

AEDES ALBOPICTUS AND THE WORLD TRADE IN USED TIRES, 1988-1995: THE SHAPE OF THINGS TO COME?

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ABSTRACT. In the decade since used tires were identified as the mode of introduction of *Aedes albopictus* to the United States, similar infestations have been reported from 10 other countries in the Americas and 2 in Europe. Millions of used tires are still being traded throughout the world and although a few governments have implemented inspection procedures to prevent further introductions, these are unlikely to be effective. Further introductions of mosquitoes of potential public health significance are inevitable.

KEY WORDS Asian tiger mosquito, *Aedes albopictus*, *Aedes aegypti*, used tires, transportation, dispersal

BACKGROUND

In June 1983, a single adult specimen of *Aedes* (*Stegomyia*) *albopictus* (Skuse), a mosquito native to Asia, was captured in a cemetery park in Memphis, TN. Speculating on its mode of arrival, Reiter and Darsie (1984) drew attention to 2 major innovations in the transportation industry—containerization and the Lighter Aboard Ship (LASH) system—and suggested that these would lead to further introductions of medically important insects.

In January 1986, the Centers for Disease Control (CDC) were notified by health authorities in Texas that heavy infestations of *Ae. albopictus* had been detected in Harris County, TX, which includes the city of Houston. Discarded used tires were identified as the principal breeding site. The abundance and distribution of the species within the county suggested that it could have been present for several years (Sprenger and Wuithiranyagool 1986). Subsequent investigations revealed that, since the late 1960s, the new transportation technology had facilitated an extensive national and international trade in used tires (Reiter and Sprenger 1987). Millions of tires were being imported annually from all over the world to destinations throughout the United States. It appeared likely that the new species had been imported in such tires, perhaps from Japan, the world's major used tire exporter.

In May 1986, an alert from the Pan American Health Organization (PAHO) prompted national authorities in Brazil to examine specimens of an unknown *Aedes* species that had been awaiting identification at the Entomology Laboratories of the Federal Headquarters of the National Health Foundation in Brasilia. These also proved to be *Ae. albopictus*, and by the end of July, infestations had been detected in 63 municipalities of 3 Brazilian states (Forattini 1986). By September of the same year, surveys in 12 U.S. states (Alabama, Arkansas, Florida, Georgia, Illinois, Indiana, Louisiana, Mississippi, Missouri, Ohio, Tennessee, and Texas) revealed that 48 of 57 counties surveyed (84%) were positive for *Ae. albopictus* (CDC 1986a, 1986b,

1986c, 1987). Meanwhile, studies of cold-hardiness and winter diapause yielded evidence that the North American *Ae. albopictus* was probably native to a nontropical region of Asia (Hawley et al. 1987), supporting the hypothesis that these mosquitoes had probably originated in Japan. Inspections of containers arriving at West Coast ports confirmed the presence of live *Ae. albopictus* and 4 other mosquito species in used tires arriving from Japan (Craven et al. 1988). Thus, by the close of 1986 it was clear that the mosquito was widely established in the United States and Brazil, and it seemed likely that 1) *Ae. albopictus* had been present in both countries for a number of years, 2) it had been introduced to both countries in shipments of used tires, 3) the U.S. *Ae. albopictus* had originated in Japan, 4) the infestations were the result of multiple introductions, and 5) interstate traffic in used tires was a major factor in continued dispersal within both countries.

The establishment of any exotic vector is cause for concern. Laboratory studies had shown that *Ae. albopictus* is capable of vertical and horizontal transmission of dengue and other important human arboviruses, including several that are native to the Americas (see reviews by Shroyer 1986, Mitchell et al. 1987). Little information was available on the role of this species as a vector in the field, although it was known to transmit dengue in some countries. Eradication was clearly not an achievable goal, but there was considerable pressure for the U.S. government to prevent further introductions, on the grounds that this would limit the genetic variance of the newly established population and prevent the introduction of exotic viruses (Moore et al. 1988). For this reason, the U.S. government instituted a legal requirement that all used tires imported from Asia should be certified as dry, clean, and free of insects (see below). Enforcement became the responsibility of the CDC Division of Quarantine.

Since 1986, tire shipments infested with *Ae. albopictus* have been found in Barbados (PAHO 1993), South Africa (Cornel and Hunt 1991), Aus-

