sufficient to kill a majority of wild *quadrimaculatus* eggs on rice-field soils.

Bibliography

DARROW, E. M. 1949. Factors in the elimination of the immature stages of *Anopheles quadrimaculatus* Say in a water level fluctuation cycle. *Amer. J. Hyg.*, 50:207–235.

DEANE, M. P., and CAUSEY, O. R. 1943. Viability of *Anopheles gambiae* eggs and morphology of unusual types found in Brazil. *Amer. J. Trop. Med.*, 23:95–101.

HILL, R. B., and CAMBOURNAC, F. J. C. 1941. Intermittent irrigation in rice cultivation and its effect on yield, water consumption, and *Anopheles* production. *Amer. J. Trop. Med.*, 21:123–144.

MAYNE, B. 1926. Notes on influence of temperature and humidity on oviposition and early life of *Anopheles*. *Pub. Health Rep.*, 41: 986–990.

NELSON, M. 1944. Rotation, cultural, and irrigation practices affecting rice production. *U. Ark. Agric. Exp. Sta. Bull.* No. 445.

STONE, W. S., and REYNOLDS, F. H. K. 1939. Hibernation of anopheline eggs in the tropics. *Science*, 90:371–372.

MOSQUITO CONTROL ON ARMY POSTS IN THE FAR EAST

A. W. MORRILL, JR.,[1] A. N. DANDOY,[2] M. S. JOHNSON,[3] J. F. POOLE,[4] and R. H. VINCENT[5]

Mosquito control at all fixed Army installations in Japan, Okinawa, the Philippines, Guam and Korea is a responsibility of the Post Engineer, as it is in the United States. Utilizing local civilian employees, trained by civilian entomologists in the Corps of Engineers, crews have been established and control operations placed upon regular schedules. The work was supervised by American civilian and enlisted men, by locally employed entomologists and by local crew members who demonstrated abilities of such calibre as to warrant their being given further specialized training and higher responsibility. Close coordination has been maintained between the Engineer organizations and the Army Medical Service, whose survey and control units conduct all operations in combat areas, and whose survey and laboratory units under the direction of Medical Service entomologists have been an integral part of the program.[6] In 1946, most of these control units of the Army Medical Service had been rapidly deactivated and until the local civilian crews could be recruited and trained, operations were often quite unsatisfactory. However, in every area, both the local employees and the American civilians and enlisted men proved to be interested in the work, energetic and capable, and soon developed a high morale and a very considerable efficiency.

Principal Species of Mosquitoes: The principal disease-bearing mosquitoes and their primary breeding places were as follows: *Anopheles hyrcanus sinensis*—(rice paddies); *Anopheles maculatus*—(streams); *Anopheles minimus flavirostris*—(clear streams); *Anopheles subpictus*—(swamp and mud holes); *Aedes albopictus*—(scrap yards, flooded ruins, water containers); *Culex quinquefasciatus* (*fatigans*)—(stagnant water, water con-

[1] Formerly Entomologist, GHQ, Far East Comd.; now with Eng. Res & Dev. Lab. Ft. Belvoir, Va.

[2] Formerly Entomologist, Phil. Base Comd.; Manila; now Ryukyus Cmd.

[3] Entomologist, Hq & Sv Cmd, Tokyo, Japan.

[4] Entomologist, Ryukyus Cmd; Okinawa.

[5] Formerly Entomologist, Marianas-Bonin Cmd; Guam, now Asst. Chief, I & R Sect., OCE, Wash., D. C.

[6] Especially invaluable aid has been supplied by Lt. Col. S. C. Dews, 8th Army, Lt. Col. J. E. Webb, Jr., Brooke Army Med. Ctr., Lt. Col. S. O. Hill, Brooke Army Med. Ctr., Capt. H. C. Barnett, 406th MGL, Tokyo, Japan, & Dr. William Suyemoto, 406th MGL, Tokyo, Japan.

tainers); *Culex pipiens*—(water containers, paddies, stagnant water); *Culex tritaeniorhynchus* — (water containers, early season paddies). In addition, *Anopheles limosus* breeding in paddies in the Philippines, and *Aedes pandani,* breeding in pandanus bracts and other standing water in the boondocks or jungle on Guam, were pests of considerable importance, although *pandani* rarely entered houses.

