

DISPERSAL OF MOSQUITOES THROUGH TRANSPORTATION, WITH PARTICULAR REFERENCE TO IMMATURE STAGES

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The accidental dispersal of insects through various modes of transportation has always posed a threat to the welfare of man and has often resulted in serious hardship to him. Such dispersal made it possible for many species to become established along various trade routes of the world.

Although numerous insects have been transported in the adult stage, it has not been unusual for them to be dispersed in the larval or other immature stage of their life history. It is with the latter phase of dispersal that this paper is primarily concerned. Accordingly, the writers have cited a few examples showing how mosquitoes have been dispersed, often in their larval stage, and sometimes have become established in areas new to the species. An interesting early discussion on the subject of dispersal of mosquitoes by various types of conveyances is given by Howard *et al.* (1912).

MOSQUITO ESTABLISHMENT FOLLOWING DISPERSAL BY SHIP: ESTABLISHMENT OF MOSQUITOES DURING EARLY DAYS. Although there were undoubtedly many species of mosquitoes established along world shipping routes during the nineteenth century or earlier, a few examples will suffice in pointing out such implantations.

In writing on mosquitoes of Australia, Skuse (1889) described a species of *Culex* which he did not name but which, from the description given, might well have been *Culex quinquefasciatus* Say. He indicated that this mosquito may have been introduced into Australia from Europe on old sailing vessels where it could have

bred in water tanks. He suggested that the same species had been widely dispersed in Australia by means of railroads and that it was then being further communicated to other places on the coast by water traffic.

Mosquitoes were unknown to the Hawaiian Islands until the late eighteenth or early nineteenth century, when they were brought there by sailing vessels on which they undoubtedly were breeding. According to Osten-Sacken (1884) mosquitoes most likely were introduced into Hawaii about 1828 to 1830. He suggested that larvae of *Culex* probably were imported in water tanks on an old sailing vessel from Mexico which was abandoned on the coast of one of the "Sandwich Islands" during that period. Van Dine (1904), in writing on the introduction of mosquitoes into Hawaii, indicated that they were introduced into the Island of Maui in 1826 on the ship "Wellington," which came from Mexico. According to Van Dine's report the first species of mosquito introduced into the Hawaiian Islands presumably was *C. quinquefasciatus*, while *Aedes aegypti* (Linn.) and *Aedes albopictus* Skuse arrived somewhat later. Kirkaldy (1907), mentioned a reference which attributed to one of the Islands' older historians a statement to the effect that mosquitoes were not known there until the arrival of Captain Cook's ships, implying that they were brought in about 1778 or 1779.

Although there may be some controversy as to the actual date of introduction, it is rather well established that three species, *Culex quinquefasciatus*, *Aedes aegypti*, and *Ae. albopictus*, were brought to the Hawaiian Islands by sailing vessels. These species apparently have remained the only mosquitoes which have become established in the Islands by accident. Although the three species are present there today, it is the writers' understanding that the num-

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ber of *Ae. aegypti* is being reduced gradually.

In addition to the three species of mosquitoes mentioned for Hawaii, attempts were made in 1929 by Pemberton (Williams, 1931) to establish the carnivorous *Toxorhynchites* (*-Megarhinus*) *inornatus* (Walker), and in 1950 by Bonnet and Hu (1951) to establish *Toxorhynchites brevipalpis* Theobald. It was hoped by the workers mentioned that the carnivorous larvae of these non-biting mosquitoes would assist materially in the control of *Ae. albopictus* by attacking its immature stages.

ESTABLISHMENT OF MOSQUITOES IN THE CENTRAL PACIFIC AREA. Throughout the years mosquitoes have continued to gain a foothold in areas new to the species involved. Such was the case in some of the Central Pacific Islands during the World War II period.

Anopheles subpictus indefinitus Ludlow, a species indigenous to the Philippines, was found established on Guam in 1948, according to Yamaguti and LaCasse (1950), Reeves and Rudnick (1951), and Reeves (1953). This appears to have been the only time an anopheline mosquito has become established in the Central Pacific-Micronesian area. The same workers, in addition to reporting on *An. subpictus indefinitus*, also reported the finding of *Ae. albopictus* on Guam in 1948, in what was presumed to have been the first record of this species for Guam. However, Hull (1952) mentioned that larvae of *Ae. albopictus* actually were found on the island as early as 1944.

