HAWAII AGRICULTURAL EXPERIMENT STATION.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 6.

MOSQUITOES IN HAWAII

BY

D. L. VAN DINE,

ENTOMOLOGIST, HAWAII AGRICULTURAL EXPERIMENT STATION.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS.

U. S. Department of Agriculture.

HONOLULU:

HAWAIIAN GAZETTE COMPANY, LTD.

1904.

HAWAII AGRICULTURAL EXPERIMENT STATION,
HONOLULU.

[Under the supervision of A. C. True, Director of the Office of Experiment Stations, United States Department of Agriculture.]

STATION STAFF.

Jared G. Smith, *Special Agent in Charge.*
D. L. Van Dine, *Entomologist.*
Edmund C. Shorey, *Chemist.*
J. E. Higgins, *Horticulturist.*
Q. Q. Bradford, *Farm Foreman.*

LETTER OF TRANSMITTAL.

HONOLULU, Hawaii, May 25, 1904.

SIR: I have the honor to transmit and recommend for publication as Bulletin No. 6 of this station the accompanying article on "Mosquitoes in Hawaii," prepared under my direction by Mr. D. L. Van Dine.

As a result of the efforts of public-spirited citizens a "mosquito campaign" is now in progress in Honolulu. It has been found possible by watchful vigilance and proper methods to keep this tropical city almost free of mosquitoes. The work is supported by voluntary contributions. A salaried Agent is in charge, cooperating with the Board of Health and the Department of Public Works. The first step was to clean the city alleys and vacant lots, removing and destroying tins, bottles, soy tubs and other discarded debris capable of retaining water. A few hundred tons of this rubbish were dumped into the ocean. After this, work of a permanent character was undertaken, such as the drainage of low-lying places or the filling in of ponds and holes containing stagnant water. It has been possible to lessen greatly the annual mosquito crop in Honolulu and promote the comfort and health of the inhabitants of a tropical city of 50,000 people at a cost not exceeding $200 per month.

The aim of Mr. Van Dine in this bulletin is to bring the scientific facts concerning mosquito extermination before the people of this Territory in a thoroughly practical manner. The rules laid down are the results of three years' work and investigation. If these rules are followed with due care and vigilance, Hawaii can soon be well-nigh rid of the swarms of mosquitoes that rob life in the open air and sunshine of this Paradise of the Pacific of all charm and comfort.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Recommended for publication.

A. C. TRUE, *Director.*

Publication authorized.

JAMES WILSON, *Secretary of Agriculture.*

CONTENTS.

ILLUSTRATIONS.

MOSQUITOES IN HAWAII.

(Order, *Diptera* or true flies. Family, *Culicidae*).

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 story, as told by the late Rev. Wm. Richards,[a] at that time in charge of the Mission Station at Lahaina, is as follows: Mr. Richards was returning to Lahaina one evening and met a native who informed him that there was a new "fly" in the place. The native described the insect as being a very peculiar "fly" that made its presence known by "a singing in the ear." Shortly after this, Mr. Richards being on the outlook for the new fly, heard the "singing" in his ear and recognized the sound as that of the mosquito, which up to that time had never been seen or heard of in the Islands. Furthermore, up to the year 1826 there was no word in the Hawaiian language for mosquito. The native term is "makika," a corruption of the word mosquito. Lahaina was at that time the port for incoming and outgoing ships. It is easy to understand that the ships coming here were few and far between and how general opinion could center on the ship "Wellington" as the carrier of the pest.

Since the mosquito introduced in 1826 on the ship "Wellington" was a so-called "night" mosquito, the writer infers that the species determined as *Culex pipiens* Linn., so abundant and wide-spread here, was the one introduced at that time. The two species of Stegomyia or "day" mosquitoes were introduced during the present generation.

DISTRIBUTION AND ABUNDANCE OF MOSQUITOES IN HAWAII.

The mosquitoes were a long time spreading over the Islands. Two generations ago there were many districts entirely free from this pest. Today such places are exceptional. In the eighties there were no mosquitoes at Makawao on the same Island as Lahaina. Makawao is some fifty miles from Lahaina "as the crow flies," with a mountain range

---

[a]The writer is indebted to Prof. W. D. Alexander of Honolulu for this account.

nearly six thousand feet in elevation intervening. The building of roads, making settlement and communication possible, and the intimate inter-island communication of late years, has so favored the distribution of this pest that only a few places at the higher elevations can offer to visitors the inducement that the district is free from mosquitoes.

The abundance of mosquitoes in Hawaii may be accounted for by the facts that up to this time there has been no effort to do away with their breeding places, that the number of natural breeding places is unusually large, and that the pest is not checked at any season of the year by climatic conditions, it being possible for them to breed uninterruptedly during the entire year.

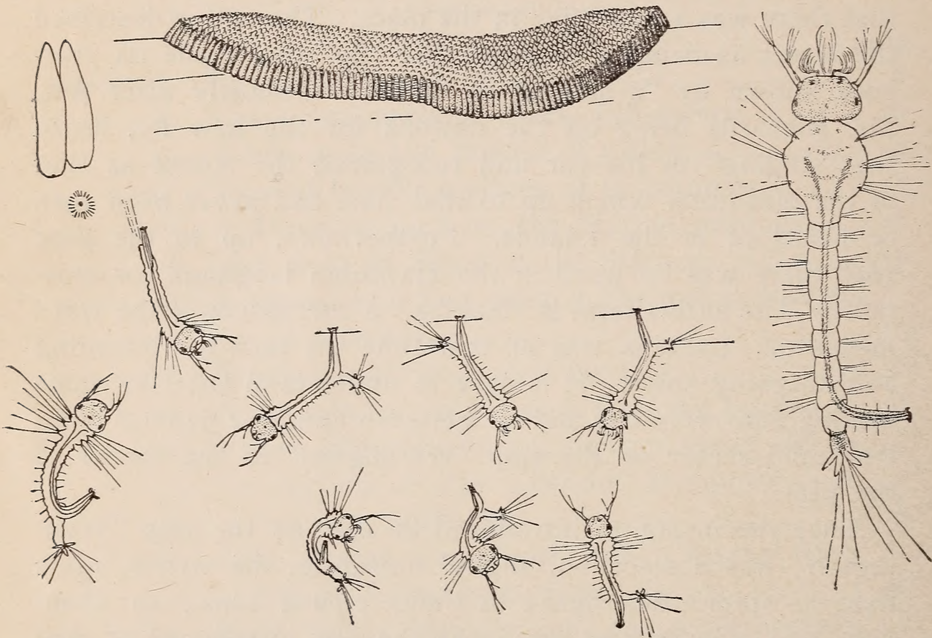

Fig. 1.—Egg-cluster as it appears floating on the surface of the water, and larvae of Culex. Enlarged. (From Howard, Bul. 25, new series, Division of Entomology, U. S. Department of Agriculture.)

A GENERAL ACCOUNT OF MOSQUITOES.

