly, dengue activity in the Americas has increased considerably in the past two decades. The major events relative to dengue and dengue hemorrhagic fever in the Americas during 1927-1986 are summarized in the following table:

Year	YF/Dengue Type	Country/Region	Events/Persons Afflicted
1927	DEN	Caribbean	
1952	DEN-2	Trinidad	First isolation
1963	DEN-3	Am. Region	Pandemic DEN-2,3 endemic in Haiti, Dominican Republic and Puerto Rico
Up to 1977	DEN-2-3	Caribbean Northern part of South America	Several epidemics 1.5 million cases in Colombia alone
1977-80	DEN-1	American Region	702,000 cases
1981	DHF/DSS	Cuba	Of 344,203 cases, 24,000 with DHF; of 10,000 shock cases, 158 deaths, predominantly in children 15 y.o.
1981-84	DEN-4	Caribbena Central America Northern part of South America	
1982	DEN-1-4	Brazil	12,000 cases in Boa Vista
1984	DEN-1,2,4	Mexico	
1984-86	DEN-1	Aruba, Nicaragua, Brazil	17,483 cases in Nicaragua 25,000 cases in Aruba; 200,000 estimated cases in Brazil (areas of 10 million population)*

* Provisional data based on serosurvey

The most notable episodes of dengue in the Americas in recent years have been the pandemic of dengue-1 in the Caribbean, northern South America, Central America, Mexico and Texas during 1977-1980, with approximately 702,000 cases; the epidemic in Cuba in 1981 with 340,000 cases of dengue-2, which included 24,000 with DHF and 158 deaths; and the current epidemic of dengue-1 in Brazil, with an estimated 200,000 cases thus far.

Other sporadic episodes of DHF involving small numbers of cases have been observed during 1968-1985 in dengue outbreaks in Curaçao, Puerto Rico, Honduras, Suriname, Mexico, and Aruba.

The Cuban outbreak of DHF added a new dimension to the problem of dengue in the Americas. The fact that DHF spread to several other Asian countries in the years following its recognition in the Philippines in 1953 raises the concern that a similar event may take place in the Americas.

Aedes albopictus has been associated with many epidemics of dengue in Asia and the Pacific over the years. A review of both experimental and natural transmission data clearly documents that Aedes albopictus is a very efficient vector of epidemic dengue and its hemorrhagic complications, and has a higher susceptibility to oral infection with these viruses than Aedes aegypti, the principal epidemic vector in Asia. Moreover, Aedes albopictus has been shown to transmit all four dengue serotypes transovarially and transstadially. This, plus the high susceptibility, makes it highly likely that it could play an important role in the maintenance cycle of dengue viruses, providing a mechanism for the viruses to exist in an area during interepidemic periods.

Thus, we are faced with a highly anthropophilic, ecologically adaptable species which is a more efficient horizontal and vertical transmitter of dengue viruses than the indigenous Aedes aegypti, which can occupy both urban and rural environments and which has the capability to invade the entire American Region, including countries with hard winters.

3.2 Yellow Fever

Yellow fever continues as a major threat in endemic zones of South America and in adjacent areas where the virus is able to reappear after long intervals of quiescence. It is essentially a disease of workers engaged in forest activities. The occurrence of outbreaks in the vicinity of Aedes aegypti-infested towns, documented in recent years, raises a great concern of the possibility of urbanization of jungle yellow fever.

Most cases of yellow fever in the Americas are reported by five countries: Bolivia, Brazil, Colombia, Ecuador and Peru. These countries report 100 to 200 cases of yellow fever annually. However, the true incidence is probably tenfold higher.

Yellow fever in the Americas is currently maintained enzootically only in certain forested areas of South America. The virus circulates in at least 30% of the continent's territory. Virus reservoirs remain in tropical forests like those of the Amazon region, and in the Orinoco and Magdalena valleys. In these forests yellow fever virus is transmitted between non-human primates mainly by Haemagogus mosquitoes. Colonists and temporary workers from non-endemic zones, together with natives from enzootic areas engaged in agricultural and forest activities, are the main target of the disease. Typically, most patients are males 15 to 45 years old. Males outnumber females by a large proportion and almost 90% of cases are above the age of 15 years. The last urban cases in South America were reported in 1942. Epidemiological evidence suggested that urban transmission took place in Trinidad during the 1954 outbreak.

