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ARTICLES

THE ERADICATION OF *ANOPHELES ALBIMANUS* IN
PUERTO RICO—AN ECOLOGIC DISCUSSION

JOHN M. HENDERSON, C.E.

Professor of Sanitary Science, Columbia University School of Public Health

PART I

I. Introduction

In a previous article,¹ the feasibility and justification for eradicating the malaria vector, *Anopheles albimanus*, in Puerto Rico were explored. Preliminary consideration was given to both technical and administrative factors involved in the planning and performance of operations for this purpose.

It is the author's opinion that administrative aspects of the subject are at least equal in importance to those of a technologic character, since they include the need for creating a special organization vested by law with unusual powers and staffed with personnel possessing a rare combination of biologic training, and operational and administrative ability. This article, however, will be confined to technologic considerations, principally biologic in character, in the interest of more adequate presentation of this phase of the problem.

The technologic feasibility of eradicating an undesirable insect species is controlled by four broad variables:

(1) The total biologic characteristics of the species and the extent to which these are known to man; (2) the character and extent of the environment; (3) the species effectiveness of existing insecticidal methods; and (4) the hazards of re-importation. While final judgment demands the synthesis of all four factors, biologic char-

acteristics considered independently offer a convenient approach. Following this procedure, any mosquito species may be placed tentatively in one of the following categories; (1) Easy to eradicate; (2) Difficult; (3) Impossible; and (4) Unclassifiable due to lack of information. These categories are of course relative; even an easily eradicatable species may require prodigious operational effort; "impossible" is used in its practical sense. Present knowledge of the bionomics of *Anopheles quadrimaculatus* and *Anopheles albimanus* suggests placing these species tentatively within the category of "difficult." Although this article is concerned with the eradication of *Anopheles albimanus*, examples of "Easy" and "Impossible" species are cited for perspective.

Hypothetically, the easiest species to eradicate is one that: is highly domesticated in adult behavior and larval habitat, is very selective in choice of breeding place, oviposits only in water, is exclusively androphilic in feeding habits of the mature female, has a short flight range, uses man's habitations as its sole resting place, possesses no significant estivating or hibernating characteristics in the mature stage, and develops rapidly and is susceptible to desiccation in the immature stages. Of the species important to man, *Anopheles gambiae* during dry weather seasons in its brief tenure as an imported species in Brazil and in the Nile Valley, and *Aedes aegypti* in some climatic situations approach, but do not meet, these specifications.

An example at the other extreme, i.e., "Impossible" to eradicate, is provided by

¹ "On the Possibility of Eradicating the Malaria Mosquito in Puerto Rico." Boletín Asociación Médica de Puerto Rico, XXXIX (3):89-96, March 1947. Presented before Sixth Annual Meeting, Puerto Rico Public Health Association February 5, 1947.

some of the long flying species of the genus *Aedes*, the ova of which may remain viable in nature for several years, which enter and rest in the habitations of man only to a limited extent, and are dispersed in nature after leaving the vicinity of the breeding place. The eradication of such species may be dismissed as impractical at the present time wherever breeding places are numerous and abundance is great enough to constitute a problem.

II. Bionomics and Physiology of *Anopheles Albimanus*

This species in its West Indian environment may be considered typical of the genus *Anopheles* in most physiologic characteristics. For this reason, much of the general physiology of the species is omitted. The mean temperature for January in Puerto Rico is about 6° F. lower than for July. Accordingly, significant seasonal change in temperature does not exist as a motivation for excessive prolongation of the immature stage, hibernation of the adult, or lengthy pre-hibernating flight. Field experience indicates that the developmental time of the immature stage ranges from 7-9 days to about 21 days, the latter occurring in the winter. The immature stage does not appear to resist drying, nor has prolonged dormancy of the ovum, larva or pupa been noted in Puerto Rico under any other circumstances, although little attention has been paid to these factors. Estivation of a few adult specimens to perpetuate the species through periods of hot, dry weather is considered more probable, although in none of the island areas in which *Anopheles albimanus* is indigenous are climatological conditions such as clearly to establish the biological necessity for this phenomenon.

Bionomically, *Anopheles albimanus* possesses a number of characteristics which set it apart from many other anophelines. Some of these add greatly to difficulty of control and even more to that of eradication. The species is probably more closely similar to *Anopheles aquasalis* in its envi-

ronmental responses than to any other species.

