STUDIES ON THE CONTROL OF *CULEX PIPIENS FATIGANS* WIEDEMANN

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I. INTRODUCTION. The WHO Filariasis Research Unit was established in Rangoon, Burma, in October 1962 under an agreement with the Government of Burma and the World Health Organization.[6] Rangoon was selected as the site for the unit because the disease was endemic in the area and only limited control work had been done. The Revolutionary Government of Burma and the Directorate of Health were most cooperative and laboratory space was made available at the Harcourt Butler Institute (now the Burma Medical Research Institute).

In the words of the agreement, the objective was "to perform entomological, taxonomic, ecological, genetical, serological and parasitological research directed towards the development of methods and techniques for the control" of *Culex pipiens fatigans* Wiedemann, the main mosquito vector of bancroftian filariasis in Rangoon.

The aims and objectives of the FRU have been simply but more precisely stated as follows: [7]

(1) Investigation into quantitative and qualitative biology of *Culex fatigans* with a view to establishing methods of assessing changes in the population following control (1963–1965).

(2) Determination of baseline data on susceptibility to insecticides and the selection of the most appropriate ones for trial (1963–1965).

(3) Small scale field trials for the insecticide selected (1965–1966).

(4) Establishment of methods for epidemiological assessment (1965).

(5) Institution of a large-scale field trial during which the assessment technique developed will be put under test (1966–1967).

The work of the FRU to date can be divided into four phases. The first phase, from October 1962 to June 1963 was devoted to planning, to training the national staff and to preliminary studies of *C. p. fatigans*. The second phase, from June 1963 to December 1965, was a period of intense activity during which extensive studies were conducted on the biology and ecology of the vector, on parasitology and epidemiology, and on insecticidal control. Much of the work done during this phase has been reported in the *Bulletin of the World Health Organization*, 36, No. 1. The third phase of the unit's work was control of the vector in a small area of the Kemmendine section of Rangoon based on the information obtained in studies conducted in the second phase. This area was designated as the Kemmendine Experimental Field Trial or KEFT. Epidemiological assessment to determine if vector control has interrupted transmission will be conducted in KEFT. The fourth phase of the unit's work was the expansion of control in January 1967 around

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[7] Inter-regional Seminar on Filariasis, Manila, 22 November–1 December, 1965, WHO/Fil/66.47.

KEFT to include a total control area of 1.56 square miles (4.0 km^2) surrounded, where possible and necessary, by a barrier zone of about 1,000 ft wide (304.8 m) where control was also in effect (Fig. 1). The new area was called the expanded area, EA, and it and KEFT together were called the control area or CA.

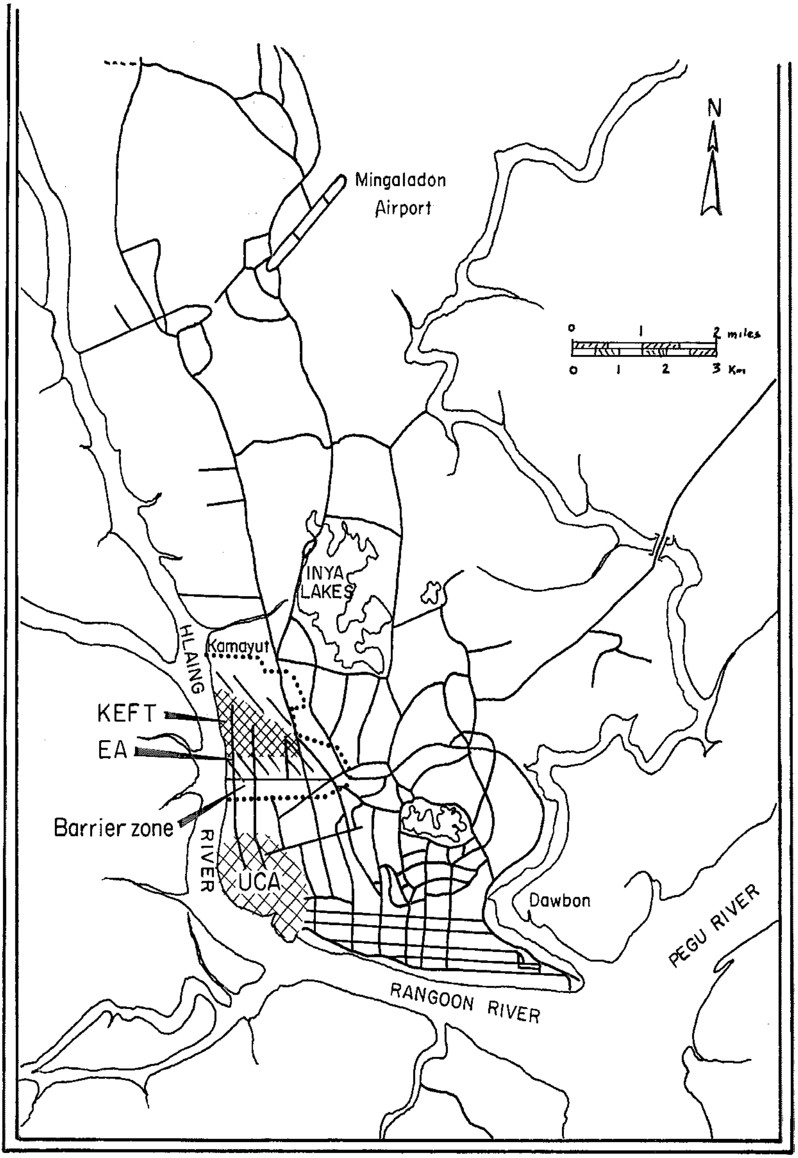

Fig. 1.—Map of Rangoon showing areas of city used for FRU studies.

The expansion to 1.5 square miles (4 km^2) of control area was necessary to give information on problems and costs of a larger control area and to provide additional protection against mosquito infiltration into KEFT where epidemiological evaluation will take place. The barrier zone gives protection to both EA and KEFT. Lindquist *et al.* (1967) found that about 80 percent of the tagged and released *C. p. fatigans* travel 1,800 ft. (549 m) or less. Present procedures provide for 3,000 ft. (914.4 m) of controlled area between KEFT and major producing areas. Evaluation of control is made in the controlled area but not the barrier zone. The barrier zone apparently is functioning effectively in keeping the number of mosquitoes entering CA from unsprayed areas very low since most mosquitoes found in both KEFT and EA appear to come from missed sources in the control area.