To make this paper of practical value to the people of Hawaii in fighting this general pest, the accepted facts regarding mosquitoes are briefly given. Dr. L. O. Howard, Entomologist of the United States Department of Agriculture, first advanced the idea of the "wholesale" destruction of this insect. His book, "Mosquitoes,"[a] is the authoritative work on the subject. In 1892 Dr. Howard conducted during the sum-

[a]Mosquitoes: How they live; How they carry disease; How they are classified; How they may be destroyed. Howard. 1900.

mer experiments in the Catskill Mountains, New York, the success of which became widely known throughout the United States. Since that time it has been repeatedly demonstrated in different mosquito-ridden sections of the country that it is unnecessary for any community to submit to the mosquito nuisance. Particularly convincing are the experiments being carried on in the State of New Jersey in which Dr. J. B. Smith of the New Jersey Experiment Station is taking an active interest. *The work of destruction is directed against the breeding places.*

The Breeding Place of Mosquitoes.—The post-embryonic development of the mosquito, that is, the interval between the egg state and the adult winged form, occurs entirely beneath the surface of water. The young during this portion of their life-cycle are true aquatic insects with one exception, they do not breathe the air dissolved in the water as do fish, but by a special structure, a respiratory siphon (see figure 8 C), breathe the free air above the surface of the water; deprived of this they perish. By nature of their structure the young of mosquitoes can develop only in water and then only under certain conditions. As a rule mosquitoes breed in small collections of standing fresh water. Specimens are sometimes found in streams and some species are known to breed in salt or brackish water. For all economic purposes the statement is correct that mosquitoes breed only in water, usually stagnant fresh water in artificial places. *Do away with these places and it becomes impossible for mosquitoes to breed.*

Life History of Mosquitoes.—The determination of methods for destroying an injurious insect implies a careful study of its life-history in order to find the vulnerable point in the life-cycle of the pest. All insects undergo during their developmental period remarkable changes in form, structure and habits. One can certainly detect no resemblance between the wriggling larva of the mosquito in the water and the adult winged insect in the air. In the higher animals there are no distinct periods or stages of development. The young on hatching from the egg or at birth resemble the parent with the exception that they are smaller in size and undeveloped, but as growth continues they gradually acquire the size and characteristics of the adult. The life history of insects, on the other hand, is, generally speaking, divided into three distinct stages after hatching from the egg: the young or larva, the growing stage in the life of the insect; the pupa, a period of development during which a wonderful change or transformation in the form, structure and habits occurs; and the adult or winged insect, the form we usually recognize.

The eggs of the common mosquito, Culex, are deposited on the surface of standing water. (See figure 1.) Under the right conditions of temperature they hatch in about twenty-four hours. The larvae develop to their full size in the course of eight to fourteen days during which time they moult or cast off their outer covering several times to provide for

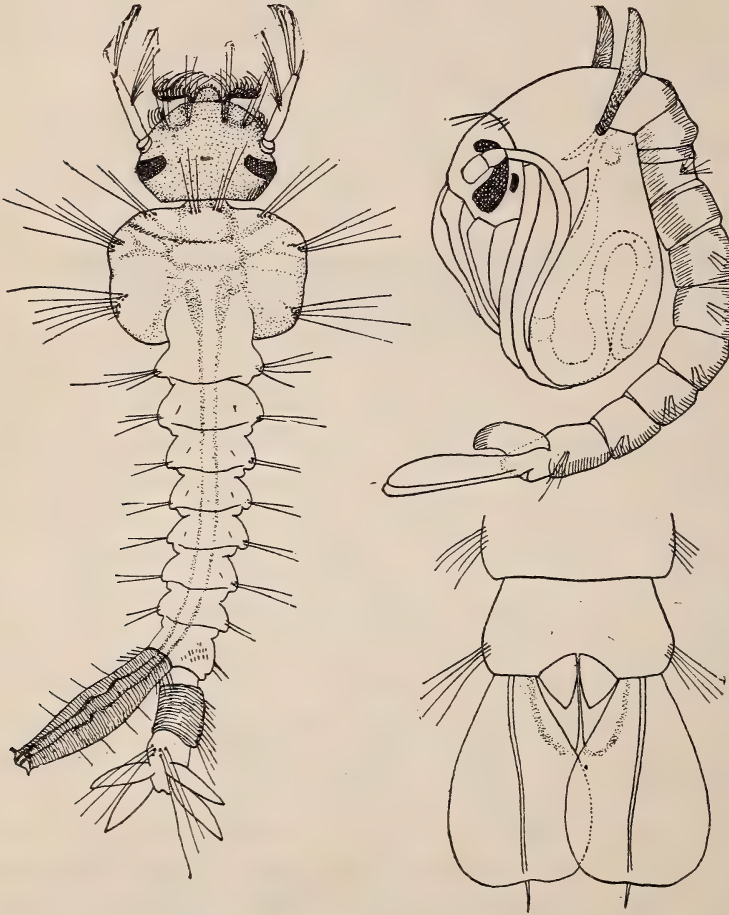

Fig. 2.—Full-grown larva at left and pupa at right of Culex, enlarged, showing "swimming- flaps" of pupa at right, below, greatly enlarged. (From Howard, Bul. 25, new series, Division of Entomology, U. S. Department of Agriculture.)

increase in size. (See figure 2.) The development of the larvae depends on the temperature of the water and the food supply. Their food consists of the plant and animal matter, often microscopical in size, common to standing water.

The pupa of the mosquito is also aquatic, normally resting inactive at the surface. (See figure 2.) This is the period during which the mosquito transforms from an aquatic insect to one of the air. The young or growing stage has passed. The pupa takes no food and moves only when disturbed as a matter of protection. The pupal stage is much shorter than the larval. In two or three days the pupa transforms to the adult mosquito and becomes the notorious household pest, the entire life-cycle being a matter of eleven to eighteen days.

The only remedy for adult mosquitoes is protection by screening, or the burning of insect powder. These remedies bring only temporary relief and do not remove the source of the nuisance. The importance, then, of not allowing mosquitoes to develop beyond the pupal or final aquatic stage is evident. *No practical method of destroying adult mosquitoes is known.*

The length of the life of adult mosquitoes varies. It is difficult to get insects to repeat correctly in confinement what their life-history and habits would be under natural conditions; therefore the length of the life of the adult cannot be determined by experiment. As a rule the males of insects do not live any great length of time after maturity, and the females die soon after depositing their eggs. In a tropical country, like Hawaii, where no difficulty is encountered by the gravid female in securing favorable breeding places throughout the year, the length of the adult life is probably at the most only a matter of several weeks. In cold countries the male mosquitoes are known to die in the early winter and the females hibernate during the cold season, a period of several months, until suitable conditions for egg-laying prevail.

