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# GLOBAL DISTRIBUTION AND CONTINUING SPREAD OF *AEDES ALBOPICTUS*

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*Abstract*. *Aedes albopictus* ranks second only to *Ae. aegypti* in importance to man as a vector of dengue and dengue haemorrhagic fever (DHF) which viruses place at risk a potential population of 2 billion people living in tropical and sub-tropical regions. Due to its predilection for breeding in a plethora of habitat within urban and suburban environs as well as peri-rural areas it is spreading rapidly where suitable breeding is available. It exhibits strain differences ranging from the cold-hardy to tropic loving, yet despite limited flight range, it has spread beyond the Orient to China, the Pacific, the Indian Ocean islands, the Americas, parts of continental Africa and into southern Europe. This has been done principally by means of transport of eggs in used tyres via rapid air and sea transport. Egg positive used tyres, when shipped, and later rehydrated by rainfall, produce adult mosquitoes within a few days rapidly infesting new areas. Although dengue and other vector-borne arboviral diseases have not been in Europe in epidemic form for many decades, travelers do not infrequently return from dengue endemic areas with dengue and other similar infections. *Aedes albopictus* is a potential vector of a number of arboviruses and can transmit them in a vertical or transvenereal manner in nature, thereby providing a means for their maintenance and transmission. Where *Ae. albopictus* newly occurs, the affected populace immediately are aware of a new daytime, nuisance biting mosquito and complaints addressed to local mosquito control authorities increase significantly. The biological characteristics of the mosquito make its spread within Europe highly probable. The paper offers several avenues to be pursued to reduce the global spread of *Ae. albopictus*, when examined within the context of Europe and the wider world community.

*Key words*: nuisance mosquito, *Aedes albopictus*, arboviruses, transmission, dengue, dengue haemorrhagic fever, Europe.

*Aedes albopictus*, received the nick-name, "Tiger mosquito", in south-east Asia, due to its vivid median silvery line extending from the head to the dorsum and distinct tarsal strips. It is considered to be an aggressive and colourful mosquito, catching the fancy of biologists and the public alike. It is one of more than 25 *Aedes stegomyia* species found around the globe. Belkin (1962) indicated that the *Ae. albopictus* did not occur in the South Pacific and that it was unlikely that it would become established there, as it did not seem to be able to compete successfully with other related species.

At that time (1962), the species was found to be present in the Oriental and Indomalayan regions, also occurring in Mauritius, Japan, the Bonins, Marianas (Savage *et al.*, 1993) and Hawaii, Chagos Islands, Seychelles, the Reunion Islands, Madagascar and West Irian. Were John Belkin from the University of California, Los Angeles, alive today, he would have been amazed at how rapidly this species has moved into new territories in just over three decades. In Japan, where it has been established for a long time, the species exhibits some unusual indoor larval foci (Ishii, 1987) such as basement floor catchment basins. The seasonal distribution and habitat selected by *Ae. albopictus* is still being studied there where it exploits such habitat as bamboo stumps, stone vases and discarded tyres (Sota *et al.*, 1992).

*Aedes albopictus* ranks second only to *Ae. aegypti* in importance to man as a disease vector of dengue and dengue haemorrhagic fever (DHF) which viruses place at risk a potential population of 2 billion people living in urban environments in tropical and sub-tropical regions around the world. The type locality of this species, from which it was first identified was in Calcutta, India (1894) (Knight and Stone, 1977).

Due to its predilection for urban and suburban environs as well as peri-rural areas, parks and forest fringes, it has a lengthy history in association with man. Just prior to the

turn of the century, she was designated by Skuse as *Culex albopictus*, but in 1920, Edwards placed her into the genus *Aedes*.

Today, this species exhibits strain differences ranging from the cold-hardy to tropic loving, yet despite a very limited flight range, has indeed spread beyond the Orient to China, the Pacific, the Indian Ocean islands, the Americas, parts of continental Africa and into southern Europe. She has done this through a remarkable mechanism which is so characteristic of lifestyles found in the final decades of this millennium, i.e., rapid air and sea transport. Dispersal has not principally been via winged adults, or aquatic stages, but by "ova express" in used tyres and other containers such as vases into which eggs have been laid.

