

Paper and Proceedings of 25th Annual Meeting,

Part III.

MALARIA ERADICATION: WHAT IT HAS ACHIEVED¹

DONALD R. JOHNSON²

After more than a decade of intensive malaria eradication activities throughout many countries of the world, it has become apparent that global malaria eradication, *per se*, at this moment is still a distant goal. In fact, one of the world's leading malariologists, Dr. Arnaldo Gabaldon (1968) of Venezuela, recently stated "... world malaria eradication has become at the present time an unattainable goal until a new breakthrough in the anti-malaria armamentary is found."

Problems encountered indeed are great. When one learns of anopheline resistance to insecticides, outdoor transmission of malaria, parasite resistance to antimalaria drugs—compounded by wars, famines, political insecurity, geographic barriers, administrative shortcomings, plus the inadequacies of monetary and trained human resources—a feeling of despondency can easily prevail. That is, pessimism can override other considerations—unless we look carefully at the total picture of what has been achieved by the malaria eradication program.

Russell has prepared many excellent articles vividly describing the adverse effects of malaria around the world. The most recent of these (1968) tells how the early colonists in our own country suffered

terribly. Probably the Spanish colonists with their Negro slaves brought malaria with them when they landed in July 1526 at Cape Fear River in North Carolina. *Anopheles quadrimaculatus* no doubt was prevalent at that time and easily could have transmitted the disease to the indigenous Indian population. The English colonists brought malaria to Jamestown, Virginia, in 1607. Russell tells of the hardships brought on by this disease and relates the belief that malaria was largely responsible for the transfer of the capital of the colony from Jamestown to Williamsburg in 1699.

Williams (1938) stated that malaria in the mid-1930's probably was costing the United States more than one-half billion dollars annually, when some 4 million cases were occurring each year in this country. Since then indigenous malaria has been eradicated from the U.S., as described by Bradley (1966).

We know, from many descriptive articles, of the devastating effects of malaria in Europe, Africa, Asia, and the Americas. Ross in 1911 stated, as quoted by Sinton (1935-1936), "Malaria is the great enemy of the explorer, the missionary, the planter, the merchant, the soldier, the farmer, the administrator, the villager and the poor, and has, I believe, modified the world's history by tending to render the whole of the tropics comparatively unsuitable for the full development of civilisation." Bruce-Chwatt (1965) aptly stated "... (Malaria) today still divides the rich world from the poor." The "poor" world presently consists of millions of square miles, principally in tropical and semitropical countries, and does in fact include most of the so-called malarious

¹ Presented at the American Mosquito Control Association 25th Annual Meeting, February 23-26, 1969, Williamsburg, Virginia.

² Research Officer, Malaria Eradication Program, National Communicable Disease Center, Health Services & Mental Health Administration, Public Health Service, U.S. Department of Health, Education, and Welfare, Atlanta, Georgia 30333. This Program is supported by the Agency for International Development, U.S. Department of State.

areas. Paradoxically it includes lush fertile valleys, rich volcanic islands, vast forests, lands with a great wealth of minerals and oils—populated everywhere to varying degrees with that greatly underdeveloped resource, people. These same areas also have a rich fauna of many species of anopheline vectors, and the human population frequently is host to the malaria parasites that are transmitted by these anophelines. Malaria eradication campaigns have done much to change this bleak picture.

ACHIEVEMENTS—POPULATION PROTECTION. There are many ways to measure the achievements of malaria eradication programs. The most easily measured parameter is that showing the number of persons protected in the various program phases. Table 1 compares the 1962 summarization of World Health Organization (WHO) data (WHO, 1963, 1968a, 1969) with the totals for 1967 and 1968. From 1962 to 1968, the total malarious area population (column 1) had risen by 243.2 million due to a combination of more accurate reporting, better delimitation of malarious areas, and population increases. Of the 1.7 billion persons in 1968 living in areas once considered malarious, 1.35 billion were receiving some degree of protection, ranging from complete elimination (maintenance phase, column 2) to areas where DDT house spraying and other anti mosquito and/or anti-parasite work was in progress (consolidation and attack phases, columns 3, 4).

The fact that this many people were protected against malaria, as reported by WHO (1969), attests to the enormity of the campaign and its remarkable achievements. Even though nearly 12 million have entered the preparatory phase (column 5), an additional 357 million still have no program whatsoever (column 6) representing a combined total of 21.5 percent of the malarious areas. These, unfortunately, include people living in some of the most difficult areas of the world, and for some there appears to be no relief in sight due to lack of available resources.