Of special concern has been the occurrence of yellow fever in close proximity to urban settings infested with Aedes aegypti and the consequent risk of jungle yellow fever urbanization. Several outbreaks of urban yellow fever documented in the past have been traced to persons infected in sylvatic environments who came to urban settings. Among these were the urban outbreaks which occurred in Brazil (Rio de Janeiro, Teofilo Ottoni, Cambara), Colombia (Bucaramanga, Socorro), Bolivia (Santa Cruz) and Venezuela (Guasipati and Tumeremo), all in the 20's and 30's. The largest of these outbreaks was the one recorded in Rio de Janeiro in 1928-1929, only two decades after the disease had been wiped out from the city as a result of an intensive Aedes aegypti control program. No proven cases of urban yellow fever have been documented in South America since 1942, and, undoubtedly, the elimination of the disease from urban centers is due to effective vaccination programs and to Aedes aegypti control/eradication activities. The re-establishment and burgeoning of Aedes aegypti populations in extensive areas of South America, including rural areas, brings again the threat of urbanization of sylvatic yellow fever.

In recent years, infected human cases of yellow fever have been introduced into suburban areas of Colombia and Brazil. It is believed that one reason for the limited introduction of the virus has been the absence of a vector that can effectively utilize both the urban-suburban environment and the heavily vegetated, underdeveloped, and sparsely populated rural or jungle areas. Experience in Asia and the Pacific clearly indicate that Aedes albopictus can bridge these environments and develop large populations in both environments. If Aedes albopictus is found to be an effective experimental vector of yellow fever, this would be a serious problem. It is questionable if there is any hope of controlling a population of Aedes albopictus once it is established in a jungle environment.

3.3 Other Viruses

Besides the field and laboratory studies that have established Aedes albopictus as an efficient vector of dengue viruses, at least one additional arbovirus, Chikungunya, has been isolated from field-collected

Aedes albopictus in Asia. This species has also been evaluated in laboratory studies for its susceptibility to a number of arbovirus known to infect man. The list includes Japanese and St. Louis encephalitis, West Nile, and Kunjin viruses, all flaviviruses; Ross River, an alphavirus (as is Chikungunya); and Batai, La Crosse, and San Angelo viruses, all Bunyaviruses (the latter two belong to the California serogroup and are endemic in the United States). Of these viruses, vertical (transovarial) transmission has been demonstrated for dengue, Japanese encephalitis, Kunjin, San Angelo, and La Crosse. The wide spectrum of arboviruses to which Aedes albopictus has been shown to be susceptible suggests that Aedes albopictus has the potential to serve as a vector for several endemic arboviruses in the Americas.

A large number of mosquito-borne viruses, other than dengue and yellow fever, are known to occur in Latin America. Viruses such as Mayaro are known to be of public health importance. It is feasible to select some of these viruses and determine if Aedes albopictus could serve as a vector if its distribution extends to interface with the distribution of these viruses.

The demonstration in the laboratory that several arboviruses can be transmitted vertically further extends its potential importance as an arbovirus reservoir. Vertical transmission would provide a mechanism whereby arboviruses could be maintained in temperate areas during periods unfavorable for continued mosquito activity. This ability would be enhanced because of the general cold-hardiness of the species and its ability to diapause in the egg stage. Thus, Aedes albopictus could potentially serve as an efficient maintenance vector for viruses and provide a mechanism for virus persistence from one season to the next without reintroduction.

The presence of an established population of Aedes albopictus in the Americas has serious implications. If Aedes albopictus is introduced and established in Latin America, it will represent the second Stegomyia mosquito to be introduced that is a proven effective dengue vector. It is not known if the presence of a second vector species will significantly increase dengue transmission or the proportion of cases that develop serious hemorrhagic complications. It is believed it would be better to minimize the spread of Aedes albopictus than to study the effect of its having become established in Latin America.

4. POSSIBLE APPROACHES TO THE AEDES ALBOPICTUS PROBLEM

The presence of Aedes albopictus in the Americas represents a regional problem the solution of which will require concerted international cooperation. PAHO's responsibilities towards this new problem are intrinsic to those related to Aedes aegypti, as these two mosquitoes have many similarities in terms of disease transmission. Consequently, many of the recommendations already approved by PAHO's Governing Bodies dealing with Aedes aegypti may be applicable to Aedes albopictus.