Final determination of the effects of larval control of the vector on transmission of filariasis is not yet possible and is not considered here. In regard to this, Abdulcader (1971) states:

> The effect of the control measures on the transmission of filariasis is at present difficult to assess, owing to the long prepatent period in bancroftian filariasis and to the persistence of microfilaraemia for periods of up to ten years. Blood surveys of Burmese schoolchildren aged 5–14 years in 1968 and 1969 recorded a fall in the number of positive cases in both sprayed and unsprayed areas—in the former by 63.6 percent and in the latter by 58.3 percent. These figures merely show that it is still too early to assess any change in the rate of transmission of the disease. Indeed, the results will be apparent only in children born in the experimental area after April 1967, when the extended spraying programme was effectively established. As school entry in Burma is at age 4 years 9 months, changes in the microfilaraemia status of the youngest age group of schoolchildren cannot be expected before 1972.

This paper is primarily concerned with the procedures and results of the third and fourth phases of the work from April 1966 until 31 May 1970.

II. THE MOSQUITO CONTROL PROBLEM. De Meillon and others (1967a) as part of the unit's work during the second phase found that *C. p. fatigans* rests in large numbers in out-of-doors shelters of various kinds and will bite readily in this environment. Since many of the residents of Rangoon frequently sleep out-of-doors during the hot season, an indoor spraying program would not be satisfactory and a larvicide program was adopted. Fenthion was selected as the larvicide of choice because it was found to be effective against larvae of *C. p. fatigans* at low concentrations and persisted longer than other available organophosphorus insecticides in the polluted larval habitats of Rangoon.[8] Rosen (1967) tested DDT and dieldrin against larvae from 17 different habitats in Rangoon and found that part of each population was resistant. Tadano and Brown (1966) showed that some populations were resistant to DDT and some other chlorinated hydrocarbons and it is probable that resistance would develop soon if these compounds were used. They also conducted tests with fenthion, the results of which indicated that resistance to this compound would not develop readily. Hamon and Mouchet (1967) also indicate that chlorinated hydrocarbons are apt to be unsatisfactory for long-term larviciding of *C. p. fatigans.*

Fenthion, known also as OMS 2, was tested as part of a regular WHO insecticide testing program which involves careful laboratory testing followed by extensive and intensive field testing procedures under a variety of conditions and for a variety of uses.

Fenthion has now been in use for larviciding for well over 3 years in Rangoon and routine susceptibility tests using larvae from the control area show no indications

[8] Insecticides studies carried out at the Filariasis Research Unit. Inter-Regional Seminar on Filariasis, Manila, 22 November–December 1965 Fil/WP/8.65 Rev. 1.

of resistance (Self and Tun, 1970a). The FRU and WHO collaborative laboratories elsewhere have conducted tests with a number of other compounds in order to have information on which to base a change to another toxicant if resistance to fenthion does develop. The results of this testing program have been reported by Self and Tun (1970b).

The area selected for control (KEFT) in March 1966 was chosen because larval surveys by Khan[9] had shown that mosquito populations were high and nearly all the types of larval habitats of *C. p. fatigans* in Rangoon could be found in KEFT. Also, the government wished control to be done in this poorly developed area with high mosquito densities and human microfilaraemia cases. The sources for this species listed by Khan are pukka drains, kutcha drains, septic tanks, soakage or catch pits, underground drains, culverts and grit chambers, latrine sumps, masonry tanks, unused wells partly filled with rubbish, road puddles and excavations, artificial containers, tree holes, and overhead water storage tanks. The last two are minor sources and generally have been ignored by the control program.

Pukka drains are well-engineered, cement-lined drains serving to carry sewage and other waste water away from populated areas. They were originally designed to carry rain water and other waste water but the increase in human population without a similar increase in sanitary facilities has necessitated these drains being used for additional functions. When the drains are clean, water flows readily and mosquito production, if it occurs at all, is low. However, the drains are frequently blocked by debris and rats, causing highly polluted water to back up, become stagnant and produce large numbers of *C. p. fatigans*. Garbage and refuse collection is not adequate in KEFT and many other areas of Rangoon resulting in accumulations of trash near the drain and frequently partially filling the drains. The rat population is high and in many places dirt from their digging also accumulates in the drains. Cleaning is sporadic and inadequate, and pukka drains are consequently the most prolific sources of this mosquito in Rangoon.

Kutcha drains are unlined channels dug in the earth which vary greatly in both depth and width. Even when the drains are clean they still have accumulations of water because the bottoms are not smooth or even. These drains are important mosquito sources during the monsoon but become less important during the dry season when most of them dry up completely.

Soakage or catch pits as well as road puddles and excavations are similar to kutcha drains in that they represent accumulations of water in excavations in the earth. Soakage pits are dug to collect domestic water and keep it from spreading. In many cases soakage pits are really deeper excavations in a kutcha drain but in some cases no connecting drain exists between soakage pits. Latrine sumps are a similar control problem, differing only in their location and contents and breeding is more intense during the rainy season when the contents of sumps become diluted.

Septic tanks are readily defined sources and in most instances easily controlled. Control problems develop when access to the tank for spraying is difficult, but open or partially covered tanks may be more attractive to ovipositing females.

Underground drains, culverts and grit chambers normally do not contribute to mosquito populations during the wet season but during the dry season water sometimes becomes stagnant because of retarded flow and debris clogging the drain. At this time underground drains may become serious control problems, largely because of the difficulty involved in treating them.

Wells are suitable habitats for *C. p. fatigans* when they become filled with

[9] FRU/Report No. 13. The *Culex pipiens fatigans* larval survey in the Kemmendine experimental area. June 1963–May 1964. WHO/Vector Control/137.65.

debris and other pollutants, but in the Kemmendine area positive well sites are normally too few to pose a serious control problem; moreover, during the monsoon period the pollution is so dilute that the water is not so attractive to ovipositing females. As long as the water remains clean enough for human use, including bathing, it is usually not a larval habitat for *C. p. fatigans*.

Masonry tanks listed by Khan can best be considered with other artificial containers which include barrels, wooden tubs and various types of earthen jars, called pegu jars, used for water storage. These sources are generally not major contributors to the vector populations but some sections of the control area have so many of these small sources that they do become important contributors to the control problem. Many of them are difficult and time-consuming to find. Water must stand in small containers long enough to become polluted and frequently the broken and discarded containers become the worst offenders because they are ignored. Water barrels that are being used produce *Aedes aegypti* (L.) but usually not *C. p. fatigans*.