Although it is not known how or in what stage of their life history *An. subpictus indefinitus* and *Ae. albopictus* gained entrance to Guam, Reeves (1953) indicated that they may have entered by means of surface craft during military operations.

Ae. aegypti and *C. quinquefasciatus* were found on Wake Island in a survey of 1947 and 1948; however, according to Reeves (1953), apparently there were no mosquitoes on the island as late as Decem-

ber 1941. Their mode of entry to Wake, whether by aircraft or surface vessel, is unknown.

Reeves (1953) also reported that he collected *C. quinquefasciatus* on Kwajelein Atoll from which it had not been reported.

There are additional records of permanent or temporary establishment of mosquitoes in other Pacific islands during the World War II period which need not be cited here.

EARLY TRANSPORTATION OF *Aedes aegypti* AND OTHER MOSQUITOES BY SHIPS. The Public Health Service in its broad health programs has been actively interested over the years in the accidental transportation of arthropod vectors of diseases such as plague, typhus, and yellow fever. Some specific examples, recorded by various workers approximately 50 years ago will be mentioned.

At the beginning of the present century, soon after *Ae. aegypti* was proved beyond doubt to be the vector of yellow fever, a number of Public Health Service workers conducted studies on the transportation of *Ae. aegypti* to United States ports. Interest in this work was given impetus by the presence of yellow fever in a number of countries to the south and, from time to time, in our own country. The last epidemic of yellow fever to occur in the United States was in 1905. At that time it was confined almost entirely to Louisiana (Surgeon General, 1907), and resulted in 8,399 cases with 908 deaths.

In 1901 Cumming (1901), a Public Health Service medical officer, who later became Surgeon General of the Public Health Service, reported the presence of what he termed a "perfect plague" of mosquitoes on board the Spanish bark Maria Blanquer which arrived at a quarantine station in the South from Rio de Janeiro. Although the master was positive that there were no mosquitoes on board until the twenty-second day at sea, when they were observed in a water tank which was opened, they were so abundant upon arrival that, following fumigation, they could be gathered up by the handfuls.

In 1902 Grubbs (1903), a Public Health Service medical officer at a southern quarantine station, conducted studies to determine to what extent yellow fever mosquitoes were being carried by ships arriving at that station. During the summer of 1902 observations were made on 82 ships (78 sailing vessels and 4 steamers) which arrived from ports where *Ae. aegypti* was present. In addition to on-arrival inspection, consideration was also given to the presence of mosquitoes on these ships prior to departure for the United States and while en route. Of the ships observed, 17 had mosquitoes on board at some time during the voyage, but only three arrived with *Ae. aegypti* present. Of these three vessels, only one had larvae of *Ae. aegypti* present on arrival, although adults of this species were observed on all three throughout the voyage. Undoubtedly, mosquito breeding occurred on all three vessels during their voyages to the United States from Vera Cruz, Mexico, which required 13 or more days for each ship.

Parker *et al.* (1903), in commenting on the transportation of mosquitoes by ships at the beginning of the present century, stated that thousands of larvae of *Ae. aegypti* were found in wooden tanks and in other fresh-water containers on the American schooner John H. Crandon sometime following its arrival in Mexico from a southern United States port. This ship, which was examined at the Mexican port where a case of yellow fever occurred among the crew, subsequently departed, still heavily infested with mosquitoes. Grubbs (1903) reported that it arrived at a United States port with many mosquito larvae and adults on board.

The foregoing will suffice to indicate that mosquito breeding was common on ships early in the century.

RECENT RECORDS OF MOSQUITO BREEDING ON SHIPS AND AIRCRAFT: MOSQUITO BREEDING IN SHIPMENTS OF OLD TIRES. There have been several instances in which mosquito breeding has occurred in old tires which were being shipped to the United States or elsewhere. The most out-

standing example of mosquito breeding in tires transported to the United States was reported by Pratt *et al.* (1946). During 1945 and early 1946, 12 ships which arrived at Los Angeles, California, contained cargoes comprising thousands of old tires and other salvaged equipment from combat areas of the Pacific. Routine examination of these ships by Public Health Service quarantine personnel revealed the presence of fresh water in numerous tires in 8 of the 12 ships involved. The quantity of water per tire varied from a very small amount to as much as five gallons. The water presumably gained entrance to the tires, as well as to other equipment, during heavy rains when stored out of doors prior to being loaded on ships. Mosquito breeding was observed in tires on three of the ships. Tires in holds of the first ship examined contained an estimated 20 to 30 mosquito larvae per tire. Mosquito breeding was from medium to sparse on the remaining two infested ships. In addition to the larvae being present in the water in the tires, numerous adult mosquitoes were found in the holds.