A meeting of personnel with experience in arboviruses and vector biology and control from PAHO and from the United States Centers for Disease Control (CDC) was convened in Washington, D.C., 22-23 August 1986 to review the current situation and to recommend possible actions. The following strategic approaches to the problem come primarily from the recommendation made at that meeting. The responsibility for actions to be taken falls both upon PAHO and upon the Member Governments.

4.1 Collection and Dissemination of Information

As Aedes albopictus is an exotic mosquito in the Americas, limited information is available in Member Countries concerning this vector. Therefore, PAHO has initiated the distribution of technical information to national health authorities. This includes data on taxonomic features, keys of identification, biology of the mosquito, vector competence and insecticide susceptibility. Obviously such information derives from observations made with Aedes albopictus populations from Asia. Nevertheless it is expected that information concerning Aedes albopictus populations present in the Americas will be progressively available in the near future. It will be also important to keep countries informed of current distribution of the mosquito in the Region. The need for establishing a reporting system for Aedes aegypti- and Aedes albopictus-infested areas should be seriously considered. PAHO will also develop and distribute guidelines and protocols for the surveillance, surveys and control methods of Aedes albopictus.

4.2 Surveys and Surveillance

Since information on Aedes albopictus is currently very limited in Central and South America, the most important initial step will be to gain information on the presence, distribution, breeding habitats and insecticide susceptibility of this species in the various countries. This can best be achieved through initial surveys and establishment or expansion of the current continuous Aedes aegypti surveillance system. This information will be critical for planning and organizing control/eradication campaigns for Aedes albopictus.

4.2.1 Geographical Distribution

- 1) PAHO will develop protocols for surveys and surveillance, to be distributed and promoted in all of the countries of the region. Preliminary keys, which have already been distributed, will be modified to include the central and South American and Caribbean species, and will be translated into Spanish.
- 2) A rapid system for reporting the discovery and surveillance of Aedes albopictus should be developed.
- 3) The system of surveys and surveillance should utilize the current Aedes aegypti program structure, personnel and methodologies as much as possible. Where these are deficient, they must be strengthened.

- 4) Priorities for surveys should be given to those countries with most importations of used tires from infested areas, such as the United States of America, Brazil and Asia. Areas with known infestation should also be surveyed to determine distribution and habitat preference.
- 5) The initial surveys should be done in localities with highest risk of introduction and in habitats with greatest probability of proliferation of this mosquito. Key sites in each country are sea ports, airports, bus terminals, train stations and cargo shipment companies. Tire dumps and cemeteries in these areas receive highest priority. Traditional larval surveys will be done, but field workers should also carry gear for adult collections.
- 6) As part of the planning for implementation of surveys and expansion of surveillance, it will be important to have mosquito collections, both larvae and adult, identified as quickly as possible. This may require some decentralization of the identification procedure, and will require additional equipment such as microscopes and personnel training in identification of container-breeding mosquitoes.
- 7) Surveys, organized to detect rapidly the presence of Aedes albopictus, can best be implemented by organizing international entomological teams consisting of PAHO, other international and national entomologists. These teams will visit key cities in Central and South America, conduct short (one day) training workshops on survey procedures and mosquito identification, and actually conduct field surveys in these areas. It will be extremely important to include key local Aedes aegypti surveillance and control personnel in the actual surveys conducted. These initial surveys, conducted for the purpose of rapidly establishing the presence or absence of Aedes albopictus in each country, should be conducted as soon as possible.
- 8) A surveillance network should be established in the same countries and in the same localities as the initial surveys, using, in addition to periodic larval and adult surveys, oviposition traps, which should be checked weekly.
9. Incoming ships and aircraft, from countries known to be infested with Aedes albopictus should be inspected and disinfested continuously.
- 10) Upon discovery of an infestation of Aedes albopictus an attempt should first be made to obtain live eggs for colonization in a laboratory in the United States (e.g. CDC) for definitive identification, biological typification and susceptibility testing before the focus is eliminated. Colonization should not be attempted in a country with a very low infestation.

4.2.2 Surveys of Breeding Habitats

Detailed surveys of Aedes albopictus breeding habitats in infested areas of the Americas are urgently needed. In addition to the identification of the breeding habitats, these surveys should also provide a careful assessment of their contribution to mosquito population density. Such information will be of crucial importance for the design of appropriate strategies for the control of the mosquito species.