Aquatic Habitat—*An. albimanus* is popularly termed a universal breeder. It is found commonly in permanent and temporary breeding places, preferring the latter. Large water surfaces are not required; as many as 50 large larvae and pupae may be found in a single hoofprint. It breeds prolifically in fresh and brackish water; in fact production appears to be stimulated by salinity up to about 25% of sea water concentration. It appears able to tolerate a concentration of at least 50% of sea water salinity before production is terminated.^{2,3} While not found in swift currents, larvae and pupae are commonly present in prolific numbers along stream edges in still water pools of heel print size and up. Breeding in artificial containers is seldom a problem in controlling malaria transmitted by this species, but is a factor in eradication. Its ability to utilize the wide range of microflora and fauna found in fresh, salty and alkali waters in temporary to permanent situations also suggests tolerance to at least moderate pollution and turbidity. Pupae have been noted by the author in hoofprints constantly muddied by grazing cattle. Survival of fourth instar larvae and pupae in water grossly fouled with cattle urine also has been noted, although it is questionable whether development from ovum to imago takes place in such situations.

One ecologic factor exists however, which markedly inhibits production—*Anopheles albimanus* is heliophilic to such a degree that fully shaded situations are not of concern to the control worker. But its resourcefulness in utilizing favorable water surfaces approaching a micro-size means that shade must be continuous to insure the total absence of production.

The seasonal reduction in the abun-

² Hurlbut, H. S. 1943. Observations on the Use of Sea Water in the Control of *Anopheles albimanus*. J. Parasitology, XXIX (5):356.

³ Weathersbee, A. A. 1946. Malaria Control Activities During the Construction of an Advanced Tropical Naval Base. J. Nat. Mal. Soc. V(4):263.

dance of *Anopheles albimanus* which usually occurs in Puerto Rico during the period January through April or May can be utilized advantageously in the planning of eradication operations.

At that time collections of imagoes in animal bait traps commonly fall to as little as 1 to 5% of those obtained for sustained periods within the remaining months of the year.⁴ At some locations this reduction appears associated primarily with the relative dearth of temporary collections of water resulting from lack of rainfall, but the number of larvae found in more permanent waters also declines sharply. At times, reduced production in permanent waters seems partly due to lowered temperatures, but more obscure biological factors also appear to play a prominent role.

Conversely, both control and eradication operations can be greatly impeded by the surges in production which occur in the less favorable months of the year. These adverse conditions are unavoidable in any program extending beyond the late winter-early spring season, as would be the case with island-wide eradication in Puerto Rico. Operational planning also is complicated by moderate variation in the pattern of scarcity and abundance for different parts of the island, and from year to year.

Flight Range.—Extremes of opinion as to the flight range of this species in sufficient numbers to constitute a malaria hazard, range from 1 to as much as 25 miles.⁵ In Puerto Rico, the range is considered as from 1 to about 3½ miles. The length of this *effective flight* appears most prominently related to abundance of the species although other factors are acknowledged as significant. This more limited range is in closer agreement with general malariological opinion, although

some might consider the figure of 3½ miles excessive.

The flight distance of the longest flying single individual female as an element in eradication can only be speculated on. In theory, this maximum flight as well as the effective flight mentioned above is in proportion to species abundance. Hence, the sparse populations prevailing after initial eradication efforts may well hold both in check.

Zoophilism and Resting Places.—*An. albimanus* may be classed on the zoophilic side in blood meal preference. In Puerto Rico several studies have been made to determine the comparative attractiveness of various animals, including man. The ratio of attractiveness of a small scrub horse to adult man has been found by one investigator (Weathersbee)⁶ to be in the order of about 20:1. The calf is less attractive than the horse but more so than man.⁷ Another related characteristic is its prejudice against man-made habitations as a day-time resting place. This may also tend to reduce the resting time within dwellings at night. Not only does virtually every remaining female leave between dawn and sunrise^{8,9} but many engorged specimens depart during the night even when no other buildings are nearby.⁹

Accordingly, the effectiveness of DDT residual house spray as an eradication

⁶ Weathersbee, A. A. 1944. Observations on the Relative Attractiveness of Man and Horse for *Anopheles albimanus*. Am. J. Trop. Med. XXIV (1):25.

⁷ Results of unpublished tests in Puerto Rico by Malaria Control in War Areas, U.S.P.H.S., 1942. Also observations by W. C. Earle and staff members of Bureau of Malaria Control, Dept. of Health of Puerto Rico, 1925-35. (Author's Note: These studies were made to determine baits for use in animal bait traps [stable traps] and to correlate these collections with the attractiveness of human populations. Restricted size of bait traps precludes the use of mature cattle and horses of large size.)

⁸ Weathersbee, A. A. 1944. Observations on the Nocturnal Activity of *Anopheles* and Certain Other Mosquitoes in Eastern Puerto Rico, P.R.J. Pub. Hlth. & Trop. Med. XIX:626-34.

⁹ Unpublished study, Malaria Control in War Areas, U.S.P.H.S., 1942.

⁴ Unpublished collection records. Malaria Control in War Areas, U. S. Public Health Service, 1942-46.