Species of mosquitoes found in the tires on the infested ships, as reported by Pratt *et al.* (1946), were the following, all seven of which are non-indigenous to continental United States, and some of which have been incriminated in the transmission of disease to man: *Aedes scutellaris* (Walker) (as *Ae. scutellaris hebrideus* Edwards), *Aedes albopictus* Skuse, *Armigeres milnensis* Lee (as *Armigeres obturbans milnensis* Lee), *Culex annulirostris* Skuse, *Culex papuensis* Taylor, *Toxorhynchites* (-*Megarhinus*) species, and *Tripteroides* (near) *quasiornata* (Taylor).

Aedes scutellaris and *Armigeres milnensis* were recovered from most of the tires in the first shipment in which mosquitoes were found breeding; however, they were less numerous in the other mosquito-infested shipments. There was breeding by all of the species found in the tires, with exception of *Culex annulirostris* which was represented by one dead adult female.

Control measures were applied to the cargo of the infested ships to prevent escape of adult mosquitoes. Also, as the tires were removed from the holds of the ships, those containing water were treated with a DDT-kerosene solution. Unfortunately, in connection with the unloading of the first mosquito-infested cargo ship, three "box-type" freight cars were inadvertently loaded prior to applying DDT-kerosene solution to the tires which contained water. However, these three loaded railroad cars were treated with a Freon-pyrethrum aerosol and immediately sealed. Following arrival of the loaded cars at their destination, which was 40 miles from Los Angeles, they were again treated with a Freon-pyrethrum aerosol to kill any adult mosquitoes that might have emerged while the cars were en route. When the cars were opened for the purpose of examining the tires, living mosquito larvae were found in many of the untreated tires. Necessary control measures were then applied. In view of the number of times these tires were handled it is interesting that sufficient water remained to sustain living mosquito larvae. Also noteworthy is the fact that, in spite of two applications of an insecticidal aerosol containing pyrethrins, numerous larvae survived. Fortunately, there have been no reports of the establishment of any of these species in the United States as a result of these importations in tires.

Another example of mosquito breeding in tires which were being transported by ship was reported by Perry (1947). He stated that spray crews boarding ships arriving at Noumea, New Caledonia, during World War II encountered hordes of *Ae. aegypti* adults in the holds of a freighter, which subsequently departed for the United States with a cargo of salvaged tires.

Twelve larvae of *Culex quinquefasciatus* were found in a shipment of 200 bulldozer tires that arrived at Honolulu from Saipan during March of 1947. Bonnet (1948) reported that larvae of this species were present in approximately nine percent of

the shipment of 200 tires, and that there was no doubt but that the larvae were of foreign origin. This appears to be the only record of mosquito larvae observed on ships or aircraft arriving in Hawaii in recent years.

Not only have mosquitoes been found in old tires being transported by ships, they have been found on two occasions in old tires transported on aircraft. In the first instance, more than 100 larvae of *Culex quinquefasciatus* were recovered from water in aircraft tires flown from Colombia to Miami, Florida, for recapping. Inspection of the tires by Public Health Service quarantine personnel at the Miami airport during August 1955 revealed the presence of *Culex quinquefasciatus* larvae in water in three of the old tires. The remaining tires contained no water. In addition to the *C. quinquefasciatus* larvae, adults of *Anopheles albimanus* Wiedemann (1, dead) and *Mansonia indubitans* D. and S. (7, dead) were found on the aircraft. Another cargo plane arrived at Miami from Colombia October 1955 with old tires in which three larvae of *C. quinquefasciatus* were found.

Whether being transported on ships, aircraft, or railroad cars, or whether lying in grassy yards or stacked in piles at junk yards, obviously old tires are often conducive to a high index of *Ae. aegypti* and other mosquitoes which adapt themselves to breeding in this type habitat. Actually, old tires would appear to constitute a more formidable enemy to mosquito control programs than did the old sailing vessels with their open water supplies.

