CURRENT EFFORTS IN MOSQUITO CONTROL IN HAWAII

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What we are about to say may alienate us with our Visitors Bureau for we are about to admit that even in the Paradise of the Pacific we are bothered by mosquitoes. In the same breath, however, we would like to restore harmony by stating that we in Hawaii have to contend with only three species whereas Florida and California boast about their approximately 70 and 40 species, respectively.

Actually, mosquitoes are recent immigrants to Hawaii. The first species to establish itself was the night mosquito, *Culex quinquefasciatus*.

Van Dine (1904) states: "Previous to the year 1826 mosquitoes were unknown in Hawaii. During that year they were brought to the port of Lahaina, on the island of Maui, in the ship 'Wellington' from San Blas, Mexico." The exact dates of the introduction of the remaining two species are not established, but according to Usinger (1944), *"aegypti* was widespread in Hawaii when Perkins [1] started his collection for Fauna Hawaiiensis in 1892, whereas *albopictus* 'did not come to notice' until 1902." Subsequently, over the past 57 years there has been no further successful introduction of noxious mosquitoes into Hawaii. Potentially, however, there always exists the threat of new introductions. According to U. S. Public Health Service record in Hawaii from 1939 to March 1959, 46 species [2] have been recovered from aircraft arriving in Hawaii. In October 1958, a mosquito specimen recovered during the routine check was found to be *Culex tritaeniorhynchus,* the primary vector of Japanese B encephalitis.

The Hawaiian Archipelago is a group of islands, reefs and shores strung out from southeast to northwest for 1,600 miles between 150° 40′ and 175° 75′ w. longitude and 18° 54′ to 28° 15′ n. latitude. Generally speaking, however, the Hawaiian Islands are limited to a group of eight islands totalling 6,430 square miles and include, in order of their sizes, Hawaii, 4,030 square miles; Maui, 728 square miles; Oahu, 604 square miles; Kauai, 555 square miles; Molokai, 260 square miles; Lanai, 141 square miles; Niihau, 72 square miles; and Kahoolawe, 45 square miles. The total population of Hawaii, the 50th State, numbers 585,025; the distribution by islands being as follows: Hawaii, 62,464; Maui, 36,600; Oahu, 449,910; Kauai, 28,035; Molokai, 5,596; Lanai, 2,267; and Niihau, 243. The island of Kahoolawe is unpopulated.

The climate of Hawaii is mild and temperate and relatively free from any uncomfortable extremes. In Fahrenheit readings the maximum is about 90° and the minimum about 55°. The annual average is about 70° in downtown Honolulu with a daily range of about ten degrees between the low and the high. The average temperature on Oahu decreases with the elevation but up to over 1,000 feet the extreme maxima are higher and the extreme minima are lower than in downtown Honolulu, and in residential sections a few miles inland the daily range is several degrees greater. As to rainfall, the average amount in the city of Honolulu is less than 25 inches per year. However, progressing inland from downtown Honolulu toward the mountains there is a rapid increase to an annual average rainfall of over 50 inches within a radius of two miles; one mile further inland, the average is from 90 to 100 inches. In general, the mosquito breeding index increases in direct proportion with the rainfall and

[1] Perkins, R. C. L. 1913. Fauna Hawaiiensis, Introduction. Vol. I, Pt. 6, p. clxxxi, University Press, Cambridge, England.

[2] Personal communication with Dr. Charles R. Joyce, Medical Entomologist, USPHS, Quarantine Branch, Honolulu, Hawaii.

hence, it is not unusual to encounter conspicuous fluctuation in breeding indices in areas separated by a mere mile or two.

The three species of biting moquitoes in Hawaii are *Aedes aegypti*, *Aedes albopictus* and *Culex quinquefasciatus*. The two *Aedes* species because of their daytime biting habit are referred to as the day mosquitoes; the *Culex* species, on the other hand, bites during the night and is commonly called the night mosquito. All three species are notorious vectors of human diseases. Fortunately, however, dengue is the only mosquito-borne disease which has occurred in the Islands in epidemic proportions. Significant outbreaks have occurred in 1903, 1912, and 1943–44. To summarize the disease transmitting potential, all three species have been shown to be natural or experimental vectors of the following diseases:

Aedes aegypti: Yellow fever, dengue, filariasis and encephalitis.