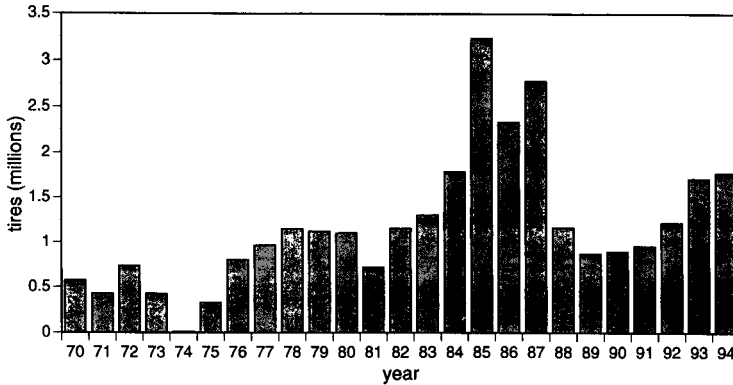


Fig 1. United States. Imports of used tires, 1970–94.¹

tralia (Kay et al. 1990), and New Zealand (Calder and Laird 1994). Established infestations of *Ae. albopictus* have been recognized in Albania (Adhami and Murati 1987, Adhami and Reiter 1997), 1,012 counties in 8 states of Brazil (Nelson, PAHO, personal communication), Italy (Dalla Pozza and Majori 1992), Nigeria (Savage et al. 1992), the Dominican Republic (Pena 1993), Mexico (Ibáñez-Bernal and Martínez-Campos 1994), Cuba (Nelson, PAHO, personal communication, 1996), Guatemala (Ogata and Lopez Samayoa 1996), El Salvador (de Navarro, El Salvador, personal communication, 1996), Bolivia (Nelson, PAHO, personal communication, 1997), Colombia (Suarez, Colombia, personal communication, 1997), and the Cayman Islands (Petrie, personal communication, 1997). There are reports that the Bolivian and Cuban infestations have been eradicated, but these have not been confirmed. In this paper I review recent import and export data for used tires, summarize the international response to the spread of *Ae. albopictus*, and examine the rationale for port inspections.

IMPORT AND EXPORT DATA

Trade data for used tires were obtained for Belgium–Luxembourg, France, Germany, Italy, Hong Kong, Japan, Macau, Mexico, the Netherlands, Singapore, South Korea, Taiwan, the United States, and the United Kingdom.

United States

Annual imports of used tires from 1970 through 1994 are shown in Fig. 1. Imports (1989–94) are summarized by country of shipment in Table 1. In the 6-year period, 7,451,127 tires were imported from 50 countries, 4,993,034 (67%) from Asia and 2,008,770 (27%) from Europe. Japan provided the largest portion (63%), followed by Germany (14%), Canada (6%), the Netherlands (5%), the United Kingdom (4%), and Korea (3%). Of the Asian imports, 4,698,033 (94%) were from Japan, 259,694

(5%) were from South Korea, and all but 1,176 (0.02%) were from countries where *Ae. albopictus* is indigenous. Exports (1989–94) from the United States are summarized by country of destination in Table 2. In the 6-year period, 5,687,273 tires were exported to 110 countries, 2,642,230 (46%) to North and Central America and the Caribbean (25 countries) and 2,142,003 (38%) to South America (12 countries). The remaining 903,005 (16%) were shipped to 18 countries in Asia, 21 countries in Europe, 26 countries in Africa, and 8 countries in Australia and Oceania. Mean exports to all countries were 947,879 per year, nearly 12 times the annual mean (79,298) for the period 1978–85 (Reiter and Sprenger 1987).

Japan

Japan is by far the biggest exporter of used tires in the world, and ships to more countries than any other nation (Table 3). In 8 years (1988–95), 49,005,870 tires were exported to 137 countries, of which 24,633,773 (50%) went to 34 other Asian countries, 11,726,879 (24%) to 24 countries in North and Central America and the Caribbean, 6,361,375 (13%) to 17 countries in Australia and Oceania, 4,310,382 (9%) to 28 countries in Africa, 1,716,053 (3.5%) to 22 countries in Europe, and 257,408 (0.5%) to 12 countries in South America. One third of the world total (16,002,234) went to Hong Kong (see below). The United States was the next largest importer (6,183,204; 13%), followed by South Africa (3,957,932; 8%), the Dominican Republic (3,764,553; 8%), Australia (3,657,216; 7%), and New Zealand (2,463,753; 5%). Mean exports to all countries were 6,125,734 per year, more

¹ United States Department of Commerce, Bureau of the Census. *Harmonized tariff schedule. Imports of merchandise*. Data listed under heading 4012.20.0000 and 5 sub-headings: 4012.20.1000, 4012.20.1500, 4012.20.4500, 4012.20.6000, and 4012.20.8000. Available in electronic form only. The Bureau charges \$250–300 per search.

Table 1. United States. Imports of used tires, 1989-94.¹

Country of origin	No. tires
Asia	
Japan	4,698,033
Korea	259,694
Taiwan	8,797
China	7,780
Sri Lanka	5,030
Indonesia	2,406
India	1,842
Israel	7,774
Jordan	576
Malaysia	341
Thailand	320
Hong Kong	290
Singapore	117
Mauritius	34
Total	4,993,034
Europe	
Germany	1,035,441
Netherlands	359,006
United Kingdom	265,697
Switzerland	136,375
Austria	62,120
Belgium	57,916
France	52,865
Italy	14,295
Romania	4,618
Yugoslavia	3,918
Hungary	3,833
Luxembourg	3,780
Denmark	3,205
Spain	1,451
Russia	1,419
Sweden	1,330
Greece	282
Former USSR	261
Poland	220
Turkey	220
Bulgaria	210
Ireland	117
Finland	112
Czechoslovakia	56
Norway	23
Total	2,008,770
North America, Central America, Caribbean	
Canada	442,658
Mexico	381
Trinidad	120
Panama	41
Dominican Republic	38
Costa Rica	12
Total	443,250
South America	
Brazil	1,473
Argentina	472
Colombia	128
Venezuela	75
Total	2,148

Table 1. Continued.