It may be noted in Table 1 that from 1967 to 1968 there has been a reduction of some 6 million persons from maintenance and 14 million persons from consolidation, with a net increase of 80 million in the attack phase. These changes in large part are due to the India and Ceylon programs where serious reversals took place, with inadequate maintenance measures contributing to the recrudescence of malaria. In India, diversion of financial and human resources to other programs also contributed to the subsequent reversions of some 90 million persons to attack phase from either consolidation or maintenance phases. In Ceylon, the National Eradication Program was discontinued in 1964 after a low of only 17 cases was reported in 1963. The case rate gradually built up until some 3,400 cases were reported in 1967. In 1968, an outbreak of an estimated one million cases occurred. These have been bitter and expensive lessons for these countries. It also is a warning to all countries that vigilance must not be relaxed as long as the danger of malaria exists.

RELATIONSHIP TO ECONOMIC GROWTH. The elimination of malaria frequently results in economic growth that may be expressed in various ways. One index frequently used is the change in land values. Property often increases in value in areas of high malaria incidence after malaria is eliminated. The most fertile bottom lands with rich agricultural potential also frequently have conditions very conducive to anopheline breeding and malaria transmission. In the Caspian Sea area of Iran, long notorious for its high prevalence of malaria, malaria was eliminated and the area quickly became very desirable for resorts. Land values boomed. In Ethiopia, malaria was controlled in sections of the country previously avoided because of the high prevalence of malaria. Again, land values increased tremendously.

With the attainment of better health through elimination of malaria, one of the conditions precedent to a strong economy is met. An economic enterprise, such as development of a rubber planta-

TABLE I.—Worldwide malaria eradication program: population phasing—1962, 1967, 1968^a
(in Millions)

Year	Total Malarious 1.	Maintenance 2.	Consolidation 3.	Attack 4.	Preparatory 5.	No Program 6.
1962	1472.5 (100%)	329.1 (22.3)	243.2 (16.5)	461.1 (31.3)	33.3 (2.3)	405.8 (28.0)
1967	1692.4 (100%)	654.3 (39.0)	355.2 (21.0)	277.0 (16.4)	41.9 (2.5)	364.0 (21.5)
1968	1715.7 (100%)	648.3 (37.8)	341.6 (19.9)	357.0 (20.8)	11.9 (0.7)	356.9 (20.8)

^a WHO: 1963, 1968a, 1969.

tion in Malaysia, an oil refinery in Sumatra, or a diamond mine in Africa, requires a healthy and alert staff of administrators, technicians, and laborers. Malaria can quickly decimate the entire staff. Therefore, before such an endeavor is fully implemented in a malarious area, the disease is brought under control by a combination of anti-mosquito and anti-parasite measures. The Panama Canal could not be built until malaria and yellow fever were controlled. Examples are endless, but only a few are cited here.

In Java, Indonesia, during the 1950's, the writer saw rich coastal rice fields, not cultivated because of high incidence of malaria, quickly brought into production when malaria transmission was stopped by the DDT spraying of houses. Control of malaria alone, of course, was not responsible. Irrigation was improved, new varieties of rice were introduced, and fertilizers were obtained. Nevertheless, the economy of this area would not have developed in such a rapid manner if malaria had continued unabated.

It must be remembered that malaria eradication is not intended to be an end in itself. Merely doing away with malaria may not improve the economy. It may, however, markedly improve the health of the people, and a healthy economy must be based on a healthy people. In the Philippines, two men in an area freed of malaria could do the work that required three men before malaria was controlled (Smith, 1950). On the other hand, in countries where there is a surplus of untrained labor and a dearth of jobs, the elimination of malaria in certain areas may not necessarily improve the economy. There must be an outlet for the healthier people through a balanced program of education, economic improvement, and family planning in order that a viable economy can develop in the absence of the malaria burden.

In Thailand, various studies show the economic significance of eliminating malaria. One agricultural settlement in central Thailand, notorious for malaria, reported by Ayurakit-Kosol and Griffith (1962), had a population of less than 9,000

with low agricultural production. With the reduction of malaria, the population doubled within five years, and a thriving farm community developed. Ayurakit-Kosol and Griffith estimated a loss of more than 15 million work days annually in agricultural workers throughout Thailand because of malaria prior to the eradication program. They also pointed out that the military losses are significant. One contingent of 50,000 troops in northern Thailand during World War II suffered over 80,000 cases of malaria in less than two years, with over 3,000 deaths and many cases of protracted disability. With the subsequent elimination of malaria, such losses disappeared.

