

use of *Ae. aegypti* for bioassay tests and the elimination of all laboratory colonies. There will be a more immediate need for restrictions on colonies located in the eradication area (Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, South Carolina, Texas, Puerto Rico and Virgin Islands), and possibly in other places where either active infestations in nature are found on future inspections or where the climatic conditions favor survival of such natural infestations.

It is certain that some regulation of *Ae. aegypti* colonies must replace the present unrestricted use of the species as a laboratory subject. If there is to be a desirable period of transition, directors of research may wish to give early consideration to the following suggestions:

1. Plan to employ species other than

*Ae. aegypti* on future research projects.

2. Discontinue the use of *Ae. aegypti* for fish food, for lecture demonstrations, and for bioassay.

3. Organizations with colonies of *Ae. aegypti* are urged to:

a. Restrict shipment or transfer of the species to qualified researchers who presently maintain the species.

b. Review insectary procedures to decrease the hazard of accidental release.

c. Review current research to determine if objectives may be reached by phasing out investigations with *Ae. aegypti* and substituting indigenous species such as *Aedes triseriatus* (Say) or *Psorophora varipes* (Coquillett).

## THE AFRICAN *Aedes aegypti*

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Although sound in its principle, the concept of eradication is bound to encounter some problems in its application. For instance, in Leopoldville (former Belgian Congo) despite the use of powerful means of action, we had been unable to eradicate *Aedes aegypti* on a city-wide basis whereas some South American nations had succeeded on a nation-wide basis. Nevertheless we had been able to eradicate from the city limits such species as *Simulium damnosum* or even *Anopheles gambiae*, of which, for instance, an annual average of only 3 positive breeding places were found between 1955 and 1959 and only at the point of re-invasion, at the outskirts of the city close to the shoals of the river. During the same

period, on the other hand, we had an average of 320 positive breeding places for *Aedes aegypti*; for a city of 400,000 inhabitants in which about 1,200,000 houses and premises were visited each year. It was not too poor an "*Aedes aegypti* index." But anyway, this still was a threshold under which we seemed unable to go. Why?

Is there any vital potentiality of the complex *Aedes*-environment which lends itself to eradication of the species in one place and not in another place? We started diligent search for an answer to this problem, but, unfortunately, the subsequent political events precluded any further research in this specific area. It is only recently that it has been possible to come to some reasonable understanding of the situation as observed in Africa versus the situation as observed in the Americas.

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Indeed, the numerous studies published in the last five years in relation to the morphology, biology and the genetics of *A. aegypti* have shed some light on this problem. In the following paragraphs, I shall try to assemble some pieces of this puzzle and to present a theory by which a hygienist could possibly explain, or at least understand, the observations made in Africa, and particularly in Congo, by my predecessors, my colleagues and myself. Much of this is a working hypothesis or a mere theory, but, as Louis Pasteur said: "Without theory, practice is but routine born of habit, for theory alone can bring forth and develop the spirit of invention."

In trying to determine whether the lack of complete eradication of *A. aegypti* in Leopoldville merely rested with human failure rather than with a variation in the habits of this particular species in this specific area, we were quick to consider, perhaps presumptuously, that the first of these alternatives was very unlikely.

Many factors indeed were pleading against it. Through the years, various competent hygienists, some of them very prominent, such as Duren and Wanson, had been in charge in that city showing their "know-how" by various achievements; among others, by eradicating within the limits of the urban area such species as *An. gambiae* and *Simulium damnosum*. On the other hand, no other city in the *Aedes aegypti* area in Africa had succeeded as yet in eradicating this mosquito despite the number of proficient hygienists and entomologists who had been working in this whole region.

Moreover, our system of vector control whereby every single one of the about 25,000 backyards, gardens, etc., was inspected once a week, our semiannual house spraying program, our monthly program of city spraying by helicopters, all working jointly did not leave any chances for an *endogenous* brood to survive if there had not been something else.

For instance, it is strange indeed to see that *An. gambiae* after having been

eradicated from the city was kept out by a simple belt of houses sprayed with insecticides at the city outskirts, while *A. aegypti* was always found, although in very low numbers, within the city limits (7).

What this "something else" exactly is, we did not get enough time to find out; but many factors, then unknown, have been unraveled recently. The most important contribution in understanding this problem has been made by Mattingly's studies (1-2). He described *A. aegypti* morphological and biological variations that had been overlooked so far and he pictured three forms of the species:

(1) *Aedes aegypti* sensu stricto, the type form widely distributed throughout the range of the species.

(2) *Aedes aegypti* var. *queenslandensis* often mixed with the former variety.

(3) *Aedes aegypti* var. *formosus* located only in Africa south of Sahara.

