AEDES ALBOPICTUS IN MEMPHIS, TENNESSEE (USA): AN ACHIEVEMENT OF MODERN TRANSPORTATION?[1]

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ABSTRACT. Containerization and the Lighter Aboard Ship (LASH) concept have transformed the international shipping industry in the past decade. These technological advances and their potential significance to medical entomology are discussed in the light of the capture of an adult female *Aedes albopictus* in the center of Memphis, Tennessee.

An adult female *Aedes (Stegomyia) albopictus* (Skuse) was collected at a cemetery refuse dump in the center of Memphis, Tennessee, on the night of June 2, 1983. The insect was captured with a CDC Gravid Mosquito Trap (Reiter 1983) which had been set to collect woodland *Aedes* species by using an oak-leaf infusion as the attractant. Identification was confirmed by Y.-M. Huang at the US National Museum of Natural History, where the specimen has been deposited. Attempts to obtain further specimens in the area, with CDC Gravid Traps, standard ovitraps and daytime biting collections, were not successful.

Aedes albopictus is considered to be an important vector of dengue fever (Rudnick and Chan 1965, Gould et al. 1968, Russell et al. 1969, Chan et al. 1971a, Rosen et al. 1983). The species is indigenous to tropical Asia, but it is also established (Fig. 1) in Soviet Georgia, on the African mainland in Djibouti, on a number of islands in the Indian Ocean (including Madagascar, Mauritius, Reunion and the Seychelles), on many northern Pacific islands in the Mariana, Caroline and Hawaiian groups, in the South Pacific in some coastal cities of Irian Jaya and Papua New Guinea and on some of the Solomon and Santa Cruz islands, and in temperate regions as far north as Beijing (Peking), China and Honshu Island, Japan (Ho Beng-Chuan et al. 1973, Elliott 1980, Pashley and Pashley 1983). Like *Aedes (Stegomyia) aegypti* (Linn.), *Ae. albopictus* is a woodland species that has successfully adapted to the urban habitat. Although there is evidence that *Ae. aegypti* may be competitively dominant in domestic urban premises, whereas *Ae. albopictus* has the advantage in outdoor and sylvatic surroundings, the two species are virtually ecological homologues, and coexist in many regions, even sharing the same breeding sites (Rudnick 1965, Gilotra et al. 1967, Moore and Fisher 1969, Chan et al. 1971b). The biology and bionomics of *Ae. albopictus* have been reviewed by Ho Beng-Chuan et al. (1973).

The accidental importation of *Ae. albopictus* into the continental United States has been reported twice before (Pratt et al. 1946, Eads 1972), but there is no record of it having become established. In Beijing, China, at precisely the same latitude as Indianapolis, Indiana, (but subject to colder winters), it overwinters as an egg in diapause (Chao and Chung 1951). The photoperiodic induction of this diapause has been demonstrated in a laboratory strain of *Ae. albopictus* from Shanghai, China (Wang 1966) and in field studies in Nagasaki, Japan (Mori and Wada 1978, Mori et al. 1981). This indicates that the species, particularly strains originating from temperate regions, should be capable of surviving the winter in most parts of the United States.

At an inland city like Memphis, which is 400 miles (644 km) from the sea, air transport might appear to be the most likely source of the *Aedes albopictus* specimen. However, closer investigation reveals a number of other modes of arrival which are at least equally plausible, for Memphis is the sixth largest "distribution center" in the United States, providing up-to-date facilities for the interconnection of international air, rail, road and waterborne freight networks. The emergence and rapid growth of such centers in the past decade is the direct result of a revolution in cargo-handling methods which has had more effect on the shipping industry than any other event since the transition from sail to steam. We believe that this new situation merits careful attention by medical entomologists because it constitutes a quantum leap in the potential mobility of vector species and vector-borne pathogens throughout the world.