MOSQUITO BREEDING IN CONTAINERS OF VARIOUS TYPES ON SHIPS AND AIRCRAFT. Occasional mosquito breeding, other than in tires, has been observed in various types of receptacles on aircraft and ships arriving at United States airports and seaports during the past few years.

In 1935 Oakley (personal communication) observed mosquito larvae in a barrel of water on a schooner which had arrived at Mayaguez, Puerto Rico, from a nearby island.

Two larvae of *Ae. aegypti* were found in a water barrel on a cargo motor vessel by Public Health Service personnel at Miami, Florida, November 1945. The vessel was carrying bananas to Miami from the Dominican Republic.

Larvae of *Ae. aegypti* were found in wooden fire buckets on the main deck of a motor vessel upon arrival at the quarantine station, San Juan, P. R., November 1950. The observation was made by a Public Health Service sanitary inspector during a routine sanitary survey of the vessel.

Four mosquito larvae were found in water contained at the base of the corolla of a bird of paradise flower (*Strelitzia* species) which was being carried by a passenger on an aircraft from Panama. The larvae, intercepted by an agriculture inspector at Miami, Florida, August 1952, were later identified as *Wyeomyia* species. In addition to the mosquito larvae, four *Psychoda* species larvae were found in the same flower.

COMMENTS ON DISINSECTIZATION AND ENTOMOLOGICAL SURVEILLANCE. Although comparatively few observations have been made during recent years on the accidental transportation of immature mosquitoes on aircraft and ships, it should not be concluded that this is altogether the result of lack of endeavor on the part of health representatives. Actually, most aircraft, ships, and other carriers arriving at United States ports and, for that matter, at ports in many countries of the world, are routinely inspected for presence of insects. A program of this nature has been pursued by the Public Health Service for many years (Hughes, 1949).

More than 28,000 aircraft arriving at United States airports from abroad during the 12-month period ending June 30, 1955, were given entomological inspection. These inspections revealed the presence of insects on 14.0 percent of the aircraft. A total of 703 mosquitoes were found. There were no records of mosquito larvae for aircraft during the 12-month period.

Also in the case of surface vessels arriving at United States ports, routine sanitation inspection is made, including a search for insects and rodents. The quarantine inspectors have been instructed to observe carefully for possible breeding of mosquitoes in receptacles on board these ships. Although numerous insects, including many species of mosquitoes, have been found on ships during recent years, nearly all have been in the adult stage. Also, substantially all of the mosquitoes found on these ships are indigenous to this country.

In addition to inspection of aircraft and ships for presence of arthropods, disinsectization procedures using insecticides and methods prescribed by Public Health Service regulation (Surgeon General, 1955) are employed as an aid in preventing the importation of viable arthropod forms. Further, as a second line of defense, an entomological surveillance program is routinely carried out in the vicinity of airports and seaports, particularly in the South, to ascertain the possible presence of imported mosquitoes or other public health species, and to apply control measures when needed.

The writers are not aware of the establishment of mosquitoes in the United States resulting from importation by aircraft or, in recent years, by ship. However, Mulrennan *et al.* (1945) reported on the finding of a fourth instar larval specimen of *Anopheles albimanus* on a military base at Boca Raton, Florida, in 1944. Apparently this larval specimen was the only one of its kind found as far north in Florida as Boca Raton. It was suggested that it may have been an offspring of a gravid female mosquito which may have been imported on an aircraft at the military base where found. Reportedly, an aircraft, for which there was no disinsectization record, arrived at the base from an *albimanus* area 16 days prior to the finding of the larval specimen. Although this mosquito did not become established at Boca Raton, the record serves to point

up the importance of maintaining disinsectization and entomological surveillance programs.

CONCLUSIONS. The most obvious conclusion warranted by the records presented in this paper would appear to be that, even in the near absence of the old sailing vessel, with its open water tanks and lack of sanitation, mosquitoes continue to adapt themselves to various niches even in the modern carrier, sometimes finding them not only favorable to their transportation but also for their propagation. Since this is the case, it may well be that immature stages of mosquitoes are being transported more often than is realized. In any event, we should remain constantly on the alert to prevent such importations, particularly in view of the emphasis that is being placed on mosquito control in this country and abroad, with attention being given to the possibility of reinfestation.

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