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ENTOMOLOGICAL ASSESSMENT IN SPRAYED AREAS

by

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PART I - Methods and Techniques

PART II - Probability of Survival of Vector Through One Gonotrophic Cycle, measured by the House Visit Survival Rate.

PART I

METHODS AND TECHNIQUES

1. Introduction

When a large area has been sprayed with residual insecticide the most urgent (and recurring) question to be answered is: has malaria transmission been interrupted? - or in other words, has effective control of the vector species been achieved?

It is the malariologist who is most often expected to provide the answer by his measurements of the infant parasite rate. This method has two drawbacks: that it is not a certain method of detecting low-frequency transmission within the area, and that some months may be required to reveal its continuation.

Can the entomologist answer the question more quickly and reliably, and what methods should he use?

2. Methods in Use

Divergent methods are in use in different parts of the world, aimed at providing entomological assessment of residual spraying. In the document WHO/Mal/231 ("The Place of Entomology in Malaria Eradication"), page 6, no fewer than eleven techniques are listed which might contribute to the task. It is not suggested that all these should be used in any one investigation. The entomologist must use his judgement in deciding which to select.

Three instances of current practice are cited below for comparison.

(a) A Central American Country

"Treatments were evaluated immediately after application and at four-week intervals thereafter. Field-collected *A. albimanus* were colonised prior to the application treatments and batches from this colony were exposed to treated surfaces in WHO plastic cone wall cages for 30 minutes for the first eight weeks after treatment and for 60 minutes for subsequent evaluations. Approximately 125 monthly inspections were also made for presence of mosquitoes resting in treated and untreated houses". U.S. Department of Health, C.D.C. Technical Development Laboratories, Report of Activities for the Year Ending June 30, 1959.

(b) North Borneo

"Routine programme for entomological assessment in sprayed area.

1. Human-baited traps and their attached window traps, and window traps attached to existing houses - two mornings a week.

ii. Animal-baited traps - one night a week.

iii. Number of mosquitoes biting man - with human bait sitting outside and inside house, to collect any mosquitoes while biting, from 6 - 12:00 p.m. twice a month.

iv. Survival rate - if any anophelines collected by the above methods, particularly those collected from window traps, they may be kept for 24 hours observation.

v. Dissection - this can also be done with the anopheline mosquitoes collected by the above methods for infection rate and age determination.

vi. Bio-assay - once every three months."

- WHO/WPR/MAL/FR/17 Report on the Field Visit to North Borneo in June 1959 by C.Y. Chow (WHO Regional Entomologist).

(c) India

"In areas with a problem of persisting transmission the malariologist was to make a sample survey and the entomologist to determine densities, host of predilection, duration of gonotrophic cycle, dissections, and susceptibility to DDT and dieldrin." Review of the Work of ATME No. 2 to 30 June 1959, by the Senior Regional Malaria Adviser SEARO.

(In this Review it is made clear that the densities referred to indoor daytime resting densities of mosquitoes captured per man hour and choice of host was determined by precipitin testing of bloodmeal smears. In his comments the writer states: "... the mass survey reveals as much as 1% parasitaemia which is not consistent with malaria eradication, but it must also be considered that in these areas the entomologist found a very low density, certainly far below the critical density for effective transmission".)

3. Towards a New Choice of Techniques

It may help in comparing the merits of the three methods if we review certain factors which control the potential rate of transmission in a locality by a known vector. Three entomological factors are the number of mosquitoes biting man, its degree of contact with man, and the proportion of females of dangerous age. The most useful techniques will be those which give the most direct measurement of these factors; the advantage of direct measurement may outweigh the advantages of other techniques which, though easier, give only an indirect indication of the answer. In the following tabulation an attempt is made to distinguish between direct and indirect techniques:

Number of Vector Mosquitoes Biting Each Inhabitant

Direct methods	Indirect or indicative methods
The 24-hour man-biting rate x gonotrophic cycle (days)	adult resting density (indoor and outdoor)

Degree of Contact with Man

The human bloodmeal ratio catches on human and animal baits

Proportion of females of Dangerous Age

(i) dissection of ovarioles (Polovodova's method)

(ii) (tentative method for a highly endophilic or endophagic vector): $V^{(s/g)}$[1]

(i) nulliparity rate (by Davidson's or Detinova's method)

(ii) ratio of oöcyst rate to total infection rate

In one of the cited examples (India), while several kinds of entomological work were done, only the resting density was used in trying to provide an entomological assessment of the spray régime. This ignores such vital factors as the age-composition and the degree of contact with man, and does not take into account possible transmission by mosquitoes which rest outdoors.

