ESTIMATION OF THE NORTHERN LIMITS OF DISTRIBUTION OF *AEDES ALBOPICTUS* IN NORTH AMERICA

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An Oriental mosquito, *Aedes* (*Stegomyia*) *albopictus* (Skuse), first became established in Houston, Texas in 1985 (Sprenger and Wuithiranyagool 1986); by September of 1986, it had been found in 11 other states including localities as far north as Indianapolis, Indiana and St. Louis, Missouri (Centers for Disease Control 1986). Unlike its cosmotropical relative, *Aedes* (*Stegomyia*) *aegypti* (Linnaeus) *Ae. albopictus* is not confined to tropical areas, but is also found in temperate areas of China, Japan and South Korea. Asian populations of *Ae. albopictus* show geographic variation in their overwintering adaptations. Only strains from temperate zone Asia have a photoperiodically-controlled dormancy in the egg stage. In addition, eggs of north Asian strains survive sub-freezing temperatures better than those of tropical strains. North American strains of *Ae. albopictus* exhibit overwintering characteristics similar to temperate Asian strains, not to tropical strains of this species (Hawley et al., 1987). One might therefore speculate that a large but undefined part of North America may eventually be colonized by this mosquito. We here make an attempt to estimate more precisely the potential northern range of *Ae. albopictus* in North America, based on published reports of its north Asian distribution and climatological data for Asia and North America.

The northern range of *Ae. albopictus* may be categorized into two types: overwintering and late summer expansion ranges. The overwintering range includes the area where *Ae. albopictus* survives winter conditions. The range of late summer expansion extends from the overwintering range to the northernmost sites where this species occurs, usually on an irregular basis.

In China, *Ae. albopictus* has been reported as far north as Beijing (Fig. 1). However, overwintering probably does not occur there; Feng (1939) states that "This species is only rarely found in Peking in August, and in some years is not found at all." But 350 km to the south, in Tsinan, *Ae. albopictus* is abundant in July and August each year, suggesting successful overwintering there (Lu and Sun 1959).

South Korea is the location of one of the few direct observations on overwintering in *Ae. albopictus*. Hong et al. (1971) collected eggs of overwintering mosquitoes at two separate sites in March 1971 by taking samples from the interior of tree holes and artificial containers. Eggs were hatched and the larvae reared for identification. At Kumsan, about 100 km south of Seoul, many viable *Ae. albopictus* eggs were collected, indicating that overwintering had occurred. Near Seoul, viable eggs of four *Aedes* species were collected but none were *Ae. albopictus*. However, by late August 1971, larval and adult *Ae. albopictus* were found in Seoul (Tanaka et al. 1979), suggesting that this species was able to expand northward to that city despite its apparent inability to overwinter there.

In Japan, the northernmost demonstration of overwintering for *Ae. albopictus* is in Ashikaga, about 80 km northwest of Tokyo, where larvae were recovered from tree holes in mid-April (Kurashige and Ogawa 1967). Although *Ae. albopictus* has been found as far north as Sendai (Kamimura 1968), we know of no data on its overwintering capabilities there.

Climatic data for the Asian localities mentioned above were obtained from the literature (Arakawa and Taga 1969, Watts 1969). Table 1 lists these locations and their daily mean January temperatures. Daily mean January temperatures were used as a crude measure of the severity of winter at these sites, since January is the coldest month at every site and such data were available for all the relevant localities on both continents.

In China and South Korea, the putative overwintering areas have daily mean January temperatures no less than −3°C, while sites on the fringe of the late summer expansion range have daily mean January temperatures near −5°C. Curiously, *Ae. albopictus* is apparently absent from areas in Japan with daily mean January temperatures less than 0°C. It seems unlikely that *Ae. albopictus* has been overlooked in the northern part of Honshu Island. The survey of Kamimura (1968), in particular, is based on widespread and intensive collecting. If climatic factors other than winter temperatures have limited this mosquito's distribution, it is unclear what these are. Rainfall, the most obvious candidate, is heavier in northern Honshu than it is in many areas of continental Asia where *Ae. albopictus* is common. In addition, summer temperatures in northern Honshu are only 2–4°C lower than those near Seoul and Beijing (Arakawa and Taga 1969, Watts 1969). It may be that the climate of northern Honshu is not inimical