Two major innovations are of special interest: containerization and the Lighter Aboard Ship

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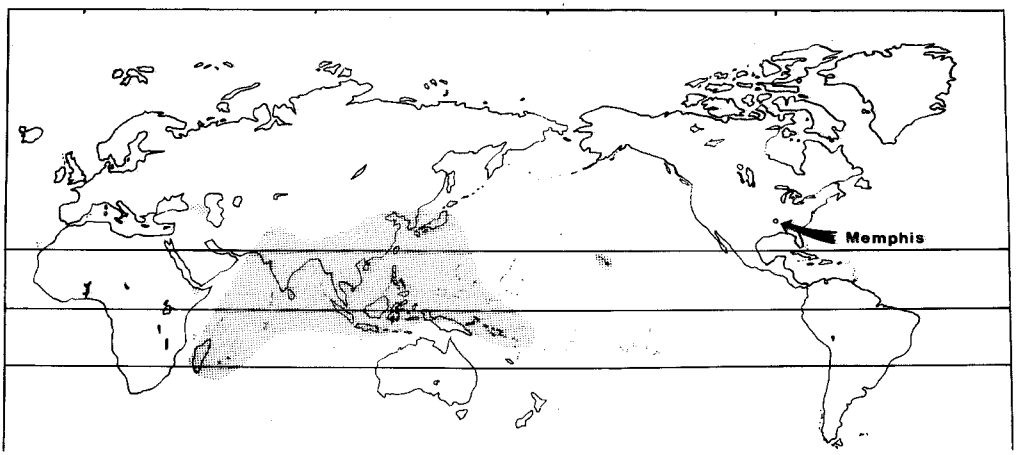

Fig. 1. Geographic distribution of *Aedes albopictus*.

(LASH) system. Containerization involves packing cargo into tightly closed steel chambers, usually 20 or 40 × 8 × 8 ft (6.1 or 12.2 × 2.4 × 2.4 m) which are designed to clamp easily onto the chassis of a standard tractor-trailer road vehicle. The containers can also function as a box on a railroad car, a warehouse at the dockside, or a cargo-hold in a ship. Apart from their obvious advantages in ease of packing, handling, and systematization, the fact that they are tightly closed protects cargoes from salt air, foul weather, shipboard vermin and pilferage. More than 3 million containers (calculated in 20 ft equivalents) will be handled in foreign trade by ports on the U.S. west coast in 1984 (Port Authority Information, Ports of Seattle, Oakland, and Los Angeles).

A modern containerized cargo vessel (Fig. 2) can ship up to 2500 20-ft containers at a speed of 33 knots. Turnaround time in port is incredibly rapid, often as little as 2 hr, in contrast to the days or even weeks which were required when individual items of cargo were handled by pallet. Sailing schedules are published months in advance. The progress of each voyage and every item of freight is continuously monitored by a system of computers and satellite communication. Potential delays can be circumvented by the redeployment of other ships, and it is rare for a cargo to be delivered more than a few hours late. On a typical run, for example, the vessel pictured in Fig. 2 left Karachi, Pakistan, on November 16, 1983 and called at Bombay, India; Colombo, Sri Lanka;

Fig. 2. A typical modern container vessel. Note that many containers are carried above-decks, so that tight seals and good insulation are required to isolate cargo from the elements. *Photograph courtesy of Maersk Line.*

Port Kelang, Malaysia; Penang, Malaysia; Jakarta (Java) Indonesia; Bangkok, Thailand; Belawan (Sumatra) Indonesia; Surabaya, (Java) Indonesia; Singapore; Manila, Philippines; Kaohsiung, Taiwan; Hong Kong; Pusan, South Korea; Keelung, Taiwan; and Kobe, Japan, finally arriving at Tokyo, Japan, on December 9. In 23 days, the voyage had covered the entire indigenous range of *Ae. albopictus* and many other important vectors and vector-borne diseases. The last leg, across the Pacific, took 8 days, so that cargo from all these countries arrived at Long Beach, California, on December 17 (Maersk Line 1983). The same schedule incorporates "overland common point" (OCP) transportation to 11 distribution sites in the United States. For example, cargo loaded in Taiwan on December 5 was guaranteed for delivery in Memphis 17 days later, on December 22. In 1984 this transit time has been reduced to 15 days. Alternatively, transfer to other carriers would have enabled the same cargo to be unloaded in Puerto Rico by December 28; Jamaica, December 29; Honduras, December 30; Ecuador, January 6 or Rio de Janeiro on January 8.