4.2.3 Surveys of Insecticide Susceptibility

Susceptibility tests of Aedes albopictus to insecticides should be done in newly detected areas of infestation. Temephos, malathion and fenitrothion, among others, are the insecticides to be used in the tests. Following initial surveys, the susceptibility tests should be regularly carried out as part of vector control activities. Resistance of Aedes albopictus to organophosphate insecticides has been reported from Madagascar, Malaysia, Singapore, Sri Lanka and Vietnam (Tenth Report of the WHO Expert Committee on Vector Biology and Control, TRS, 1986). The Houston and New Orleans Aedes albopictus populations have been shown to be relatively resistant to malathion but susceptible to resmethrin, a synthetic pyrethroid. It should be noted, however, that resistance does not necessarily imply that the insecticide is ineffective under operational field conditions.

4.3 Surveillance for Aedes-transmitted Disease

Control, and ultimately prevention of epidemic dengue, dengue hemorrhagic fever and yellow fever in the Americas will require improved, laboratory-based surveillance for Aedes-transmitted diseases in all countries of the Region. To achieve this goal, PAHO and CDC will continue and increase their collaborative efforts to implement effective surveillance programs for these diseases in selected countries. Specifically, this should include the following:

- a) Upgrade and strengthen laboratories and train personnel to insure that each country has, at a minimum, serologic diagnostic capability for dengue and yellow fever viruses.
- b) Strengthen epidemiologic competence in all countries of the Region so that sufficient competent staff are available to implement laboratory-based surveillance for dengue and yellow fever.
- c) Implement a program to educate and train the medical community in affected countries about dengue, dengue hemorrhagic fever and yellow fever.
- d) Initiate a case reporting surveillance system for dengue by making this disease reportable, as is yellow fever.

- e) Implement a laboratory-based surveillance for dengue and yellow fever viruses in appropriate cities using selected physicians, health centers and hospitals. Blood and other appropriate samples should be taken from cases of dengue-like illness, and all cases with hemorrhagic disease or jaundice. These samples should be submitted to a competent local laboratory for serologic and virologic diagnosis.

If serologic and/or virologic diagnostic capability is not available locally, specimens should be sent to a reference laboratory for study as soon as possible after the cases occur.

- f) PAHO will collaborate with National governments to establish a system of routine information exchange and a communication network to insure that information of any increased or unusual activity is rapidly available. This will allow appropriate consultation and facilitate initiation of proper studies to obtain maximum information during epidemic activity.
- g) PAHO will promote the development of studies on the social and economic impact of epidemic dengue. This information from various countries can be summarized in a document that is used to help justify increased support for epidemic disease control from national and international health agencies. Such studies should include consideration of the direct and indirect costs of dengue and dengue hemorrhagic fever, including losses associated with absenteeism and the tourist industry.

4.4 Control Activities

The introduction of Aedes albopictus into the Americas necessitates both new strategies and the strengthening of the existing mosquito control programs. Control activities in receptive areas that are not yet infested must be oriented towards reduction of their receptiveness, whereas in newly infested areas measures should concentrate on elimination of infested foci; and in areas where infestations are already established, work should concentrate on the prevention of exportation, suppression of populations and, where possible, elimination of the infestation. The formulation of the most efficient control measures will depend on the results of surveys of breeding habitat and insecticide susceptibility, on biological studies and on field trials of the treatment methods.

4.4.1 Prevention

An important component is the prevention of the infestation with Aedes albopictus, which depends directly on early detection and surveillance, especially in areas of high risk, e.g. tire importation sites, tire retreading centers, and sea and airports, as well as other ports of entry. Ships and aircraft arriving from infested countries should be inspected and disinfested.

Source reduction is a major measure to be employed in the prevention of Aedes albopictus and will also have the added benefit of reducing populations of Aedes aegypti.

4.4.2 Control in Newly-infested Areas

Control in areas with new infestation must be treated as an emergency. New resources must be put into the existing control program and every effort must be made to eradicate the infested foci. Once a focus of infestation of Aedes albopictus is recognized, the immediate responsibility is to contain the infestation and eliminate it if possible, to prevent further spread. Priorities require the identification and treatment of such infested sites which are most likely to spread to other high risk areas where elimination or control may be even more difficult. Included would be used tires dealers and others likely to sell or transport water-holding containers.