These forms differ from each other not only by their morphology but also by many distinctive traits such as degree of domesticity, host preference, choice of breeding place, biting cycles and perhaps the ability to harbour and transmit diseases.

Other recent studies made at Notre Dame by George B. Craig, Jr., and his group have shown in this species such an extreme genetic plasticity in the laboratory that there is no reason to believe that it does not exist in nature (3).

All those studies shed a special light on much of the unpublished information in our archives. Some of these new observations provide (to a certain extent) an explanation for the permanent presence of this mosquito in African cities such as Leopoldville, in spite of the strong and powerful control action that was carried on.

In the Western Hemisphere the *Aedes aegypti* population is made up of the type form and of the var. *queenslandensis*, two varieties with very strong domestic habits and strong association with man (4-5).

This is fortunate for the Americas, facing the problem of eradication. Indeed,

appropriate measures of control can be limited in space (which implies of course in time, personnel, equipment, and money) to the places where man lives and to his immediate surroundings, with, as the facts have proven, a complete assurance of success, in the framework, of course, of a well-administered program.

Another beneficial factor in the Americas in that *Aedes aegypti* is relatively a newcomer to this area. Every available fact seems to indicate that Africa is the original home of *A. aegypti* (4) and that the species was introduced relatively recently in the Americas.

Now, we all know that it is much easier to get rid of an undesirable immigrant than a deep-rooted citizen. The most striking example certainly is the eradication of *Anopheles gambiae* in Brazil in a relatively short time with rather simple means (6). This is an excellent demonstration that it is possible to eradicate a new species at the time of its implantation; later, when a species gets adapted and well established in its environment, eradication is much more difficult, or impossible, and the only substitute left is control.

In Africa, I believe the situation is quite different from the Americas. The *A. aegypti* is in its native area, completely adapted to its environment; in fact, so well adapted that one variety, *formosus*, can breed in the wilderness, far away from man (4-5).

In Africa, it is common to find *A. aegypti* breeding in such places as tree-holes, rock pools, fallen leaves, animal footprints, etc. Scrapings and dry dirt collected in tree holes in Leopoldville and Boma, before the time of aerial insecticide spraying, have regularly given off *A. aegypti*. Many plants or trees provide excellent breeding places in the natural receptacles resulting from the particular structure of their trunk or from the ensheathing design of their leaves or of other parts. In Congo, the following seventeen botanical species have been found harbouring *A. aegypti* larvae in

one or another, or many, of their morphological structures (7).

*Crinum giganteum* Andr.

*Colocasia antiquorum* Schoot, (Elephant ear)

*Pandanus pacificus* Hort. (Screw pine)

*Billbergia iridifolia* Lindl.

*Pandanus pacificus* Veitch

*Pandanus giganticus* De Wild

*Musa laurenti* De Wild (Banana tree)

*Musa sinensis* Sagot. (Banana tree)

*Canna indica*

*Ravenala madagascariensis* J. F. Gmel. (Traveler's Tree)

*Cocos nucifera* L. (Coconut tree)

*Bambusa vulgaris* Shrad. (Feathery bamboo)

*Carica papaya* L. (Papaya tree)

*Poinciana regia* Boj. (Flamboyant tree)

*Mangifera indica* L. (Mango)

*Adansonia digitata* L. (Baobab tree)

*Borassus flabellifer* L. (Palmyra Palm)

This wide variety of natural breeding places is a partial explanation for the constant finding of new specimens in African cities where the control of artificial breeding places as it is performed in the Americas could even be perfect.

Besides, as a direct consequence of these peculiarities and of the presence of the var. *formosus*, the wild natural environment in which African cities (at least south of Sahara) are generally set is able to provide the permanent supply of those few specimens which are found in the city limits.

Still stranger is the fact that the plants which provide good breeding places in one area of Africa would not give off any *Aedes aegypti* in another area. For instance, a systematic inspection of the leaves making the crown of the coconut trees in Leopoldville was negative for *A. aegypti* whereas, at the same time, the mosquito was found in 77 percent of the same trees inspected in Dar-es-Salaam and in many coconut trees in Loanda (Angola).

We will not speak of the other biological characteristics which made *A. aegypti* mosquito difficult to eradicate, such as

the capability of the egg to sustain very long periods of dryness, the ability of the female to "hibernate" when temperature drops below 20° C. and yet to lay eggs, even after a long wait, as soon as the adequate level of heat has returned. Those and other characteristics are actually all common to the American and the African *Aedes* populations.

In Africa, the species can survive without man providing the artificial breeding places or even the needed blood meal. In the Americas, on the other hand, shall we say fortunately, the species is still tightly man-bound (4-5).