The LASH concept is essentially a system of floating containers. A "mother ship" carries nests of steel "lighters" (barges) which can be hoisted aboard, fully laden, by shipboard cranes. A typical mother ship carries 80 lighters, each 60 × 30 × 15 ft (18.3 × 9.1 × 4.6 m). The lighters are fitted with watertight steel hatch covers so that, like the containers, they are impervious to the elements and to pilferage. An outstanding advantage of the LASH system is that cargo can be loaded and unloaded at points inaccessible to larger vessels or even road vehicles. For example, a cargo of crude natural rubber can be loaded from a plantation warehouse at a river station in the rain forests of Borneo and hoisted ashore from the Mississippi at Memphis, Tennessee, in the space of a few weeks.

Condensation, due to the cooling of humid air within ships by the sea, is a problem that has always plagued marine transport, particularly since the age of steel ships, and especially on voyages from the tropics to cooler climates. For this reason, large quantities of rough-cut wood planks, known as dunnage, are used to isolate cargoes from the dripping sides of the cargo unit. Dunnage also serves to partition cargo and as packing to prevent it from shifting in heavy seas.

In the United States the inspection of imports to minimize the introduction of exotic pests is the responsibility of the United States Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine Division (USDA, APHIS, PPQ). A complex set of regulations governs the importation and inspection of animal and plant materials (USDA APHIS PPQ Manual; continuously updated) but the USDA is not required to search for insects of medical importance, nor even to record if they happen to be present, except in the case of deliberate importations for scientific or other purposes. Moreover, although all cargoes from India are quarantined, and all from Bombay are fumigated, the inspection of containers from other countries is restricted to cargoes and dunnage timber deemed likely to be of agricultural or veterinary significance, a mere fraction of the total imported tonnage.

The number of infested cargoes which are intercepted annually by the USDA is increasing at an alarming rate. Total interceptions involving insects rose from 18,928 in 1980 to 20,261 in 1981 to 30,071 in 1982, an overall increase of 58.9% (USDA APHIS PPQ 1982, 1983). One hundred and fifty-nine countries contributed to the 1982 total. The majority of interceptions involved containers or LASH barges, clear evidence that the cool, humid interior of these modern cargo units provides an excellent environment for the rapid transit of live insects. Although no specific information is available, it is reasonable to suppose that this would apply to insects of medical importance as well. The probability that adult mosquitoes will infest cargo units will be especially high wherever breeding occurs in the loading area, particularly when stacks of dunnage and other resting sites are dismantled during loading. In addition, water on the floors of the cargo units may enable mosquitoes to breed *en passage*, much as was the case in the days of sailing vessels (Hughes and Porter 1956).

The very factors that have favored the widespread use of the new transportation technologies make inspection of the cargo units very difficult. The speed of routine handling and the rigidly maintained schedules mean that delays of any kind are hard to justify, yet compact stowage means that units can only be inspected during unloading. This is particularly true for containers, which generally have their access hatches at one end. Moreover, at the dockside, containers are often stacked one on top of another, usually up to four high, but can only be opened and unloaded at ground level. Efficient road transport enables containers to reach a multitude of destinations, even in the most remote areas, within a few days, so that inspection after delivery is also impractical. Similarly, LASH barges can be towed to factory sites in any part of the extensive national waterway system.

The appearance of an exotic vector species is clearly cause for concern, particularly when it is capable of colonizing its new environment and the chances for repeated importations are high. Imports to the United States from the Association of South-East Asian Trading Nations (ASEAN) alone (Indonesia, Malaysia, Philippines, Singapore and Thailand) increased by over 1200% in the last decade, and the area, already the fourth largest trading partner of the United States, is rapidly emerging as a new center of world economic power (United States Department of Commerce 1981). It therefore seems prudent to suggest that the advent of the new transportation technologies has made it more important than ever for mosquito abatement officers and other professional entomologists in all parts of the world to remain alert to the possible presence of exotic species, and to implement appropriate surveillance measures at sites of particular risk.

ACKNOWLEDGMENTS

We wish to thank the USDA APHIS PPQ (Memphis) and the Maersk Line Agency (Memphis) for supplying much useful information, and Dr. Donald A. Shroyer for a helpful review of the manuscript.

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