Country of origin	No. tires
Africa	
Cameroon	1,651
Total	1,651
Australia and Oceania	
Australia	2,167
Marshall Islands	107
Total	2,274
World total	7,451,127

¹ United States Department of Commerce, Bureau of the Census. *Harmonized tariff schedule. Imports of merchandise.* Data listed under heading 4012.20.0000 and 5 subheadings: 4012.20.1000, 4012.20.1500, 4012.20.4500, 4012.20.6000, and 4012.20.8000. Available in electronic form only.

than 3 times the annual mean (1,951,364) for the period 1978-85 (Reiter and Sprenger 1987).

Hong Kong

Hong Kong ranked 2nd to Japan as an Asian exporter of used tires. In 8 years (1989-95), 15,006,645 tires were exported (Table 4), mostly to China (13,521,849; 90%). Export data from Macau² indicate that a portion of Hong Kong's exports to that country (1,268,882; 9%) are reexported to China. For example, in 1993, Macau received 133,098 used tires from Hong Kong and exported 55,000 used tires to China. No other country, except Hong Kong, is listed in these data.

There appears to be a discrepancy between the figures for exports to Hong Kong published by other countries and the Hong Kong export data. Thus, for 1989-95, Japanese data list 1,833,573 more tires exported to Hong Kong than the total of Hong Kong's world exports, and the imbalance is exacerbated by export data from Taiwan (3,569,788 in 1989-94) and South Korea (94,488 in 1993-94). Import data for Hong Kong were only available for 1992-95 (Table 5), but for years that we can compare (1992-94), Japanese and Taiwanese exports to the colony were 5,746,724 and 3,060,492 tires respectively (total: 8,807,216), whereas Hong Kong data gave total exports to all countries as 5,457,078. In 1993, only 305,189 motor vehicles were registered in Hong Kong (Commissioner for Census and Statistics, Hong Kong, personal communication), so this apparent surplus of 3,350,138 tires can hardly be attributed to home consumption. Whatever the explanation, it is certain that Hong Kong imports large numbers of tires from Japan and Taiwan, most of which are reexported to China.

² Government of Macau, Direcção de Serviços de Estatística e Censos. *Estatísticas Oficiais, Exportação Definitiva.* HS code 4012.20.00. Obtained from the Macau Census and Statistics Department, Rua Inacio Baptista, 4D-6, 3 Andar, Macau.

Table 2. United States. Exports of used tires, 1989-94.¹

Destination	No. tires
Asia	
Lebanon	135,817
Israel	112,195
Jordan	42,723
Kuwait	24,535
Saudi Arabia	21,618
United Arab Emirates	10,678
Yemen Arab Republic	8,913
India	8,578
Thailand	7,292
Malaysia	4,341
Singapore	3,802
Indonesia	3,197
Philippines	2,923
China	1,560
South Korea	577
Hong Kong	29
Taiwan	14
Japan	1
Total	388,793
Europe	
Netherlands	69,795
Former USSR	45,590
Italy	44,687
Germany	22,410
Russia	20,693
Greece	20,606
United Kingdom	14,033
France	13,441
Sweden	11,728
Belgium	7,970
Iceland	5,318
Cyprus	3,756
Denmark	3,664
Ireland	3,250
Norway	2,932
Spain	2,765
Ukraine	1,270
Switzerland	823
Finland	317
Estonia	316
Austria	65
Total	295,429
North America, Central America, Caribbean	
Mexico	698,217
El Salvador	530,471
Panama	340,421
Honduras	316,035
Guatemala	210,108
Trinidad and Tobago	150,026
Canada	126,271
Dominican Republic	59,957
Nicaragua	46,529
Costa Rica	40,049
Belize	37,037
Aruba	18,742
St. Vincent	16,452
Haiti	12,470
Jamaica	11,874
Netherlands Antilles	9,247
Bahamas	7,314
Grenada	4,693
Antigua	3,868

Table 2. Continued.

Destination	No. tires
Martinique	1,173
St. Lucia	859
St. Christopher and Nevis	275
Montserrat	102
Bermuda	37
Cayman Islands	3
Total	2,642,230
South America	
Colombia	1,374,314
Venezuela	312,604
Guyana	208,629
Suriname	77,185
Ecuador	71,760
Peru	36,983
Bolivia	27,476
Chile	18,030
Brazil	7,856
Paraguay	4,205
Uruguay	2,543
Argentina	418
Total	2,142,003
Africa	
South Africa	42,812
Guinea	12,891
Liberia	10,959
Nigeria	9,571
Ghana	6,758
Sierra Leone	5,343
Benin	4,211
Niger	3,962
Gabon	3,413
Congo	3,000
Morocco	1,456
Cameroon	1,339
Zaire	1,283
Gambia	805
Senegal	568
Ivory Coast	462
Burkina Fasso	322
Mali	258
Kenya	182
Somalia	173
Algeria	66
Togo	55
Uganda	51
Zambia	35
Tanzania	31
Angola	20
Total	110,026
Australia and Oceania	
Australia	88,662
New Zealand	17,264
Fiji	1,201
Micronesia	1,022
Tonga	313
Western Samoa	289
Cook Island	31
Marshall Islands	10
Total	108,792
World total	5,687,273

¹ United States Department of Commerce, Bureau of the Census. *Harmonized tariff schedule. Exports of merchandise.* Data listed under heading 4012.20.0000 and 5 subheadings: 4012.20.1000, 4012.20.1500, 4012.20.4500, 4012.20.6000, and 4012.20.8000. Available in electronic form only.

