Certain Aspects of Medical Entomology in Hawaii

By DAVID D. BONNET

(Presidential address, presented at the meeting of December 8, 1947)

Introduction

One of the benefits which can be ascribed to the recent war (if one can say war produces any benefits) has been an increased recognition of the importance of insects in the transmission of disease. Doctors with the armed forces came in contact with malaria, dengue, tsutsugamushi, plague, filariasis, endemic typhus, dysenteries, and many other diseases which they had heard of but had never seen before. Specialized groups were organized by the armed forces to study these relatively unknown diseases and entomologists were prominent as members of these teams. Considerable publicity was given to the development of new insecticides of which DDT is, perhaps, the best known. Better insect repellents and substitutes for quinine were discovered. These facts together awakened the interest of the public toward the problems of insect-borne diseases.

A cursory examination of the recent entomological journals demonstrates the contribution of entomologists to the war. Because of this general enlightenment many health departments have added entomologists to their staffs. The United States Public Health Service now has entomologists as commissioned officers in the regular public health service corps. Previously, such commissions were restricted to medical men and to engineers. The Public Health Service has changed one war-time division, namely, Malaria Control in War Areas into a permanent division entitled the Communicable Disease Center, which is located in Atlanta, Ga., and at this Center particular emphasis is placed upon the study of diseases transmitted by insects as well as diseases resulting from insanitary conditions.

As a result of the dengue epidemic in Honolulu in 1943, the Department of Health of the Territory of Hawaii established the position of medical entomologist in the Division of Sanitation in 1945. This is a position in addition to the position of chief of the Bureau of Mosquito Control. The medical entomologist has been charged with the task of preparing a complete bibliography on the insects and other arthropods of medical importance found in the Territory. This is far from complete but will serve as the basis for our discussion at this time. A brief review of this subject has been previously presented by Pemberton (1943).

An arthropod is of interest to the medical entomologist, if it can be included in one or more of the following categories:

A. Vectors of Disease	
1. Biological transmission through bite or faecal contamination.	Malaria, dengue, plague, typhus, etc.
2. Mechanical transmission through food contamination.	Dysenteries, etc.
B. Production of Pathological Condition	Scabies, head louse, etc.
C. Stinging or Biting Arthropods	Mites, spiders, ants, wasps, scorpions, etc.

Many insects will fall into two or more classifications depending upon the presence or absence of diseases, which they can transmit. Many insects, such as the bedbug, *Cimex lectularius* Linn. must be included because of their close association with man, even though they are not known to transmit disease. Such insects must be considered suspects in possible insect-borne diseases. The question of animal reservoirs must also be kept in mind, although it will be necessary to exclude a discussion of this important problem from this paper.

Insects of Medical Importance

Siphonaptera

This group contains the most important insect vectors of disease in the Territory. The principal information is found in the work of Eskey (1934) who worked on the local epidemiology of bubonic plague. *Xenopsylla cheopis* (Rothschild) is found throughout the Islands and is the classic vector of plague. This species is also incriminated as a vector of endemic typhus fever. As a result of Eskey's work, a species of flea new to science was discovered on the local rat, *Rattus hawaiiensis*. This species was described by Jordan (1932) as *Xenopsylla hawaiiensis* and has since been synonymized by Augustson (1947) with *Xenopsylla vexabilis* Jordan, described from Australia. This synonymy is of considerable importance since the Hawaiian rat has been considered the principle reservoir of plague in the Islands and the fleas associated with them are responsible for plague transmission. Eskey was able to transmit plague with *X. hawaiiensis* (=*X. vexabilis*) in one experiment and further reported that this species outnumbered *X. cheopis* two to one in the plague area of the island of Hawaii. Eskey has shown that rats obtained from within buildings show a higher infestation of *Xenopsylla cheopis* than rats taken outside of buildings. He has also shown that it was possible to culture *X. cheopis* without the addition of grass cuttings, essential in the culture of *X. hawaiiensis* (= *X. vexabilis*). Apparently, *X. cheopis* prefers to breed within the shelter of buildings, while *X. hawaiiensis* (= *X. vexabilis*) may be considered to be

much more of a field flea. The continuous smoldering of plague amongst the field rodents of Hamakua, Hawaii, and Makawao, Maui, with occasional human cases may be the result of different rates or degrees of transmission by these two species. This is a problem which needs much further investigation. *Nosopsylla fasciata* (Bosch), the northern rat flea, is found principally at higher elevations in the Territory. In the Kula region of Maui 44 per cent of the rats trapped above an elevation of 2,500 feet were found to be infested with this species (Eskey 1934). *Leptopsylla segnis* (Schönherr) is also prevalent at these higher elevations. Neither of these species is believed to be involved in the transmission of plague in the Territory.

