ARTICLES

A REVIEW OF THE STATUS OF YELLOW FEVER AND Aedes aegypti ERADICATION PROGRAMS IN THE AMERICAS

D. J. SCHLIESSMANN AND L. B. CALHEiros

Introduction. Within the context of this symposium on vector-borne diseases and their control, yellow fever in the Americas cannot be considered independently of dengue fever and their common vector, Aedes aegypti. Because the epidemiology and control of dengue is similar to urban yellow fever, only brief reference will be made to that disease.

This paper reviews the status of yellow fever in the hemisphere, events leading to the establishment of the goal of eradicating A. aegypti from the Americas and progress of the eradication effort.

Yellow Fever in the Americas. In 1972, 22 cases of jungle yellow fever were reported in 4 states of Venezuela following an absence of human infections since 1966. The cases were preceded by an epizootic in monkeys. A. aegypti mosquitoes are prevalent in the country. Approximately 500,000 people in vulnerable areas were vaccinated.

From December 6, 1972 to January 17, 1973 (date of last information), 18 fatal cases of jungle yellow fever have been reported from widely dispersed areas in the state of Goiás, Brazil. With the appearance of the first case, vaccination of the population was intensified.

In early 1973, the Government of Panama undertook the vaccination of the indigenous population and of personnel constructing a hydroelectric dam and the extension of the Pan American Highway in the eastern part of the country that has experienced cyclic epizootics of jungle yellow fever. The action was taken subsequent to observations of A. aegypti indices exceeding 5 percent in Panama City, following the discovery of the second reinfestation of the country. Because of the potential danger, the Government is considering the renewal of its requirement that people entering the country from endemic areas possess a valid yellow fever vaccination certificate.

The above events are illustrative of the continuing concern of governments over the threat of yellow fever which, during the 18th and 19th centuries, was considered one of the most dreaded diseases in the Americas when epidemics decimated populations and paralyzed industry and trade. The probability that the disease would pose a similar threat in the 20th century was eliminated by the initiation of anti-mosquito programs by cities and countries exposed to the threat of yellow fever following demonstrations in the early 1900's by the Walter Reed Commission in Cuba and General Gorgas in Panama that the disease (and incidentally malaria) could be prevented by mosquito control. By 1925, yellow fever had been eradicated from the West Coast of South America, and outbreaks in Brazil, Colombia, El Salvador, Honduras, Nicaragua, Mexico, Venezuela and the United States of America had been suppressed (Strode, 1951).

Since 1930, yellow fever transmission by A. aegypti has been limited to 14 localities in the Americas. Transmission in each instance followed the introduction of the virus from the jungle. None of the epi-
sodes resulted in the establishment of an endemic focus (Soper, 1963). Thirteen of the episodes occurred between 1932 and 1942 in Bolivia, Brazil, Colombia and Paraguay. The last occurrence of yellow fever transmitted by A. aegypti in the Americas was in 1954 in Port of Spain, Trinidad.

Despite the limited transmission of urban yellow fever by A. aegypti, the disease has been reported every year from one or more countries of the Americas since 1930. The virus is maintained in vertebrates other than man in large areas of the Amazon Basin (Bolivia, Brazil, Colombia, Ecuador and Peru), the Magdalena Valley of Colombia and forested areas of the Orinoco tributaries in Venezuela. Haemagogus mosquitoes are primary vectors in enzootic and epizootic transmission and in infecting humans who live, visit or work in enzootic areas. Epizootics periodically occur on the fringes of enzootic areas and occasionally spread throughout jungle and forested areas well beyond their enzootic foci. Areas of French Guiana, Surinam, Guyana and the Darien Province of eastern Panama have been suspected of harboring jungle yellow fever, and all have experienced cyclic epizootics (Galindo and Srinongse, 1967).

Cases of yellow fever reported by countries by 10-year periods from 1930 through 1969 are shown in Table 1. Fatalities represent the majority of reported cases. Because infections occur primarily in remote forested areas having minimal health services, considerable under-reporting is believed to occur. Though the increase in countries recording cases by time may reflect improved reporting procedures, the occurrence of human cases outside known endemic areas (Argentina, Costa Rica, Guatemala, Guyana, Honduras, Nicaragua, Panama, Surinam and Trinidad and Tobago) is indicative of movement of the virus during epizootics.

The number of cases reported by countries from 1963 through 1972 shows the

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<tr>
<th>Table 1.—Number of cases of yellow fever reported by countries of the Americas by 10-year periods, 1930-1969.</th>
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<tr>
<td><strong>Country</strong></td>
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<td>Brazil</td>
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<td>Surinam</td>
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<tr>
<td>Trinidad &amp; Tobago</td>
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<td>Venezuela</td>
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<tr>
<td><strong>Total</strong></td>
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<th>Table 2.—Reported cases of jungle yellow fever in the Americas, 1963-1972.</th>
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<td><strong>Country</strong></td>
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<td>Surinam</td>
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<td>Venezuela</td>
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<tr>
<td><strong>Total</strong></td>
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*Tentative.*
annual variation in infections in countries having known enzootic areas and the sporadic occurrence of cases in those outside endemic areas (Table 2 and Figure 1). Though an epizootic occurred in eastern Panama during this period, no human cases were reported.

