ARTICLES

A REVIEW OF THE STATUS OF YELLOW FEVER AND *AEDES AEGYPTI* ERADICATION PROGRAMS IN THE AMERICAS

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INTRODUCTION. Within the context of this symposium on vector-borne diseases and their control,[2] 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 Goias, 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 hydro-electric 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-

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[2] Houston meeting of AMCA, March, 1973.

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 Srihongse, 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

TABLE 1.—Number of cases of yellow fever reported by countries of the Americas by 10 year periods, 1930–1969.

Country	Number of Cases			
	1930–39	1940–49	1950–59	1960–69
Argentina	0	1	0	54
Bolivia	47	214	408	233
Brazil	937	208	373	206
Colombia	219	231	192	98
Costa Rica	0	0	278	0
Ecuador	0	1	42	1
Guatemala	0	0	3	0
Guyana	0	2	0	3
Honduras	0	0	1	0
Nicaragua	0	0	15	0
Panama	0	9	11	0
Paraguay	1	0	0	0
Peru	33	24	57	278
Surinam	0	0	0	2
Trinidad & Tobago	0	0	19	0
Venezuela	0	50	67	30
Total	1,237	740	1,466	905

TABLE 2.—Reported cases of jungle yellow fever in the Americas, 1963–1972.

	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972[1]
Argentina	...	..	2	51	1	..	..	2	..	..
Bolivia	81	13	19	69	..	27	8	2	8	8
Brazil	...	13	14	167	2	2	4	2	11	12
Colombia	10	10	2	3	5	11	7	7	9	3
Ecuador	...	..	..	...	1	..	..	..	..	..
Guyana	...	..	..	...	..	1	..	..	..	..
Peru	49	60	45	9	3	5	28	75	..	7
Surinam	...	..	..	...	..	1	1	..	..	1
Venezuela	1	2	5	5	..	..	..	..	..	22
Total	141	98	87	304	12	47	48	86	28	53

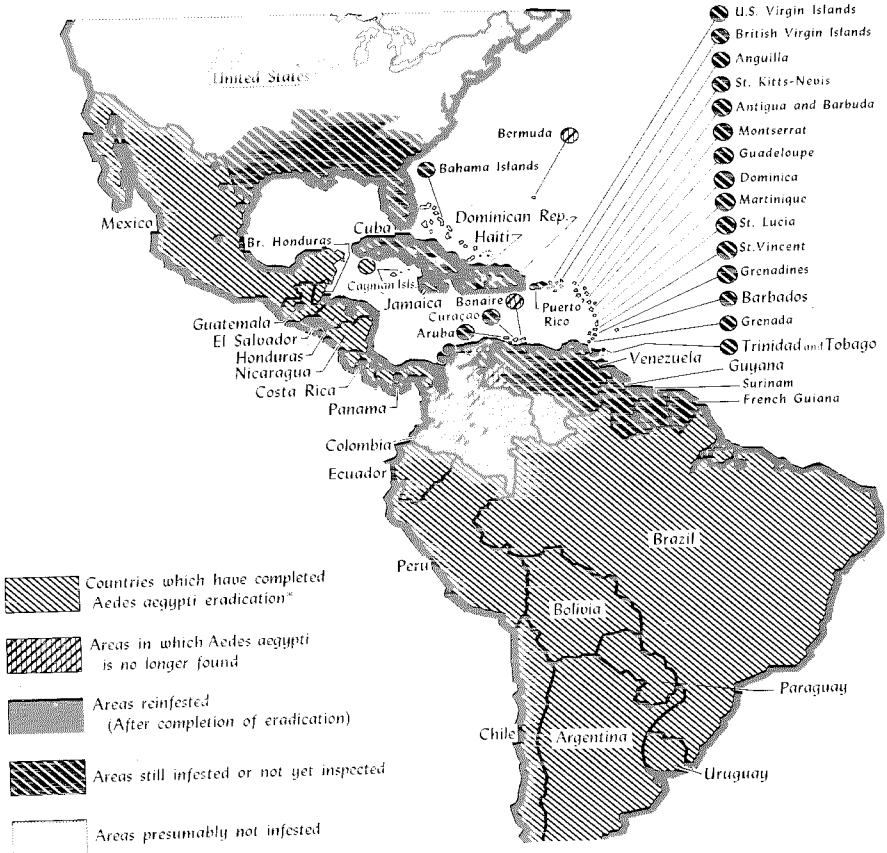
[1] Tentative.