- 1) Surveillance should be intensified to monitor known foci, and to detect the spread into new areas or new habitats. Data should be obtained on the relative utilization of both artificial and natural containers in the domestic and peridomestic environment and at greater distances from human habitation. Information obtained will be essential to guide control efforts.
- 2) Intensive continuous control efforts must be made to eliminate infestation before it can spread to new areas:
 - a) Adulticides should be applied to infested areas to suppress adult populations until larviciding and source reduction campaigns are completed. Considering that the United States population of Aedes albopictus has been shown to be at least partially resistant to malathion, susceptibility tests of mosquitos in new infestations should be done immediately against insecticides being contemplated for use in control of this species.
 - b) Larvicides having long residual effectiveness or slow release formulations should be applied to all water-holding containers. Special attention should be given to tires, drums, buckets and other larges containers. Tree holes, bromeliads, rock holes, and other natural containers must also be included.
 - c) Source reduction campaigns should be used in problem foci areas where there are large accumulations of containers.
 - d) Public information systems should be used to inform and enlist the support of the public.

4.4.3 Aedes albopictus Control in Areas with Established Infestations

In each American country where Aedes albopictus is already well established (e.g. United States of America and Brazil), the decision must be made whether to attempt to eradicate this species or to merely contain it, prevent its further spread, and maintain the populations at low levels at which arboviral disease outbreaks cannot occur.

Programs in these countries will be similar to Aedes aegypti programs and the two may be integrated, taking into consideration any differences in distribution, biology, ecology, or insecticide susceptibility of the two species.

Improved solid waste programs are vital and considered to be an essential element if source reduction campaigns are to succeed. Accumulations of quantities of water-holding containers are generally the result of inadequate garbage collection systems. Usually, the least effective systems are in areas where they are most needed, on the lower end of the socioeconomic scale.

Creation and enforcement of legislation to support control operations, where appropriate, under local conditions, may be a valuable tool.

4.4.4 Emergency Control during Disease Outbreaks

In the event an Aedes-borne disease outbreak, rapid emergency control measures must be implemented. Aerial ULV application of adulticides, applied at the correct time of day, with appropriate dosage rates, speed of application, appropriate climatic conditions, etc., must be used for sufficient reduction of the target Aedes adult populations. Ground ULV spraying or thermal fogging, although less rapid and sometimes less effective than aerial ULV, may be used where it is not possible to utilize aerial ULV.

Such measures must be coordinated with all levels of government and allied agencies, including the media, to insure correct information dissemination and cooperation from officials and the public.

Adulticiding efforts should be directed to areas having the greatest amount of new virus activity, and for this reason it is essential to obtain and transfer epidemiologic information to the mosquito control program on a frequent and timely basis.

Areas such as tire dumps, ports of entry and densely populated high-rise urban areas will benefit from methodical fogging operations, where speed of applications, dosage rates, wind conditions etc, must all be considered.

Public education is an important aspect of disease prevention. An informed public is able to provide some protection for themselves in their own environment by, for example, using household insecticides to kill adult mosquitoes and by eliminating or covering of water-holding containers.

Source reduction along with public education efforts should be concentrated in areas having large numbers of containers and populations of mosquitoes, with or without cases of dengue or other viruses.

The effectiveness of control methods must be monitored or evaluated to ensure that they are accomplishing the desired objectives. Failure to evaluate control methods can result in wasteful and ineffective programs.

4.5 Yellow Fever Vaccination

Previous studies showed that orally infected Aedes albopictus is able to transmit yellow fever virus. If South American strains of the mosquito are shown to be efficient vectors of yellow fever virus, then the threat of urbanization of the disease will be enhanced. A way of preventing this serious situation will be to increase immunization coverage against yellow fever. This will require availability of large supplies of the 17D vaccine. As a result of PAHO's efforts to modernize the yellow fever vaccine production facilities in South America, the Oswaldo Cruz Foundation, Rio de Janeiro, has completed a full renovation of its vaccine facilities and modernized its production methods. At present the foundation has 30 million doses of vaccine on stock, and plans are underway to double this.

4.6 Training

Training on all aspects of the biology and control of Aedes albopictus should be carried out at both the international and the national level. Courses should include the taxonomic aspects, biology, ecology, survey and surveillance methods, vector competence, control strategies and insecticide susceptibility for both Aedes albopictus and Aedes aegypti, showing the known differences and similarities between the two. PAHO has already scheduled a workshop on Aedes albopictus in CAREC, Trinidad, for late October 1986, primarily for vector control workers from the Caribbean region. At least one other international course, for the non-English speaking Latin American countries, will be planned for 1986-1987 for the chief entomologists or other officials responsible for Aedes surveillance of each of the Aedes aegypti country programs.