Migrations of Mosquitoes.—The adult mosquito (see figure 3) is a very feeble flyer and is usually found in the vicinity of its breeding place. Instances are on record where mosquitoes have been carried in large numbers for long distances by the wind, but invasions from one locality to another are exceptional. It is well known that on windy days mosquitoes are less in evidence and the general belief is that they "have been blown out to sea." It is evident from the structure of their organs of flight that mosquitoes cannot long endure in a high wind. In an infested locality, mosquitoes are always in evidence immediately after a wind subsides, especially in places where the vegetation is abundant, in the foliage of which they seek shelter from the wind. Smith says that the habits of mosquitoes in regard to their flying any distance varies with the different species. He discusses[a]

[a]Special Bulletin T. New Jersey Experiment Station.

a salt-water species, *Culex sollicitans,* which is apparently a true migratory form. *It can be stated without qualifications that the source of mosquitoes is generally the immediate vicinity of the infested places.*

The above statement is subject to exceptions as proved by the observations of Mr. H. W. Henshaw, the well-known naturalist of Hilo, Hawaii. The writer has not observed evidences of migration among the species of mosquitoes occurring in these Islands. Invariably the source of mosquitoes infesting any district has been found to be nearby natural and

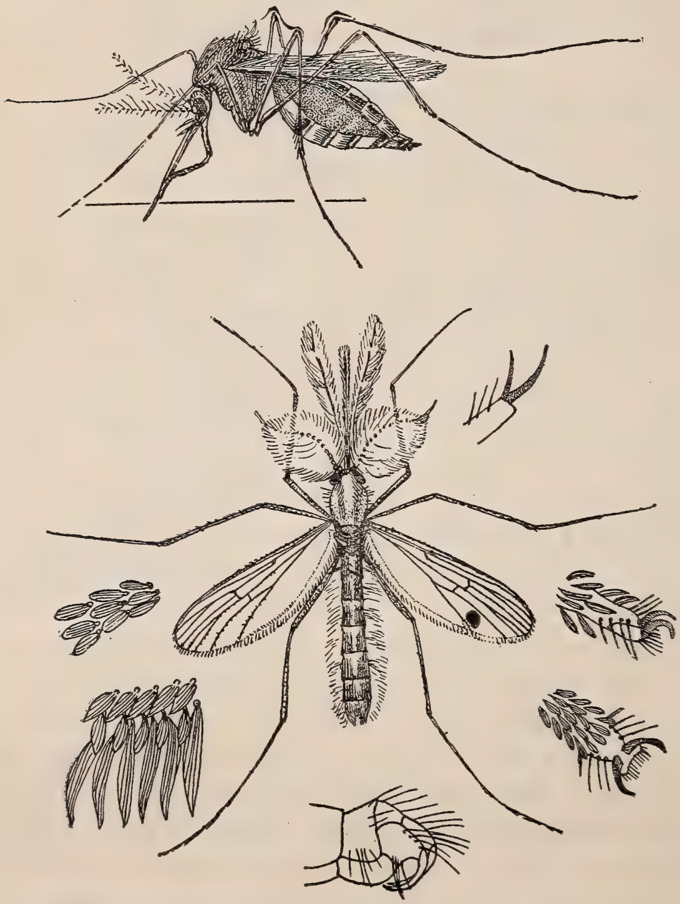

Fig. 3.—Adult female above and male below of Culex. (From Howard, Bul. 25, new series, Division of Entomology, U. S. Department of Agriculture.)

artificial collections of water, usually artificial collections in the immediate vicinity. Mr. Henshaw in speaking of invasions of mosquitoes says in a letter to the writer:

So far as my own observations extend such accidental invasions of mosquitoes are rare in these Islands, the insects here as a rule being extremely local. Nevertheless that such accidental dispersal of the pests in the Islands does actually occur is proved by an instance in point which came under my personal observation in June, 1899, at Pahala, Kau (Island of Hawaii). Mr. C. M. Walton, the then manager of the plantation, informed me that prior to the visitation of the pests about to be described, mosquitoes were practically unknown about the village; if found at all it was in such small numbers as to cause no annoyance, and mosquito-nets were unknown.

In the spring of 1899 there was an unusual quantity of waste water from the mill and this ran down to the flats about a mile below and there formed a series of small ponds aggregating a considerable expanse of shallow water. Not long after the formation of the ponds swarms of mosquitoes made their appearance about the mill and in all the dwellings, evidently brought there by the strong trade winds which blew directly from the ponds. At the time of my visit the mosquitoes *(Culex pipiens)* put in an appearance about dusk and soon rendered life a burden and sleep impossible except under nets which every householder had been compelled to provide for every bed.

A few days later I visited the Kapapala Ranch, distant from Pahala about four miles in an air line and about five miles from the ponds in question and there found a similar state of affairs. Mr. Julian Monserratt, manager of the ranch, told me that the invasion occurred at the same time as at Pahala prior to which no mosquitoes had been seen at or near the ranch headquarters where, indeed, there was no possible breeding place for them.

Unquestionably the clouds of mosquitoes originated in the same ponds below Pahala and were carried by the trade winds not only to Kapapala but for miles over the surrounding country in the direct track of the breezes. At Pahala, at least, the colonization has proved to be permanent as here, as elsewhere on cane plantations where water flumes are in use, leaky flumes form small pools at many points along their track which make ideal breeding places for mosquitoes.

At the time I speak of, comparatively little information had reached the general public in relation to the methods of abating the mosquito nuisance, though Mr. Walton had tried experiments with kerosene on some of the pools, if I remember correctly, with poor success and they had been abandoned. With our present knowledge of the use of the heavy crude petroleums it cannot be doubted that prompt and regular treatment of the ponds in question with proper oil, together with frequent inspection and treatment about the village itself, would have abated the nuisance within a reasonable time. In eternal vigilance and in prompt remedial measures alone lies safety from mosquitoes in the tropics.

Mr. Henshaw has since informed the writer that the ponds mentioned are quite exposed and unsheltered by vegetation, and agrees with the writer that had the ponds been surrounded by trees or had vegetation intervened to which the insects could have clung for shelter, the distribution would not, probably, have been so widespread.

THE FOOD OF ADULT MOSQUITOES.—Their food consists of the blood of animals and the juices of plants and fruits. Mosquitoes are normally plant-feeding insects and only the female is a blood-feeding insect when that is obtainable. The male satisfies his appetite on the juices of fruits or other liquids since the proboscis is not constructed, as is that of the female, for piercing anything with any degree of resistance, as the skin of animals or the epidermis of plants. Howard says, speaking of female mosquitoes: "It is safe to say that only an infinitesimal proportion of them ever taste the blood of a warm-blooded animal."

Mosquitoes and Disease.—The greatest impetus to the warfare against mosquitoes was given by the recent positive demonstrations that certain species are the carriers of disease, that is, the agents (germs) responsible for the disease are parasitic to certain mosquitoes during an intermediate stage in their developmental cycle. In fact it has been proved in the case of yellow-fever and malaria that without certain species of mosquitoes as hosts, the life-cycle of the organisms responsible for the disease is interrupted. This has changed the mosquito problem from one of discomfort alone to one of health also. The most complete work in preventive medicine is the result of experiments along these lines. That yellow-fever and malaria are conveyed from diseased persons to healthy people by the bites of certain species of mosquitoes is an acknowledged fact in recent medical literature.

Aside from yellow-fever and malaria, mosquitoes are credited with the dissemination of elephantiasis, filariasis, and possibly the dengue fever and leprosy. The relation of certain insects to diseases, both plant and animal, is a study which in the future will do much to prevent their present serious work.

THE COMMON HAWAIIAN MOSQUITOES.[a]

The abundant mosquito in Hawaii, known locally as the "night" mosquito, is a species of the well-known genus Culex, *Culex pipiens* Linn. All members of this genus taken generally from the Islands of Hawaii, Maui, Oahu and Kauai belong to this one species. The vicious "day" mosquito proved to be the dangerous Cuban yellow-fever mosquito, *Stegomyia fasciata* Fabr.[b] Another species of this genus, *Stegomyia scutellaris* Walker, occurs here but is not so abundant in the towns and cities as the former species and, being found to a great extent breeding in small natural collections of water in the forest, such as the leaves of plants and the hollow decayed stumps of trees and branches, it is referred to as the forest mosquito to distinguish it locally from the yellow-fever species.