Knowledge of the importance, interrelations and habits of these various mosquitoes was greatly aided by the advice and assistance of entomologists native to or long resident in the areas.[7]

Quite diverse problems of mosquito breeding and habits were encountered in the various areas. In the Philippines, the only lowland vector of malaria is *Anopheles mininus flavirostris,* which breeds almost solely in clear, uncontaminated streams. *A. maculatus,* breeding in both streams and paddies and implicated in the rare transmission occurring in the mountains, does not breed in the lowlands. *Anopheles hyrcanus sinensis,* a rice paddy breeder which is the carrier of malaria in Okinawa, Japan and Korea, while numerous in the Philippines, is not considered to be a carrier there. The problem of malaria control, therefore, centered upon treatment of all streams in or around the Army and Air Force areas. Even extremely small tributaries, many of which were completely hidden under the relatively short, thick-growing *cogon* and the pampas-like *talahib* bunch grasses, were capable of producing dangerous populations of *minimus.*

In Guam in 1944, an epidemic of dengue caused a brief but energetic eradication campaign which eliminated *Aedes aegypti* from the island. It has not reappeared. However, in 1947, it was discovered that, since the war and presumably by means of insufficiently treated aircraft, two new disease vectors had been introduced to Guam. One, *Aedes albopictus,* the very efficient dengue carrier of the Philippines, breeds so much more indiscrimately than *aegypti* that control has been vastly more difficult. It is found in all untreated areas where water stands in old tires, car bodies, junked machinery, war-time scrap, household water storage tanks, or discarded tin cans. The other, *Anopheles subpictus,* an inefficient but potential malaria carrier from the Celebes, breeds in a wide variety of types of standing open water. This natural standing water is relatively scarce. The encephalitis carrier, *Culex quinquefasciatus,* breeds in loosely-covered drainage pits under community wash houses as well as in rainwater storage drums, old tires, discarded equipment, etc., and its control is almost entirely one of community sanitation. The only other important mosquito, *Aedes pandani,* is a vicious biter, but rarely goes far from the boondock or jungle made up of pandanus, coconut, papaya, jack-fruit, and vines, even more rarely enters houses, and carries no disease.

In Okinawa and the whole Ryukyus, the malaria vector, *Anopheles sinensis,* breeds in paddies and the encephalitis carriers, *Culex quinquefasciatus* and *C. tritaeniorhynchus,* also breed in paddies but more especially in discarded tin cans, scrap vehicles, tires, cisterns, privies, drains, and similar places.

South of Okinawa, both *Anopheles minimus* and *A. sinensis* are found in slowly-flowing paddies and streams. *Culex quinquefasciatus,* the supposed vector of encephalitis, and *Aedes albopictus,* the dengue vector, breed in cisterns, ditches and *benjos* (privies). Dr. S. Ohama of Yaeyama Retto discovered *A. sapperoi* breeding in rivers in Ishigaki in far larger numbers than have ever been found in Okinawa, from which it was described by Bohart, but where it has not since been recaptured. Because of its abundance and other apparent indices, Dr. Ohama believes it to have been a principal vector of

[7] Notably Dr. Francisco Dy, WHO, Manila; Mr. Fernando Gutierrez, Univ. of Phil.; Dr. A. Ejercito, Phil. Bur. Health; Mr. R. Urbino, Phil. Bur. Health; Dr. T. Koiima, Tokyo Univ.; Dr. K. Shiraki, ESS, Tokyo; Dr. S. Ohama, Health Officer, Yaeyama Retto (Ryukyus).

malaria in Yaeyama prior to its control. His efforts at control of the mosquito were so successful, however, that malaria dropped to a near-vanishing point and he was unable to complete his studies.

In Japan, malaria is carried by *Anopheles sinensis,* but it has been a disease of minor importance. On the other hand, encephalitis carried by *Culex pipiens* and *C. quinquefasciatus* has been a very grave problem. Potential breeding sources are so numerous that some authorities have felt that attempts at larval control would be useless. Breeding occurs in *benjos,* or privies, in ditches, in bamboo stumps, or posts, in cemeteries and in broken shards and rubble. With the advancing clean-up and restoration of Japan to pre-war standards of neatness and higher ones of sanitation, the roadside ditches now constitute the principal breeding source. Inasmuch as nearly every street and road, save only the ones in the center of the largest cities, is bordered with such ditches, either uncovered or loosely covered with boards or concrete slabs, it will be seen that this one source is at present more than enough to require a vast amount of effort to be expended in order to secure larval control. Korea presents a problem which is a combination of Japan, with its urban breeding places and Okinawa with its extensive paddy breeding, plus the exigencies created by the unstable political and military situation.