Taiwan

In 6 years (1989–94), Taiwan exported 5,754,062 used tires (Table 6), slightly more than the total for the United States in the same period. The bulk of these (5,495,939; 96%) went to other Asian countries, notably Hong Kong (3,569,788; 62%) and Singapore (868,343; 15%), presumably for reexport. Most of the tires are probably derived from the home market as imports from Japan were small (37,548 tires in 8 years), and no other major exporting country listed Taiwan as a significant export destination.

South Korea

Data were only available for 1993–94 (Table 7). In those 2 years, 1,089,343 tires were exported to more than 30 countries. In the same period, Japanese exports were 13,540,276 tires to 98 countries; Taiwanese exports were 4,196,966 tires, 23 countries; Hong Kong, 3,215,661 tires, 12 countries; and the United States, 626,319 tires, 76 countries. Apart from countries where *Ae. albopictus* is indigenous, the principal destinations were South Africa (177,302 tires; 16%), United States (153,696; 14%), Australia (134,547; 12%), and New Zealand (124,855; 11%).

Singapore

Singapore imports and exports used tires (e.g., 1,424,902 tires from Japan in 1988–95), but the export figures are published in combination with re-tread tires, which are unlikely to harbor live insects, so the data are not included here.

European Community

Export data of the European Community (EC) are categorized as intra-EC (between EC members) or extra-EC (outside the Community). Data for France, Belgium–Luxembourg, Germany, Italy, and the United Kingdom from 1993–95 are summarized in Table 8. Intra-EC trade is analogous to intrastate trade in the United States; merchandise moves freely between EC countries. For this reason, commodities listed in extra-EC trade do not necessarily originate in the exporting country. Thus, Italy, the only country in the EC known to be infested with *Ae. albopictus*, exported 12,902 metric tons of used tires (Table 9) in the period 1993–95, of which 6,700 tons (52%) went to France, Germany, and the Netherlands, perhaps for export outside the Community. Of the remainder, 3,502 tons (57%) went to other countries in Europe (including EC) and 2,017 tons (33%) went to countries in Africa.

Mexico

Mexico exported 105,509 used tires to Cuba in the period 1990–March 1996.³ A small quantity of tires (79 metric tons) was exported from Italy to Cuba in 1995, but none in the previous 2 years. Larger quantities (2,815 tons) were exported from other European countries, principally Germany, in 1994–95 (1,814; 64%). In the same period, 2,935 tons were shipped from Italy to Germany, so it is possible that at least a portion of these were eventually landed in Cuba.

SOURCES OF NEW INFESTATIONS

Most countries derive their imported tires from several sources. Table 10 shows the percent contribution of 6 *Ae. albopictus*-infested tire-exporting countries to the imports of 8 newly infested tire-importing countries, derived from the export data of the countries concerned. It appears likely that the infestations in the United States, Brazil, and the Dominican Republic were acquired directly from Japan, whereas the infestations in Mexico, Guatemala, and Nigeria were probably derived from the United States. Evidence exists that Italy was also infested from the United States (Dalla Pozza et al. 1994, Romi 1995), although a substantial proportion of Italian imports (44% in 1993–95) also come from Japan (Table 2). The Cuban infestation may have been derived from Mexico or another Latin American country, although it is also possible that tires originating in the United States are transhipped to Cuba through an intermediary country to avoid a trade embargo.

The likelihood that an infestation will occur is probably a direct function of the number of infested tires imported, unless factors such as diapause or cold-hardiness (Hawley et al. 1987) hinder colonization. The mean number of tires exported by Japan per year to the infested countries listed in Table 10 (508,551) was 7.6 times greater than the number exported by the United States (67,002), which suggests that introductions may have been more frequent in the countries that derived their infestations from Japan.

NATIONAL RESPONSES TO THE SPREAD OF *AE. ALBOPICTUS*

In 1993, Venezuela banned all imports of used tires. The ban was enforced despite strong opposition from local dealers, who argued that cheap tires should be available because of the poor state of the economy (Rubio Palis, personal communication).

³ Government of Mexico, Subsecretaría de Negociaciones Comerciales Internacionales, Dirección General de Información y Estadística. *Systema de Consulta de la Tarifa, Arancelaria de Exportación*. Fracción 4012.20. Data obtained by H. Gómez Dantés.

