Distribution of *Aedes albopictus* (Diptera: Culicidae) in Northwestern China

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Abstract

The Asian tiger mosquito, *Aedes albopictus* (Diptera: Culicidae), has a wide distribution in China with its northwestern limits among seven provinces. During 2006–2008, distribution information was collected in 33 urban and rural areas in those boundary provinces by collecting larvae or adult mosquito from different breeding sites. Additional information of seven sites was gathered from local health authorities. Three generally accepted climatic delineations affecting distribution of the species were studied for the northwestern distribution using a geographic information system software (ArcGIS). Climatic analysis showed that the annual mean temperature higher than 11°C, the mean temperature of the coldest month, January, higher than -5°C, and the annual precipitation above 500 mm covered almost all the confirmed areas and the seasonal expansion reached areas with nearly -10°C of the mean January temperature. As a main vector of dengue fever virus in a large part of China, where *Aedes aegypti* is absent, *Ae. albopictus* is also responsible for the risk for future epidemic of dengue fever and other viral diseases in China.

Key Words: *Aedes albopictus*—China—Distribution—Mosquito-borne diseases.

Introduction

As a mosquito native to Asia, *Aedes albopictus* Skuse, 1894 (Diptera: Culicidae) has been one of the fastest invasive species over the past decades and it has colonized at least 28 countries in North America, South America, Europe, and Africa (Benedict et al. 2007). Its ability to breed in artificial containers and lay desiccation-resistant eggs that may remain viable for several months facilitate their passive spread through main transportation routes (Hawley et al. 1987, Hawley 1988).

*Ae. albopictus* thrives in a wider range of water-filled breeding sites than *Aedes aegypti*, including bamboo stumps, tree holes, and rock pools, in addition to artificial containers such as scrap tires and saucers beneath plant pots (Hawley 1988, Romi 1995). This diversity of habitats underlies the abundance of *Ae. albopictus* in rural as well as in urban areas (Sota et al. 1992). *Ae. albopictus* is both a biting nuisance and a public health concern due to its ability to transmit at least 22 arboviruses in laboratory to human, including dengue, chikungunya, and Japanese encephalitis (Mitchell 1995). In China, *Ae. aegypti* was the primary vector in the coastal areas of the tropical zone below 22° N latitude, being *Ae. albopictus* considered as a secondary or maintenance vector in these areas. However, *Ae. albopictus* has a vast area of distribution in China from 41° N latitude to the southern reaches of the country (Zhao 2008), being involved as the primary vector of dengue fever and should be responsible for dengue transmission in Guangdong and Zhejiang provinces in recent years, where *Ae. aegypti* is uncommon (Jiang and Yan 2008, Lu et al. 2009).

Between 1979 and 1982, the distribution of *Ae. albopictus* in northwestern China was exhaustively studied and was found to extend into areas of Liaoning, Hebei, Shanxi, Shaanxi, Sichuan, and Xizang provinces (Xu 1990, Guo 2008). To obtain a better understanding of the current distribution of *Ae. albopictus* in northwestern China, we have studied the distribution of this species through larval and adult mosquito surveys from 2006 to 2008. Associations between this distribution and climatic factors were studied using a geographic information system (ArcGIS) software. We also combined the potential distribution of *Ae. albopictus* output from the CLIMEX model with the distribution of dengue fever outbreaks in recent years to evaluate the risk for future epidemic of the disease in China.

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Materials and Methods

Study site

Based on the historical and recent reports, mosquitoes were collected at 33 sites in Liaoning, Hebei, Shanxi, Shaanxi, Sichuan, and Gansu provinces for the current survey. Additional distribution information of another seven sites in Hebei, Shanxi, Shaanxi, Sichuan, and Gansu provinces and Beijing were also generated from vector surveillance by local health authorities in recent years. For half of these 40 sites, historical records were available.

Collection and identification of larval and adult mosquitoes

Between 2006 and 2008, mosquito larvae were collected during July to September, when the population density was expected to be the highest (Kobayashi et al. 2002, Roiz et al. 2008). The larvae were collected from artificial containers such as garden vases, stacks of scrap tires, discarded cans or plastic containers, holes in trees, and pools, using a plastic pipette or metal ladle. Larvae were held in our insectary until adults emerged, and were then identified to species using taxonomic keys (Lu 1990). Adult mosquitoes were collected using aspirators as they were attracted to humans, and identified as described above.

Analysis of temperature using GIS and CLIMEX model

Analysis of local climate was performed on the basis of the annual mean temperature, the monthly mean temperature in January, and the annual precipitation. Map of the raster temperature surface was obtained from Data Sharing Infrastructure of Earth System Science (www.geodata.cn), which has a resolution of 500 m.

The potential distribution of *Ae. albopictus* in China was determined using the CLIMEX model (Sutherst et al. 2004). CLIMEX infers the response of a species to climate from its known distribution elsewhere and describes the potential for permanent establishment with an Ecoclimatic Index (EI) for each location. The CLIMEX model of *Ae. albopictus* (Russell et al. 2005) was accepted to predict the potential distribution incursion by both tropical and temperate strain, based on climatic data from 1961 to 1990 obtained from China Meteorological Data Sharing Service System (http://cdc.cma.gov.cn/) and Taiwan province from Central Weather Bureau (www.cwb.gov.tw/).

We collected details of the locations of dengue fever outbreaks in China between 1990 and 2008 from literature and official published reports (Zhao 2008). All data were imported into geographic information system (ArcGIS) software for mapping.