Eggs deposited in a variety of rain water filled containers such as used tyres, or drums can remain viable for a year or more. When such containers are shipped and rehydrated, the eggs can hatch within hours and in a few days adult mosquitos emerge and disperse.

From this remarkable story, concerning the spread of such an important arthropod into virgin territory it seems that there must be a lesson which Europe can learn in order not to repeat such history. In terms of the Americas, *Ae. albopictus* had tried several times to gain a toe hold, albeit unsuccessfully. In the literature we are aware of interceptions of the species in California in the early 1950s. There have been interceptions along the west coast of the USA without the species becoming established as reported from California (1987) and from Washington (1986). Each documented account of the introduction of this species has principally been carried out through the used tyres trade with man as the accomplice.

The worldwide trade in used tyres (Gould, 1994) is enormous, for example, in the USA alone, more than 230 million tons of used tyres are generated each year, resulting in huge piles either at designated tyre dumps, land fills or elsewhere to catch rain water and become potential breeding sites for mosquitos and other Diptera. Calder and Laird (1994) called upon the international community for regulations within the used tyre trade in order to control the continued spread of *Ae. albopictus*.

In the USA, subsequent to the detection of *Ae. albopictus* in Texas in 1985, an earlier report was published by Reiter and Darsie (1984) when a single female was collected near the center of Memphis, Tennessee using a CDC Gravid Mosquito Trap. At the time the report was dismissed as being an isolated, dead-end introduction possibly coming from Japan via surface cargo.

## Distribution

In terms of global distribution, the present distribution of the subject of our discussion is considerably greater than it was even in 1986. We will examine the spread of *Ae. albopictus* by world regions (Table 1).

### *The Americas*

*North America*. The first certain infestation of the species within continental USA was reported to the Centers for Disease Control (CDC) on 30 January 1986 (Moore, 1986) as published by Sprenger and Wuithiranyagool (1986) that the Asian "tiger mosquito" had become established in Harris County, Texas. By mid 1992, there were 75 out of the 254 counties in Texas with *Ae. albopictus* densities (Womack, 1993). This author addressed the question of the significance of the introduction of the species into the south-east United States (Knudsen, 1986). Infestations from Louisiana followed in March 1986, in Florida the first report came in 1986 (Peacock et al.). During 1994, Georgia became the first state to document *Ae. albopictus* in all counties of the state (Carl Mitchell, personal communication). Florida also joined such ranks in late 1994 with every one of the state's 67 counties infested (O'Meara, 1994).

In the United States, in September 1992 the CDC reported that the species was established in 345 counties in 22 of the contiguous United States (Moore, 1992). As of November 1994, *Ae. albopictus* is believed to be established in 537 counties in 24 states (Carl Mitchell and Roger S. Nasci, personal communication) including Hawaii, with Chicago, Illinois, being the northern most infestation. If one includes the US territory of Guam, the total is 25, as *Ae. albopictus* has also been present in there for quite some time. It has been found, but is no longer present in Minnesota, New Mexico and California (see Table 2).

*Mexico*. Infestations have been reported along the Texas-Mexico border with the species well established in the states of Nuevo Leon and

Table 1. List of 50+ cour
shipments. * Tyre shipme

| |
|---|
| Albania |
| Australia |
| Bangladesh |
| Barbados* |
| Bonin Islands |
| Borneo |
| Brazil (5 states) |
| Brunei Daresalem |
| Cambodia |
| Chagos Islands |
| China |
| Cocos Islands |
| Cook Islands |
| Dominican Republic |
| Fiji |
| Guam |
| Hawaii |
| Hong Kong |
| India (type locality) |
| *Indonesia* |
| Italy |
| Japan |
| North Korea |
| South Korea |
| Laos |
| Nepal |
| Madagascar |