Table 3. Japan. Exports of used tires, 1988-95.¹

Destination	No. tires
Asia	
Hong Kong	16,002,234
North Korea	1,756,818
Pakistan	1,539,638
Singapore	1,424,902
United Arab Republic	1,287,120
China	1,220,110
Lebanon	481,979
Malaysia	416,867
Vietnam	124,356
Afghanistan	98,385
Jordan	63,850
Taiwan	37,548
Bahrain	37,028
Philippines	33,791
Brunei	18,897
Cambodia	12,905
India	11,199
Indonesia	10,349
Macao	10,080
Iran	9,859
Myanmar	9,266
South Korea	7,124
Thailand	4,844
Bangladesh	3,955
Saudi Arabia	3,817
Mongolia	1,960
Gaza	1,635
Israel	1,284
Kuwait	620
Syria	515
East Timor	299
Oman	264
Uzbekistan	243
Sri Lanka	32
Total	24,633,733
Europe	
Netherlands	508,126
Belgium	285,398
United Kingdom	228,483
Former USSR/Russia	175,689
Germany	155,536
France	104,352
Spain	73,311
Italy	48,032
Ireland	37,403
Portugal	22,150
Denmark	20,478
Cyprus	18,784
Sweden	7,741
Ukraine	6,927
Greece	5,235
Iceland	4,737
Finland	4,342
Austria	3,792
Norway	2,597
Switzerland	2,301
Latvia	489
Malta	150
Total	1,716,053

Table 3. Continued.

Destination	No. tires
North America, Central America, Caribbean	
United States	6,183,204
Dominican Republic	3,764,553
Canada	455,879
Panama	410,225
Haiti	219,152
Trinidad	166,896
Honduras	120,823
Jamaica	74,225
El Salvador	68,364
Canal Zone	64,359
Dominica	59,683
Guatemala	57,283
Puerto Rico	46,921
Barbados	14,829
Netherlands Antilles	5,835
Nicaragua	4,947
Mexico	2,878
French West Indies	2,367
U.S. Virgin Islands	1,360
St. Lucia	1,023
St. Vincent	875
U.K. Virgin Islands	798
St. Pierre/Miquelon	250
Belize	150
Total	11,726,879
South America	
Brazil	195,259
Chile	29,933
Peru	8,251
Paraguay	6,478
Ecuador	6,036
Venezuela	3,155
Surinam	2,483
Guyana	2,220
Bolivia	1,555
Argentina	1,284
Colombia	474
Uruguay	280
Total	257,408
Africa	
South Africa	3,957,932
Kenya	122,876
Uganda	77,040
Cameroon	31,938
Senegal	26,590
Ghana	25,186
Namibia	16,274
Mauritius	13,648
Swaziland	5,288
Togo	4,590
Tanzania	3,146
Morocco	3,000
Mozambique	2,872
Madagascar	2,700
Ivory Coast	2,644
Comoros Islands	2,200
Botswana	1,988
Zimbabwe	1,638
Benin	1,500
Canary Islands	1,500

Table 3. Continued.

Destination	No. tires
Seychelles	1,340
Zaire	1,130
Guinea	952
Libya	892
Mali	800
Nigeria	400
Gabon	228
Ethiopia	90
Total	4,310,382
Australia and Oceania	
Australia	3,657,216
New Zealand	2,463,753
Papua New Guinea	86,008
Fiji	40,328
Tonga	24,304
Micronesia	17,437
Palau	16,777
West Samoa	15,014
Marianna Islands	13,898
Caroline Islands	12,167
Marshall Islands	4,409
Kiribati	2,395
Solomon Islands	2,205
Atlantic Ocean	1,994
Cook Islands	1,417
Vanuatu	1,185
Guam	868
Total	6,361,375
World total	49,005,870

¹ Japan Tariff Association. *Japan exports and imports (commodity by country)*. Data listed under: Used pneumatic tyres, of rubber. 4012.20.000. Obtained from the Japan External Trade Organization (JETRO), 1221 Avenue of the Americas, New York, NY 10020.

Annual combined exports from the United States, Japan, and Taiwan to Venezuela dropped from 117,420 in 1992 to 773 in 1994. Bermuda also imposed a ban, and since 1992 is not listed by any of the exporting countries that I have reviewed. Chile and Costa Rica are said to have a ban (Nathan, PAHO, personal communication), but this is not borne out by the export data of other countries.

The Dominican Republic is the largest importer of used Japanese tires in the tropical Americas. Surveys by the national government in 1986–87, corroborated by external review (Reiter, 1987, unpublished report to PAHO) did not reveal any *Ae. albopictus* infestations. A national plan was devised to prevent future infestations, but the species was discovered in the Santo Domingo area in 1991 (Pena 1993) and has now spread to much of the country.

Little is known about the Cuban infestation, and no information has been published. According to PAHO sources, infestations were first recognized in November 1995. Energetic eradication efforts commenced immediately and were declared successful in March 1996. No information is available as to

how eradication was confirmed, nor whether measures have been implemented to prevent further importations.

Jamaica, Barbados, and several other island countries in the Caribbean conduct routine inspections to prevent the importation of *Ae. albopictus* (Nathan, PAHO, personal communication). The Jamaican government fumigates all containers of imported used tires with handheld thermal fogging machines and inspects the tires before release to the importer.

