EENY-761

Asian Bush Mosquito, Asian Rock Pool Mosquito *Aedes japonicus japonicus* (Theobald, 1901) (Insecta: Diptera: Culicidae)[1]

Catherine Lippi, Phillip Kaufman, and Eva A. Buckner[2]

Introduction

Aedes japonicus japonicus (Theobald, 1901; Figure 1), commonly known as the Asian bush or rock pool mosquito, is an invasive container-inhabiting mosquito native to Korea, Japan, Taiwan, southern China, and Russia that has become established in parts of Europe, Canada, and throughout most of the eastern United States (Tanaka et al. 1979, Kaufman and Fonseca 2014). Successful establishment beyond its native distribution is partly due to this species' adaptability to a broad range of environmental conditions. *Aedes japonicus* adjusts well to human environments and is more tolerant of cooler, temperate climates than other invasive container-inhabiting mosquito species, enabling it to successfully invade a diverse array of habitats (Versteirt et al. 2009).

While *Aedes japonicus* has not been implicated as an important arthropod-borne virus (arbovirus) vector (Kampen and Werner 2014), its documented human blood feeding and propensity to live in close association with humans warrants surveillance and management activities, especially in areas at risk of new introductions (Fonseca and Kaufman 2010, Jansen et al. 2018). *Aedes japonicus*' pathway of introduction is unknown in many instances, but transportation in used tires (Figure 2) via international trade is a likely candidate. This introduction pathway was confirmed in New Zealand, where larval *Aedes japonicus* were found in shipments of tires arriving from Japan (Laird et al. 1994). International tire trade was also the introduction pathway for another important invasive mosquito species, the Asian tiger mosquito, *Aedes albopictus* (Skuse), making this the suspected source of *Aedes japonicus* in many other countries, where adults are often detected in tire yards (Hawley et al. 1987, Versteirt et al. 2009).

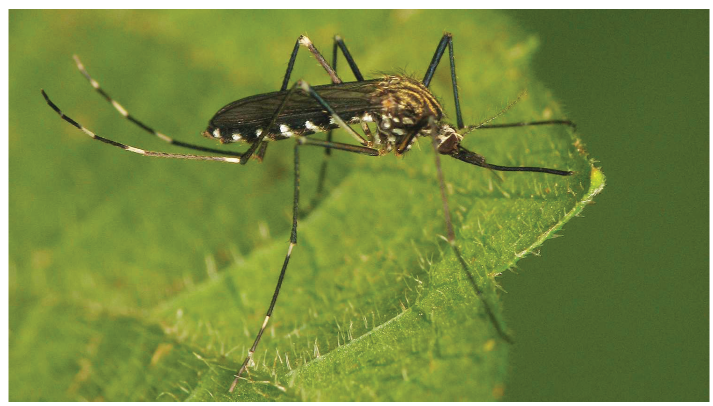

Figure 1. Adult female *Aedes japonicus* (Theobald) with golden stripes on scutum (dorsal area of thorax).
Credits: Sean McCann, Simon Fraser University

Synonymy

Ochlerotatus japonicus japonicus (Reinert 2000)

Hulecoeteomyia japonica japonica (Reinert et al. 2006)

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2. Catherine Lippi; Phillip Kaufman, professor; and Eva A. Buckner, assistant professor/Extension specialist; UF/IFAS Extension, Gainesville, FL 32611.

Figure 2. In addition to serving as a potential method of transport, tires that are discarded and left in the environment collect water, providing developmental habitat for container-inhabiting species like *Aedes japonicas* (Theobald).
Credits: Amy Hallock, University of Florida

Distribution

In its native range of Korea, Japan, Taiwan, Southern China, and Russia, *Aedes japonicus japonicus* is one of four subspecies and two sibling species that are difficult to differentiate between using only morphological characteristics: *Aedes japonicus japonicus*, *Aedes japonicus shintienensis* Tsai & Lien, 1950, *Aedes japonicus amamiensis* Tanaka, Mizusawa & Saugstad, 1979, *Aedes japonicus yaeyamensis* Tanaka, Mizusawa & Saugstad, 1979, and *Aedes koreicus* (Tanaka et al. 1979). For reasons not quite understood, *Aedes japonicus japonicus* has become an aggressive invasive species in North America and Europe, establishing itself well beyond its native range in eastern Asia within the past two decades. *Aedes japonicus* was first documented in the United States in 1998, where it was detected in Connecticut and shortly thereafter, New York and New Jersey (Peyton et al. 1999, Andreadis et al. 2001). *Aedes japonicus* rapidly expanded its North American range, becoming established throughout much of eastern United States and parts of Canada in approximately fifteen years. Population genetic analyses of this species show that its spread throughout the Northeast was made possible through multiple introductions (Fonseca et al. 2001).

Aedes japonicus has also been found in all states east of the Mississippi river, in addition to midwestern states (Iowa, Missouri, and Minnesota), south central states (Arkansas and Oklahoma), the Pacific Northwest (Oregon and Washington), and Hawaii (Figure 3; Peyton et al. 1999, Bevins 2007, Kaufman and Fonseca 2014, Riles et al. 2017, Bradt et al. 2018). *Aedes japonicus* in Florida was first documented in Okaloosa County in 2012. It has since been recorded in other counties in the Panhandle of Florida, including Bay, Leon, Santa Rosa, and Walton counties (Riles et al. 2017).