The increase in human population without a corresponding increase in sanitary facilities, and, in fact, to some degree a deterioration and decay of existing sanitary facilities have led to greater accumulations of polluted water and consequently greater numbers of *C. p. fatigans*. Jolly (1933) reports *Culex fatigans* as being almost as abundant as *Aedes argenteus* (=*A. aegypti*) and states "for example an uncovered drain extending along a whole street in the modern city area was observed to be swarming with larvae of this mosquito."

Similar conditions exist in most of the drains today and it is inconceivable that anyone now would use a single drain as an example without mentioning that it was a typical condition. *Aedes aegypti* is still common in Rangoon but is not nearly as abundant as *C. p. fatigans*.

Larviciding was selected as the vector control procedure to determine if this relatively simple procedure would effectively reduce populations and interrupt transmission of filariasis. In an integrated vector control program many other procedures should also be used. The elimination or reduction of polluted water would be such a procedure and would be particularly effective in situations like Rangoon.

A general improvement in sanitation procedures along with a complete sewage disposal system would largely eliminate the problem there. In present circumstances costs of complete sewage disposal may be prohibitive but some useful action can be taken. Cleaning and flushing of pukka drains would greatly reduce the problem and cost relatively little. Properly constructed and maintained septic tanks would also effectively reduce mosquito production.

These procedures are now being used in Rangoon since the program has moved into more of an operational program and the results are promising. As the program continues to develop, reductions in sources of *C. p. fatigans* should continue until all kinds are greatly reduced in number or eliminated entirely.

III. CONTROL PROCEDURES. The control area is 1.5 square miles (4 km^2) and is surrounded, where possible and necessary, by a barrier zone, also under control, about 1,000 ft. (304.8 m) wide. The control area is divided into six zones and each zone is further divided into three sub-zones. A spray team consisting of two men is assigned to each zone and is to cover each sub-zone in about a day. An additional spray team is also assigned to the barrier zone. Three of the better spraymen are assigned to the position of "floater." "Floaters" fill in when spraymen are absent, check behind the spraymen for missed sources and perform other miscellaneous tasks.

Spraymen, "floaters," and their supervisors report at 6:30 a.m. and continue until 12:30 p.m. This time schedule helps avoid most of the rains during the monsoon season and avoids the hottest part of the day during the dry season.

Counting the 12 spraymen and the 3 "floaters," there are 15 men available to spray sources of *C. p. fatigans* in the controlled area of 1.5 square miles (4 km^2). Several factors necessitate this large number of men. The FRU is, as the name implies, a research unit and some of the duties of the Control and Evaluation Section involve the collection of data. There are, for example, 22 permanent stations for the collection of mosquitoes resting indoors or biting outdoors. In addition, on each Monday morning, outdoor resting collections are made. Most spraying should be completed in 3 days with perhaps some left over for part of the fourth day. In actual practice, spraying sometimes goes on for 5 days because of the number of men on leave.

Each team of two men has to cover one quarter of a square mile (2.6 km^2) per week. If this were open water with easy access it would be much easier to treat and would take less time. Much time is consumed searching for and treating many varied sources. Septic tanks, for example, require that the lid be lifted for spraying. Since the human population is dense and the dwellings close together, there are sometimes several septic tanks in a limited area. Problems of this type are time-consuming. Treatment of some septic tanks requires that the home owner be called to the door, an explanation made as to what needs to be done and why, and then a sprayman goes through the house to treat one or two small sources. In some areas several hours can be consumed in this manner and only a short distance covered.

The insecticide of choice, fenthion 50 percent emulsifiable concentrate, is distributed to the spraymen each morning in 55 cc plastic vials. The vials are prepared at the Kemmendine depot by a "floater" using rubber gloves and a protective rubber apron, both of which can be readily washed. The spraymen are provided with plastic gloves so that there need be no direct contact with the concentrate. Each vial contains enough concentrate for one loading of a Hudson X-pert compression sprayer that holds approximately 2 gallons of ready-to-spray liquid when loaded. This amount of concentrate was selected to give approximately 1 ppm of fenthion in pukka drains after spraying. This concentration is about 100 times the LC_{95} value in clean laboratory water but was selected, after field tests, because of its effectiveness for a longer period of time in the drains and other stagnant sources, and also to allow for normal variation in spraying procedures and water depth of the treated site. In actual practice, it is possible that normal spraying procedures may result in control failures because the concentration in the water does not remain at a lethal level long enough, for example, in larger drains with slow water flow with depths sufficient to maintain larvae. Heavy downpours during the monsoons flush out insecticide and larvae.

Self and Tun (1970b) have summarized the results of the unit's insecticide field trials for the period of 1964–1969. Fenthion at 1.0 ppm was normally effective for 11, 21 and 28 days in stagnant concrete drains, pit latrines and septic tanks, respectively. Dursban was found to be more effective after the control program started, and high oil dosages were required to obtain at least 1–2 weeks of field activity similar to that of certain organophosphorus emulsion concentrates.

After spraying, a post-treatment inspection is conducted by the "floaters" and other supervisory personnel of the unit. Since there is not enough time for the supervisory personnel and the "floaters" to cover all the sources, post-treatment inspection is done on a random basis. Whenever missed sources are found the spraymen are brought back to retreat the area.

Pegu jars and other small containers are generally emptied rather than sprayed, and the owner is notified of the reasons and asked to cooperate with the program by preventing such accumulations of water. The paramedical personnel of the Health Department also render assistance in this respect.

Control is done on a weekly basis because this schedule is convenient and should normally kill all the larvae before they change to pupae which are much more resistant to insecticides than the larvae. There is a possibility that this schedule, under certain conditions, would permit some eggs to hatch, and larvae to mature between sprayings if little residual effect was obtained in the treated habitat such as flowing drains. De Meillon *et al.* (1967b) found that in the laboratory the duration of larval life was less than 6 days. However, since spraymen also treat sources with egg rafts, the danger of larvae maturing between sprayings is reduced. Moreover, application to stable sources such as some septic tanks may remain effective for 2 or more weeks and kill newly hatched larvae on holidays when spraymen are not working.