The U.S. government has made a major effort to prevent further importation of the mosquito. By Federal Regulation,⁴ all used tires arriving from Japan, Korea, Taiwan, Hong Kong, Thailand, and all other Asian countries where *Ae. albopictus* is known to occur, must be dry, clean, and disinfected. Panama has enacted similar legislation. Disinsection must be accomplished by one of the following methods: fumigation with at least 2 pounds of methyl bromide per 1,000 ft.³ (28.3 m³) for 24 h; application of dry heat at 120°F (88°C) for more than 30 min; steam cleaning; or cleaning with a pressurized spray of detergent/water solution at 88°C (190°F). The exporter is required to sign a certificate, specifying the method of disinsection that was used and the date of the treatment. This certificate must be cosigned by the importer or the importer's agent during clearance by the U.S. Customs Service. The cargo cannot be released unless accompanied by a certificate validated according to these rules. Shipments without correct documentation are transported to a holding site and treated at the shipper's expense. At the port of Los Angeles, CA, costs per 40-ft. container are: fumigation, \$65; fumigation, cleaning, and water removal, \$665; trucking and related expenses, \$300. Thus, the maximum charge per container is around \$1,000. The law does not enable the authorities to charge penalties for noncompliance, even to repeat offenders.

CAN WE PREVENT THE IMPORTATION OF *AE. ALBOPICTUS*?

For nearly a decade, the CDC Division of Quarantine has conducted random inspections to monitor compliance with the law. The task of unloading, inspecting, and repacking containers that are tightly crammed with used tires is labor-intensive and time-consuming. Moreover, despite energetic application of the regulations, it is clear that the approach is almost totally ineffective. In 1994–96, for example, 436 containers (126,440 used tires) were inspected by the CDC at the ports of Chicago, IL, Seattle, WA, Los Angeles, CA, Miami, FL, San Francisco, CA, and New York, NY. No mosquitoes were found, but 54% of the inspected containers

⁴ Public Law 78-410, Public Health Service Act, Section 361, and 42 CFR 71.32(c).

Table 4. Hong Kong. Exports of used tires, 1989-95.¹

Destination	No. tires
Asia	
China	13,521,849
Macau	1,268,882
West Malaysia	63,854
Japan	26,706
Singapore	20,782
Sabah	14,167
Afghanistan	5,740
Vietnam	4,490
Thailand	1,801
Pakistan	1,800
United Arab Emirates	1,634
Kampuchea	900
Taiwan	115
Sri Lanka	75
India	60
Philippines	56
Iran	40
Brunei	28
Total	14,932,979
Europe	
Czech Republic	3,950
Netherlands	200
Total	4,150
Americas	
Canada	4,794
Chile	371
Panama Republic	230
United States	108
Total	5,503
Africa	
South Africa	39,967
Malawi	112
Total	40,079
Australia and Oceania	
Australia	18,336
New Zealand	5,598
Total	23,934
World total	15,006,645

¹ Hong Kong Census and Statistics Department. *Re-exports from Hong Kong*. Data listed under SITC 625991 before 1992, and HKHS 40122000 from 1992 onwards. Obtained from the Census and Statistics Department, Economic Statistics Division, Trade Statistics Dissemination Section, 19th Floor, Wanchai Tower, 12 Harbour Road, Wan Chai, Hong Kong.

were rejected because the tires contained water, spiders, or debris. The rejected cargoes (237 containers, 68,730 tires) were treated at the expense of the shippers, who presumably were content to set the cost off against the 5,699 other containers (1,778,174 tires) that escaped inspection. In other words, nearly one half of all tires entering these ports should have been rejected but were cleared on the basis of their certificate. Moreover, tires that appear clean and dry can contain *Ae. albopictus* eggs that hatch when immersed in water, as was

Table 5. Hong Kong. Imports of used tires, 1992-95.¹

Country of origin	No. tires
Japan	5,334,801
Country unknown	2,489,727
Taiwan	192,726
Korea Republic	97,078
China	54,250
Malaysia	43,637
Thailand	13,900
Indonesia	8,900
Singapore	6,809
North Korea	6,160
United States	4,800
Philippines	2,800
Canada	1,649
Macau	1,290
United Arab Republic	1,230
France	1,000
Australia	860
Germany	600
Netherlands	474
United Kingdom	10
Total	8,262,701

¹ Hong Kong Census and Statistics Department. *Imports to Hong Kong*. Data listed under SITC 625991 before 1992, and HKHS 40122000 from 1992 onwards. Obtained from the Census and Statistics Department, Economic Statistics Division, Trade Statistics Dissemination Section, 19th Floor, Wanchai Tower, 12 Harbour Road, Wan Chai, Hong Kong.

demonstrated in airplane tires shipped from Atlanta, GA, to Maserà, Italy (Dalla Pozza et al. 1994). Also, nearly one half of all used tires imported into the United States entered through ports where there are no CDC inspection facilities at all, and the law does not require certification or inspection of tires imported from any of the countries in Africa, Europe, or South America that are infested with *Ae. albopictus*.

Even if the law were highly effective, it is difficult to determine what purpose it would serve. Established populations of *Ae. albopictus* have been recorded in 674 counties of 24 states (Moore and Mitchell 1997), and it is certain that many more infestations remain undetected. Despite suggestions that the winter diapause mechanism (Hawley et al. 1987) might limit the southward spread of the species into Florida, the entire state is now infested. Interestingly, this invasion has been associated with a major decline of *Ae. aegypti* (Linn.) (O'Meara et al. 1995). It is now reasonable to assume that the new species has reached the approximate limits of its potential distribution in the United States, but that the interstate used tire trade and other dispersal mechanisms will ensure continued colonization within those limits. In terms of the vast size and distribution of the existing population, the number of mosquitoes that could be introduced from overseas is certainly insignificant.