⁵ Curry, D. P. 1943. Twenty-three Years Experience in Malaria Control in the Canal Zone. Proceedings, XXX Annual Meeting, N. J. Mosq. Ext. Assn. p. 60.

measure can be adjudged as being far lower for *An. albimanus* than for other species which are androphilic, house-loving, or both. Major effectiveness can be anticipated only where human population is not only present but superior in mass attraction to competing animal blood meals. Such situations are encountered commonly in malaria control, but have minor significance in a terrain-wide program of eradicating this species. In this connection it is noted from studies by Trapido in Panama¹⁰ that DDT residual spray applied to all dwellings in a village where there was little reported competition from domestic animals, did not influence collections from a stable trap 300 yards distant from the village area. Reduction was noted in a trap 100 yards from the village area, there being no intervening traps. Studies of DDT house spraying by Stephens and Pratt in Puerto Rico,^{11, 12} conducted under different circumstances, showed no reduction in the adult population at large in a village area.

Most biologists, while aware that even slight reduction in the population of gravid females of an insect species means fewer eggs oviposited, vigorously oppose the reasoning that the rate of imaginal production is perceptibly affected by small reductions in the former. Hence, any adulticidal method which only slightly lowers the area-wide population of gravid females would appear valueless unless combined with other methods of adult mosquito control and a substantial accumulative effect obtained. For these reasons, the residual spraying of houses with DDT cannot be considered *per se* a significant weapon in eradicating this species over a large agricultural terrain such as that of Puerto Rico.

The search for other adulticidal meth-

ods which might effectively complement DDT residual house spraying in eradicating this species is made difficult by failure of the imago to congregate anywhere in the day-time. Little is known of its day-time resting places, but the search over many years has been assiduous and extensive enough to indicate that resting adults are dispersed. They have been seen scattered through the deep shade of some mangrove swamps, resting near the water line. But breeding places were nearby, and there is no evidence that the specimens had returned after leaving the breeding place. Until more definitive evidence is available, it can only be assumed that they rest under the cover of terrestrial as well as aquatic vegetation. The micro-climate offered by tall stands of mature sugar cane bordering small ditches and other water-courses must not differ greatly from that of water surfaces shaded by aquatic shrubs and plants. The dispersion of adults while at rest and the lack of knowledge as to their location preclude the present use of exterior space spraying in the day-time as an effective weapon in eradication. Their absence from habitations in the day-time similarly precludes the day-time use of interior space sprays. Furthermore, exterior space spraying at night in the manner practiced against *Aedes* species in New Jersey offers more promise of protecting a few clumps of blood meal sources than of becoming a major weapon in eradicating *An. albimanus*.

The residual spraying of cattle and other farm animals with aqueous suspensions of DDT or other insecticides however, offers promise in Puerto Rico of being surpassed in value only by larviciding. Where these animals are housed at night in barns and stables, the effectiveness of cattle spraying can be supplemented importantly by spraying the buildings. Agriculture is the principal means of support for Puerto Rico's population. On an area basis, the terrain in which *An. albimanus* is abundant consists largely of farm lands and adjoining swamps, marshes and water-courses. Moreover, the farm lands are

¹⁰ Trapido, Harold. 1946. The Residual Spraying of Dwellings with DDT in the Control of Malaria Transmission in Panama, with Special Reference to *Anopheles albimanus*. Am. J. Trop. Med. XXVI (4):383.

¹¹ Stephens, P. A., and Pratt, H. D. 1947. Work with Residual DDT Spray in Puerto Rico. Science CV (2715):32.

¹² Pratt, H. D. 1947. Personal Communication.

mainly given over to the production of sugar cane or grazing. The draft oxen and the overseer's horse are symbolic of sugar cane culture. While Puerto Rico cannot be credited with a meat raising economy and the ratio of animal to human population is not high, the two live closely

together and domestic animals are available to virtually the entire population of *An. albimanus* in Puerto Rico. In exceptional situations, such as the Island of Vieques, the population of farm animals approaches the human population in number.

(Part II of this article will appear in the September number.)

A NEW "JEEP" MOSQUITO CONTROL ASSEMBLY

Reported by T. D. Mulhern, Administrative Assistant,
New Jersey Agricultural Experiment Station.

A new "Jeep" spray outfit developed by Mr. L. D. McCarter, Supt., Hudson County Mosquito Extermination Commission (N. J.), may be of interest to other mosquito control workers.

The Hardie triplex pump alongside the driver is driven from the power take-off for ordinary spraying (600 lb. pressure). TIFA fog machine, shown on the "Jeep," is replaced by rectangular liquid spray supply tank when using Hardie pump. The Jeep is dual wheel equipped on rear axle, and trailer holds 40 army style 5 gal. cans.