It appears to me that this is the basic difference between the American and the African *Aedes aegypti*. It could be interpreted as a consequence of the fact that in Africa the species is in its natural milieu to which it is completely adapted, while in the Americas the species is still a new-comer fighting its way, and therefore more limited in its vital potential.

It is of interest in this regard to compare the eradication of *An. gambiae* and *A. aegypti* in Brazil.

Whereas, the former was of very recent immigration, the latter was established in the Americas for a long period, but still a very short one when compared with Africa.

Whereas the latter shows a unique genetic plasticity, the former seems to be much more stable and consequently less adaptable. I wonder whether it would be the opinion of those who carried on the work that the *An. gambiae* has been also eradicated more easily than *A. aegypti*!

To hit a new species before it can get adapted to its new environment seems to me of utmost importance, especially if that species is known for its plasticity, its adaptability.

As far as it is known, there is a complete crossability among the three subspecies of *A. aegypti*. It has also been found that the feral varietas *formosus* is purely African . . . so far. Therefore, would it be farfetched to hypothe-

size that this wild variety is accountable for distributing throughout the African population the genetical material responsible for that plasticity of adaptation to various conditions? Would it not be possible that the two American varieties be still "pure" enough as to need, for their survival, an intimate association with man and his artificial environment?

Actually, we do not know yet because very little is known about var. *formosus*! But if this hypothesis should be true, it is certainly one of the most important justifications for starting and completing in the Americas a program of eradication of the species as early and as vigorously as possible while the survival of the species is still restricted to man-colonized areas.

In Trinidad and Puerto-Rico some out-of-line behaviour has already been recorded: breeding in tree holes, and in rock holes (3) peculiar pattern of resistance to insecticides (8). Are these signs of a better adaptation to the American environment?

What could be the consequences of the establishment of var. *formosus* in the Americas? With the modern, fast, and frequent means of transportation between Africa and the Americas, this is a permanent Damocles' sword hanging over this hemisphere.

Remember the bridgehead of *An. gambiae* in Brazil some years ago and its elimination! Only fast action saved the situation. Although the foothold gained by *A. aegypti* is stronger, it has been amply demonstrated in South America that eradication is still feasible, that it is not too late for success; but delaying action in other areas of the western hemisphere would perhaps be an irreparable mistake.

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## THE USE OF BAYTEX AS A MIDGE LARVICIDE<sup>1</sup>

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Both BHC and EPN were used extensively in Florida as midge larvicides in the early 1950's according to Lieux and Mulrennan (1956). Following apparent failures with these insecticides, control measures were shifted from the use of larvicides to adulticides, utilizing thermal aerosol fogging. This has been very effective, but fogging has its limitations for controlling these insects.

In the intervening years since the apparent failures of BHC and EPN, numerous other chemicals have been screened as midge larvicides. Of these, Baytex (o, o-Dimethyl o-[4-(methylthio)-m-tolyl] phosphorothioate) has shown the most promise in Florida.

It was reported by Patterson and von Windeguth (1964) that Baytex, applied at the rate of 0.2 pound per acre in a one percent granular formulation to small ponds with water depth of about 3 feet, gave excellent control of midge larvae for about 2 months. This granular formulation exhibited no overt toxic effect on fresh water copepods, ostracods, Hydra, annelid worms, snails, clams, or the mosquito fish *Gambusia affinis*; however, it was very toxic to Cladocera. The Baytex did not affect the pH of the water, nor

did it influence the speciation or production of fresh water algae.

Tests designed for the determination of effective dosage and insecticide coverage were conducted in 55-gallon containers placed in a lake. Results from these tests indicated that a 1 percent Baytex sand-core granule gave a quicker kill and was slightly more effective than a 1 percent clay granule. A 5 percent Baytex granular clay formulation was only about half as effective at the same dosage rate per acre as the 1 percent formulation, apparently owing to the greater distribution and degree of contact for the latter. The dosage rate found most effective was between 0.20 and 0.25 pound of technical Baytex per acre. This dosage results in a Baytex concentration of about 4 p.p.b. in a lake having an average depth of about 17 feet.

Following these preliminary studies, granular Baytex was applied to Little Lake Winterset at Winter Haven and to Lake Barton at Orlando, Florida for control of the midge *Glyptotendipes paripes*. This is a report of the results of these lake tests.

**METHODS.** Granular formulations of Baytex were applied twice to Little Lake Winterset, which is a 50-acre bay of a larger lake, but well isolated. The inlet between the two bodies of water is only

<sup>1</sup> Contribution of the Entomological Research Center, Florida State Board of Health.