The Rapti Valley in Nepal was one of the most highly malarious areas of the country. The valley was forested and fertile, but was very sparsely inhabited because of the high incidence of malaria. During the 1960's, malaria was brought under control in the Rapti Valley principally through DDT house spraying, and the area became a booming frontier. People migrated to the valley, forests were cleared, roads and trails were built, farmers built homes, and crops were planted. In 1967, these crops produced a yield valued at \$11 million. Today more than 250,000 people live and work in this valley—a 1,000 percent population increase in just this one rapidly growing and prosperous area of the country.

Malaria in India usually is a tremendous burden where it has not been brought under control. When one reads some of the works of authors, such as Sinton (1935-1936), it is easier to comprehend the misery and poverty resulting from malaria. "There is no aspect of life in this country which is not affected, either directly or indirectly, by this disease. It constitutes one of the most important causes of economic misfortune, engendering poverty, diminishing the quantity and quality of the food supply, lowering the physical and intellectual standards of the nation, and hampering increased prosperity and economic progress in every way." Sinton stated that malaria through its direct and in-

direct effects was responsible for some 2 million deaths among 200 million cases annually in India.

The Government of India in its Fourth Five-Year Plan (Anon, 1968) states that in 1952 malaria was causing an economic loss of 7.5 billion rupees annually due to illness of 75 million people, calculated on the basis of 100 rupees cost per case of malaria. By 1966, as a result of the nationwide malaria eradication program, the loss was cut to 15 million.

AUXILIARY BENEFITS. Perhaps less known, but tremendously important, are some of the auxiliary benefits derived from the malaria eradication efforts of nations. These include the following:

1. *Mapping, census accomplished*

Malaria eradication requires geographic reconnaissance before the program can be put into effect. Frequently the malaria eradication service maps are the first accurate maps made of lesser-developed remote areas. Likewise, the census of human population of malarious areas is the most accurate and up-to-date census available in many countries. Thus, the program has resulted in accurate mapping and census taking where neither may have been available previously.

2. *Government images strengthened*

The first and only contact some rural people have with their government is the contact with the malaria staff who visit the houses throughout the country regularly. It is remarkable indeed to travel to some of the most inaccessible hidden areas of the world—whether it be in remote dense jungles of the Philippines, rugged mountain valleys in the Himalayas of Nepal hundreds of miles from “jeepable” trails, or up the many branches of the mighty Amazon River—only to find the houses numbered, sprayed with DDT, and visited regularly for collection of blood slides. Where there are people in malarious areas, the malaria program staff has been there. This prompted D. K. Viswanathan (1958) to make the statement that only the collector of taxes and the malaria worker visit every house of India. The malaria worker for

the most part is a welcome visitor because he performs a personal service for each individual. He sprays the house; he dispenses antimalaria drugs. According to Viswanathan, the DDT spraying may be the first positive government benefit that has ever been apparent to villagers. Throughout many nations of the world the malaria eradication programs have helped significantly to strengthen the image of the respective governments.

3. *Skills developed*

Skills must be developed and people employed to carry on a wide diversity of tasks. Microscopists must be trained; house visitors learn the techniques of interview, making of blood slides, and administration of drugs. Many spraymen are hired to apply insecticides. Drivers and mechanics for vehicles were practically nonexistent in some areas before the program started. In many countries vast malaria training programs, ranging from maintenance of hand-compression sprayers to advanced courses in epidemiology of malaria, have developed a large number of trained personnel. Although the skills are put to use in the malaria program, many of the trained persons not only advance to higher positions in the malaria eradication program but also are utilized in other programs as they learn and gain experience. University training often is provided to capable technicians. The numbers employed are large. In India, more than 200,000 malaria workers were employed at the peak of the program with approximately 150,000 presently employed. In Haiti today, the malaria program probably is the single largest employer of people in the country. The effect of the malaria program in terms of developing skills and employment of local personnel has been a significant factor in the Haitian national economy.