It has been suggested that the genetic diversity of the established population can be limited if fur-

Table 6. Taiwan. Exports of used tires, 1989-94.¹

Destination	No. tires
Asia	
Hong Kong	3,569,788
Singapore	868,343
Japan	381,282
Malaysia	368,351
China	144,560
Cambodia	101,288
Afghanistan	67,590
Vietnam	57,407
Jordan	1,414
Qatar	1,312
Sri Lanka	1,140
Thailand	880
Bahrain	174
Total	5,495,939
Europe	
Germany	42,507
Italy	1,550
Portugal	966
France	910
United Kingdom	615
Netherlands	450
Greece	67
Total	47,065
North America, Central America, Caribbean	
United States	18,410
Dominican Republic	10,564
Venezuela	8,907
Surinam	5,844
Trinidad	3,442
Mexico	2,119
Guyana	1,716
Chile	962
Panama	192
Puerto Rico	160
Canada	114
Total	52,430
Africa	
Benin	10,924
Nigeria	4,000
Guinea	3,070
Senegal	901
Total	86,485
Australia and Oceania	
New Zealand	53,444
Australia	18,576
Fiji	123
Total	72,143
World total	5,754,062

¹ Government of Taiwan. *Exports, Quantity and Value of: by Commodity and Country*. Listed under 401220100-2 and 4012209000-5. Obtained from the Taipei Economic and Cultural Representative's Office, 4301 Connecticut Avenue NW, Suite 420, Washington, DC 20008.

Table 7. South Korea. Exports of used tires, 1993-94.¹

Destination	No. tires
Asia	
Malaysia	172,669
Hong Kong	94,488
China	73,596
Japan	25,064
Lebanon	15,200
Singapore	5,092
Bahrain	1,500
Brunei	1,300
Total	388,909
Europe	
Russia	66,034
Netherlands	12,736
Spain	4,209
Denmark	1,600
United Kingdom	810
Austria	205
Total	85,594
Americas	
United States	153,696
Canada	5,883
Brazil	2,500
Puerto Rico	1,997
Panama	1,500
Belize	402
Ecuador	120
Chile	100
Bolivia	100
Total	166,298
Africa	
South Africa	177,302
Niger	1,400
Ghana	200
Zimbabwe	121
Total	179,023
Australia and Oceania	
Australia	134,547
New Zealand	124,855
Fiji	9,901
Total	269,303
Others	216
World total	1,089,343

¹ Government of South Korea. *Exports by Commodity and Country*. Listed under 4012-20-1000 (625931), 4012-20-9010 (6259391), 4012-20-9020 (6259392), 4012-20-9030 (6259393), 4012-20-9040 (6259394), and 4012-20-9090 (6259399). Obtained from the Korean Foreign Trade Office, 1800 K Street NW, Washington, DC 20006.

ther imports are prevented, but this presupposes that the original introduction was from a discrete source, which is unlikely, and that genetic homogeneity exists over the vast infested area, which is not the case (Black et al. 1988, Kambhampati et al. 1990, Kambhampati and Rai 1991, Rai 1991). Some may argue that inspections could prevent the importation of other species, but the sheer volume of used tire imports from all over the world makes

Table 8. Exports of used tires from member countries, European Economic Community (EC). 1993-95.¹

Exporting country	Metric tons of tires exported	
	Intra-EC	Extra-EC
Germany	19,842	28,068
Netherlands	45,884	14,069
France	14,339	14,046
Belgium-Luxembourg	6,312	6,148
United Kingdom	6,375	3,693
Italy	3,190	2,737
Total	95,942	68,761

¹ European Economic Community. *EUROSTAT. Intra and Extra European Union Statistics. Flow: Exped/Export. Products: 401220. Statistical Office of the European Communities, L-2920 Luxembourg.*

this an impracticable goal. Moreover, the number of species colonizing tires is small compared to those that could arrive in the tens of millions of containers containing other cargoes that reach these shores each year.

CONCLUSIONS

Aedes albopictus has joined the housefly (*Musca domestica* Linn.), the flour beetles (*Tenebrio* spp.), various species of cockroach (Blattoidea), the Mediterranean fruit-fly (*Ceratitidis capitata* Weidemann), the yellow fever mosquito (*Ae. aegypti*), and many other insects that have vastly extended their range by virtue of their association with mankind. Time will tell whether *Ae. albopictus* also joins the list of exotic vectors that transmit human or animal pathogens.

It would be comforting if we could view the story of *Ae. albopictus* as a learning experience that will help us avoid the introduction of other species in the future. Unfortunately, the realities of modern commerce and transportation imply the opposite: as international trade increases, introductions will be more frequent and prevention less practicable. The establishment of *Wyeomyia mitchellii* (Theobald) in Hawaii (Shroyer 1981) and a *Culex* (*Micraedes*) species in Florida (O'Meara and Evans 1997), both suspected to have arrived in fresh bromeliads, and the discovery of *Ae. atropalpus* (Coquillett) in Italy (Romi et al. 1997), are probably better indicators of the presence of competent local taxonomists than of the number of introductions worldwide.