Ctenocephalides felis (Bouché) is the most common flea in the Territory and is found on cats, dogs, mongoose, rats and it occasionally bites man. Large outbreaks of this flea occur from time to time particularly upon removal of a cat or a dog and usually following periods of dry weather. This species has recently been incriminated in the transmission of typhus fever (Irons *et al.* 1944).

Pulex irritans Linn., the human flea, has been occasionally found in Hawaii, principally on dogs, and rarely on rats. It is not considered an important problem in the Territory. Both *Pulex irritans* and *Ctenocephalides canis* have been investigated recently in relation to the transmission of *Salmonella enteritidis* (Varela and Olarte 1946).

Echidnophaga gallinacea (Westw.). The sticktight flea is quite common in the Territory on chickens, dogs, cats, pigs, mongoose and rats. Wheeler, *et al.* (1941) has recently reported this species as being found naturally infected with plague. Illingworth (1916) has studied this species in Hawaii and has shown that the life cycle from egg to adult is approximately three weeks. From a half pint of dried dirt from the floor of an infested hen house, he collected a total of 1,027 fleas. This species has been shown by Alicata (1942) to be capable of transmitting endemic typhus fever, and Brigham (1941) reported the recovery of typhus from naturally infected *E. gallinacea.*

There are many features in the life history, ecology, behavior, and general distribution of fleas which we would like to know in order to be able to plan plague and typhus control programs more efficiently. In the past, it has been believed that plague could be controlled entirely by the control of the rodents. It is now realized that one must approach the problem from all aspects and that the fleas responsible for transmission of plague and typhus must be studied and controlled.

Diptera

The next group of insects to be considered from the standpoint of health in the Territory are the Diptera. The most important members of this group are the mosquitoes of which there are three species in the Territory. Usinger (1944) has reviewed the biology and Bonnet (1947) has discussed the breeding container distribution for these species in Hawaii.

Aedes aegypti (Linn.). This species is the classic vector for yellow fever. It is also a vector for dengue fever, filariasis, and possibly a vector for the encephalitides, and lymphocytic choriomeningitis. This species is highly domesticated and is usually found breeding in all types of artificial containers. Its distribution is much more limited than that of the other species, and it is usually restricted to the warmer, drier areas of the Islands (Bonnet, 1945).

Aedes albopictus (Skuse) is a proven vector of dengue fever (Simmons, St. John, and Reynolds, 1930) and has also been demonstrated in the laboratory as capable of transmitting yellow fever (Snijders, 1931). This species is widely distributed in the Hawaiian Islands being found at both low and high elevations. It is found in artificial containers along with *Aedes aegypti* but is also commonly found in natural containers such as treeholes, rock holes, and water-holding plants. The flight range of this species in Hawaii has been reported as usually less than 200 yards (Bonnet and Worcester, 1946).

Culex quinquefasciatus Say. This species is by far the most abundant and the most annoying of the mosquitoes in Hawaii. It commonly breeds in ground pools, swamps, and irrigation ditches, as well as in artificial containers. It is particularly abundant in waters of high organic content such as sewage effluents and run-off from pig and dairy farms. This species is a known vector for filariasis (*Wuchereria bancrofti*) in the West Indies; although a few human carriers are known to be present in the Territory, no case of locally acquired filariasis is known. Recent experiments by the Army (Webb, 1946) in the Territory of Hawaii have demonstrated that the local *Culex* will, when infected, permit the filarial worm to develop to the infectious state. Apparently, there is too small a reservoir of infected humans to permit this abundant mosquito to become infected frequently enough to effect transmission.

At the present time there are no *Anopheles* mosquitoes, the vector for malaria, in the Territory of Hawaii. However, human malaria carriers are present in significant numbers and the successful establishment of malaria mosquitoes would produce a devastating effect upon the health and economy of the Islands.

Musca domestica Linn. The common house fly present in the Territory may not be the *Musca domestica* of Europe and North

America. Illingworth (1923) has shown that the specimens found locally appear to be an intermediate form between *Musca domestica* and *Musca vicina* Macquart. These flies breed in all types of manure and rotting organic matter and at times are a considerable problem around houses and in restaurants. Recent studies (Pipkin, 1942) have shown an interesting relationship between flies and dysentery. House flies fed upon cultures containing cysts of *Entamoeba histolytica* selectively ate the cysts in preference to other food items. These cysts then passed through the intestinal tract of the fly and were still viable. Apparently, the cysts were of a size favorable for ingestion by the fly. Because of the habit of the fly, of defecating while feeding, a positive means of distribution is present, rather than the haphazard mechanical transmission such as that of the amoebic cysts sticking to the legs or body. It is probable that this phenomenon also has significance in the transmission of the bacillary dysenteries.