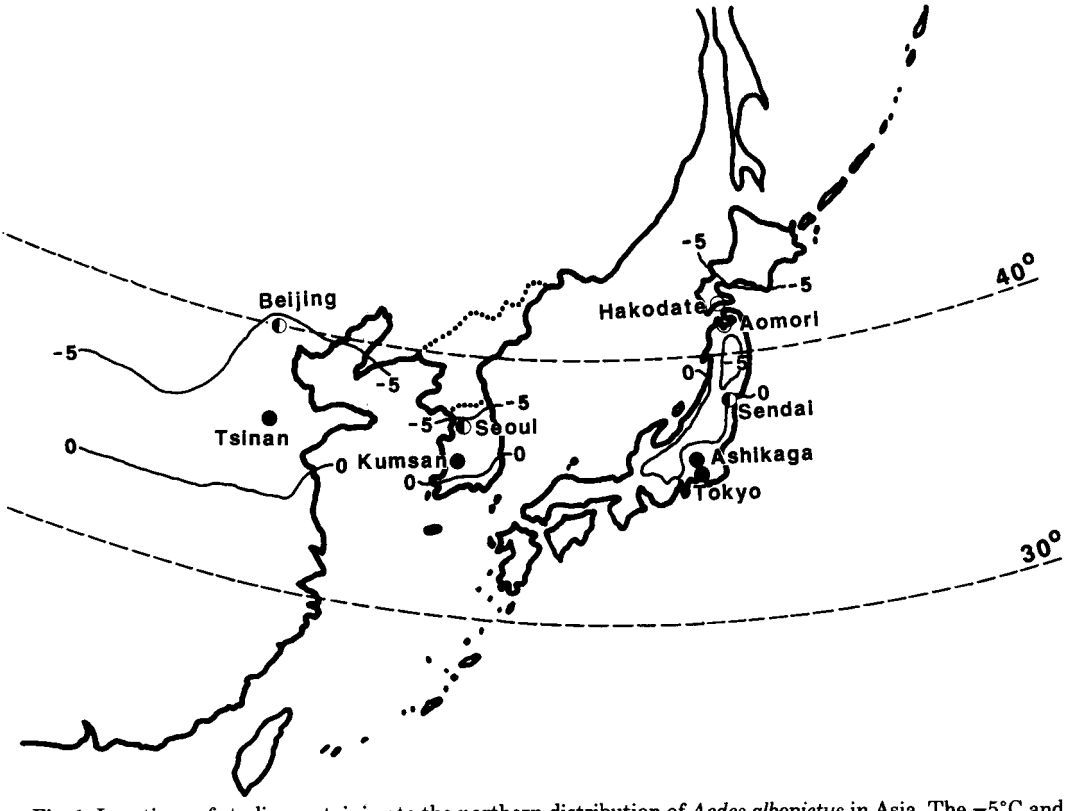

Fig. 1. Locations of studies pertaining to the northern distribution of *Aedes albopictus* in Asia. The −5°C and 0°C daily mean January temperature isotherms of these areas are shown. ●—*Ae. albopictus* overwinters, ◐—*Ae. albopictus* present but does not overwinter or overwintering status is unknown, ○—*Ae. albopictus* absent.

Table 1. List of north Asian localities, their daily mean January temperatures, and distribution and overwintering records for *Aedes albopictus*.

Location	Latitude (°N)	Daily mean January temp. (°C)	*Aedes albopictus* present?	*Aedes albopictus* overwinters?
Kumsan, Korea	36	−3 (approx.)	Yes	Yes
Tsinan, China	37	−1.2	Yes	Probably ?
Seoul, Korea	38	−4.9	Yes	No
Beijing, China	40	−4.7	Yes	No
Ashikaga, Japan	36	2.4	Yes	Yes
Sendai, Japan	38	0.1	Yes	Unknown
Aomori, Japan	41	−2.7	No	—
Hakodate, Japan	42	−4.1	No	—

to colonization by *Ae. albopictus*, but that this species has not yet dispersed into this area. Human economic activity may play an important but unknown role in such dispersal.