Results

*Ae. albopictus* was confirmed in 26 of the 40 survey sites, including sites within cities, towns, and villages (Fig. 1). The mosquito was found for the first time at three sites in the southeast of Gansu province, one site in the west of Liaoning province and one site in northern Shanxi province. *Ae. albopictus* was, however, not found at several sites where it had previously been reported, including one site in central Hebei.

FIG. 1. Distribution of *Aedes albopictus* in northwestern China. Inset map shows the locations of the provinces where the present study was performed.
province, one site in central Shanxi province, and one site in southern Sichuan. *Aedes chemulpoensis, Aedes japonicus, Aedes koreicus, Anopheles sinensis, Aedes punctor, Aedes flavivorsalis,* and *Aedes dorsalis* were also collected during our survey.

Correlations between climatic factors and the distribution of *Ae. albopictus* were studied (Figs. 2 and 3). We observed that most of the confirmed areas were located in the zone where the annual mean temperature is above 11°C and the January mean temperature is above −5°C. However, the mosquito was also found at two sites in Liaoning province and one site in Shanxi province, where the annual mean temperature is between 8°C and 11°C and the January mean temperature is between −5°C and −10°C. Two of these exceptions were new confirmed sites. All survey sites experienced the annual precipitation above 500 mm.

The results of the CLIMEX model indicated that most provinces and cities in China had the potential to support *Ae. albopictus* populations, although south China was most suitable (Fig. 4). The predicted distributions in Liaoning, Hebei, Shanxi, Shannxi, Sichuan, and Gansu provinces were generally consistent with our field data. Between 1990 and 2008, dengue outbreaks were reported not only in southern areas of China where the EI was higher than 40 but also in some east coast cities where the EI was between 22 and 31.

**Discussion**

Three sites in Hebei, Shanxi, and Sichuan became *Ae. albopictus*–free possibly as a result of recent changes in water source management (Dutta et al. 1998). However, further surveillance is required to confirm the situation because it is difficult to eradicate the mosquito once it has been established (Roiz et al. 2008, Zhao 2008, Takumi et al. 2009).

Climate is considered the main determinant for the potential distribution of *Ae. albopictus* (Hawley 1988, Xu 1990). Nearly all the confirmed sites (23 of 26) experienced the annual mean temperature above 11°C and the January mean temperature above −5°C (Fig. 2). This annual mean temperature is consistent with the development zero of this mosquito and the same was found for the northern distribution limit of *Ae. albopictus* in Japan (Kobayashi et al. 2002). Besides, the distribution limit of *Ae. albopictus* was reported to correlate with a January mean temperature of 0°C in the United States (Hawley et al. 1989) and −2°C in Japan (Kobayashi et al. 2002). However, in our study over half the confirmed sites experienced the January mean temperature lower than −2°C. The mosquito was also found in three sites, which experienced the annual mean temperature below 11°C and the January mean temperature below −5°C. Two of them were newly confirmed ones, whereas another site in northern Liaoning province had limited surveillance record for the mosquito (Xu 1990, Wang et al. 2009). Recent studies by local health officials found no evidence of the mosquito overwintered in those sites (Wang et al. 2009); therefore, the spread of the species into these areas may be due to summer expansion. The limit for summer expansion was reported to be −5°C in January mean temperature (Hawley et al. 1989); however, these sites all lay beyond and experienced nearly −10°C of the mean January temperature.
FIG. 3. Relationship between annual precipitation and the distribution of Ae. albopictus.

FIG. 4. The potential distribution of Ae. albopictus as determined by climate in China, estimated by the CLIMEX Ecoclimatic Index with a scale from 0 to 100 throughout the year. Darker shades indicate pixels with higher Ecoclimatic Index value. Dengue fever outbreaks in China between 1990 and 2008 (square) are also shown.
All confirmed survey sites experienced the annual precipitation above 500 mm (Fig. 3), which was reported as the typical lower limit (Knudsen et al. 1996).

Environment data for *Ae. albopictus* occurrence demonstrates that it can establish itself in areas with much more restrictive conditions and that *Ae. albopictus* eggs are extremely cold tolerant (Hawley 1988, Benedict et al. 2007). Our study clearly showed, that the distribution of *Ae. albopictus* in northwestern China extended to the isotherm of the mean temperature of −5°C in January and that the maximum northward expansion during summer can explore to nearly −10°C in January.

*Ae. albopictus* is the most important mosquito implicated in dengue transmission in China due to its wider distribution (Guo 2008). In particular, it is an important maintenance vector, as it is susceptible to all four serotypes of the dengue virus and can support transovarial transmission of the virus (Jiang and Yan 2008). During 1990–2008, 16,000 dengue cases were reported across mainland China, and *Ae. albopictus* was considered responsible for almost all those outbreaks (Fig. 4) (Zhao 2008). Most areas with E1 value >22 have a potential risk for dengue outbreaks in that they can support survival and development of the vector. Although most inland provinces are sufficiently cold that disease risk is low, the predicted climate change for the next decades increases the chance of dengue expansion (Hales et al. 2007).

The first Chikungunya outbreak was reported in Guangdong province in October 2010 with >40 confirmed cases (www.moh.gov.cn), and the adaptive mutation A226V in E1 had been found from some imported cases (Zheng et al. 2010), a real threat arises that this virus will cause major epidemics (Knudsen et al. 1996).

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**Disclosure Statement**

No competing financial interests exist.

**References**


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