4. *Strengthens governmental relationships*

Malaria eradication programs have provided a common bond to strengthen relationships between neighboring countries or between dissident groups within nations. India and Pakistan for years have had frequent conferences to solve common problems of malaria transmission in border areas. This also has been done by Vietnam,

Cambodia, Laos, Thailand, Burma, and Malaya starting in the 1950's through the Anti-malaria Coordination Board of these six countries. Thailand provided a team to Laos for several years to assist with the organization and execution of the program there. The Malaria Eradication Services of Jordan and Israel coordinated their findings for many years through the good offices of the WHO Eastern Mediterranean Regional Office.

Within countries with internal disorder, dissident groups sometimes have not welcomed central government authorities in their territory—but malaria workers frequently are requested to provide their services. In Indonesia during the 1950's, anti-government forces were permitting and even asking government malaria teams to spray their houses.

5. *Health programs developed*

Perhaps some of the most lasting values derived from malaria eradication programs are those of organization and development of health programs in general. When malaria was selected as a prime target by the Pan American Health Organization (PAHO), WHO, United Nations Children's Fund (UNICEF), and the U. S. Government, it already had been determined that the disease normally would respond to certain treatment directed at the mosquito vector and the parasite itself. Organization of national and international resources was required on a worldwide scale. The sheer magnitude of the program and its popular appeal led to strengthening of the international health agencies. Within the individual countries, it also was necessary to develop strong organizations to carry out the national malaria eradication programs in conformance with the international guidelines. This, therefore, required training of professional personnel, establishment of an administrative foundation (including necessary legislation), increasing of health budgets, and health education measures to acquaint the public with the problem and solutions.

Malaria is a disease which has such a strong adverse effect on people that intense efforts are made to eliminate it. Fortunately the disease usually responds to these efforts, and the elimination or reduction in incidence often produces dramatic results. The

population often responds in an understandable manner. When freed from the oppression, they are grateful. However, they also become more demanding. During the 1965 visit to Karikal, India, where a successful malaria eradication program had reached its maintenance phase, the Deputy Mayor made a speech to the visiting independent appraisal team of which the writer was a member. The Deputy Mayor profusely thanked the Governments of the United States and India for the cooperative efforts that had resulted in the elimination of malaria from Karikal. He went on to say that one of the important lessons that he and his people had learned from this program was that the control of disease over a wide area is possible—something that they had not realized previously. Now, as a result of this successful effort, they were determined to attack other public health problems because they could never again be content in letting controllable diseases go uncontrolled.

Gabaldon (1968) stated that the malaria eradication service should eventually be transformed into a vector-borne disease control organization. The WHO Expert Committee on Malaria (1957) endorsed the idea that, where a national public health service is not adequately developed, the malaria eradication service of the country will serve as a nucleus around which an efficient public health service may be built. In this country, the Malaria Control in War Areas program of the U. S. Public Health Service in World War II became what now is the National Communicable Disease Center in Atlanta. In India, the Central Malaria Bureau founded in 1909 eventually became the Malaria Survey of India, then the Malaria Institute of India, and in 1963 widened its scope and became the National Institute of Communicable Diseases. In Iran, the School of Public Health of Teheran University developed as an offshoot of the Institute of Malariology.

So it has been in many places. Malaria eradication leads to development of other health programs. In Dinajpur, East Pakistan, smallpox eradication activities were tied into the malaria program in an experimental trial because health authorities observed the great success of the malaria eradication organization. During the consolidation phase of malaria eradication, the house visitors, in addition to taking blood slides and administering drugs, were

trained to perform smallpox vaccinations and certain other duties. This was tried in an area of 150,000 persons. It was learned that approximately one-third more house visitors were needed to perform the combined tasks with a considerable saving in costs due to consolidation of duties primarily performed by individuals specializing only in one disease. Despite certain administrative drawbacks, the integration of these programs was a step toward eventual progression from malaria eradication toward a full public health program for the rural areas of Pakistan.

6. *International cooperation developed*

U. S. Government foreign aid assistance to the malaria eradication program has been of mutual benefit to the United States and various other governments, not only in economic aspects, but also because of favorable international relationships that have developed through the program. Johnson (1966) reviewed the development of the U. S. Government aid to the international campaign from its inception to 1966. The program has been an effective method of assisting 30 countries³ to varying degrees since 1958. At present, the National Communicable Disease Center (NCDC) through a Participating Agency Service Agreement with AID continues to work with 18⁴ of these countries.