The correct identification of the common house fly in Hawaii is of considerable interest since the habits of *Musca domestica* are reported to be quite different from *Musca vicina.* Chang (1943) states that the latter species does not frequent human faeces but prefers cooked vegetable refuse, and hence in China is known as the "rice fly." Negative results were obtained by Chang when the gut contents of *Musca vicina* were examined for human intestinal parasites, although *Chrysomia megacephala* (Fabr.) and *Lucilia sericata* (Meigen) were both shown as positive carriers of *Entâmoeba histolytica.*

There are present in the Territory various flies which may be involved in myiasis, the principal one being *Hermetia illucens* (Linn.) which was first reported in Hilo, Hawaii, around 1930 (Williams, 1933), and is now widely distributed. The blow flies *Chrysomyia megacephala* and *Lucilia sericata* are potent food contaminators due to their habit of breeding in filth and feeding on sweets (Chang 1943). They may also be involved in cases of human myiasis. The former species is believed to have been accidentally introduced into the Territory around 1900 (Perkins 1913, *vide* Bryan 1934).

There are a number of biting flies present such as *Stomoxys calcitrans* (Linn.) and *Haematobia irritans* (Linn.) which are normally associated with horses and cattle but which may occasionally attack man. Although these species are not known to transmit disease to man, it is within the realm of possibility that they do, because of their biting habits; they cannot be overlooked, particularly in view of the presence of equine encephalitis in horses and Q-fever in cattle, which are pathogenic to humans.

Orthoptera

Mention should be made of the cockroaches found in the Territory since they are frequently incriminated in the mechanical transmission of the dysenteries. *Periplaneta americana* (Linn.) and *Periplaneta australasiae* (Fabr.) are frequently found in restaurants and homes, and can always be collected from just inside the tops of cesspools and sewer man-holes. *Leucophaea maderae* (Fabr.) is readily collected from chicken coops and pig farms where they are often present in tremendous numbers. The small cockroach *Blattella germanica* (Linn.) a common inhabitant of homes and stores is often confused with *Blattella lituricollis* (Walker) which is also present. *Supella supellectilium* (Serville), a common household pest in the tropics, is also present. Illingworth (1915) calls attention to the former medicinal uses of cockroaches in dropsy, whooping cough and Bright's disease and the external application of cockroach oil as a cure for warts.

Hemiptera

Among the Hemiptera, there are two species that attack man in the Territory. The bedbug, *Cimex lectularius,* is a common inhabitant of tenements, hotels, and "flop houses". It may also be found in chicken houses. Although the bedbug has been frequently considered as a possible vector for many different diseases, there is no positive evidence that it is responsible for transmitting any disease. This is one pest against which DDT is extremely effective, and it may be possible that complete extermination will result.

Triatoma rubrofasciata (DeGeer) is the largest blood-sucking insect in the Territory. Although it is known as a possible vector of Chagas' disease (South American trypanosomiasis), this disease has not been reported in Hawaii. *Trypanosoma cruzi* Chagas, the etiological agent for Chagas' disease, may be easily confused with *Trypanosoma conorhini* Donovan, the latter having been reported in *Triatoma rubrofasciata* from Oahu (Wood 1946).

Anopleura

Head lice, *Pediculus humanus* var. *capitis* DeGeer, and crab lice, *Phthirus pubis* Linn., are both known in Hawaii, but are not known to transmit any disease locally. The head louse produces a local irritation of the scalp which may become quite severe. Ten per cent DDT dust has proven extremely effective in the control of the louse and the Department of Health in collaboration with the Department of Public Instruction has instituted a program of control for head lice in school children.

Hymenoptera

There are numerous insects including the honey bee, *Apis mellifica* Linn. and *Polistes macaensis* (Fabr.) and others which sting

and produce more or less severe local reactions. Special mention should be made of the fire ant, *Solenopsis geminata rufa* (Jerdon) which is found on Oahu and Hawaii. The name is derived from the fiery sting, which is hard to believe can be produced by such a small insect. It is interesting to note that bee stings have been used for the relief of arthritic conditions (Guyton 1947).

Miscellaneous

Arthropods of Medical Interest. A number of arthropods other than insects are present which sting or bite or are vectors of disease and hence are of medical importance.