In order to secure control in military installations, which are often small and are almost always surrounded by large and complex breeding areas, an interrelated program of survey, regularly recurrent treatments and coördination with civil programs was developed. Surveys were usually carried out by Medical Department personnel, some of them civilians formerly in Philippine Scout Malaria Survey Detatchments, and these surveys were directed toward determining not only the sites where breeding occurred but also the weekly population levels, which would indicate the effectiveness of control applications. In some areas, as in Guam, no Medical Department detachments existed and these civilians formerly in the Medical Department units were employed by the Corps of Engineers. In Japan, there were but two medical units and survey was useful only to indicate breeding sites; population levels were determined by local Engineer employees trained by the entomologists. In Korea, on the other hand, the Medical Department units did little survey but provided supervision for civilian Post Engineer employees organized as control teams.

Since installations were small, permanent larval breeding control was usually secured in the military area by the very construction of the installation itself and the establishment of its primary drainage. This however, was a minor part of the potential breeding area in most localities and the control problem was therefore largely one of preventing entry of mosquitoes originating outside the military enclosure, and of destroying those which managed to penetrate the barrier. Commencing with the eradication of breeding in the military area, control of adults was initiated with the residual spraying of building interiors. These were sprayed at intervals of not over 60 days during the warm weather, which ranged from a period of 3 months in Hokkaido to the year round in Guam and the Philippines. A residual treatment of DDT was applied with a flat spray to walls and ceilings, paying particular attention, of course, to areas behind doors, cabinets, and draperies and to the under surfaces of beds, chairs, desks, and tables. Screen doors and windows were given more frequent applications, because of fly control, usually at about 30-day intervals. Screening was required on all housing and recreation buildings.

Sprays and dusts were used to apply residual coatings to open buildings, such as bath houses, stables and sheds, both in the military area and in farm and urban areas closely surrounding the military enclosures. Fog generators, capable of producing sustained wet fogs of approximately 30 micron particle size, and power dusters were used extensively to place a

residual coating on foliage and shrubbery and thus form a protective barrier zone to the migration of adult mosquitoes. These were found to be very effective, especially the dusts, which effectively penetrated shrubbery and tree plantings and among buildings and withstood weathering for a week or ten days. Even outdoor theatres such as the amphitheatre in Hibiya Park in downtown Tokyo and the Meiji Park Stadium were effectively protected.

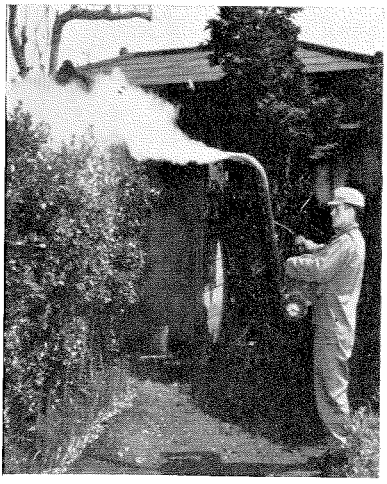

FIG. 1. Clouds of DDT dust, drifted through vegetation and back-yards of occupation homes and Japanese areas adjacent to Occupation housing units, greatly reduce populations of flies and mosquitoes which are potential invaders of military installations.

Breeding places in regions contiguous to but not under the control of the military were also treated in conjunction with or by permission of the local authorities. These treatments were usually sprays or dusts applied by hand-operated equipment carried by individual operators who sought out ditches, privies, drains, rubble, rubbish, paddies, and streams. The regular scheduling of treatments of all areas by the Post Engineer crews is believed to have been a major factor in creating the almost complete freedom of many military enclosures from mosquitoes of all sorts as well as a factor in the economy of the operations. Disease rates among military personnel dropped to very low levels with the progressive efficacy of the control. Among surrounding populations in Japan and Okinawa, where community control was practiced, similar though less marked reductions in disease prevalence occurred.

On Okinawa, and occasionally in Japan, off-post operations covered extensive rice paddies, and power equipment was often utilized; in Okinawa, aircraft dispersal was especially beneficial, dust being used during the latter part of the season when penetration of mature rice plantings with oil sprays was impossible. Like the interior residual applications, these outdoor treatments were scheduled on a regularly recurrent basis, being usually applied at 10-day intervals. Both with air and ground equipment a dispersal of 1–5 pounds of dust per acre was attempted and surveys showed that both adult and larval populations were either greatly reduced or eliminated.