It is evident from this brief review that yellow fever, based on parameters of morbidity and mortality, has been reduced to a level whereby the disease does not constitute a significant health problem in the hemisphere. As noted above, however, concern over the potential resurgence of

FIGURE 2

Status of the Aedes aegypti eradication campaign in the Americas, December 1972

- Countries which have completed Aedes aegypti eradication
- Areas in which Aedes aegypti is no longer found
- Areas recolonized (After completion of eradication)
- Areas still infected or not yet inspected
- Areas presumably not infected

* Eradication carried out according to the standards established by the Pan American Health Organization
urban outbreaks results in immediate re-
sponse by governments following reports
of cases of jungle yellow fever. For rea-
sons noted subsequently, the future is
unknown as to whether trends of the past
40 years will continue or if there will be
a recurrence of urban yellow fever in
the Americas.

Current Status of Programs for the
Eradication of Aedes aegypti. Various
members of the Walter Reed Commission
suggested in the early 1950’s that eradi-
cation of yellow fever was feasible (Strode,
1951). The success achieved in preventing
the disease during the first quarter of the
century revived support in the concept of
disease eradication. At the time, knowl-
edge of the epidemiology of the disease
was limited to the man-mosquito-man
cycle of transmission, and the effectiveness
of mosquito control measures in reducing
A. aegypti populations to a level whereby
the virus could not sustain itself had been
demonstrated.

Confirmation in the early 1930’s that the
jungle cycle of yellow fever provided a
permanent reservoir of virus for infection
of man and A. aegypti voided the concept
of disease eradication by control of the
urban vector. Nevertheless, subsequent
observations that A. aegypti had been eradi-
cated in areas of Brazil, and the country
of Bolivia by anti-mosquito control pro-
grams, focused attention on the feasibility
of eliminating the threat of urban yellow
fever by eradicating the vector. The con-
cern of countries with the health and eco-


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<th>Countries or territories</th>
<th>Mainland of continents</th>
<th>Caribbean</th>
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<tbody>
<tr>
<td>Initially infected</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Eradication campaigns</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>started</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campaings continuing—</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>1973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infected and lacking</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Programs—1973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eradication achieved</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Reinfection following</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>eradication</td>
<td></td>
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</tr>
</tbody>
</table>

*Includes conduct of vigilance activities in
countries free of A. aegypti.

During this period, the vector was eradi-
cated from 19 countries and territories con-
taining 8,690,843 square kilometers or 73.5
percent of initially infested land areas of
the hemisphere (Table 4 and Figure 2).

Eradication was confirmed between 1955
and 1965 in 17 of the 23 initially infested
countries on the continents. Since 1965,
continued progress has been affected by
the suspension of 1 program, inadequate
financial resources in 5 campaigns and
reinfections in 7 of the 17 countries that
had previously achieved eradication of the
vector. While the initial reinfection of
each country was limited in scope, diffi-
culties have been experienced in combating
the reappearance of the vector. In the
Caribbean, eradication has been accom-
plished in only 2 of 26 countries and ter-
ritories. Factors which have limited the
rate of progress include the number, size
and dependency of several of the areas;
limitations in financial resources; lack of
simultaneous action by all political units;
initiation of programs by only 22 of the
26 infested areas, and the subsequent in-
terruption of campaigns in 2, and the
probable frequent reintroduction of the
species resulting from extensive inter-island
tourism and commerce by small unchar-
tered boats. Additionally, progress in some
countries has been adversely affected by
operational, administrative or technical
problems.
FIGURE 2
JUNGLE YELLOW FEVER IN THE AMERICAS
1968-1972

AREAS SUBJECT TO PERIODIC OUTBREAKS OF JUNGLE YELLOW FEVER

LOCALITIES WITH NOTIFIED CASES OF JUNGLE YELLOW FEVER
(By county or its equivalent)

☐ 1968
☐ 1969
☐ 1970
☐ 1971
☐ 1972*

*Tentative
Because of the extensive outbreaks of dengue fever in the Caribbean, Venezuela, and Colombia in the last 10 years, and the annual occurrence of cases of jungle yellow fever, several countries of the Americas express continuing concern over the threat of *Aedes aegypti*-transmitted diseases in view of the current status of the eradication effort and problems of reinfestations. This concern has been manifested by frequent resolutions of member nations of the Pan American Health Organization that all infested countries initiate and/or intensify efforts to eradicate the urban vector of yellow fever.