Mention must be made of the centipedes, *Scolopendra subspinipes* Leach and *Otostigmus scaber* Porat, the scorpion, *Isometrus maculatus* DeGeer, and the black widow spider, *Latrodectus mactans* (Fabr.) which are capable of producing severe symptoms of poisoning by their bites or stings. Also present in Hawaii is *Latrodectus geometricus* Koch, a less poisonous, closely-related form frequently mistaken for the less abundant *Latrodectus mactans*. Both of these spiders are highly parasitized by a small wasp (*Eurytoma* sp.) (Bianchi 1947).

Occasional complaints are received relative to the bites and irritations from mites. Usually, these are caused by the bird mite, *Liponyssus bursa* (Berlese) or occasionally by the grocer's itch mite, *Tyroglyphus* sp. *Laelaps nuttalli* Hirst (=*Laelaps hawaiiensis* Ewing) has been incriminated as a possible vector of endemic typhus fever (Rumreich and Koepke 1945), while the rat mite, *Bdellonyssus bacoti* (Hirst) (= *Liponyssus bacoti* [Hirst]) and *Polyplax spinulosus* (Burmeister) are known to transmit endemic typhus fever among rodents (Dove and Shelmire 1931, Mooser, Castaneda, and Zinsser 1931). The human itch mite, *Sarcoptes scabiei* (Linn.) is also found in the Territory. Many diseases have been demonstrated to be transmitted by ticks, such as Rocky Mountain spotted fever, tick-borne relapsing fever, Q-fever, tick bite fever and tularemia. Hawaii is fortunate, however, in having only two ticks, the dog tick *Rhipicephalus sanguineus* (Latreille) and the spinose ear tick of cattle, *Ornithodoros megnini* (Dugés). Although neither of these ticks regularly attacks man, the former species has been incriminated as a possible vector of most of the tick-borne diseases.

Although not generally included in lists of medically important arthropods, mention should be made of the presence in Hawaii of several species of fresh-water copepods of the genus *Cyclops*, including *Cyclops prasinus, strenuus* and *serrulatus*. These have all been incriminated as intermediate hosts for various parasitic worms, including *Dracunculus medinensis, Diphyllobothrium latum, D. mansoni, D. houghtoni, Drepanidotaenia lanceolata* and *Gnathostoma spinigerum* (Craig and Faust 1943).

Conclusion

A review of the arthropods found in Hawaii indicates no lack of vectors for most of the known insect-borne diseases. Most of these vectors have been introduced into the Territory of Hawaii during the last one hundred years. Hawaii has been more fortunate than many areas in lacking either the vector or the disease as a result of its insular position. This feature of "insular protection" is a thing of the past. Fast ship and airplane travel can bring persons to the Islands, well within the incubation period of most diseases. This means a person infected with an illness in China, the Philippines, or anywhere in the world, may arrive in Hawaii before the onset of the disease. At the present time, no place is further than seventy-two hours distant and this "time-distance" is rapidly diminishing. The probability of new diseases that are insect-borne being discovered is high-lighted by the recent work on the encephalitides (Hammon and Reeves 1947) and the discovery in 1946 of Rickettsial pox in Kew Gardens, Long Island, which is transmitted by the mouse mite, *Allodermanyssus sanguineus* (Hirst) (Huebner *et al.* 1946).

This brief review of the arthropods of medical importance to Hawaii demonstrates the need for constant vigilance. One cannot be complaisant concerning possible invasion by insects which attack plants or transmit plant disease, nor can we ignore the dangers which would result from an invasion by insects that attack man and transmit disease.

REFERENCES

Alicata, J. E. 1942. Experimental Transmission of Endemic Typhus Fever by the Sticktight Fleas, Echidnophaga Gallinacea. Jour. Washington Acad. of Science, **32**: 57-60.

Augustson, Gustaf F. 1947. Xenopsylla Fleas of the Hawaiian Islands (Siphonaptera: Pulicidae). Proc. Hawaiian Ent. Soc., **13**: 33-36, 1 fig.

Bianchi, F. 1947. Eurytoma on Latrodectus. Proc. Hawaiian Ent. Soc., **13**: 17.

Bonnet, D. D. 1945. Certain Biological Aspects of Mosquito Control in the Territory of Hawaii (Abstract). Proc. Hawaiian Acad. of Science, 19th and 20th Meetings, University of Hawaii.

Bonnet, D. D. and Worcester, D. J. 1946. The Dispersal of Aedes albopictus in the Territory of Hawaii. Amer. Jour. Trop. Med., **26**: 465-476.

Brigham, G. D. 1941. Two Strains of Endemic Typhus Fever Virus Isolated from Naturally Infected Chicken Fleas (Echidnophaga gallinacea). Public Health Reports **56**: 1803-1804.