---

[a]The specimens from which the determinations were made were forwarded to Dr. L. O. Howard, Entomologist of the United States Department of Agriculture, and were examined and reported upon by Mr. D. W. Coquillett of the Division of Entomology.

[b]This species is recorded from these Islands by Grimshaw under the name Culex taeniatus Wied. Fauna Hawaiiensis. Diptera. Vol. III, Part 1, p. 6.

THF ABUNDANT MOSQUITO, *Culex pipiens.*—The members of the genus Culex are distributed generally over the world and seem to be limited by neither altitude nor climate. The species so abundant here, *Culex pipiens,* is the common species of the genus and the mosquito whose life-history and habits are most generally known. This mosquito is reported from all parts of the United States and is recorded by Theobald as occurring generally in Europe.

BREEDING PLACES.—The places chosen by the female of this

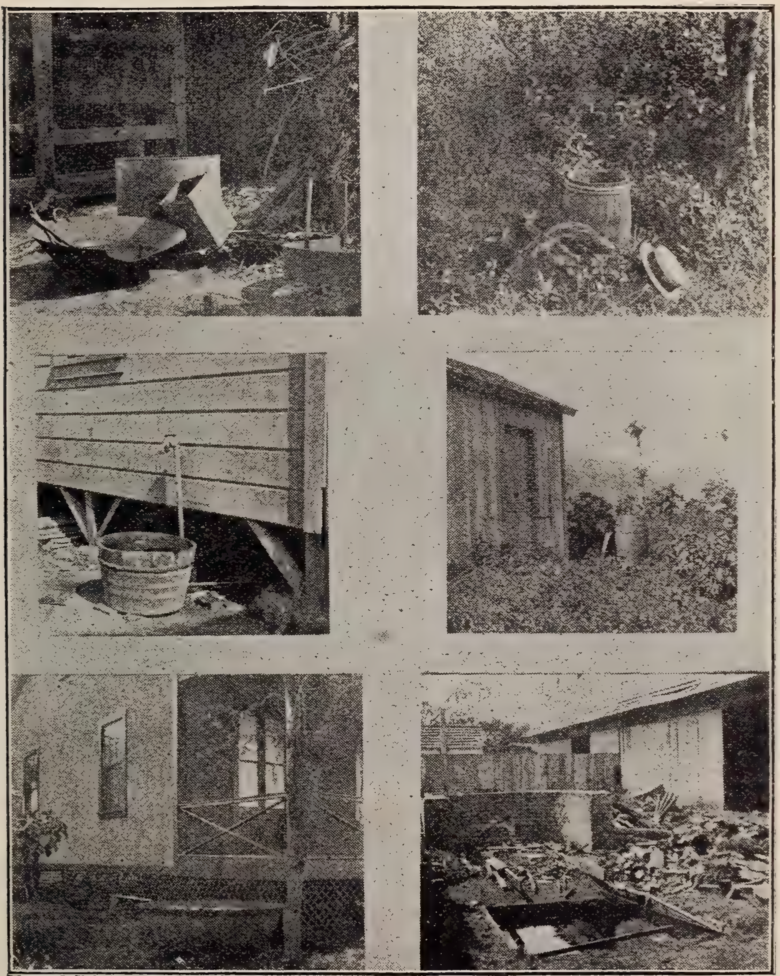

Fig. 4.—Typical breeding places of mosquitoes.

species for depositing her eggs are many and varied. (See figure 4.) There is, however, a decided preference for certain places. Where there is a choice between water containing a supply of decomposing vegetable or animal matter and uncontaminated water, the insect will invariably choose the water containing the organic matter, serving as it does as food for the young.

The above fact was nicely shown in observations at the Station last year. Several attempts had been made the previous year to dig a cess-pool. The nearness of the rock to the surface of the ground necessitated abandoning several sites. Two of these were deep enough to retain the surface water which drained into them. The yard-boy used one of these depressions (see figure 5) to throw the sweepings of the yard—grass, leaves, weeds, etc. When the writer made a survey of the Station grounds to locate the breeding places of mosquitoes these two

Fig. 5.—A breeding pool found at the Station, almost completely hidden by the dense foliage about it.

places were found within two hundred feet of the laboratory. A person could, however, walk within a few feet of either place and not observe the presence of water, so dense was the growth of vegetation about them. The larger one, containing the decaying refuse, was about six feet across and its greatest depth was a little over one foot. The water of this pool was literally a living mass of wrigglers or the young of mosquitoes. A small ladle, used for collecting larvae, was dipped into the center of the pool and over two hundred larvae by actual count were obtained by the one operation. The capacity of the ladle was three ounces. On the following morning, January 16, 1903, the writer collected one hundred and eighty-five egg-clusters from the surface of this pool. An egg-cluster is the product of one female and contains from two hundred to three hundred eggs.

The other excavation, somewhat smaller in diameter, did not at first appear to contain wrigglers but closer observation showed that larvae were present though not in numbers comparable to the first pool. When regarding the place as a possible source of mosquitoes, however, the conditions were sufficient for it alone to play an important part in the general discomfort of the surrounding community. This second pool was found, by aid of the dip-net and ladle, to contain, at least, several thousand larvae. Here and there about the margin the egg-clusters were found the following morning.

Fig. 6.—Filling in breeding places at the Station.

The conditions regarding the temperature, location and source of the water were exactly the same and the writer can account for the great difference in the numbers of the larvae in the two instances in no other way than that the gravid female chose the pool containing the decaying vegetable matter in preference to the one containing the clear water. These places were promptly filled in (see figure 6) and removed for once and all time as possible breeding places for mosquitoes.

The places mentioned by different writers as the breeding places of this species of mosquito are water-tanks, tubs and buckets under water-taps, wells, cisterns, barrels, open sewers, cess-pools, swamps, small pools, wayside ditches, empty oil tins, biscuit tins, sardine and tomato cans, gourds, flower pots, vases, cuspidors, broken and unbroken bottles, crockery, pottery and tins on rubbish heaps, hollow stumps, post-holes and other excavations left unfilled, fire-buckets, gutters and eaves which are imperfect or which have become clogged, water-traps in sinks and closets, watering-troughs for stock, neglected lily ponds and fountains, and catch basins from leaders.

Aside from these typical places the writer has taken the larvae from tins containing water, placed under the legs of tables and meat-safes as a protection against ants, a common practice here, from urns and flower vases on graves in cemeteries, from beneath racks used in washing wagons, from water-

Fig. 7.—A typical breeding place in the makai districts of Honolulu.

butts and sunken reservoirs in blacksmith shops and carriage factories used in cooling horse-shoes and wagon-tires, and from the hoof prints of a cow near the edge of a rice field. As to the amount of water necessary for breeding purposes, the writer has found this mosquito breeding in a small beaker containing less than three ounces of water. A person might reason that if a small container would breed mosquitoes, a larger one would be even a greater source. This is no doubt true when comparing a small beaker containing a few ounces with, for example, a tub of water, but as far as the experience of the writer goes, a tub of standing water may be as prolific a breeding place as a pond or pool containing many hundred times the volume of water.

Close inspection and treatment of the typical breeding places, mainly artificial, as enumerated above, will rid any infested locality of this mosquito.