IV. RELATIVE COSTS OF LARVICIDING WITH OIL AND FENTHION. Besides the area under control by the FRU, the city of Rangoon is currently conducting a mosquito control program using a light oil as a larvicide. This program is considerably less effective than the one conducted by the FRU, so much so that the FRU is using a part of the area controlled by the city as an "unsprayed check area." Although observations in this area indicate that the city's program destroys some larvae, the adult populations remain much higher, as much as 50 times higher during some periods than in the area controlled by the FRU.

Since oils of various types have historically been used as a mosquito larvicide and are still widely used today in many areas besides Rangoon, an analysis of relative costs and effectiveness of oil and fenthion in Rangoon is appropriate.

There is no question that mosquito larvae can be destroyed by oil sprayed on the larval habitat and that larval mortality can be 100 percent when adequate amounts of oil are properly applied. Experience with oil in mosquito control programs in the United States has shown that 30 to 50 gallons (113–199 litres) of oil per acre (0.4 hectare) were required for adequate larval control but this amount for various reasons such as wind or vegetation did not always result in 100 percent control. Some promising results have been reported with low gallonage treatments. However, to obtain residual effectiveness of at least 1 week, the FRU had to apply dosages equivalent to 80 gallons (302.4 litres) per acre (0.4 hectare) in pukka drains. Applications of 175 gallons (661.5 litres) per acre (0.4 hectare) to septic tanks were effective for only about 2 weeks despite the stability of the habitat (Self and Tun, 1970b).

The cost of oil at these concentrations approximates the cost of fenthion applied at 1 ppm which is about 20 times higher than dosages normally used for mosquito larviciding. Even at these high concentrations the cost of the toxicant is a very small fraction of the total costs involved in control and if other factors were equal there would be little to choose between them, but other factors make oil much less desirable than fenthion.

Oil, as stated above, can be an effective larvicide when properly applied in adequate quantities, but relatively large quantities are required, particularly if some residual effectiveness is desired. Fenthion in water can be applied at 1 ppm at rates equivalent to 4 to 5 gallons (15–19 litres) of finished spray per acre (0.4 hectare). Oil must be applied for consistently similar results at concentrations at least 10 to 20 times as high. Any saving which might be achieved with oil produced locally and inexpensively would be quickly dissipated in labor costs. In addition, oil is less pleasant to handle than emulsifiable concentrates with water as a carrier and proper application of oil requires rigorous supervision of spraymen. Also problems of logistics exist in transporting oil in sufficient quantities to field depots and into the actual area to be treated. Water is readily available in the areas under treatment in Rangoon and the daily required concentrate of fenthion is easily carried into the field.

A direct comparison of the mosquito

control program of the city of Rangoon and that of the FRU is not possible because the city's program is strictly operational and that of the FRU is for the most part research. Supervision in the FRU is generally related to research activities, particularly in regard to some evaluation procedures. Converting the FRU to a strictly operational program and curtailing research activities would permit a substantial reduction in supervisory and evaluation procedures without reducing control effectiveness. For the city of Rangoon, using oil as a larvicide, to approach the level of control obtained by the FRU using fenthion emulsifiable concentrate would require a great increase in labor, supervision and almost certainly the quantity of oil used. It would likely necessitate basic and more expensive changes in control procedures.

The problems involved in the transportation and spraying of oil make its use too costly in an effective large-scale larvicidal program regardless of the initial cost of the oil when a suitable emulsifiable concentrate is available.

V. METHODS OF EVALUATING CONTROL. In order to evaluate the effectiveness of control a check area was selected south of the control area. The unsprayed check area (UCA) was as similar to the control area as possible but it was not completely satisfactory because mosquito production was not as great and the rate of *Wuchereria bancrofti* (Cobbald) infection of the mosquitoes was less than in the control area. In addition, the UCA is under mosquito control by the Rangoon Corporation which is using oil as a larvicide. All of these factors made the UCA less productive of mosquitoes than KEFT and EA would have been without control. Comparisons of mosquito populations in CA and UCA after control in CA probably indicate less of a reduction for the controlled area than has occurred. KEFT and the area around it, EA, were selected because of the very large numbers of mosquitoes produced there and because of the variety of control problems present. All types of *C. p. fatigans* sources found in Rangoon are found in Kemmendine.

Knight (1964) reviewed the methods of measuring larval populations but none of them are applicable to the situation in Rangoon and none are designed to measure larval populations over a wide area. Graham and Bradley (1962) have developed and used methods of measuring relative larval populations over wide areas but these procedures have required the use of graduate students in entomology for data collection and could not be applied even if the problems in Rangoon were similar.

Evaluation of control is done with both larval and adult populations in CA and UCA. Larval surveys are conducted by both the Research and Development Section and the Control and Evaluation Section of the FRU. Studies conducted by the Research and Development Section (Self *et al.*, 1971) show there is a wide diversity in the productive potential of the various larval habitats of *C. p. fatigans* in Rangoon and methods for accurate quantitative determination of the numbers produced by each type of habitat are either lacking or too cumbersome for practical application. They took the only practical course of listing the types of habitats and comparing the numbers and percent positive in the controlled areas and the unsprayed check area. Their data support data presented below that indicate control procedures were extremely effective in reducing numbers of the vector.

Measurements of adult populations are made in three different ways: Outdoor resting counts in the control area, and indoor resting and outdoor biting counts in both CA and UCA.

Early in the experience of the FRU, De Meillon *et al.* (1967c) found that nearly all *C. p. fatigans* in Rangoon had a greenish color when they first emerged but the green color gradually faded and disappeared in about 72 hours. Since part of the work of the unit involves age grading of mosquitoes, and includes dissection for parous determination and infection with *W. bancrofti,* the discovery that young mosquitoes were green became a labor-saving device because these mosquitoes could be assumed to be nulliparous and non-infected. Dissections, using the dilatation method of Detinova (1962), of some of these indicate this assumption to be essentially correct. Green mosquitoes taken in adult collections are assumed to have emerged recently from a nearby source and are not considered to have a role in the transmission of filariasis.

Outdoor resting counts are made from 07:00 to 09:00 and from 09:30 to 11:30 hours in the control area at random to find adult mosquitoes emerged from sources missed by spraymen. Green mosquitoes are regarded as particularly important since they would be close to the source from which they emerged and the emergence would be recent. When several green mosquitoes are found in a particular area, special efforts are made to find the source. This is not a measurement population reduction but an indication of control failure.