This assistance has helped to engender strong favorable relationships through the development of healthier populations and stronger economies in these countries. This, in turn, also has helped create new markets for U.S. products abroad. It has helped to permit more economical production through elimination of what Pampana and Russell (1955) describe as a 5 percent hidden cost attributable to malaria. Based on the actual expenditures for antimalaria measures by

commercial enterprises in malarious areas, they estimated that the cost of imports of minerals, hardwoods, coffee, cocoa, vegetable oils, waxes, and fruits from malarious countries are increased by at least 5 percent.

Not only does elimination of this extra cost help U.S. economy, but most of the dollar assistance we have provided to these countries is in the form of commodities purchased from U.S. manufacturers. For the 11-year period starting in 1958, the United States has either loaned or granted some \$219 million to these countries for malaria eradication. DDT, spraying equipment, vehicles, drugs, laboratory equipment—almost all purchased in this country—have been shipped overseas, with most of the dollars staying in the United States.

7. *Technological benefits to control of other vector-borne diseases*

The direct relationship of antimalaria activities to general vector control methodology is obvious. The malaria eradication activities are in large part anti-anopheline in nature. As a result, a great deal of developmental work and research has been in the field of insecticides and application equipment. The major use for DDT exported from this country during the past decade has been in the malaria program. As a result of problems experienced with early DDT formulations, water dispersible powder formulations have been improved tremendously during this time, principally because of studies carried out by the Technical Development Laboratories (TDL) of NCDC at Savannah, Georgia, in cooperation with the commercial formulating companies. Application equipment also has undergone important changes as a result of government-industry cooperation.

New insecticides or other control methods have been developed. For example, developmental work on DDVP (dichlorvos) was done by TDL in connection with the malaria eradication program, resulting in the "residual fumigant" principle whereby DDVP was formulated with wax or plastic in order that slow release of toxic vapors would take place over a period of many weeks. Many malaria research projects financed by the U.S. Government, WHO, PAHO, and other organizations on various aspects of anopheline mosquitoes and their control affect the entire field of vector control.

³ *Far East*—Cambodia, China (Taiwan), Indonesia, Laos, Philippines, Thailand, Vietnam.

Near East and South Asia—Ceylon, India, Iran, Jordan, Nepal, Pakistan.

Africa—Ethiopia, Liberia, Libya.

Latin America—Bolivia, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru.

⁴ Brazil, Costa Rica, Ecuador, El Salvador, Ethiopia, Guatemala, Haiti, Honduras, India, Jordan, Nepal, Nicaragua, Pakistan, Panama, Paraguay, Philippines, Thailand, Vietnam.

8. Other insects and diseases controlled

Species of insects other than anophelines sometimes are controlled as a result of the attack phase measures, and diseases in addition to malaria may be alleviated. Ants, fleas, scorpions, mosquitoes, spiders, termites, and even rodents may be controlled by the malaria eradication program spray treatment; but such relief may only be transitory.

Phlebotomus flies often are controlled by the residual application of DDT to the inside of the houses. As a result, visceral leishmaniasis (kala azar) and cutaneous leishmaniasis (oriental sore) where present usually disappear, at least temporarily, during the course of malaria eradication program attack measures. The same is true of sandfly (or pappataci) fever, which is caused by *Phlebotomus*-borne viruses. This has been noted in India, Pakistan, and other Asian countries. Yellow fever, dengue fever, and hemorrhagic fever may be reduced if *Aedes aegypti* is susceptible to the residual house spraying measures. Plague often has been reduced or eliminated because of destruction of fleas by the DDT house treatment. In Venezuela, dieldrin has been used as a residual spray to control both anopheline vectors of malaria and triatomid vectors of Chagas' disease. Filariasis control has sometimes been combined with control of malaria, where the mosquito vectors are susceptible to DDT. The mosquito-borne viral encephalitides also may be reduced by the insecticide spraying operation.

MEASUREMENT OF ACHIEVEMENTS. One of the frustrating problems faced by malariologists is that it is so difficult to quantitate accurately the effects of malaria suppression or elimination. It is known that many beneficial effects have resulted from the control or eradication of this disease. However, the public health workers have not adequately quantitated the before and after effects of malaria.