The frequent rains which only occasionally are abundant enough to form streams, do form, however, natural breeding places in the uneven beds of streams and ditches and surface of the ground. This is especially true in the makai districts having a costal plain of any width. (See figure 7.) In the mauka regions these collections of water are not permanent owing to the prevailing steep slope and the general looseness of the soil affording natural drainage. These small collections of water on the lower levels, of long duration during the rainy season, create numerous breeding places for this species which continue until the water disappears under the action of the wind and sun in the drier seasons. Communities situated in such localities in the Islands have a more serious problem before them in any effort to reduce the numbers of mosquitoes. *Filling in or draining or the regular use of oil during a season of rain are the only remedies for these places.*

LIFE-HISTORY OF *Culex pipiens*.—(See figures 1, 2 and 3.) The eggs of the "night" mosquito are easily observed in the places where they occur. They appear a raft-like mass floating on the surface of the water and resemble a small piece of charcoal about one-fourth of an inch in length. This manner of depositing the eggs is characteristic of the members of the genus Culex. The egg-mass or "raft" is the product of one female and according to Theobald is "laid soon after sunrise and also at dusk if the weather is warm and still."[a] Examination under a hand-lens shows a distinct structure to the mass, it being made up of individual eggs, standing close together in an upright position, the bottom of the egg being larger than the top, thus making the raft boat-shaped. Each raft is estimated to contain from two to three hundred eggs, the individual egg being hardly visible to one unaccustomed to looking at objects so small. The lightness of the mass insures its floating on the surface. Howard says that if the eggs are kept completely immersed the larvae will never develop, this being because of the inability of the developing embryos to obtain the necessary air supply. The peculiar structure of the bottom of the eggs prevents the water from actually wetting them.

When the eggs hatch they open downward letting the larvae into the water. This occurs from twenty-four hours, under favor-

---

[a]A Monograph of the Culicidae of the World. Theobald. 1901.

able conditions, to two or three days, after the eggs are deposited. Naturally the young on hatching are very small but develop in a few days into fair sized wrigglers. These are the common natural history objects of the rain-water barrel which, as youngsters, we all believed were "rained down."

The larva of this species is found normally at the surface of the water with its head in a downward position. The explanation of this peculiar position is this: the larvae of this and all species of mosquitoes, though aquatic as regards living in and obtaining their food from the water, are true air-breathers and must necessarily come to the surface to obtain the air. How this operation is performed is shown in the figure of the larva. The larva while breathing at the surface continues to feed beneath; hence the position of the head downward. It moves away when disturbed and can frequently be seen foraging about in the water for food but coming regularly to the surface to breathe. Its food consists of the decaying organic matter and the microscopical organisms common to standing water. Only one comment in favor of the generally condemned mosquito can be found and that is in regard to the larvae. Comstock says: "The larvae of mosquitoes are doubtless beneficial insects, for they feed on the decaying matter in water, and thus act as scavengers," and then he adds, "but the annoyance caused by the bites of the adult female more than balances this good." The length of the larval life was found to vary under different conditions from seven to fifteen days.

At the last larval moult, the pupal stage begins. The pupa is an ungainly looking creature resting quietly at the surface, tail-end downwards and further distinguished from the larva by its big head. This "head" is really the head and thorax of the insect fused together. The pupa has also two breathing-tubes, instead of one, rising, not from the tail-end of the body but from the upper side from that portion known as the thorax. The end of the abdomen is supplied with two broad flaps (see figure 2) used for swimming, with which by vigorous motions of the body the insect drives itself down into the water when disturbed. The manner in which the pupa rises to the surface without effort demonstrates that its weight is less than that of the water. The characteristics of the structure of the pupa are well illustrated in the figure. The length of the pupal stage is a matter of about two days.

The length of the life-cycle of *Culex pipiens* was obtained by placing eggs laid the previous night (collected in vessels exposed for the purpose) on water of ordinary temperature. The water was kept shaded and no food was added. The eggs were placed in the breeding jars on January 16. They hatched in the forenoon of January 17. The first larvae changed to pupae on January 31. The first adults issued from the pupal cases on February 2. The life-cycle in this instance was 17 days.

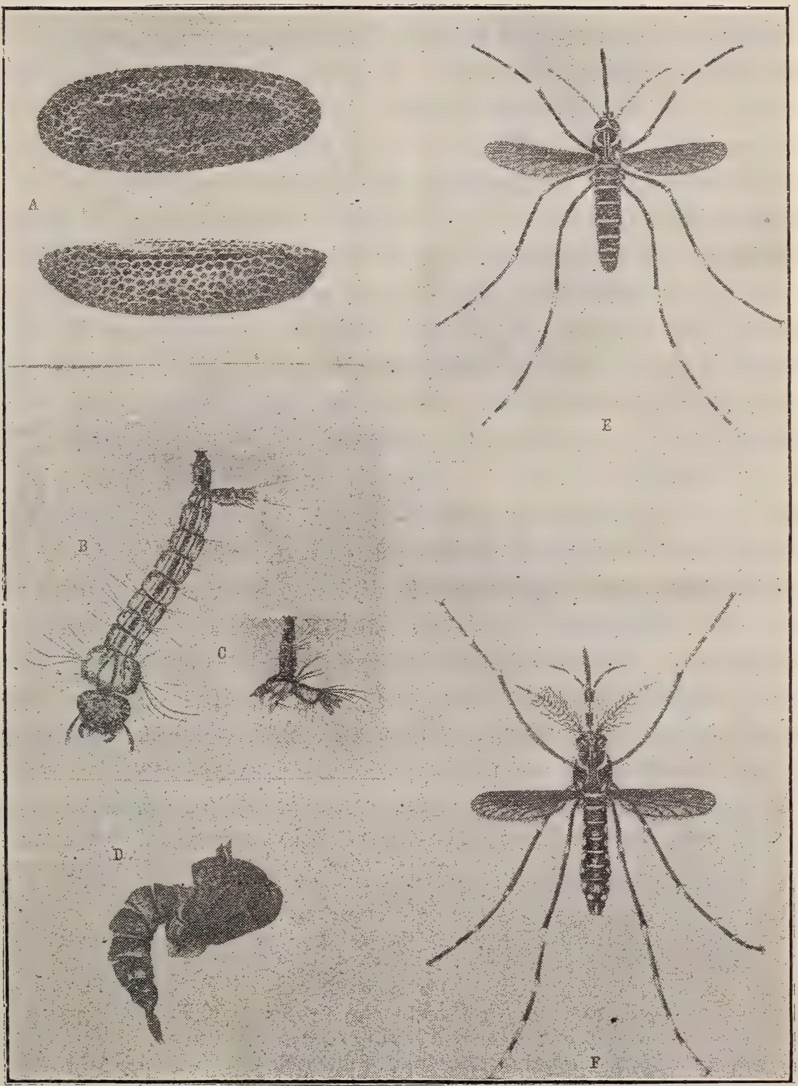

Fig. 8.—Life-cycle of Stegomyia fasciata. (From Bul. No. 13, Yellow Fever Institute, U. S. Public Health and Marine Hospital Service.) A. Upper and side view of a single egg, greatly enlarged B. Full-grown larva, enlarged. C. Breathing-tube or respiratory siphon of larva, greatly enlarged. D. Pupa, full-grown, enlarged. E. Adult female. F. Adult male.

To illustrate the effect of temperature on the hatching of the eggs, several newly laid clusters were placed on ice-water and put in an ice-chest. These did not hatch until three days afterward, while on the other hand egg-clusters collected the same day, December 23, 1902, hatched the same afternoon.