Indoor resting counts made in both CA and UCA are used by the unit to indicate control effectiveness. The counts are made at 22 permanent stations, 6 in KEFT, 9 in EA and 7 in UCA (Fig. 2). Catches are made from 20:00 to 21:00 at each station. The information is of value to the unit and is reported here although differences in the stations and other factors involved make the data less precise and reliable than outdoor biting counts. Indoor resting catches have approximately the same patterns but indicate somewhat less effective control than do outdoor biting collections.

Outdoor biting collections are made from 21.00 to 24.00 at the same 22 stations as indoor resting collections, but the collector sits outside with a flashlight and an aspirator collecting mosquitoes landing on him. Collectors are rotated between stations to prevent bias related to differences in attractiveness to mosquitoes. Studies carried out by the Research and Development Section showed that spraymen, despite routine daily contact with fenthion, did not have sufficient residue on their bodies or clothes to repel mosquitoes. Mosquitoes taken in both indoor resting and outdoor biting collections are placed in small cages (7" x 7" x 7") (17.8 cm x 17.8 cm x 17.8 cm) consisting of a wire frame covered with cotton mosquito netting. The cages are numbered for each station and have different colors for different types of catches.

The collected mosquitoes are taken to the laboratory the following morning, identified, sexed, and counted. All males and green females, after counting and recording are generally discarded; but frequently some green females are saved for dissection as a continuing check on the nulliparity of green females. The non-green females are dissected and examined to determine if they are parous or nulliparous, and then they are further dissected to detect the presence and numbers of *W. bancrofti* larvae.

Since the non-green mosquitoes are those which could possibly be infected with the parasite and transmit the disease, this is an important measurement. Biting counts of female mosquitoes are regarded as the most precise of the three adult population measurements made by the unit for evaluating control effectiveness. Records are kept of the number of non-green females because of their role in the possible transmission of filariasis. The other two types of adult catches are used as additional information along with larval survey procedures. The collections labeled as outdoor biting collections include some mosquitoes attracted to the collector but not biting.

All of these procedures of larval surveys and adult catches serve as more or less independent checks on the efficiency and effectiveness of control. These checks are much more numerous and varied than would be necessary in an operational program over a large area.

No methods were used by the FRU to attempt to measure absolute adult or larvae populations and no such method appears practical at the FRU.

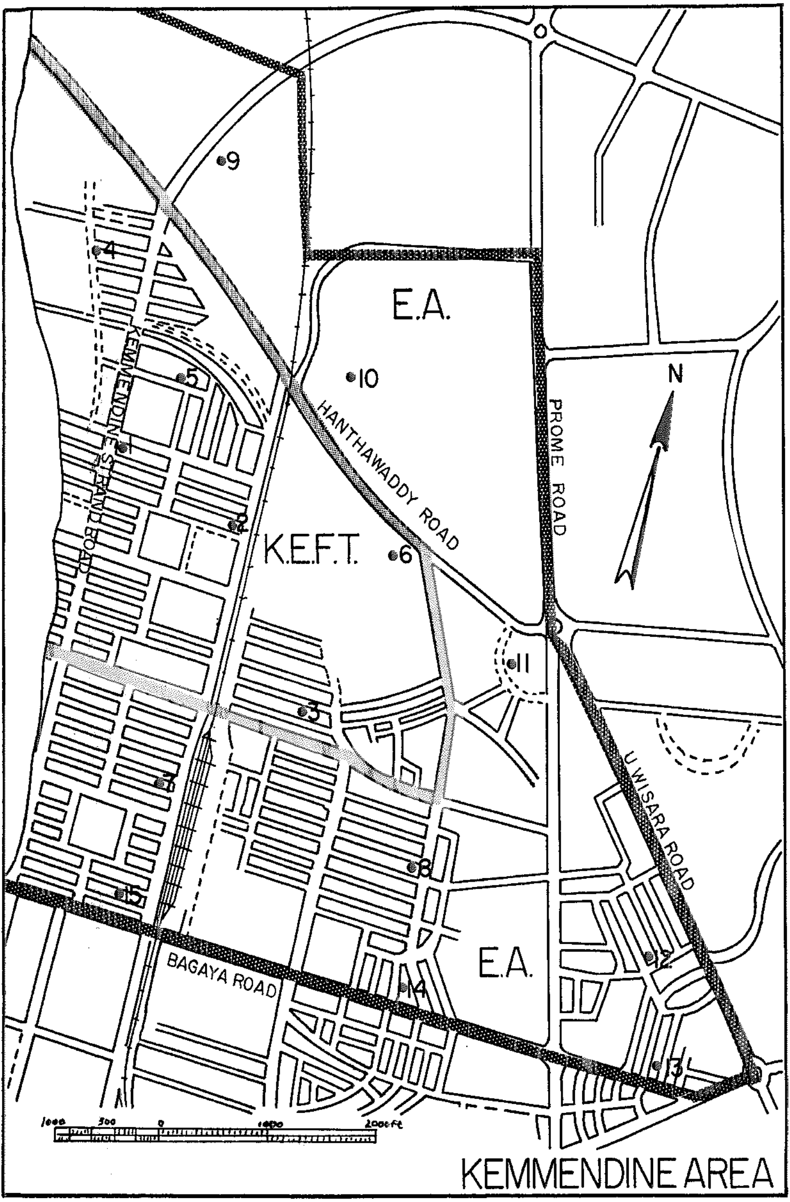

FIG. 2.—The Kemmendine area of Rangoon showing locations of mosquito catching stations in KEFT and EA.