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 1

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



*Eradication carried out according to the standards established by the Pan American Health Organization

urban outbreaks results in immediate response by governments following reports of cases of jungle yellow fever. For reasons noted subsequently, the future is unknown as to whether trends of the past 40 years will continue or if there will be a recrudescence 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 1900's that eradication 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, knowledge 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 eradicated in areas of Brazil, and the country of Bolivia by anti-mosquito control programs, focused attention on the feasibility of eliminating the threat of urban yellow fever by eradicating the vector. The concern of countries with the health and economic consequences of epidemics in areas with high vector densities resulted in the 1947 resolution by member nations of the Pan American Health Organization to eradicate *A. aegypti* from the hemisphere.

At the time, *A. aegypti* was present in all countries and territories of the hemisphere with the exception of Canada and Bolivia. In the 25 years since the initial resolution to eradicate the vector, programs have been undertaken by all 23 infested countries and territories on the mainland of the continents and in 22 of 26 political sub-divisions in the Caribbean (Table 3).

TABLE 3.—Progress and status of *Aedes aegypti* eradication campaigns in the Americas during the period, 1947–1972.

Countries or territories	Number	
	Mainland of continents	Caribbean
Initially infested	23	26
Eradication campaigns started	23	22
Campaigns continuing—1973 *	22	18
Infested and lacking programs—1973	1	6
Eradication achieved	17	2
Reinfested following eradication	7	0

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

During this period, the vector was eradicated from 19 countries and territories containing 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 1958 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 reinfestations in 7 of the 17 countries that had previously achieved eradication of the vector. While the initial reinfestation of each country was limited in scope, difficulties have been experienced in combating the reappearance of the vector. In the Caribbean, eradication has been accomplished in only 2 of 26 countries and territories. 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 interruption of campaigns in 2, and the probable frequent reintroduction of the species resulting from extensive inter-island tourism and commerce by small unchartered boats. Additionally, progress in some countries has been adversely affected by operational, administrative or technical problems.