National-level courses should be held in every country for the survey personnel, and will cover classroom and laboratory exercises and field training.

4.7 Research

Considerable investigation is needed to increase our understanding of the biology and control of Aedes albopictus and the diseases it may transmit.

Research priorities are here divided into four categories:

- 1) Studies to evaluate the ability of Aedes albopictus to spread to new areas.
- 2) Studies to establish vectorial capacity.
- 3) Studies to determine the role of Aedes albopictus in dengue outbreaks in the Americas.
- 4) Studies related to Aedes albopictus control.

Countries in the Americas that have become infested by Aedes albopictus will be encouraged to conduct research on the topics listed below.

4.7.1 Studies to Evaluate the Ability of Aedes albopictus to Spread to New Areas

- 1) By mark-release-recapture or other suitable methods, determine the flight range of Aedes albopictus. Identify behaviors (e.g., host following) that increase the likelihood of distribution by man.
- 2) Determine the ability of Aedes albopictus populations to enter diapause, in order to assess the potential for spread of the mosquito to areas with cold climates.
- 3) In areas where Aedes albopictus occurs, determine, by means of appropriate field studies, the ability of this species to compete with native species in selected larval habitats (especially treeholes and other natural containers).
- 4) Mode of passive dispersal of Aedes albopictus among and within countries.

a) The role of tires and large cargo containers:

The introduction of Aedes albopictus to the United States of America was probably by shipment of tires in large cargo container from Japan. Since Central and South American and Caribbean countries import large numbers of used tires coming both from the United States and directly from Asian countries, it will be important to determine the most likely source of importation of Aedes albopictus into Latin America in order to avoid further introductions once control programs have been initiated.

Information on used tire commerce in Central and South America should be obtained. This should include ports receiving used tires, route and modes of distribution, and uses.

b) Other modes of spread:

Passive movement of Aedes albopictus from locality to locality is probably similar to that of Aedes aegypti. Besides transport in tires, larvae and eggs of Aedes are known to be carried from place to place in other containers, such as drums, flower vases, boat bottoms and numerous other receptacles associated with man. Adult mosquitoes are frequently found in motor vehicles, ships and aircraft. The importance of all container types and possible means of transport needs to be evaluated.

4.7.2 Studies to Evaluate the Vectorial Capacity of Aedes albopictus

The existence of multiple components in vector-borne diseases (i.e., host(s), vector(s), pathogen) may lead to highly complex systems that may react in unexpected ways. Control activities at one point in the system may cause unanticipated changes elsewhere in the system, resulting in a net increase in disease transmission. For example, larvicides may allow a small number of survivors to better utilize scarce nutrients in the habitat, resulting in larger, longer-lived adults with increased opportunity to transmit disease. Hence effective suppression or control strategies require a thorough understanding of the foregoing interactions:

- 1) Evaluate the potential for transmission of dengue and yellow fever viruses of American populations of Aedes albopictus. These studies should include testing of different strains of each virus and determination of efficiency of both horizontal and transovarial transmission, in comparison with Aedes aegypti.
- 2) Determine median time to infectivity (extrinsic incubation) of dengue and yellow fever viruses in American populations of Aedes albopictus under differing environmental conditions (especially temperature).
- 3) Determine vertebrate host preference and feeding behavior of Aedes albopictus in the Americas. If possible, determine forage ratios to eliminate bias introduced by differing numbers of each host species.
- 4) Develop life tables for adult Aedes albopictus, with particular emphasis on daily survival, length of gonotrophic cycle, number of blood meals per cycle, and the role of autogeny (production of viable eggs without a blood meal) in population dynamics.

- 5) Determine the effect of larval nutrition on survival rate and vector competence and correlate this information with size-related changes in susceptibility to arboviruses (e.g., dengue and yellow fever).