The Director General of WHO (WHO, 1968b) called for a reexamination of the global strategy for malaria eradication as a result of a resolution of the Twentieth World Health Assembly. He listed as one of the main problems the "... lack of

complete and accurate information on the impact of malaria on the social and economic conditions in countries where the disease occurs. . . ." At the Twenty-second World Health Assembly in Boston, the Assembly passed a resolution (WHA, 22.39, July 24, 1969) "... recognizing the part played by socio-economic, financial, administrative and operational factors . . ." and recommended that WHO "... continue to provide assistance for the study of the socio-economic impact of malaria and of its eradication and develop a methodology for the socio-economic evaluation of the programmes under way . . ." The Assembly further recommended that WHO stimulate and intensify multidisciplinary research on malaria, including the economic and social aspects.

Hopefully, various studies will be initiated as a result of experience to date. Only if accurate, pertinent, and convincing data acceptable to the economists, the administrators, the Ministers of Finance, and the heads of governments are forthcoming will the financial and human resources required to continue the task of eradication be made available.

CONCLUSIONS. The accomplishments of malaria eradication activities are impressive. Of the 1.7 billion persons living in malarious areas, 1.35 billion now are protected by the program. Many of these people now are living under improved economic conditions as a direct result of the removal of the malaria burden. Elimination of malaria has many effects such as development of sections of countries where malaria presence precluded adequate agricultural or industrial utilization. As a result, land values often increase dramatically after the program is instituted.

Some of the auxiliary, lesser known benefits also are of significance in the developing countries where the programs are in progress. Malaria eradication activities require mapping of all portions of a country and an accurate census. Often the malaria geographic reconnaissance

results in the development of the first accurate maps and census. Also, the rural populations in particular are visited by government workers who are doing something positive for the people. The DDT application inside of their houses not only makes life more pleasant for them by reducing the anopheline mosquito population, but even more important thereby helps to reduce malaria transmission. Antimalaria drugs given to the people on a regular basis further strengthen the government image in the minds of these people. Of less significance perhaps, but also helpful to the government, is the fact that other arthropods of public health or pest importance may be reduced in numbers by the insecticide.

Frequently the malaria program is of major importance in strengthening the health programs in general because of its good organization and thorough implementation over an entire country. The malaria eradication effort makes a people conscious of effective public health operation, and they demand more extensive and intensive health programs. People receive training who may never have had the opportunities to learn a skill, because the antimalaria organization requires certain specialties normally not available in some countries (e.g. microscopists, health visitors).

Not only may relationships within countries be improved, but neighboring nations usually cooperate in an excellent manner when common border malaria problems are to be solved. Malaria eradication activities also are an important segment of international cooperation of the U. S. Government, resulting in mutually beneficial relationships between the U.S. and the assisted countries.

Finally, malaria eradication problems have resulted in operational research activities that have been instrumental in development of new insecticides, improved application equipment, additional drugs for parasite control, and other methods of vector control applicable to a wide range of entomological problems. These con-

tinuing studies hopefully will provide still further benefits to mosquito control and other public health workers everywhere.

The program has been the major cooperative health activity of many nations of the world assisted by WHO, PAHO, UNICEF, and the U.S. Government. It has represented the largest single health expenditure of many governments, but the returns to mankind have been impressive indeed.

References Cited⁵

- ANON. 1968. Government of India National Malaria Eradication Programme—4th Five Year Plan (1969-1970 to 1973-1974). (mimeo. document)
- AYURAKIT-KOSOL, LUANG, and GRIFFITH, MELVIN E. 1962. Progress toward malaria eradication in Thailand. Proc. 9th Pac. Sci. Cong. 1957, pp. 122-136.
- BRADLEY, GEORGE H. 1966. A review of malaria control and eradication in the United States. Mosq. News 26(4):462-470.
- BRUCE-CHWATT, L. J. 1965. Malaria research for malaria eradication. Trans. Roy. Soc. Trop. Med. & Hyg. 59:105-137.
- GABALDON, ARNOLDO. 1968. Global malaria eradication: changes of strategy and future outlook. Presented at 8th Int. Cong. on Trop. Med. & Malaria, Teheran, Iran, Sept. 1968. (mimeo. manuscript)
- JOHNSON, DONALD R. 1966. Development of the worldwide malaria eradication program. Mosq. News 26(2):113-117.
- PAMPANA, E. J., and RUSSELL, PAUL F. 1955. Malaria, a world problem. WHO Chron. 9:31-100.
- RUSSELL, PAUL F. 1968. The United States and malaria: debits and credits. Bull. N. Y. Acad. Med. 44(6):623-653.
- SINTON, J. A. 1935-1936. What malaria costs India, nationally, socially, and economically. Rec. Malaria Survey of India 5:223-264, 413-489; 6: 91-169.
- SMITH, H. F. 1950. United States-Public Health Service Report of Philippine public health rehabilitation program. July 4, 1946-June 30, 1950. 59 pp.
- VISWANATHAN, D. K. 1958. The conquest of malaria in India, an Indo-American cooperative effort. Madras, India, Company Law Institute Press. 93 pp.
- WILLIAMS, LOUIS L., JR. 1938. Economic im-