In Italy, both of the new mosquito species appear to have come from North America—*Ae. albopictus* from Georgia (Dalla Pozza et al. 1994) and *Ae. atropalpus* from Minnesota or Quebec (Romi et al. 1997). The principal urban vector of dengue and yellow fever, *Ae. aegypti*, is well established throughout the southern United States, including Georgia, having arrived there from its native Africa in the 17th century. Until World War II *Ae. aegypti* was also common in much of the Mediterranean

Table 9. Italy. Exports of used tires, 1993-95.¹

Destination	Metric tons of tires exported
Asia, Australasia	
Lebanon	232
Australia	35
Japan	24
China	15
Syria	10
Jordan	9
Israel	7
Cyprus	4
Qatar	4
Cambodia	1
Total	341
Europe	
Netherlands	2,248
France	2,227
Germany	2,225
Romania	877
Hungary	502
Slovenia	356
United Kingdom	312
Switzerland	310
Portugal	192
Bulgaria	144
Albania	96
Former Republic of Yugoslavia	90
Russia	85
Belgium-Luxembourg	70
Poland	67
Czech Republic	61
Greece	50
Sweden	42
Croatia	38
Spain	38
Ukraine	36
Austria	30
Norway	28
Malta	25
Finland	18
Slovakia	17
Bosnia-Herzegovina	10
Georgia	7
Serbia-Montenegro	6
Estonia	4
Denmark	1
Total	10,212
Americas	
Brazil	116
Cuba	79
Chile	43
Dominican Republic	33
United States	27
Argentina	21
Ecuador	7
Venezuela	5
El Salvador	1
Total	332

Table 9. Continued.

Destination	Metric tons of tires exported
Africa	
Senegal	610
Algeria	407
Togo	217
Guinea	112
Reunion	107
Ghana	104
Benin	79
Niger	73
Tunisia	48
Zaire	46
Congo	42
Tanzania	31
Nigeria	24
Libya	21
Kenya	21
Burkina Faso	12
Morocco	10
Zambia	10
Chad	9
Cameroon	9
Angola	6
Malawi	6
Sudan	4
Ivory Coast	3
Zimbabwe	3
Eritrea	2
Sierra Leone	1
Total	2,017
World total	12,902

¹ The equivalent number of tires is difficult to determine because of the great range in tire sizes. A 40-ft. container may contain 250–300 truck tires, or 1,600–2,000 tires for smaller vehicles. Data from Macau, which includes both quantity and weight of tires, yields a mean weight per tire (175,064 tires) of 12.9 kg. The U.S. Customs informed us that the average weight of imported used truck tires is about 41 kg. Tires for airplanes, construction machinery, and other large vehicles are, of course, much larger and heavier.

region (Kumm 1931), but it disappeared during the DDT era. The colonization of Italy and Albania by *Ae. albopictus* should therefore serve as a warning that *Ae. aegypti* and dengue could return to the region. Indeed, one of the largest epidemics of dengue and dengue hemorrhagic fever on record occurred in Greece in 1927–28 (Cardamatis 1929, Halstead and Papaevangelou 1980), with approximately a million cases and 1,000 deaths. Future European dengue epidemics could be even more devastating, because the densely populated urban areas have grown larger, but air conditioning, insect screens, and other protective factors (Reiter 1996) are uncommon.

Under international law, imports are solely the responsibility of the importer. There is no reason to believe that the European countries will be more successful than the United States in blocking the importation of infested cargos. In short, it seems we must accept the establishment of exotic species as an inevitable consequence of modern transportation technology.

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Table 10. Percent contribution of 6 *Aedes albopictus*-infested tire-exporting countries to the tire imports of 8 newly infested countries.¹

Infested exporting country (mean no. tires exported per year)	Infested importing countries (year of infestation)							
	United States (1985)	Brazil (1986)	Dominican Republic (1993)	Italy (1990)	Mexico (1990)	Nigeria (1991)	Guatemala (1995)	Cuba (1995)
Japan (508,551)	90.4	81.5	97.4	43.8	0.3	1.7	17.0	0
United States (67,002)	—	4.4	2.1	54.3	99.4	54.4	83.0	0
Korea (1,250)	9.0	4.2	0	0	0	0	0	0
Taiwan (3,039)	0.4	0	0.4	1.9	0.3	22.7	0	0
Italy (6,511) ²	0.3	10.0	0.2	—	0	21.1	0	9.2
Mexico (20,097)	0	0	0	0	0	0	0	90.8

¹ Infestations in the United States, Brazil, and the Dominican Republic were probably primary infestations, derived directly from Japan. Infestations in Mexico, Guatemala, and Nigeria were probably secondary, derived from the United States. The same was probably true for Italy, although a substantial proportion of Italian imports also come from Japan. The Cuban infestation may have been derived from Mexico or another Latin American country, although some imports may originate in the United States but are routed through Mexico to evade a trade embargo. The probable country of origin of infestations in importing countries is indicated by bold text.

² Calculated at 12.9 kg per tire, or 77.5 tires per ton. This figure is derived from the Macau data (see text) and is for smaller tires.

employees of the U.S. Customs Service and CDC Division of Quarantine.

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