Aedes albopictus: Dengue, yellow fever and encephalitis.

Culex quinquefasciatus: Filariasis and encephalitis.

From the standpoint of control, the night mosquito, *Culex quinquefasciatus*, is today the only serious mosquito pest which is currently demanding organized control effort. In the past, however, emphasis was on the *Aedes* species. In fact, the Bureau of Mosquito Control, Department of Health, owes its origin to these two day mosquitoes. It was created as a unit under the Department of Health in 1946 as an outgrowth of the dengue outbreak of 1943 for the specific purpose of keeping these two vectors of dengue fever under control. Today, with continuing control maintained through systematic house-to-house inspections, the *Aedes* species appear to be well under control in the city of Honolulu as reflected in a ten-year average breeding index (1949–1958) of 2.5 percent. This general city-wide average index represents a range in variation in the breeding indices from an average of 0.5 percent in the drier part of the city with approximately 20 inches of rainfall to a high of 9.7 percent in the wetter districts with 60 inches or more rainfall a year. Concerning the status of *Aedes aegypti* in Hawaii, surveys conducted by the Bureau of Mosquito Control on the island of Oahu have failed to uncover the presence of this species since about 1949. Also on Kauai *aegypti* has not been observed since its last record of observation in leeward Kauai by D. D. Bonnet in 1945 (Hess, 1957). It is still present, however, on the neighbor islands of Hawaii, Maui and Molokai.

In Hawaii, the breeding habits and characteristics of *Culex quinquefasciatus* appear to vary from that of the domestic house mosquito to those of irrigation, floodwater or salt-marsh mosquitoes. This foul-water species breeds in a great variety of water-holding containers including tin cans, buckets, barrels and other relatively small water catchments, and breeding from these small domestic foci can create significant annoyance until they are discovered and corrected. The major problem areas are, however, extensive chronic breeding areas such as naturally existing ground pools, swamps, and other lowlands located for the most part in suburban and rural areas, as well as artificially created conditions such as those associated with sugar plantation cane wash water used for irrigation or soil reclamation. According to Holway (1958), under the latter condition (breeding associated with cane water) the adult population densities produced are more characteristic of irrigation, floodwater or salt-marsh mosquitoes than that of the familiar house mosquito.

In general, concerted control action against *Culex quinquefasciatus* has been handicapped by lack of sufficient funds to carry out an adequate program. There is no enabling legislation in Hawaii for the formation of mosquito abatement districts. The extent of control that is possible on land under State jurisdiction is dependent upon the biennial state legislative appropriation to the Department of Health for mosquito control. Actual control operations are carried out by the staff

of the Bureau of Mosquito Control, Department of Health. The scope of operation of the Bureau is dictated by its limited legislative appropriation and is confined largely to surveys, inspections, education and temporary control measures such as larviciding and adulticiding. The Department of Health's program is complemented by the respective control programs of the military and private industries such as the various sugar plantations. Also interested community organizations in high infestation areas have raised funds voluntarily to pay for airplane spraying. The Department of Health assists these communities by providing technical guidance as may be necessary to effect the aerial spraying.

In spite of inadequate appropriations, significant advances towards a more effective *Culex* control program have been realized through establishment of closer liaison and coordination of efforts by the various interested organizations. An example of this mutual pooling of resources is the joint mosquito light trap survey program initiated six months ago. Under this program, each participating agency operates several light traps within its own jurisdictional area and exchanges the trap data on a once-a-week basis. For example, the U. S. Navy is operating 14 traps in the Pearl Harbor and the Barbers Point areas. The U. S. Air Force operates four traps in the Hickam Field area. The U. S. Public Health Service has two traps: one at the International Airport, Honolulu and the other at its office location in downtown Honolulu. The Department of Health is currently operating seven traps in the various areas under State's jurisdiction. The U. S. Army is now in the process of obtaining a supply of light traps for establishment in Schofield Barracks and other areas under Army jurisdiction. The data from these weekly reports are compiled into a monthly summary by the Bureau of Mosquito Control, Department of Health for dissemination to each participating agency. This joint project provides valuable "intelligence" for each agency to use in scheduling control operations such as area fogging.

Control measures applied for *Culex* control in Hawaii include chemical control, biological control and source control.