**Discussion.** The initial motivation to eliminate the threat of urban yellow fever from the hemisphere by eradicating *Aedes aegypti* stemmed from knowledge of the devastations wrought by the disease in the 18th, 19th and early 20th centuries, awareness of potential dangers of epidemics in areas having high vector populations, and demonstration that eradication of the species was possible.

There is general agreement that the prevention and elimination of urban outbreaks of yellow fever in this century resulted from control or eradication of *Aedes aegypti*. Nevertheless, the absence of urban yellow fever since 1954, the reduction in disease morbidity and mortality to a level where it is no longer considered a dominant health problem, and the magnitude of estimated budgetary requirements for eradicating the vector from infested countries has led to increasing skepticism by many of needs for continuing efforts to eradicate *Aedes aegypti*.

Aside from financial considerations, a case is made over the lack of major urban outbreaks of yellow fever for over 40 years, the availability of an effective vaccine, improvements in disease surveillance and reporting procedures, technological improvements in vector control, danger of reinfestations from Africa which would require continued expenditures for vector surveillance in absence of global eradication, questionable availability of practical control methodology as a result of increasing concern over environmental pollution with insecticides and cultural and economic changes during the past two decades, vector resistance to commonly used insecticides, the probability that the goal is unattainable because of the adaptability of a biologic species subjected to pressures of eradication; and others (Sencer, 1969).

**Proponents of *Aedes aegypti* eradication believe that reasons which prompted the initial resolution in 1947 are still valid,**
They view with concern the continuing occurrence of jungle yellow fever, the decreasing use of viscerotomy during the past 3 decades which has limited the acquisition of current information on the distribution or prevalence of the disease, cyclic epizootics which result in dispersal of the virus to countries well beyond enzootic foci, reinfestations of countries having eradicated the vector and difficulties being experienced by them in undertaking remedial action, limited rate of progress in recent years in ongoing programs of several countries which have not achieved eradication, lack of program efforts by 7 of 49 infested political units of the hemisphere, the recrudescence of dengue fever during the past 10 years with extensive and recurring outbreaks of types II and III virus in the Caribbean, possible occurrence of dengue hemorrhagic fever—shock syndrome—resulting from serial infections with 2 serotypes of dengue virus within a short time interval as postulated for its prevalence in Asia, and the potential risk of outbreaks of urban yellow fever and dengue occurring in more than 45,000,000 people residing in A. aegypti-infested islands of the Caribbean, countries of northern South America and southeastern United States.

More recently, the occurrence of some 900,000 cases of dengue in 1972 in areas of Colombia where the vector had been previously suppressed, the outbreak of jungle yellow fever in Venezuela in 1972 following an absence of the disease for 6 years, and current A. aegypti indices in sections of Panama City in excess of 5 percent following its reinfestation indicate the possible resurgence of A. aegypti-transmitted disease.

Because of the interest of members of the American Mosquito Control Association in vector-borne diseases and their control, brief reference is made to the status of yellow fever, dengue and A. aegypti in the United States. Epidemics of yellow fever occurred from Texas to New England between 1668 and 1695. The last reported outbreaks in the U.S. occurred in the southern Mississippi River Basin in 1898 and 1905 with New Orleans being most heavily affected. Recurring outbreaks of dengue fever have occurred in Puerto Rico since 1955 but the last reported transmission of the disease in continental U.S. was in 1954.

The U.S. has been a signatory nation to resolutions by the PAHO calling on all countries of the Western Hemisphere to eradicate A. aegypti. At the time field operations began in this country in June 1954, the vector had been eradicated from all mainland countries of the continents except Colombia, Guyana, French Guiana, Surinam and Venezuela where activities were in progress (Schliessmann, 1965). It is of interest that, of the countries achieving eradication, 5 have been reinfested following suspension of field operations in the U.S. and that New Orleans is now infested after an absence of the vector for several years. On November 9, 1972, the requirement that people entering the U.S. from specified countries possess a valid yellow fever certificate was cancelled. The notice of cancellation continued to recommend vaccination for U.S. citizens traveling to areas reporting cases of yellow fever.

It is suggested that lack of recent progress in eradicating A. aegypti from the hemisphere stems primarily from budgetary considerations and only secondarily to philosophical differences in the merits of eradication. Eradication is expensive. Yet, it is emphasized that the favorable status of yellow fever in the Hemisphere exists because of the sustained expenditures and efforts by many countries. It is further suggested that current trends by some countries of utilizing parameters of morbidity and mortality for establishing health priorities and allocating financial resources may not give due consideration to past efforts and expenditures which contributed to the reduction of disease and probabilities for its recrudescence.