Bryan, E. H. 1934. A Review of the Hawaiian Diptera, with Descriptions of New Species. Proc. Hawaiian Ent. Soc., **8**: 399-468.

Chang, K. 1943. Domestic Flies as Mechanical Carriers of Certain Human Intestinal Parasites in Cheng tu. Jour. West China Border Research Soc., **14**: 92-98. (In Abstract.)

Craig, C. F. and Faust, E. C. 1943. Clinical Parasitology, 3rd edition.

Dove, W. E. and Shelmire, B. 1931. Tropical Rat Mites, *Liponyssus bacoti* Hirst, Vectors of Endemic Typhus. Jour. Amer. Med. Assoc., **97**: 1506-1510.

Eskey, C. R. 1934. Epidemiological Study of Plague in the Hawaiian Islands. Public Health Bull. 213, U. S. Treasury Dept., Public Health Serv., 1-70.

Guyton, F. E. 1947. Bee Sting Therapy for Arthritis and Neuritis. Jour. Econ. Ent., 40: 469-472.

Hammon, W. McD. and Reeves, W. C. 1947. Interepidemic Studies on Arthropod Borne Virus Encephalitides and Poliomyelitis in Kern County, California, and the Yakima Valley, Washington, 1944. Amer. Jour. Hygiene, 46: 326-335.

Huebner, R. J., Jellison, W. L. and Pomerantz, Charles. 1946. Rickettsial Pox—A Newly Recognized Rickettsial Disease. IV. Isolation of a Rickettsia Apparently Identical with the Causative Agent of Rickettsial Pox from *Allodermanyssus sanguineus,* a Rodent Mite. Public Health Reports, 61: 1677-1682.

Illingworth, J. F. 1915. Use of Cockroaches in Medicine. Proc. Hawaiian Ent. Soc., 3: 112-113.

Illingworth, J. F. 1916. Notes on the Hen Flea ("Echidnophaga gallinacea" Westw.). Proc. Hawaiian Ent. Soc., 3: 252-254.

Illingworth, J. F. 1923. House-Flies. Proc. Hawaiian Ent. Soc. 5: 275-276.

Irons, J. V., Bohls, S. W., Thurman, D. C., Jr. and McGregor, T. 1944. Probable Role of the Cat Flea, Ctenocephalides felis, in Transmission of Murine Typhus. Amer. Jour. Trop. Med., 24: 359-362.

Jordan, K. 1932. A New Xenopsylla from Hawaii. Novitates Zoologicae, 38: 264-266.

Mooser, H., Castaneda, M. R. and Zinsser, H. 1931. The Transmission of the Virus of Mexican Typhus from Rat to Rat by Polyplax spinulosus. Jour. Expt. Med., 54: 567-575.

Pemberton, C. E. 1943. Insects and Other Arthropods of Medical Interest in Hawaii. Hawaii Med. Jour., 2: 191-193.

Perkins, R. C. L. 1913. Fauna Hawaiiensis, Vol. I, Part 6, Review of Diptera: 180-189.

Pipkin, A. C. 1942. Filth Flies as Transmitters of Endamoeba Histolytica. Proc. Soc. Expt. Biol., 49: 46-48.

Rumreich, A. S. and Koepke, Jean A. 1945. Epidemiological Significance of Seasonal Variations in Rodent-Ectoparasite Distribution. Public Health Reports, 60: 1421-1428.

Simmons, James S., St. John, J. H. and Reynolds, F. H. K. 1930. Dengue Fever Transmitted by Aedes albopictus, Skuse. Amer. Jour. Trop. Med., 10: 17-21.

Snijders, E. P. 1931. The Yellow Fever Problem in the Far East. Trans. 8th Congress held in Siam, December, Far Eastern Assoc. of Trop. Med., 1: 133-150.

Usinger, Robert L. 1944. Entomological Phases of the Recent Dengue Epidemic in Honolulu. Public Health Reports, 59: 423-430.

Varela, Gerardo and Olarte, J. 1946. Transmission of Salmonella Enteritidis by Pulex irritans and Ctenocephalus canis. Science, 104: 104-105.

Webb, J. 1946. Personal communication.

Wheeler, C. M., Douglas, J. R. and Evans, F. C. 1941. The Role of the Burrowing Owl and the Sticktight Flea in the Spread of Plague. Science, 94: 560-561.

Williams, F. X. 1932. Entomological Note. Proc. Hawaiian Ent. Soc., 8: 232.

Wood, Sherwin. 1946. The Occurrence of Trypanosoma conorhini Donovan in the Reduviid Bug, Triatoma rubrofasciata (DeGeer) from Oahu, T. H. Proc. Hawaiian Ent. Soc., 12: 651.