A number of considerations imposed severe restrictions on the use both of ground power dispersal equipment and aircraft for insecticiding. In Japan, because of silk culture, promiscuous and wide-spread insecticidal applications could not be permitted and use of aircraft was therefore automatically proscribed. In Guam and the Philippines natural breeding areas were largely inaccessible to sprays from aircraft and in Okinawa, Japan, Korea, Guam, and the Philippines alike, urban areas were more productive of mosquitoes in terms of larvae per acre than rural ones and these places of course were unsuitable for treatment by aircraft. On the other hand, in certain locations in the Philippines and in Okinawa, the use of liaison-type airplanes and helicopters was very useful and at least some of the areas could not feasibly have been treated otherwise.

In the Philippines, in and around Clark Air Force Base and the Ft. McKinley Philippine Scout General Hospital in Manila, lengthy streams and the Pasig and

Bamban Rivers, where the banks were open, were sprayed from the air, using small, single-engined liaison, or L-5 planes which followed the stream courses at low altitude and secured very effective control for ten-day to two-week periods. In Okinawa, during and immediately following the combat period, aerial spraying was done by means of C-47's. The control, at first apparently good, gradually became very poor and in addition damage was done to crops and trees and the balance of nature seemed to have been considerably upset. By use of the small, low-flying planes and regularly assigned pilots, it has been possible to keep anopheline populations so low as to be inappreciable in large paddy areas where the use of American power equipment is precluded by the lack of roads and even the small, more-maneuverable Japanese power equipment could not easily be used.

As has been said in discussions of each area, the mosquito control problems in the Orient are not radically different from or impossibly more severe than those in the United States. In many places, such as much of the Philippines and the southern Ryukyus, complete control seems well within the bounds of possibility. While the work done by Engineer crews outside of military boundaries was not done for the protection of the neighbors, it did have that incidental effect, and apparently encouraged many householders, in all areas, to undertake personal measures.

In Japan, with habits of neatness and of community effort and with the relatively well-defined breeding locales, the mosquito population could be brought to insignificant levels in cities and villages and even in many farm areas. Based upon the results in Army areas, it seems possible that general mosquito control could be relatively effective there if measures were applied only to public ditches and if individual home owners were taught and encouraged to treat and to reduce the breeding areas in their own yards. The chemicals are presently abundant and fairly cheap and the Japanese have a long tradition of community responsibility. While no miracles are to be expected, the Japanese investigators do not feel that the situation is hopeless and there is a growing interest on the part of the average householder in applying for himself the local measures which the Army has found so effective.

In addition to local mosquito control teams of varying degrees of efficiency, the Japanese Government has for two seasons undertaken a fairly extensive program of dusting with BHC and lindane for the control of the newly introduced fall webworm, called *Amerika hi-tori*, or American Moth. A small and easily maneuverable power duster was utilized in dusting, and overdusting rather than economy of dust was the rule. It would appear on the basis of population counts made by Medical Department entomologists, that this general and heavy dusting may have had some considerable side effect in reducing the mosquito population. No resistance to either BHC or DDT was apparent at the close of the 1951 season.

FIG. 2. Duster and Fog Generator used in Japan, Okinawa and Korea. Capacity 50 lbs. dust, 35 gallons oil/hr.

SUMMARY

In summary, the problem of preventing mosquitoes from infesting military installations centered upon the fact that the installations were relatively small and the surrounding mosquito breeding areas large. Surveys showed that disease-bearing mosquitoes bred in a wide diversity of places, but that the largest numbers came from water standing in ditches, war rubble, carelessly discarded cans, and outworn equipment and drainage pits. Rice paddies were less important than would be supposed, except on Okinawa where they supplied the malaria carrier, and clear streams were the chief locale of malaria mosquito breeding in the Philippines.

Control commenced with clearing all breeding from the military enclosure, followed by regular and frequent applications of residuals to all inhabited buildings to prevent entry and harborage of adult mosquitoes. Residual adulticides, notably dusts, were utilized to create barrier zones in foliage surrounding the installations and to leave adulticidal deposits in animal shelters, sheds, outside baths and privies and under eaves of buildings, gates, and walls. Surrounding breeding sites were treated with larvicides as far as possible, especially nearby privies, ditches, scrap heaps and paddies. Paddies were treated with dusts after the rice became well-grown because of the greater penetration. Power equipment was used in some cases for adulticiding and larviciding, and, where it was suitable, small, low-flying aircraft were routinely utilized. These were not always suitable because of silk-culture or inaccessibility of breeding places.

Control of mosquitoes in all areas, in view of the success on military installations, seems to be quite feasible and some progress has already been made in Japan and the Ryukyus. No resistance to DDT or BHC was apparent to the end of the 1951 season.