THE YELLOW-FEVER MOSQUITO, *Stegomyia fasciata*.—(See figure 8.) This mosquito is the notorious yellow-fever species of Cuba. Just how or when it came to these Islands is unknown. Dr. Howard under date of January 27, 1903, writes: "The two species of Stegomyia listed (from Hawaii) occur throughout the East Indies." Prof. V. L. Kellogg of Stanford University, in writing of his trip to the Samoan Islands a year ago says: "I am interested to learn that your day mosquito is the yellow-fever chap, Stegomyia fasciata. That is just what I found the Samoan mosquito to be. * * * This is the abundant Samoan mosquito and the one which presumably disseminates elephantiasis."

The dissemination of yellow-fever by the mosquito is not a new idea. Dr. Carlos Finlay of Havana, Cuba, was of the opinion, as early as 1881, that this disease was conveyed by this pest. This theory was proved a fact by a commission of surgeons of the United States Army by demonstrations made in Cuba in 1901. They proved beyond all doubt that this species, *Stegomyia fasciata,* was a conveyor and perhaps the only conveyor of this dreaded disease. There is no record of there ever having been a case of yellow-fever in these Islands. Certainly the quarantine regulations have not up to this time been responsible for the immunity from this disease, for it was not known until 1901 what the proper quarantine against yellow-fever was. The reason for our immunity is made clear in a statement by Dr. Geo. M. Sternberg, Surgeon General (retired) of the United States Army. In an article[a] on the transmission of yellow-fever by mosquitoes, he says:

> The propagation of the disease depends upon the introduction of an infected individual to a locality where this mosquito is found, at a season of the year when it is active. Owing to the short period of incubation (five days or less), the brief duration of the disease, and especially of the period during which the infectious agent (germ) is found in the blood (three days), it is evident that ships sailing from infected ports, upon which cases of yellow-fever develop, are not likely to introduce the disease to distant sea-ports. The continuance of an epidemic on shipboard as on land, must depend upon the presence of infected mosquitoes and of non-immune individuals. Under these conditions we can readily understand why the disease should not be carried from the West Indies or from South America to the Mediterranean, to the east coast of Africa, or to Asiatic seaport cities. On the other hand, if the disease could be transmitted by infected clothing, bedding, etc., there seems no good reason why it should not have been carried to these distant localities long ago.

The safety this country has enjoyed in the past, due, it is seen, to the length of time it has taken a vessel to come here from yellow-fever infected ports, is removed by the intimate relations about to be established by a new line of steamers between here and the Mexican coast. The possibility of the completion of the

---

[a] Smithsonian Report. 1900. p. 670.

Panama canal in the near future gives additional cause for precaution against the introduction of the most dreaded of tropical diseases.

The yellow-fever mosquito is well named a "town" species. It breeds almost exclusively about dwellings, and authorities state that it is seldom found far outside city limits unless in the vicinity of dwellings. The female will invariably choose small collections of clear water for depositing her eggs. The eggs are laid singly on or near the water and if not on the water may remain dormant for a long time until washed into the water or, as in the case of a rain-barrel, until a shower brings the water to their level. *Attention to the artificial collections of water about dwellings will be the principal factor in reducing the numbers of this species.*

The Forest Mosquito, *Stegomyia scutellaris.*—This species and the yellow-fever mosquito are known locally as the "day" mosquitoes. While *Stegomyia scutellaris* breeds in such places as mentioned in connection with the yellow-fever species, it differs from the latter in that it is not restricted to such collections of water. The writer has often found it breeding in small bodies of water in the forest. These places have been sometimes far removed from habitations and on several occasions have been discovered where, the writer ventures to say, not more than one person would visit, on an average, in a year's time. These natural breeding places are such small amounts of water as may be contained in a hollow stump of a tree or limb, a depression in a stone in the bed of a mountain stream, or the leaves of plants.

On February 25 last, the writer collected what he supposed were the eggs of the yellow-fever mosquito. These were placed in a breeding jar and hatched on March 1. On March 9 the first pupae appeared and by March 11 all had transformed to the pupal stage. The first adult issued on March 12 and proved to be *scutellaris.* Specimens continued to leave the water until March 17, when the last one completed its life-cycle. The life-cycle may be summed up as follows: the egg state is five days, the larval from eight to ten days and the pupal three to six. Mating in this species occurs at any time during the day. The adult infests for the most part shady places.

NATURAL ENEMIES AND DISEASES OF MOSQUITOES.

The dragon-flies or "mosquito-hawks" are the most effectual enemies of the mosquitoes that we have here. The dragon-flies, Odonata, are for the most part members of the single genus Agrion. The number of aquatic species of insects is far less in Hawaii than in other countries. In searching the swampy places about Honolulu for the larvae of the mosquito it was not unusual to dip up with the same dipperful of water from the net, the larvae of mosquitoes and the nymphs or young of dragon-flies, while the adult dragon-flies could be seen flying in myriads over these places. This is significant when it is known that the dragon-fly is predaceous in both the young and the adult forms; the young dragon-fly, an aquatic insect, feeding on the larvae of the mosquito in the water and the adult preying on the winged insect in the air. This highly beneficial, strong flying and beautiful insect is met at all elevations. The writer has seen it on the top of Mt. Tantalus as well as the other elevations between that point and the beach at Waikiki.

Among our fish we have two efficient enemies of mosquitoes in the ponds, rice-fields, taro-patches and ditches. They are the gobies, locally known as "oopu" and the gold-fish. In answer to a letter from the writer in regard to introducing into these Islands the top-minnow, Dr. David Starr Jordan says under date of January 21, 1903:

> The only fishes that you have that feed upon mosquitoes in the small ponds, are the different species of gobies locally known as *oopu,* and the gold-fish. The different species of oopu are found in all the streams, but whether they feed on the larvae or not must be determined by dissection.
>
> The top-minnows are entirely unrepresented in Hawaii. They are very easily transported, being extremely hardy. There are, however, none of them in California, and they would have to be brought either from the Mississippi Valley, or from Mexico. The best species for your purpose could be found in the streams of Central Mexico, but it would be a little costly to send a man down to get them. Next to these, I would recommend trying the Gulf States or Florida.
>
> These fish belong to the family of *Poeciliidae,* and there are many species, nearly all American. The single Japanese species is common in rice ditches in the extreme South of Japan and probably feeds on larvae.

After careful observations, the writer is convinced that among the fishes, hardly a more efficient enemy could be found than gold-fish. A single gold-fish in an aquarium ate over one hundred and fifty larvae in twenty-four hours' time. Other specimens placed in pools containing mosquito larvae were afterwards dissected and the stomach contents were found to consist almost entirely of the remains of the bodies of larvae. From these experiments, gold-fish were placed in watering-troughs, tanks and pools, with the result that the young of mosquitoes did not develop in these places. Search was made for larvae in lily-ponds and fountains where gold-fish occurred and conditions verified the above experiments.

The introduction of insectivorous bats to feed upon adult mosquitoes was suggested. The matter was referred to Mr. Wm. A. Bryan, Curator of Ornithology of Bishop Museum and Inspector of Birds and Animals for Hawaii. Mr. Bryan replied:

Vesperugo, the commonest of the British bats is found about old buildings, in creeks, rocks, etc. Its food is said to be gnats (mosquitoes). It will readily eat meat in captivity and becomes a nuisance in houses. I would not advise the promiscuous introduction and liberation of any species.