Table 2. *Aedes albopictus*
territories, 1994. * From a s
CA which was eliminated.
in Savage, Minn., USA, whi
gle female, *Aedes albopictu*
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| State |
|---|
| Alabama |
| Arkansas |
| California* |
| Delaware |
| Florida |
| Georgia |
| Guam |
| Hawaii |
| Iowa |
| Illinois |
| Indiana |
| Kansas |
| Kentucky |
| Louisiana |
| *Maryland* |
| Minnesota** |
| Missouri |
| Mississippi |
| North Carolina |
| Nebraska |
| New Mexico*** |
| Ohio |
| Oklahoma |
| Pennsylvania |
| South Carolina |
| Tennessee |
| Texas |
| Virginia |

Table 1. List of 50 + countries where *Aedes albopictus* is reported to be present or has been intercepted in tyre shipments. * Tyre shipment intercepted. ** Tyre shipment intercepted in California and Washington state.

| | |
|---|---|
| Albania | Malaysia |
| Australia | Maldives |
| Bangladesh | Mariana Islands |
| Barbados* | Mauritius |
| Bonin Islands | Mexico* |
| Borneo | Myanmar |
| Brazil (5 states) | New Caledonia |
| Brunei Daresalem | New Zealand* |
| Cambodia | Pakistan |
| Chagos Islands | Papua New Guinea |
| China | The Philippines |
| Cocos Islands | Reunion Islands |
| Cook Islands | Samoa |
| Dominican Republic | Seychelles |
| Fiji | Singapore |
| Guam | Solomon Islands (including S.ta Cruz) |
| Hawaii | South Africa (Durban)* |
| Hong Kong | Sri Lanka |
| India (type locality) | Tahiti |
| Indonesia | Taiwan |
| Italy | Thailand |
| Japan | Tonga |
| North Korea | Tuvalu (including Niue and Nanumea) |
| South Korea | USA (24 states)** |
| Laos | Vanuatu |
| Nepal | Viet Nam |
| Madagascar | Wallis Islands (including Horn Islands) |

Table 2. *Aedes albopictus* in the United States and its territories, 1994. * From a single positive site in Oakland, CA which was eliminated. ** From an infested tyre pile in Savage, Minn., USA, which was eliminated. *** A single female, *Aedes albopictus* was collected at Albuquerque airport which was identified and eliminated.

| State | Infection status |
|---|---|
| Alabama | Yes |
| Arkansas | Yes |
| California* | No |
| Delaware | Yes |
| Florida | Yes |
| Georgia | Yes |
| Guam | Yes |
| Hawaii | Yes |
| Iowa | Yes |
| Illinois | Yes |
| Indiana | Yes |
| Kansas | Yes |
| Kentucky | Yes |
| Louisiana | Yes |
| Maryland | Yes |
| Minnesota** | No |
| Missouri | Yes |
| Mississippi | Yes |
| North Carolina | Yes |
| Nebraska | Yes |
| New Mexico*** | No |
| Ohio | Yes |
| Oklahoma | Yes |
| Pennsylvania | Yes |
| South Carolina | Yes |
| Tennessee | Yes |
| Texas | Yes |
| Virginia | Yes |

Tamaulipas, the latter with 21 localities infested and three border localities in Coahuila State (Ibanez-Bernal and Martinez-Campos, 1994).

*The Caribbean.* A shipment of tyres from Japan was intercepted in 1987 in Barbados from which a single *Ae. albopictus* larvae was identified along with *Ae. aegypti larvae*. However the first established foci was reported in the Caribbean in May 1993, larvae and adults were captured in Santo Domingo, Dominican Republic. By December of that year infestations had been detected throughout much of the capital city (PAHO Epid Bull).

*Brazil.* According to recent personal communications from Dr Michael Nelson in Brasilia, *Ae. albopictus* now appears in 673 counties or municipalities within seven states including Espirito Santo, Minas Gerais, Rio de Janeiro, Sao Paulo, Maranhao, Bahia and Parana states. The first four states are those which originally were found to be infested in 1986. The capital of Maranhoa, Sao Luis has been reinfested after supposedly being eliminated. Bahia and Parana has small infestations near the borders with heavily infested states of Sao Paulo and Minas Gerais. All of the states are contiguous except Maranhao which is far to the north.