Because of expressions of concern over the high costs of eradication, the Pan American Health Organization with financial assistance from the United States, Trinidad, and Tobago entered into a contract with an independent company, Arthur D. Little, Inc., to conduct a cost-
benefit study on the prevention of diseases in the Americas transmitted by A. aegypti. The 1972 report concluded that for the hemisphere, the benefits would exceed the cost. In some countries, however, the costs vastly exceeded benefits. Though the conclusions were not accepted by all countries of the Americas, nations comprising the Directing Council of the PAHO reviewed the report in October 1972 and resolved “To urge the governments of the countries still infested to decide without delay to eradicate Aedes aegypti from their territories, in accordance with the resolution approved at the 1st Meeting of the Directing Council (Buenos Aires), 1947.”

**Summary and Conclusions.** Yellow fever was a dread disease of serious health and economic importance during the 18th, 19th and early part of the 20th century in the Americas. Its control and subsequent prevention in the Western Hemisphere has been attributed to A. aegypti suppression and eradication programs. The last reported urban transmission by the vector in the Americas was in 1954.

Cases of jungle yellow fever, however, continue to occur annually in countries of South America and extensive and recurring outbreaks of dengue fever in islands of the Caribbean and in Venezuela and Colombia have occurred in the past 10 years. Virus serotypes I and II are present and the possibility that dengue hemorrhagic fever may occur cannot be ignored. Some 45,000,000 people in the Caribbean and adjacent countries are in areas infested with A. aegypti. The probability that there can be a recurrence of urban yellow fever and/or the development of dengue hemorrhagic fever is controversial but the possibilities cannot be ignored.

Since the 1947 resolution by member nations of the Pan American Health Organization to eradicate A. aegypti from the Western Hemisphere, the vector of urban yellow fever has been eradicated from 19 countries or territories comprising 73.5 percent of initially infested areas. Though significant progress has been achieved, re-infestations and lack of program activities in 7 of 49 countries and territories of the Americas threaten the attainment of eradication.

It is suggested that the limited rate of progress in recent years to eradicate the vector is attributed primarily to the costs of program activities and only secondarily to recent questions concerning the necessity or feasibility of eradication. Despite recognition of costs and conceptual differences, the goal of eradication of A. aegypti from the hemisphere was again reaffirmed in October 1972 by the Third Special Conference of Health Ministers of the Americas and the XXI Meeting of the Directing Council of the Pan American Health Organization.

In conclusion, the experience in the Hemisphere during the past 2 years is believed to substantiate the concern of Dr. W. C. Reeves when he said (1972) “... I believe it would be extremely shortsighted of us if we did not also recognize that the dengue epidemics (in the Caribbean) may be an early warning of possible resurgence of epidemic urban yellow fever” and “... one can only feel that the scene is set and that a recurrence of jungle yellow fever into many susceptible areas is inevitable. Furthermore, unless Dr. Soper’s goals (of A. aegypti eradication) restated in 1963 are reestablished, an epidemic of urban yellow fever is likely to occur in Venezuela or the Caribbean. Such a development would be a catastrophic event in the 1970’s.”

**Anecdote.** Following an absence of reported cases of jungle yellow fever in Panama since 1957, 2 cases with one death were confirmed in early 1974. In the area of the cases, a vaccination program has been initiated and field investigations undertaken to determine the possible occurrence of additional human infections and the presence of the virus in indigenous monkey and mosquito populations.

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A DEVICE FOR THE PUPAL SEPARATION OF MALE
FROM FEMALE MOSQUITOES IN THE FIELD

V. P. SHARMA,1 G. C. Labrecque,2 AND R. S. Patterson2

WHO/ICMR Research Unit on the Genetic Control of Mosquitoes, 2 Ring Road, Kilokri,
New Delhi-14 India

ABSTRACT. A portable device has been de-
veloped to separate male from female mosquito
pupae in the field. Trials reveal that a high
percentage of males can be obtained with only
few females recovered when the selection level
is set for about a 40 percent recovery of the total
to be sexed. This device can be used to meet
partially or fully the demand for males in sterile
releases.

Investigations on insect control or eradica-
tion programs involving the release of
sterile males are being widely conducted to
determine whether they can be used to
supplement or replace conventional control
measures. In many cases the releases can
involve both sterile males and females, but
on occasion the release of females can be
highly detrimental. This is especially true
when the females being released are dis-
ease vectors, as in the case of mosquitoes.

That a mosquito population can be elimi-
nated by the release of genetically manipu-
lated males has been amply proven by
Laven (1967) and Patterson et al. (1970)
in Burma and the United States, respec-
tively. However, in both of these studies
the magnitude of the releases was depend-
ent upon two factors, the development of
mass rearing facilities and the accurate and
rapid separation of the sexes to insure that
only males are released. Both problems

1Senior Scientist, ICMR.
2Insects Affecting Man Research Laboratory,
ARS, USDA, Gainesville, Florida 32604.