4.7.3 Study of the Role of Aedes albopictus in Dengue Outbreaks in the Americas

Detailed studies should be carried out in areas infested with Aedes albopictus that have documented dengue transmission. The present situation in Brazil offers a unique opportunity to conduct such research. Specific studies should include the following:

- 1) Develop laboratory based disease surveillance in Aedes albopictus-infested areas that can detect and document dengue transmission at an early stage.
- 2) Either before or shortly after transmission begins, initiate community-based seroepidemiologic studies that will provide data on transmission dynamics and incidence.
- 3) Carry out detailed larval and adult mosquito surveys to define densities, species associations and principal larval habitats. Studies on adult feeding behavior and preferences should also be carried out in the transmission area to determine the extent of man-biting by Aedes albopictus.
- 4) After dengue transmission has been documented in the laboratory, collections of eggs, larvae and adult mosquitoes should be initiated to determine which species are transmitting the virus to man and whether transovarial transmission is occurring. At least 10,000 larvae collected from as many habitats as possible, or 50,000 eggs reared to larvae, should be tested for virus.
- 5) In Aedes albopictus infested areas where dengue transmission has been documented in the recent past, retrospective entomologic and seroepidemiologic studies should be carried out to obtain as much information as possible on the role of Aedes albopictus as a vector of dengue viruses.
- 6) Reference samples of adult males and females and larvae of all mosquito species collected in the study sites should be retained for future study.
- 7) Local strains of Aedes albopictus and Aedes aegypti should be colonized for subsequent studies on virus-vector relationships.

4.7.4 Studies to Formulate Control Strategies

Because of the propensity of Aedes albopictus for colonization of non-urban, forest habitats, there is a very real danger that any major

control program would rapidly select rural, treehole-breeding populations that would reinfest urban areas as soon as control is ended. This is believed to have happened in Hawaii in the 1940's.

The following studies will provide useful information for the formulation of control strategies:

- 1) Establish colonies of Aedes albopictus from different areas in the Americas found to be infested. If possible these colonies should be located in areas already infested, and always in secure facilities which effectively prevent escape of these mosquitoes.
- 2) Determine the susceptibility of Aedes albopictus populations from the Americas to currently available larvicides and adulticides. The highest priorities for testing are populations from areas of Brazil affected or threatened by epidemic dengue.
- 3) Evaluate the genetic plasticity of Aedes albopictus populations in the Americas with respect to the development of a) physiological, and b) behavioral (e.g. habitat shift) resistance to insecticide.
- 4) Determine the origin(s) of current infestations of Aedes albopictus by morphological examination, by biological characteristics and by isoenzyme and/or mitochondrial DNA analysis) to assist in developing surveillance procedures.
- 5) Evaluate the usefulness of such biological control measures as Toxorhynchites, BTI, predaceous copepods, larvivorous fish and growth regulators (e.g. methoprene).
- 6) Determine the effectiveness of traditional larval and adult Aedes aegypti control measures, such as adulticiding, larviciding and source reduction, against Aedes albopictus.

5. RESOURCES

It will be necessary to mobilize national and international human and financial resources to deal with this emerging problem. Member Governments already have programs of vector control which will need to be reinforced.

The human resources which PAHO has available to promote and coordinate activities related to vector control in general are located at both the Headquarters and at the country level. The coordination of vector control activities at the central level is under the Program of Communicable Diseases (HPT). HPT, in consultation with field staff, coordinates the preparation of programs for the control of Aedes

aegypti. In addition, HPT implements activities such as collection and dissemination of information, provides technical consultation, prepares training courses, organizes scientific and technical meetings, assists in procurement of related supplies and equipment, and cooperates in the identification of sources of financial support.

The field staff consists of seven entomologists assigned to country or regional projects. They provide direct technical assistance to countries, supervise and orient national vector control programs, organize and serve as instructors in training workshops on vector control, and assist in research projects on vector ecology, biology and control.

Resources are also made available through specific consultantships provided by experts from outside PAHO.

Because of its magnitude, the problem of Aedes albopictus in the Americas will require a careful evaluation of the personnel and funds needed for its combat. Such evaluation will have to be carried out on the basis of the strategies outlined in a plan of action. Provision of adequate resources is imperative in order to implement a vigorous program for the eradication of Aedes aegypti and Aedes albopictus in the Americas.

6. FINAL COMMENTS

Although a true assessment of the public health implications of the invasion of the Americas by Aedes albopictus remains to be made, the available information on the role of this vector in the transmission of major arbovirus diseases justifies the immediate preparation of appropriate strategies and plans of action with the activities necessary to cope with the problem. These plans should include the establishment or reinforcement of appropriate legislative measures. However, the most important precondition for success of any plan is the political commitment of each country.