*Europe*

*Aedes albopictus* was reported to be in Albania in 1987 by Adhami and Murati, followed in 1990 by Genoa, Italy (Sabatini *et al.*, 1990) and Dalla Pozza and Majori (1992) and continues to spread within the country. Others on the continent have indicated their concern for the spread of *Ae. albopictus*, including editorials by Rodhain (1993), Grist (1993) and Ward and Burgess (1993).

*Western Pacific*

*Aedes albopictus* continues to make excursions into territories where she previously has not yet become established. This is seen in the case of New Zealand where Calder and Laird (1994) reported on a survey of 9,749 tyres imported into Auckland, mainly from Japan, of which 27.2% contained water. Exotic mosquito larval infestation rates were 20 per 10,000 (wet and dry tyres) and included *Ae. albopictus* among some four species identified. The authors estimated that 2,086 infested tyres could have entered New Zealand during a four year period.

This species has been intercepted in the port cities of both the north and south islands of New Zealand and in Queensland, and the Northern Territory of Australia. Laille *et al.* (1990) reported on the presence of *Ae. albopictus* on the island Viti Levu, Fiji, in 1988 and subsequent spread to the next two largest islands in the group, posing a new and important epidemiological risk to the inhabitants. Vector control measures and strict vector surveillance were called for at ports of entry.

*Africa*

*South Africa.* Hunt *et al.* (1990), Cornel and Hunt (1991) and Jupp and Kemp (1992) reported on the early record of the species from imported tyres from Japan into Cape Town, Africa. It is still uncertain as to whether the species has become established in Durban.

*Nigeria.* The first established account of the introduction into continental Africa was reported from the Delta and Benue states in Nigeria in 1991 (CDC, 1991; Savage *et al.*, 1992). In 1994, additional infestations were found in Imo, Anambra and Enugu States (Carl Mitchell, personal communication). An additional report has been received regarding an infestation in Oyo State in 1994 as well. In Africa inasmuch as imported cargo is not routinely inspected for mosquitos other undetected populations of *Ae. albopictus* may exist on the continent (MWR, 1992).

## Implications for the rise and spread of *Aedes albopictus*

*Disease transmission potential*

Dengue and other vector-borne arboviral diseases have not been in Europe in epidemic form for many decades. We are aware that travelers do not infrequently return from dengue endemic areas of the tropics with dengue and other similar infections.

*Aedes albopictus* is a potential vector of a number of arboviruses and can transmit them in a vertical or transvenereal manner in nature, thereby providing a means for their maintenance. Is there a plausible risk in Italy for an outbreak of dengue, where the "tiger mosquito" has spread so rapidly? The answer is a resounding *yes*, the second most important vector of dengue is present and is a significant threat for a potential outbreak of dengue, should one of the four dengue serotypes be introduced into a susceptible population.

*Expanding breeding habitat*

*Aedes albopictus* has a wide range of potential habitats including peri-domestic containers such as tyres, vases, cemetery urns and natural habitat like tree cavities and leaf axils (Chan, 1985). It occupies essentially similar niches in which we commonly find *Ae. aegypti*, i.e., in almost any conceivable container in which rain water, or water for storage purposes can be found. *Aedes albopictus* was formerly seen to be mainly sylvatic in its breeding preferences, i.e., edges of gardens, parks and forests, but it has in many areas gradually moved closer to man's dwellings, where a myriad of potential breeding habitat exists among numerous discarded waste, mainly objects, symbols of Twentieth Century' culture, with an abundance of tins, jars, pots, bottles, barrels, drums, tyres, etc., and has in many places taken up residence right indoors living in vases, and other water holding vessels.

*Increased nuisance value*

Where *Ae. albopictus* newly occurs, the general populace affected immediately are aware of a new daytime, nuisance l
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Aedes albopictus *competi*
*with* Aedes aegypti

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1991), Florida (Hornby *e*
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urban areas, formerly the
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*Host preferences of* Ae. alb

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new daytime, nuisance biting mosquito and complaints addressed to local mosquito control authorities increase significantly. Rebora *et al.* (1993) commented that the biological characteristics of the mosquito, make its spread all over Europe highly probable and we might add, with significant dermatological implications due to patient reactions to bites.