Concerning natural enemies in his book on "Mosquitoes," Dr. Howard has the following in regard to Hawaii:

Mr. Albert Koebele informs me that he imported into Hawaii from California a large number of the western salamander which were liberated in the upper part of the Makiki stream in the hope of reducing the large numbers of mosquitoes breeding everywhere in small pools and taro-patchs.

Mr. R. H. Pettit of the Michigan Station mentions[a] a fungus, *Entomophthora,* as destructive to adult mosquitoes about pools in timber lands. Theobald mentions another fungus disease, *Empusa culicis,* which also "destroys Culex both in Europe and America."

Efforts have been made to determine some artificial method of arraying natural enemies against the mosquitoes but, with the exception of the fish, little has been accomplished. In this connection, Dr. Howard informs the writer that "in the matter of control not much can be done with natural enemies. Fungus disease has never amounted to anything."

METHODS OF CONTROL.

A tropical country is an out-of-door country and the mosquito problem bcomes at once a serious question. Heretofore the only effort directed against the mosquito nuisance in these Islands has been to secure protection from the adult by screening the houses, the use of nets over beds at night and the burning of buhach or insect-powder. These methods are more or less successful in obtaining individual relief but in no manner do they lessen the numbers of the pest or remove the source of the nuisance. A conservative estimate, based on figures furnished the writer by the wholesale importing houses of Honolulu, places the sum annually spent in these

---

[a]Special Bulletin 17. Michigan Experiment Station.

Islands for insect powder, wire mosquito-cloth and mosquito-netting at $27,243.00, of which $7,008.00 is for insect-powder, $9,735.00 for wire mosquito-cloth, and $10,500.00 for mosquito-netting. These figures are based on the retail price and do not include a great quantity of cheaper grades of open mesh cloth sold to orientals and the poorer classes. A landlord cannot think of offering a house or room for rent and expect a ready tenant unless he is able to insert "mosquito-proof" in the announcement, and nets are a household necessity in homes that cannot afford screening. If the above amount of money was judiciously spent in ridding the communities of this Territory of the breeding places of mosquitoes, permanent relief could be secured. In reviewing the life-history of the mosquito it is evident that the fight against the adult is futile and that the effort of control must be directed against the breeding places of the insect.

It is the common opinion here that the taro-patches and rice-fields are mainly responsible for the abundance of the mosquitoes. These collections of water are not the source of mosquitoes. They do breed to some extent in these places but the writer has found the source of mosquitoes, even in the immediate vicinity of taro-patches and rice-fields to be mainly the many exposed receptacles filled with standing water, common about the laborers' quarters. It is not in the fields, moreover, but about them in the clogged ditches and about the sides, where the water remains comparatively shallow and unchanged, that the larvae are found. The writer has, however, found that in abandoned rice-fields, where the water stands in more or less confined areas for a great length of time, the larvae do occur in large numbers.

In the outlying districts, where city water is not supplied and rain-water must be stored for use, the many containers used for this purpose, especially about the native houses and Chinese shacks, are by far the greatest source of mosquitoes. The writer has counted as many as seventeen tubs, barrels and other containers about one native house all breeding mosquitoes in immense numbers.

Generally speaking, the extermination of the mosquito cannot be accomplished. The remedy is by a systematic and continuous effort to do away with their breeding places or, if that is not practical, by the proper treatment, to render the conditions unfit for the development of the larvae. In favored localities this will result practically in extermination.

The rules for ridding any particular community of mosquitoes are simple and effective and do not require any great expenditure of money. (See figure 9.). They may be summed up as follows:

(1) Mosquitoes to breed require water, the larvae being as truly aquatic as fish. To do away, then, with all bodies of

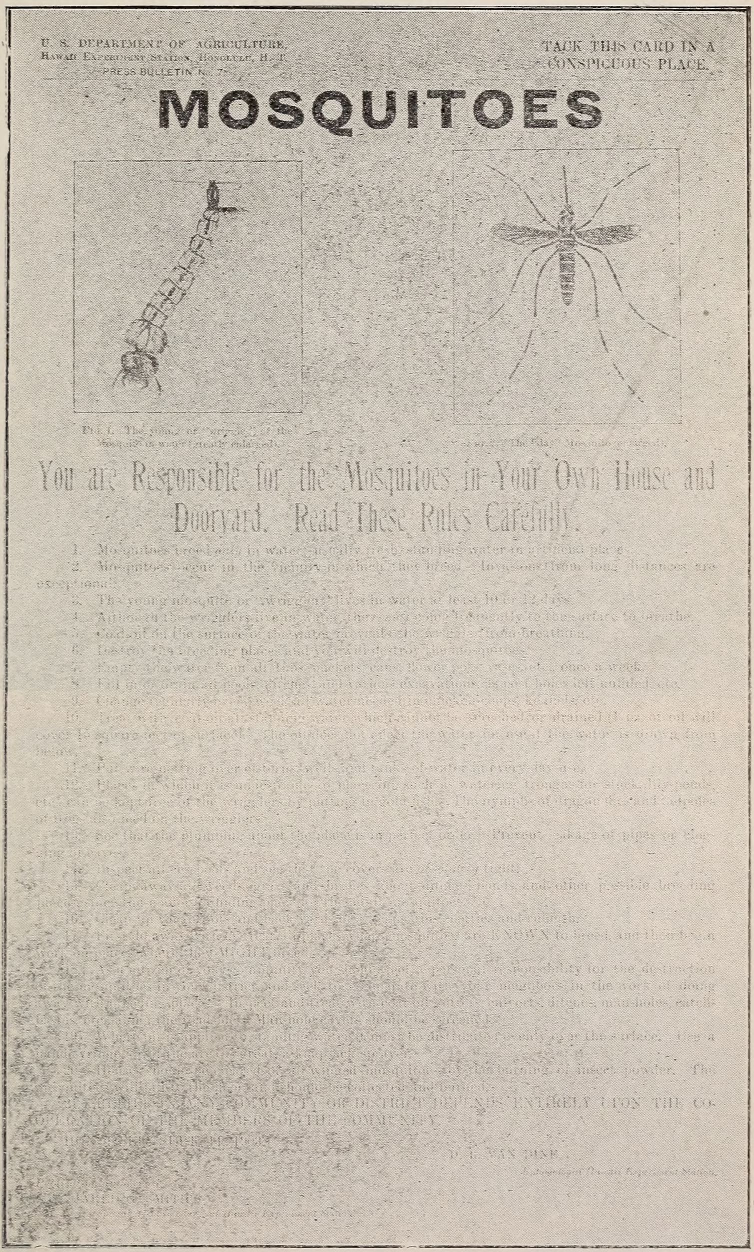

Fig. 9.—The above cut illustrates a "poster" which was printed in five languages (English, Hawaiian, Portuguese, Japanese and Chinese), giving brief rules for exterminating the mosquito, and distributed by this Station throughout the Territory.

standing water by filling or draining is the first step. (See figure 10.)

(2) Collections of water which cannot of necessity be removed, such as water tanks and barrels used for storing water should be tightly screened to prevent the gravid female from reaching them, drawing off the water for use from below.