⁵ Original sources for some of the data and other information on international programs are contained in the files of the Malaria Eradication Program, NCDC, U. S. Public Health Service, Atlanta, Georgia,

portance of malaria control. Proc. N. J. Mosq. Exter. Assn., 25th Ann. Meet., New Brunswick, pp. 148-151.

WORLD HEALTH ORGANIZATION EXPERT COMMITTEE ON MALARIA. 1957. Sixth Report, WHO Technical Report Series No. 123. 84 pp.

WORLD HEALTH ORGANIZATION. 1963. Official records of the World Health Organization No. 127. Sixteenth World Health Assembly, Geneva, 7-23 May 1963. WHO, Geneva. 212 pp.

WORLD HEALTH ORGANIZATION. 1968a. Report

on development of malaria eradication programme. 21st World Health Assembly A21/P&B/1, 13 Mar. 1968. (mimeo. document).

WORLD HEALTH ORGANIZATION. 1968b. Re-examination of the global strategy of malaria eradication. Report of the Director-General. A21/P&B/12, 29 Apr. 1968. (mimeo. document).

WORLD HEALTH ORGANIZATION. 1969. Report on development of malaria eradication programme. WHO Exec. Bd. 43rd Session. EB 43/23, 4 Jan. 1969. (mimeo. document).

TECHNIQUES FOR SUCCESSFUL COLONIZATION OF MANY MOSQUITO SPECIES¹

H. C. CHAPMAN² AND A. R. BARR³

Although much has been written about the colonization of mosquitoes, most reports refer to the colonization of a single species. Trembley (1955) listed the species that have been colonized and the various techniques used. The purpose of the present paper is to report on a rather simple method of handling that has enabled us to colonize a substantial number of mosquito species at Fresno, California and Lake Charles, Louisiana laboratories without resorting to forced mating.

MATERIALS AND METHODS. Rearing procedures were much the same in the two laboratories. Adult insectaries were maintained at a temperature of about 27° C. and 70-80 percent R.H., and colonies were started from field collections of either late-instar larvae or inseminated adults. The F₁ generations were placed in 18 x 24 x 24 in. or smaller cages.

Adult mosquitoes were provided with raisins, and most species were also offered a host (a guinea pig in Lake Charles and

a chicken in Fresno) several times a week. Also some species such as *Culex apicalis* Adams, *C. boharti* Brookman and Reeves, *C. peccator* Dyar and Knab, *C. reevesi* Wirth, *C. territans* Walker, and *Uranotaenia anhydor* Dyar had continuous access to toads maintained in the laboratory by forced feeding with ground meat.

Oviposition containers of many kinds, depending on the mosquito species involved, were kept in the cages. The natural light that entered the adult and larval rearing rooms in Lake Charles was supplemented with about four hours of artificial light during the fall, winter, and spring. At Fresno, about 16 hours of artificial light were provided in both rooms. The larval rearing rooms at both laboratories were maintained at about 27° C. Newly hatched larvae were reared in white enamel pans and most were aerated continuously (Fig. 1); also, the larvae were periodically provided with high protein pellets or rabbit chow (whole or pulverized). *Anopheles* larvae normally were not aerated and were generally fed pulverized food.

RESULTS AND DISCUSSION. As shown in Table 1, 25 species of mosquitoes were colonized from wild material and maintained in colonies for various periods. The first colonization of *Aedes tormentor*,

¹In cooperation with McNeese State College, Lake Charles, Louisiana 70601.

Presented at the 25th annual meeting, American Mosquito Control Association, Williamsburg, Va.

²Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Lake Charles, Louisiana 70601.

³School of Public Health, University of California, Los Angeles, California 90024.