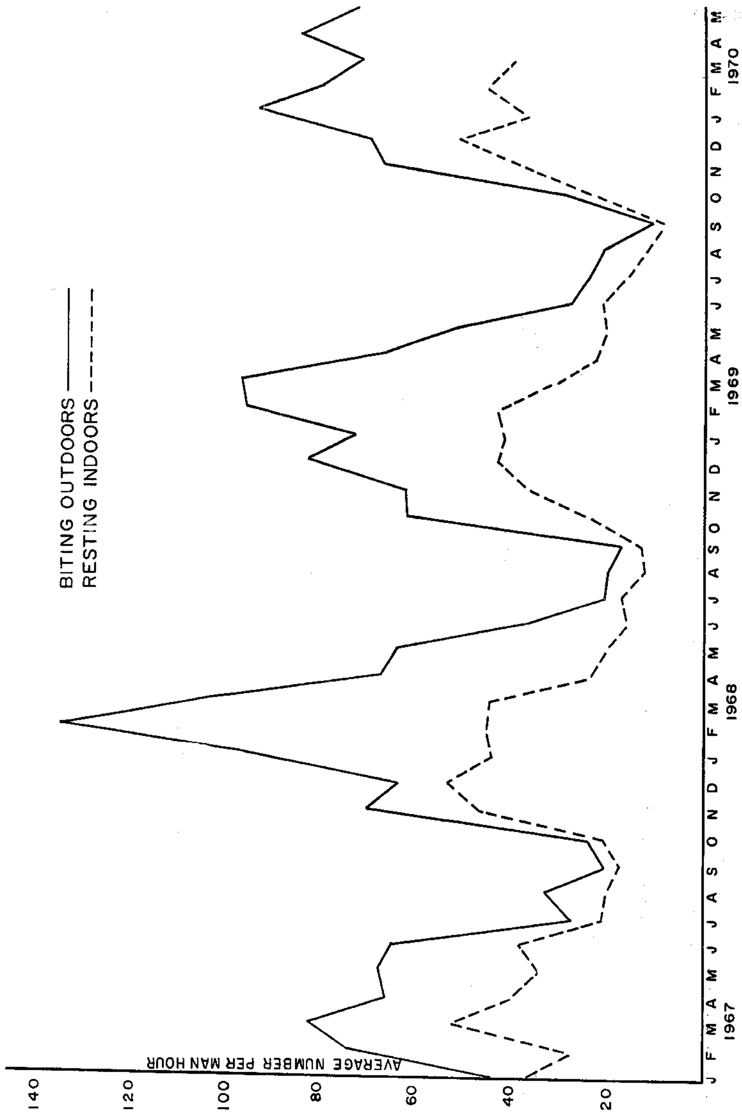

FIG. 3.—Seasonal variation in outdoor biting and indoor resting collections in UCA from January 1967 through May 1970.

Populations of *C. p. fatigans* in Rangoon normally vary greatly during the year. Production is generally greater during the dry season than during monsoon periods because the rains tend to flush the drains which are the major sources (Fig. 3).

VI. RESULTS OF CONTROL IN THE FRU. Evaluating the results of mosquito control procedures involves determining changes in mosquito populations. This can be done either by comparing mosquito densities, both larval and adult, in the area under control with the densities before control started or by comparing mosquito densities in the control area with a similar unsprayed area. Both procedures have been used by the FRU but data in the controlled area before control were not taken long enough for definite conclusions to be drawn and therefore the unsprayed check area is used for comparisons.

The evaluation of control effectiveness in KEFT before the expansion of control on 10 January 1967 was difficult because mosquitoes were moving in substantial numbers from uncontrolled sources around KEFT into the control area. Evaluation for control effectiveness is made here for the period from 10 January 1967 to the end of May 1970 using outdoor biting collections. Evaluation using indoor resting collections ceased at the end of March 1970 and those data are also included. This allows an evaluation during both wet and dry seasons with periods of time of 41 months for outdoor biting and 39 months for indoor resting.

KEFT and EA are considered separately in evaluating the effectiveness of control because there is some indication of movement of mosquitoes from uncontrolled areas into EA in spite of the barrier zone and because KEFT is the area where epidemiological evaluation will take place to determine if transmission of filariasis has been interrupted.

Populations of *C. p. fatigans* in KEFT, EA and UCA are compared in Figs. 4 and 5 and in Table 2 in outdoor biting and indoor resting collections for the period from expanded control until the end of May 1970 and the end of March 1970, respectively. For the entire period populations in KEFT compared to UCA were reduced by 97.0 percent when measured by outdoor biting collections and 91.7 percent when measured by indoor resting collections. Comparable figures for EA are 94.6 percent and 91.2 percent.

We believe outdoor biting collections give a more accurate evaluation of the actual reduction in numbers caused by control but both methods indicate extremely effective control as does larval population data which were discussed very briefly above. With experience the level of control improved. Control effort was intensified during the last two years improving the level of control even further. The overall figures of 97 percent reduction in KEFT compared to UCA are somewhat misleading because of seasonal fluctuations of populations in the unsprayed check area. During the periods of high *C. p. fatigans* production, control frequently caused a reduction of over 99 percent in KEFT when compared to UCA. Total numbers per man hour remained low in the controlled area in both wet and dry seasons. Even very small numbers of mosquitoes moving from uncontrolled areas in KEFT would have some effect on the percentage reduction there when the reduction is about 98 percent. Lindquist's studies (*op. cit.*) indicate that a few mosquitoes in the control area could have come from uncontrolled areas. Further studies by the unit in late 1969 using an orange dye gave support to Lindquist's work and also showed that very few mosquitoes travelled as far as 3,000 ft. (915 m), with the majority travelling less than 1,800 ft. (549 m) when release is in a densely populated area.

The number of non-green female mosquitoes is an important measurement, as stated above, since they are the possible vectors of filariasis. The numbers of non-green females taken at each station in KEFT are presented in Table 1, and these data indicate considerable variations between stations. Station 4 is high partly because of temporary control lapses near the station in September and October of 1967. However, even if these high counts are omitted, the station remains high. The fact that the counts did not again reach levels of September and October 1967 is worthy of note and is an indication of the improvement of control that experi-