The method recommended in North Borneo, alone of the three cited, provides for some attempt at the direct measurement of the entomological factors bearing upon the question of continued transmission. Even there, however, the way is not suggested of correlating the various types of data into a simple index that would be of optimal value in a malaria eradication campaign.

At this stage in the world-wide campaign it seems essential, whatever the practical difficulties, to break with the "mosquito-per-man-hour" tradition and to adopt a more advanced and precise method of entomological assessment.

4. The entomological Infection Potential

The most useful index the entomologist might provide is represented by the product of three entomological measurements and one demographic factor:

the number of vector-mosquitoes biting each person

x

the human population of the locality

x

the human bloodmeal ratio

x

the proportion of females of dangerous age

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[1] where $\underline{V}$ is the probability of survival through one house-visit or one gonotrophic cycle, $\underline{s}$ is the sporogonic cycle of the prevalent Plasmodium, and $\underline{g}$ is the gonotrophic cycle of the vector (under local conditions). The value $\underline{V}$ would be expressed by:

$$\frac{\text{number of trapped survivors (24 hours)}}{\text{number dead in room and in trap}}$$

The resulting figure would represent the **maximum** theoretical daily rate of transmission in the locality, that is, the rate if the infectivity of man to mosquito were 100% and the vector were 100% efficient. To take a hypothetical example, let us suppose that in a sprayed village of 1,000 inhabitants, each person gets on an average two bites per gonotrophic cycle of the vector, that half of the vector's feeds are on man, and that only 0.5% of the bites are by females of infective age. The entomological index of potential daily transmission, or the entomological infection potential, will then be -

$$2 \times 1000 \times 0.5 \times 0.005 = 5.0$$

If an entomological infection potential of 5.0 were obtained soon after the first spraying in a holoendemic locality, there would obviously be some residual transmission going on. However, the same index in an area of low endemicity, or where repeated spraying has almost drained the parasite reservoir, would demonstrate that transmission is successfully interrupted. For example, where only one person in a thousand is infective on any given day, the daily probability of an occurrence of transmission back to man would be 5.0 x .001, or 1/200. In other words we would expect one case of transmission every 200 days in these circumstances - a situation which must lead on to eradication provided that an efficient system of surveillance is operating.

5. An entomological index for areas under spraying

In practice it is more likely that the entomologist's measurements in a sprayed locality will fail to detect the survival of any vector to a dangerous age. His index will be zero, but he will not be warranted in putting it forward as valid unless the measurements to determine age (whether by Polovodova's technique or by the alternative method suggested above) are based on a large number of observations.

As long as the reservoir of infection remains high in man, a zero entomological index is the only reassuring one. But when malaria has become rare in a sprayed area the concept of a threshold infection potential should acquire importance in determining whether the interruption of transmission is secure. Only experience can show what the threshold figure is under any given conditions - e.g. in areas formerly subject to perennial transmission by a highly efficient vector. No such experience exists as yet, since probably the measurement of the entomological infection potential has nowhere been attempted. Yet this index could and should become the yardstick supplied by the entomologist for assessment of the malaria eradication attack phase.

6. Need for field trials on method

First of all the method suggested should be applied experimentally in selected projects. This might be done by operational research teams composed of two entomologists and two technicians, assigned to areas where careful malaria surveillance is already in being.

Two links in the method present practical difficulties; but every effort should be made to overcome these, as there may be no alternative techniques capable of providing the answer to the main question.

The difficulties of applying Polovodova's dissection to small vector-species are probably a matter of practice and technical competence. The dissector will require good microscopes and satisfactory working conditions close to the working site. The best means of securing these might be by means of a caravan-type or army-ambulance type of mobile laboratory.

Measurements of the rate of nulliparity are really no substitute for Polovodova's method, and should not be so used unless every effort has first been made to determine the actual physiological age of the mosquitoes. They all introduce the assumption - almost certainly a misleading one - that the probability of daily survival remains constant through the mosquito's life.