FIGURE 2

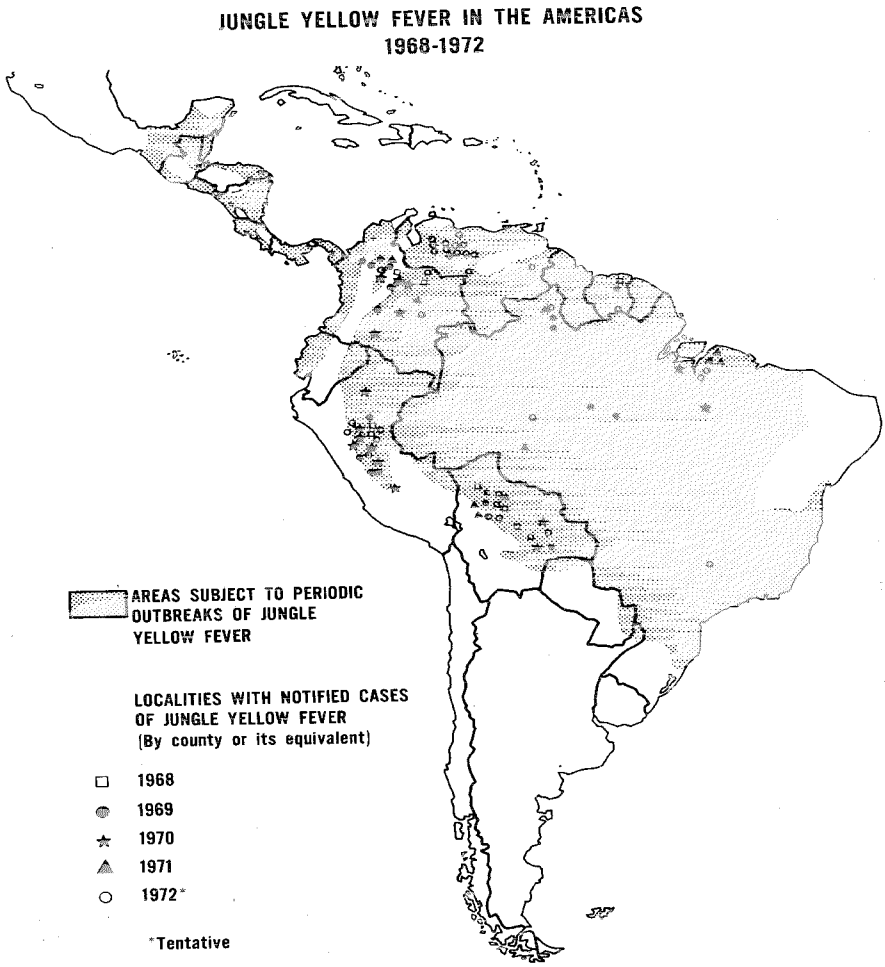

JUNGLE YELLOW FEVER IN THE AMERICAS
1968-1972
AREAS SUBJECT TO PERIODIC OUTBREAKS OF JUNGLE YELLOW FEVER
LOCALITIES WITH NOTIFIED CASES OF JUNGLE YELLOW FEVER
(By county or its equivalent)
1968
1969
1970
1971
1972*
*Tentative

TABLE 4.—Status of the *Aedes aegypti* campaign in the Americas (January 1973).

Eradication Accomplished				
Free of *A. aegypti*	Reinfested	Preparation, attack or consolidation Phase[1]		No current program
Argentina	Brazil[2]	Barbados	Curacao[3]	Dominican Republican
Bolivia	Costa Rica	Colombia	Dominica	Haiti
Chile	El Salvador	Cuba	French Guiana	Puerto Rico
Ecuador	Guatemala	Guyana	Grenada–Grenadines	United States
Nicaragua	Honduras	Jamaica	Guadaloupe	Turks and Caicos Islands
Paraguay	Mexico	Trinidad & Tobago	Martinique	Virgin Islands (UK)
Peru	Panama	Venezuela	Montserrat	Virgin Islands (US)
Uruguay			Saba	
		Antigua	St. Kitts[3]	
Bermuda		Aruba	St. Lucia	
British Honduras		Bahamas	St. Vincent	
Canal Zone		Bonaire[4]	Surinam	
Cayman Islands				

[1] Unless specified, programs are in various stages of attack.
[2] Country reported the elimination of the reinfestation.
[3] Preparatory phase.
[4] Consolidation phase.

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 *A. 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 *A. 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 *A. 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, technologic 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 *A. 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 viserotomy 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 hemorrahagic 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 500,000 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 1905. 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 1963 but the last reported transmission of the disease in continental U.S. was in 1945.

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 1964, 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 recrudescence 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, reinfestations 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 recrudescence 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."

ADDENDUM. 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

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ABSTRACT. A portable device has been developed 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 eradication 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 disease vectors, as in the case of mosquitoes. That a mosquito population can be eliminated by the release of genetically manipulated males has been amply proven by Laven (1967) and Patterson *et al.* (1970) in Burma and the United States, respectively. However, in both of these studies the magnitude of the releases was dependent 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 have now been resolved at this Unit and extensive sterile male release studies are in progress against *Culex pipiens quinquefasciatus* Say (*C. fatigans* Wied.). However, if natural occurring insects could be utilized in a release program, an additional benefit could be obtained. Not only would a lesser number of laboratory reared insects be needed, but also the number of indigenous individuals would be reduced.

Most of the devices developed for rapid sexing of mosquito pupae (McCray 1961, Gerberg *et al.*, 1969, and Sharma *et al.*, 1972) are based on the size differential between the sexes. The pupae pass through an aperture that allows exit of only individuals of a specific size; the males being normally smaller pass through whereas the females are retained. Where rearing conditions are standardized in the laboratory, these sexing devices are very efficient. Unfortunately in the field where conditions are variable this distinct thoracic size differential between sexes is not uniform from one environment to another, and therefore,

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