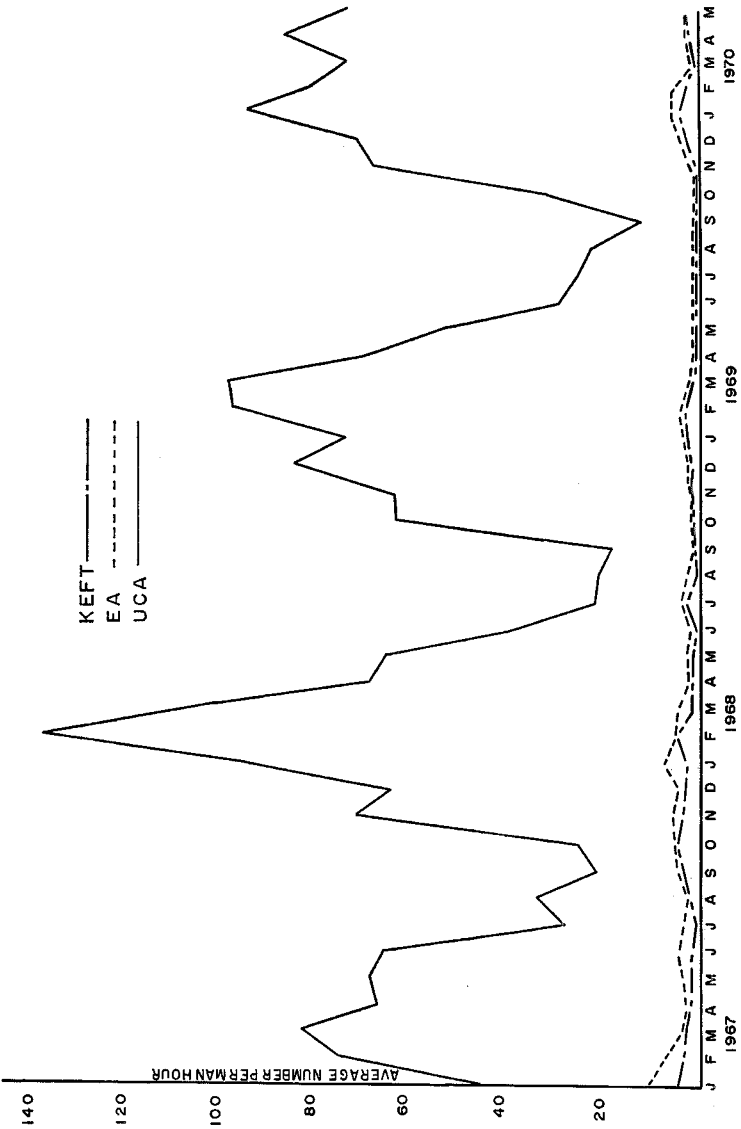

FIG. 4.—Comparison of outdoor biting collections in KEFT, EA, and UCA from January 1967 through May 1970.

ence produced. Station 6 is normally the high station in KEFT and is located in an area where many small sources make control difficult. The six stations of KEFT were selected to obtain a representative sample of the mosquito population in the area. In our opinion they do give such a sample.

Larval survey procedures by the Control and Evaluation Section and the Research and Development Section both indicate that sources missed by control are some-

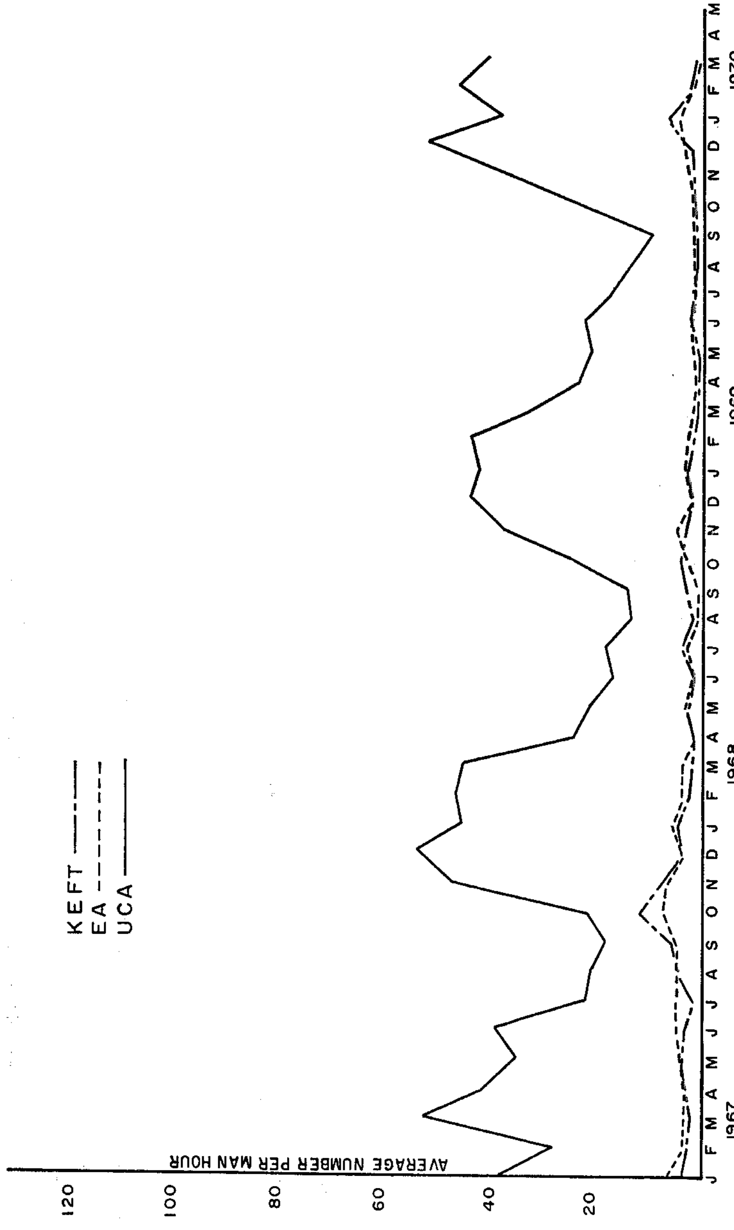

FIG. 5.—Comparison of indoor resting collections in KEFT, EA, and UCA from January 1967 through May 1970.

TABLE 1.—Non-green female *Culex pipiens fatigans* taken in biting outdoor collections in KEFT by station, from 16 January 1967 to 30 May 1970.