Can the 24-hour man-biting rate generally be measured? In many countries the difficulties are mainly social. The entomologist, trained to get close to the mosquito, here has to get as close to human beings of (it may be) another culture and race than he. It is essential to win and keep their collaboration in the capture of biting mosquitoes. Financial rewards to boys who serve as baits are often helpful, and merit official recognition. More important, however, is the permanent provision of a trained public relations officer who must repeatedly explain to the people the object of the work.

PART II

PROBABILITY OF SURVIVAL OF VECTOR THROUGH ONE GONOTROPHIC CYCLE MEASURED BY THE HOUSE-VISIT SURVIVAL-RATE

1. By fitting a sprayed room or hut with inlet valves, floor sheets and outlet traps, it should be possible to measure with a consistent degree of accuracy the probability of survival of a mosquito which enters to feed or to rest. In this way we may ascertain the local house-visit survival-rate of the vector species, at any desired interval after the spraying.

2. It is likely that some mosquitoes in every population subsist entirely out-of-doors from one oviposition to another. Others may fly from house to house, owing to the irritant action of DDT or some other stimulus. Nevertheless, in a highly endophilic vector species we may suppose that the normal behaviour-pattern of the female mosquito is to enter a house to seek a blood-meal, afterwards remaining for a shorter or longer period while the eggs are developed. Once having left the house she may be expected not to enter another until she has laid her eggs and requires another meal. Further, the bulk of deaths should occur either within the sprayed houses or as a direct result of visits to them. If this is so we may regard the house-visit survival-rate as a rough equivalent of the average probability of survival through one gonotrophic cycle, from which we may proceed to calculate what proportion survives to the minimal infective age.[1]

3. This calculation is of importance to enable the entomologist to contribute more to the assessment of residual spraying, and it has been suggested that some field experiments be initiated to evaluate the method. A WHO operational research team might be assigned to the work.

The only reliable alternative method of measuring the proportion of mosquitoes which attain minimal infective age (or "epidemiologically dangerous age") is by the difficult technique of ovariolar dissection (Polovodova). This will have to be used as a cross-check in the field experiments, which should be carried out on a species that lends itself to that dissection (perhaps *A. maculipennis*, *A. sacharovi*, *A. quadrimaculatus* or *A. hyrcanus sinensis*). If it can thus be shown that the survival rate method gives results comparable to those obtained by Polovodova's method, it may be valuable to adopt the former method in places where the ovariolar dissection is too difficult or too time-consuming.

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[1] This would be expressed by the formula $V^{(s/g)}$, where (under local conditions) V is the probability of survival through one house-visit, s is the sporogonic cycle of the prevalent Plasmodium, and g is the gonotrophic cycle of the vector. The value of V would be expressed by:

$$\frac{\text{number of survivors (24 hours)}}{\text{number dead in trap and in room}}$$

ANNEX I

PROPOSED METHOD OF DETERMINING THE SPECIFIC TRANSMISSION POTENTIAL IN SPRAYED VILLAGE (1)

24-hour man-biting rate of vector x human population

house-visit survival ratio of vector to power of (house-visiting rate of vector (2))

total number biting human population daily

human bloodmeal ratio of vector x proportion old enough to be (3) infective (multiparity ratio)

VECTOR'S INFECTION POTENTIAL (VIP) x gametocyte rate in whole population (RESERVOIR'S INFECTION POTENTIAL, RIP)

SPECIFIC TRANSMISSION POTENTIAL (i.e. maximal daily local rate of transmission)

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(1) Specific to one vector and one parasite. But the data for several species can be collected simultaneously, e.g. to discover which of several anophelines present is still a vector.

(2) The house-visiting rate of a vector is defined as the average number of visits by one female to sprayed (or sprayable) premises, in the period of one gonotrophic cycle of the parasite. It may be taken as equivalent to the number of gonotrophic cycles completed in this period, except where the vector is observed to feed and rest outdoors or to visit several rooms during one gonotrophic cycle.

(3) Ratio may also be determinable by Polovodova's dissection or (more crudely) by calculation from the nulliparity ratio. One of these alternatives must be adopted where a substantial proportion of the vector population can co... ... to ... ... any sprayed structure.