Although data on the relationship between daily mean January temperature and distribution of *Ae. albopictus* in northern Asia are sparse and not entirely consistent, daily mean January temperatures may be used to provide a rough estimate of the limits to northern expansion of this species in North America. Figure 2 shows daily mean January temperature isotherms for the eastern United States and southern Canada (Court 1974, Hare and Hay 1974). Using the 0°C isotherm as a conservative estimate for the northern limit of the overwintering range, it is apparent that *Ae. albopictus* could become entrenched in a major part of the eastern United States. If the −5°C isotherm delineates the maximum northward expansion of *Ae. albopictus* during late summer in North America as it does in continental Asia, then most of the populated

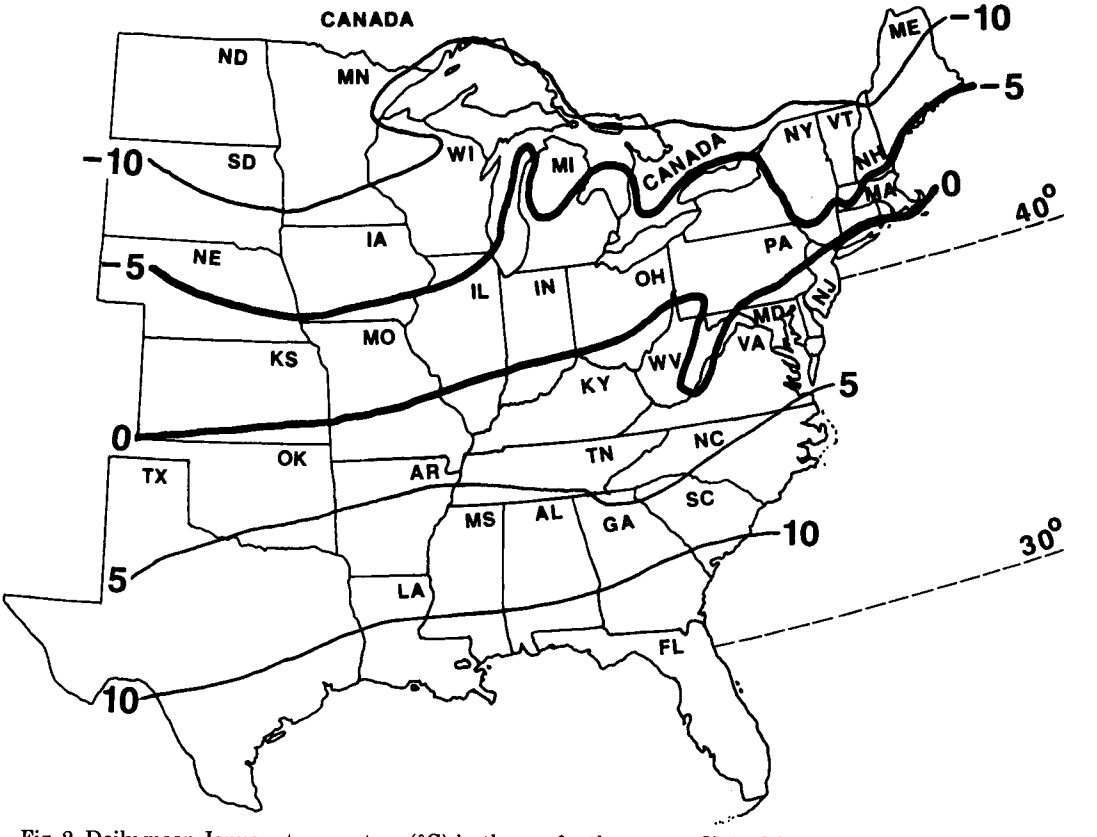

Fig. 2. Daily mean January temperature (°C) isotherms for the eastern United States and southern Canada.

areas of the eastern United States and the southern tip of Canada will come into contact with this mosquito species.

Although the 0°C isotherm extends northward into British Columbia (Hare and Hay 1974), colonization of the Pacific coast by *Ae. albopictus* may be hindered by low summer rainfall. Indeed, the failure of *Ae. aegypti* to become established in California is probably due to this factor. In contrast, the amount of summer rainfall throughout much of the American Midwest is comparable to that falling in northern Asia where *Ae. albopictus* is present. Nevertheless, *Aedes* (*Finlaya*) *togoi* (Theobald), another former exclusively-Asian mosquito species, has been found breeding in rock pools along the coasts of British Columbia and Washington (Wood et al. 1979, Belton 1980). Thus, the probability of *Ae. albopictus* becoming established along the Pacific coast may be higher in wetter, more northern localities.

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