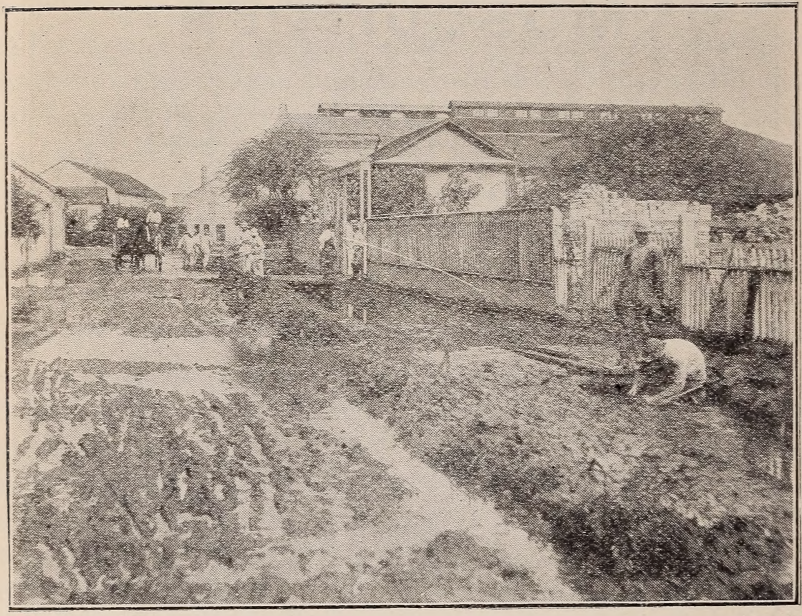

Fig. 10.—Prison labor ditching a district under the direction of the Citizens' Mosquito Committee, Honolulu.

(3) Mosquitoes can breed in water only under certain conditions, the main one being a free supply of air above the surface, which they obtain by means of breathing-tubes. Bodies of water which cannot be done away with by drainage or protected from adult mosquitoes by screening, should be treated in such a manner as to prevent the developing larvae from obtaining the necessary supply of air. The coal-oil treatment, widely understood, consists in covering the surface of exposed water with a thin layer or film of oil. The oil does not affect the water for use if the water is drawn off from below. One ounce of oil will cover about fifteen square feet of surface.

(4) If the use of oil is undesirable, for example, in the case of a lily-pond or a watering-trough for stock, the introduction of gold-fish will keep the water free from larvae.

(5) All such artificial containers of water about the dooryard as tin cans, bottles, broken pottery and crockery on

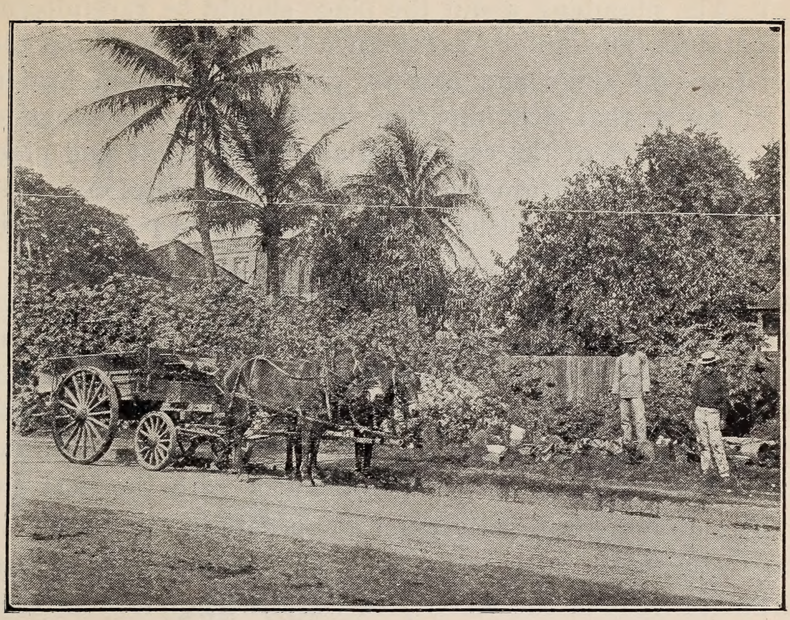

Fig. 11.—The "tin-can wagon" of the Citizens' Mosquito Committee, Honolulu.

rubbish heaps, etc., should be collected and carted away. (See figure 11.)

(6) Other containers, as tubs and buckets under water-taps, cuspidors, fire-buckets, water in chicken coops and dog kennels, etc., should be frequently emptied.

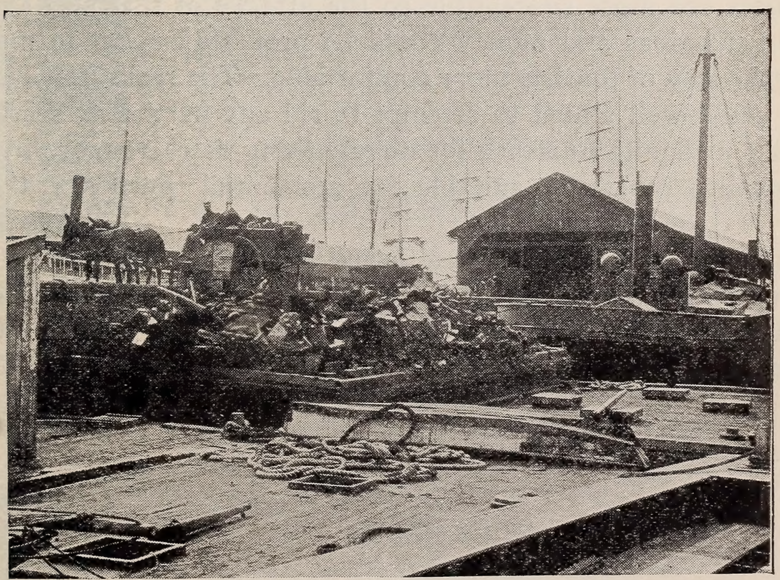

Fig. 12.—Scow loaded with tin cans and other containers ready to be towed to sea. Work carried on under the direction of the Citizens' Mosquito Committee, Honolulu.

(7) The plumbing about the place should be carefully inspected since mosquitoes are known to breed in cess-pools, water-traps in sinks and closets, catch-basins from leaders and in eaves that are imperfect or have become clogged. Make the covers of the cess-pools absolutely tight and place a screen over the opening of the vent pipe for eggs deposited in the closet tank are flushed down into the cess-pool and will hatch and develop.

(8) The work in any community must be general since a neglected tub in one yard can breed enough mosquitoes to make an entire community uncomfortable. It is seen from this that though the mosquitoes infesting any household are usually bred in the same dooryard and that invasions from any distance are exceptional, yet to do away with the pest the members of any community must co-operate in the work.

(9) The adult mosquitoes seek shelter in weeds, grass, bushes and trees in the vicinity of water. Therefore all such vegetation about ditches, pools and other collections of water should be cleared away.

It should not be necessary to present in detail the arguments why the various communities in these Islands should take concerted action against the mosquito. The reasons are self-evident. Not only does their presence detract from the natural charm of the country, but the danger attending the presence of a disease-carrying species is also apparent. Newcomers are more susceptible to the attacks of this pest than the kamaainas and money could be profitably spent in making the stay of tourists more comfortable. The real estate dealers could well afford to attempt to rid any particular section of the mosquito nuisance for no one thing detracts more from a locality otherwise suitable for residential purposes than the presence of this pest.

The one great rule of health and comfort in the tropics is to do away with or treat by methods well known to be effective *all standing water* because of the fact that only in such places mosquitoes are known to breed.