Examples of chemical control are larviciding, and adulticiding (misting and fogging). The insecticide in general use today is malathion. It has replaced DDT because of the resistance problem. Based on limited testing to date conducted independently by both the staff of the Bureau of Mosquito Control utilizing the WHO test kit and Navy personnel of Preventive Medicine Unit #6, *Culex quinquefasciatus* larvae from different areas have shown resistance levels ranging from 0.0438 ppm to 0.250 ppm. For the most part larviciding is accomplished with ground operated hydraulic power sprayers. Occasionally, airplane spraying is utilized in high infestation areas inaccessible to ground equipment. This is financed through contributions raised voluntarily by community organizations. Misting is also practiced as an emergency measure in areas of high adult prevalence. Misting is done during the daytime to kill the adults as they rest on the vegetation. Area fogging by the Army and Navy is geared to prevailing light trap indices. The Department of Health attempts to keep up with the numerous requests for fogging from districts in high *Culex* prevalence areas by trying to accommodate them on a once-a-month basis, depending upon favorable weather conditions.

Biological control is practiced whenever possible by the use of surface feeding minnows to keep mosquito breeding under control in ground pools and other semi-permanent or permanent bodies of water. An outstanding case of effective control obtained with fishes is the result obtained in the ground pool located in the crater of famous Diamond Head. In March 1958, a record 17-inch rainfall in 48 hours enlarged the existing residual ground pool of about five acres into a miniature lake of about 35–40 acres. During normal rainfall years of the past, this rain-fed intermittent pool appeared during the rainier

months of the year but dried up after the summer months. Annually, during the period of its existence, control of mosquitoes was hindered by a dense canopy of algae growth (*Oedogonium*) on the surface of the water which protected the wrigglers breeding beneath it from being contacted with chemical sprays or by minnows. In anticipation of the algae problem, about 1,500 algae-feeding fish of the species *Tilapia mossambica* (originally introduced in 1951 from Malaya by the Fish and Game Division, Board of Agriculture and Forestry), were stocked in the pool immediately following the storm in March in an attempt to control the algae growth. At the same time about 30 bucket loads of *Gambusia affinis,* which thrives in almost any fresh water pond or stream in Honolulu, were also transplanted into the crater. For about the first three months mosquito breeding was evident under protection of the rapidly forming algae growth on the surface of the pond. In July, as anticipated, the prolific *Tilapia* multiplied sufficiently so that their feeding cleared the surface growth of algae and enabled the *Gambusia* to attack the wrigglers; consequently, no further applied control has been necessary for the past ten months.

Less spectacular and significant has been the degree of control realized to date with the various species of predatory mosquitoes of the genus *Toxorhynchites* (= *Megarhinus)* introduced into Hawaii in the past for the control of *Aedes albopictus* (Bonnet and Hu, 1955). Based on periodic observations over the past few years in former release areas by staff members from the Bureau of Mosquito Control, it appears that two species have established themselves in the wetter regions on at least two islands: *T. brevipalpis* and *T. splendens* on Oahu (Waimao Valley, Palolo, Haiku, Wahiawa and Makiki) and *T. splendens* on Kauai (Lihue). Although no comprehensive evaluation of the value of *Toxorhynchites* as a biological control agent in Hawaii has been attempted to date, superficial but repeated field observations have thus far pointed to poor control, based on the consistent findings that in spite of the presence of *Toxorhynchites* larvae in recovery areas, the adult *albopictus* population was literally "as thick as flies."

In Hawaii, as elsewhere, source control through land or water management is recognized as the fundamental approach to mosquito control. Economic reasons, however, have been a prime deterrent to the realization of voluntary source control specifically for the purpose of eliminating mosquito breeding such as in naturally existing swamplands. On the other hand, involuntary source control has been progressing to an encouraging extent at the expense of real estate developments inasmuch as the scarcity of real estate in Hawaii is forcing developers to reclaim swamplands for housing areas. Also, there has been talk of the possible use of a suitable abrasive agent to replace wash water for cleaning the sugar cane stalks before grinding. It appears highly in the realm of possibility, therefore, that in the not too distant future involuntary source control through real estate developments and improvements in sugar processing methods may contribute significantly toward the abatement of the current problem species, *Culex quinquefasciatus* in Hawaii.

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