### Aedes albopictus *competition with* Aedes aegypti

The affect on the abundance and distribution of *Ae. aegypti* by the "tiger mosquito" has been reported by several authors (Black *et al.*, 1989) from a number of places. Hawaii, Louisiana (Nasci *et al.*, 1989), Alabama (Hobbs *et al.*, 1991), Florida (Hornby *et al.*, 1994), where the latter has become the dominant species in urban areas, formerly the realm of the former species. This apparently is due to interspecific mating, with both species preferring to mate with females of their own species, but albopictus are more actively promiscuous than the other species. Resultant hybrids are usually sterile, but the heterospecific insemination renders the females refractory to subsequent homospecific insemination. Others have reported that the species are reproductive isolates (Harper and Paulson, 1994). Van Handel (1994) indicated that metabolic differences which exist between the two species may be contributing reasons. *Aedes albopictus* does have a longer larval stage, during which time lipid and glycogen accumulation may occur, but *Ae. aegypti* is strictly anautogenous (will not start egg development without a blood meal), whereas a certain percentage of *Ae. albopictus* will start egg development when maintained on sugar, as seen in laboratory experiments. Duhrkopf and Hartberg (1992) wrote about interspecific mating as related to flight sound and determined that the two species use different mechanisms to locating mates.

### *Host preferences of* Ae. albopictus

From blood meal analysis, it is well known that *Ae. albopictus* is an opportunistic feeder preying upon a variety of hosts, as reported by Savage *et al.* (1993) and Niebylski *et al.* (1994). This feeding behaviour pattern can be used to argue the point that the species therefore does not present a real threat in the transmission of dengue or other of the rapidly rising arboviruses. *Ae. albopictus* in many ways is far more dangerous than other *Stegomyia* as it potentially can pick up a greater variety of zoonotic viruses from its vast menu of hosts and potentially transmit them to man.

### What is industry doing about used tyres

We are also aware that there is research being conducted within industry to solve the problem of tyre recycling. Recently there was a report in the "New Scientist" (Gould, 1994) which touched upon a technique developed by the Japanese using "supercritical" water which is at such a high temperature and pressure that its liquid and gas states merge being capable of dissolving organic components such as rubber tyres into oily mixtures of long-chain hydrocarbons. Such mixtures separate steel from rubber and textiles and are recovered for recycling. Even sulphur within tyres is converted to hydrogen sulphide.

In France a company which recycles metals and plastics has developed a new process for recycling used tyres by transforming them into a purified rubber powder, through a mechanical shredding process and the use of a liquid nitrogen cryogenic process. The end product can be put to use in a large number of applications (WAY, 1992).

### Recommendations and hope for the future

There are several avenues to be pursued to reduce the global spread of *Ae. albopictus*, and they should be examined within the context of Europe and the wider world community.

1. It is suggested that increased collaboration and rapid communications be promoted through available networking in the most rapid method; be established between concerned public health officials, entomologists and epidemiologists in Europe with linkages with other concerned officials in the Americas and elsewhere regarding the continued spread of *Ae. albopictus* in Europe.

2. It would be most appropriate if an expanded and consolidated surveillance system be increased at all ports of entry in southern Europe, especially in countries sharing common borders with those already infested.

3. It is essential that effective and cost effective vector control methods be proposed for the intervention of infested used tyres, larval

foci and existing adult populations. The experiences of North America will be of value where infestations have been eliminated.

4. It is recommended that appropriate legislation be proposed at concerned national levels as well as to the European Community concerning the importation of used tyres in order to prevent the further introduction of the "tiger mosquito" from Asia and elsewhere.

5. It is important that health authorities throughout Europe be alerted to the potential risk of the further spread of *Ae. albopictus* which can be accomplished through an informed media and the dissemination of information to schools of higher education, medical schools, etc.

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