Month	Station 1	2	3	4	5	6	Collecting hours	Monthly total	Average per man hour per month
1/67*	65	11	23	35	32	43	54	209	3.87
2/67	30	10	10	30	24	89	72	193	2.68
3/67	37	11	23	53	21	37	72	182	2.53
4/67	36	3	9	10	8	18	72	84	1.17
5/67	15	2	36	21	20	18	90	112	1.24
6/67	37	2	12	18	9	26	69	104	1.51
7/67**	18	0	3	5	0	0	33	26	0.79
8/67	10	0	4	38	11	9	63	72	1.14
9/67	25	5	2	128	10	14	72	184	2.55
10/67	35	10	9	166	36	88	90	344	3.82
11/67	28	12	6	40	20	61	69	167	2.42
12/67	27	12	10	27	19	15	72	110	1.53
1/68	8	6	6	27	11	43	90	101	1.12
2/68	14	6	10	43	19	119	72	211	2.93
3/68	11	4	4	24	5	31	72	79	1.10
4/68	16	6	3	12	10	40	90	87	0.97
5/68	13	12	5	13	7	35	72	85	1.18
6/68	9	3	7	9	12	5	72	45	0.63
7/68	3	6	6	88	8	32	90	143	1.59
8/68	4	2	2	9	4	8	72	29	0.40
9/68	7	3	7	19	8	25	90	69	0.77
10/68	8	11	1	20	25	28	72	93	1.29
11/68	5	9	7	3	25	46	72	95	1.32
12/68	11	14	6	13	14	33	90	91	1.01
1/69	8	3	9	37	21	62	72	140	1.94
2/69	14	4	13	40	30	65	72	166	2.31
3/69	6	1	8	35	19	33	90	102	1.13
4/69	1	2	6	14	5	24	72	52	0.72
5/69	1	4	5	7	6	12	72	35	0.49
6/69	19	3	5	5	10	23	90	65	0.72
7/69	2	1	1	6	1	12	72	23	0.32
8/69	3	2	1	6	5	20	72	37	0.51
9/69	2	0	2	9	0	13	90	26	0.29
10/69	5	3	0	2	5	19	72	34	0.47
11/69	0	5	1	4	6	14	72	30	0.42
12/69	11	10	5	34	41	19	90	120	1.33
1/70	14	11	12	62	48	47	72	194	2.69
2/70	7	4	10	35	52	49	72	157	2.18
3/70	7	3	3	21	2	31	90	67	0.74
4/70	8	4	12	12	8	52	72	96	1.33
5/70	3	3	8	9	14	54	72	91	1.26
Station totals	583	223	312	1189	631	1412		4350	
Collecting hours	516	516	513	519	513	519	3096		
Average per man hour per station	1.13	0.43	0.61	2.29	1.23	2.72			1.41***

* Beginning with week of 16/1/67.
** Collections made only in weeks of 24/7/67 and 31/7/67.
*** Average per man hour overall.

TABLE 2.—Percentage reduction in outdoor biting and indoor resting collections in KEFT and EA compared to UCA for each month from 16 January 1967 to 30 May 1970.

	KEFT		EA	
	Biting outdoors	Resting indoors	Biting outdoors	Resting indoors
Month	Total females	Total females	Total females	Total females
1/67	90.34	89.59	73.92	82.81
2/67	95.90	91.52	89.71	87.77
3/67	96.72	96.18	95.21	93.62
4/67	97.99	91.18	96.41	93.12
5/67	97.44	89.59	95.55	88.78
6/67	97.53	91.30	93.59	87.32
7/67	96.64	93.57	86.65	76.76
8/67	95.05	78.84	92.19	77.47
9/67	84.57	68.43	78.56	72.72
10/67	81.01	43.74	80.06	66.30
11/67	94.81	84.47	92.24	85.69
12/67	95.65	93.54	93.21	92.70
1/68	97.37	90.88	92.18	88.64
2/68	96.88	95.29	96.62	91.51
3/68	98.83	96.48	95.73	92.24
4/68	98.49	95.62	96.46	95.03
5/68	98.15	89.83	96.57	86.53
6/68	98.25	93.56	94.80	90.97
7/68	89.33	81.26	84.57	82.00
8/68	97.59	89.71	89.62	93.73
9/68	95.41	83.48	92.14	95.40
10/68	97.14	84.95	97.56	90.73
11/68	97.39	93.14	96.91	89.20
12/68	98.65	96.91	97.20	95.96
1/69	96.99	94.63	95.55	94.42
2/69	97.36	96.51	95.76	94.79
3/69	98.69	97.54	97.93	96.71
4/69	98.95	98.38	98.65	98.16
5/69	99.06	97.55	97.02	93.77
6/69	97.42	91.82	94.70	91.36
7/69	98.69	91.70	94.41	92.55
8/69	97.68	93.58	94.99	89.95
9/69	96.73	91.72	87.13	86.62
10/69	98.00	95.65	96.50	94.29
11/69	99.04	97.48	97.30	97.13
12/69	96.92	96.18	94.79	95.40
1/70	95.76	84.96	93.81	91.72
2/70	96.51	96.01	93.18	95.95
3/70	98.94	99.46	98.20	98.15
4/70	98.41		98.39	
5/70	98.27		96.07	

where between 1 percent and 5 percent of the positive sources (Self *et al., op cit.*). Observations of larval densities in the missed sources indicate lower densities than in the unsprayed check area. While these data are not considered to be as precise or reliable as adult catches, they do indicate the same level of control and help substantiate adult data.

In addition to the objective data on the effects of control, observations are made by the entomologists and supervisory personnel of the unit. Such observations are apt to be biased and cannot, by themselves, be used to evaluate control. However, such observations are used in all mosquito control programs to form impressions of the effectiveness of control and are valuable in helping substantiate more objective data. All of us have spent a considerable amount of time in the field observing control procedures and results and are unanimous in believing that very substantial reductions in mosquito populations have been obtained. All our observations in the field agree with the results of adult catches and larval surveys.

The larval control procedures developed in Rangoon and the procedures for checking on control effectiveness are of such a nature that they can be applied in other areas where *C. p. fatigans* has become a major urban problem. The control procedures outlined in Section III will effectively control this mosquito if they are properly conducted and the procedures outlined in Section V will ensure that they will be.

SUMMARY. The World Health Organization established the Filariasis Research Unit in Rangoon, Burma in October 1962; the objectives of the unit were to obtain basic data on the biology and ecology of the vector of filariasis, *Culex pipiens fatigans,* and to determine if transmission of filariasis could be effectively and economically interrupted by control of the vector alone.

After more than 3 years of basic investigations a small field trial was begun in March 1966 and expanded in January 1967 to control *C. p. fatigans* by larviciding with fenthion emulsifiable concentrate diluted in water. The control program has reduced adult mosquitoes to a very low level. During the season of greater mosquito production populations of the vector have been reduced more than 98 percent in comparison with nearby untreated areas of Rangoon.

Control procedures in Rangoon are generalized enough to be applied in other areas where similar problems exist and can greatly reduce *C. p. fatigans* populations with relatively small expenditures.

While final proof that mosquito larviciding will halt transmission of filariasis requires a number of years of epidemiological investigations, the results of control to date indicate that this possibility has considerable promise. It has been possible to demonstrate that an efficient and very effective *C. p. fatigans* control program can be carried out in a large city in Southeast Asia which can serve as a model for future programs.

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