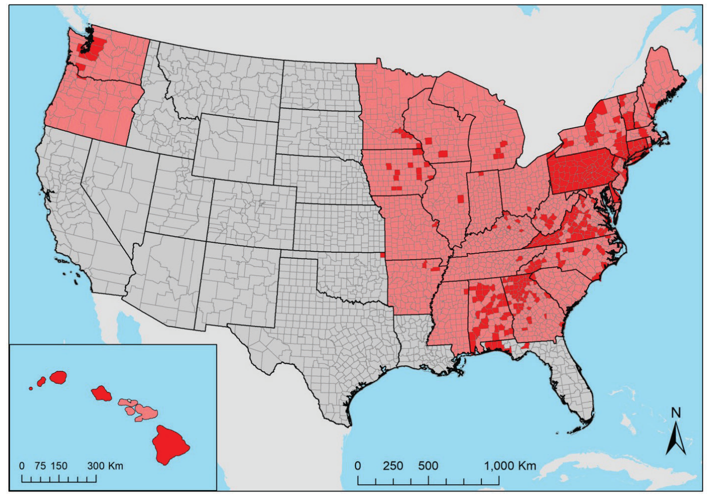

Figure 3. The current introduced range of *Aedes japonicus* (Theobald) in the United States. State-level occurrences reported in Kaufman and Fonseca 2014 are shown in pink. Documented county-level occurrences are shown in red (Peyton et al. 1999, Andreadis et al. 2001, Scott 2003, Kaufman et al. 2005, Butler et al. 2006, Bevins 2007, Andreadis et al. 2010, Johnson et al. 2010, Kaufman et al. 2012, Winchester and Kapan 2013, Egizi et al. 2016, Riles et al. 2017, Bradt et al. 2018, GMCA 2018, Hutchinson 2018, McKenzie et al. 2019, Peach et al. 2019, VAAFM 2019, Sames et al. 2020).
Credits: Map created in ArcMap (version 10.6) by Catherine Lippi, University of Florida

Life Cycle

Aedes japonicus is a cold-tolerant, multivoltine holometabolous insect, undergoing complete metamorphosis with egg, larval, pupal, and adult life stages within multiple generations a year (Andreadis et al. 2001; Byrd et al. 2019).

Eggs

After ingesting a blood meal, female mosquitoes lay their eggs in water-holding containers, above the water line. Eggs are small, approximately 0.5 mm in length, matte black in color, and cigar shaped (Figure 4; Haddow et al. 2009). *Aedes japonicus* produces eggs that are resistant to both desiccation and sub-zero temperatures, enabling the eggs to overwinter in diapause and resume development once environmental conditions become favorable (Scott 2003, Andreadis and Wolfe 2010, Medlock et al. 2015). The developmental time of eggs is temperature-dependent, although temperatures above 30°C have been shown to inhibit development and emergence in laboratory conditions (Scott 2003).

Larvae

Mosquito larvae hatch from eggs and actively feed on organic matter in the water. Larval *Aedes japonicus* are distinguished from other mosquito species found in North America by their branched setae along the front of the head capsule arranged in a straight row, a highly spiculated (spiny) anal saddle, and pecten that runs almost the entire length of the siphon with teeth that are larger and further apart closer to the siphon's tip (Figure 5).

Figure 4. The eggs of *Aedes* mosquitoes are small (0.5 mm in length), black, and cigar shaped.
Credits: CDC Public Health Image Library

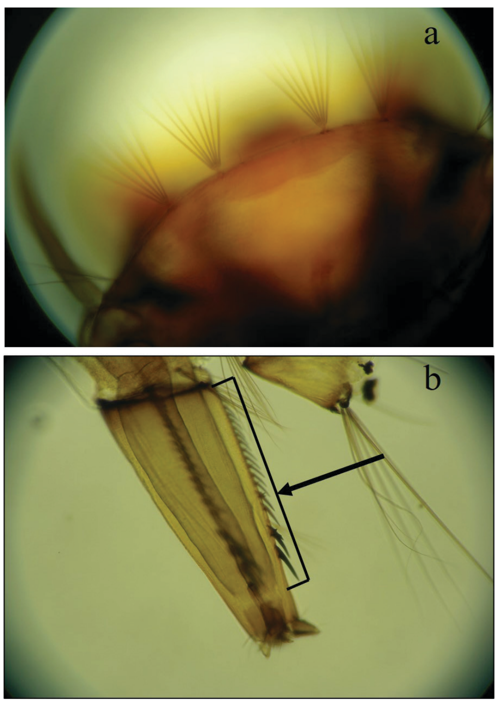

Figure 5. (a) Branched setae along front margin of larval *Aedes japonicus* (Theobald) head arranged in straight row. (b) Pecten along almost entire length of the larval *Aedes japonicus* siphon, which is made up of teeth that are larger and further apart closer to the siphon's tip.
Credits: George O'Meara, University of Florida

Compared to other *Aedes* larvae, *Aedes japonicus* can typically be found earlier in the year when temperatures are cooler. In the northeastern United States, the period of active larval development takes place from March to November (Andreadis et al. 2001). Provided there are no sustained freezes (i.e., temperatures in aquatic habitat falling below 10°C), larvae are capable of overwintering in both their native and introduced ranges. Larvae can successfully complete their development in a variety of water-filled natural (i.e., rock pools) and artificial containers, the quality of which vary considerably in light exposure and organic matter content (Andreadis et al. 2001, Juliano and Lounibos 2005, Lorenz et al. 2013, Kampen and Werner 2014). Since its establishment in the Northeast, the occurrence of immature *Aedes japonicus* has increased relative to two native species, *Aedes triseriatus,* found in discarded tires, and *Aedes atropalpus,* found in rock holes, but mechanisms underlying these changes are unclear (Andreadis and Wolfe 2010).

Pupae

Aedes japonicus larvae enter the pupal stage after their larval development is complete. Although they do not feed in this life stage, pupae are mobile, readily swimming to avoid predation. Pupae take approximately two days to develop or longer at cooler temperatures, after which adult mosquitoes emerge.

Adults

In the northeastern United States, adult *Aedes japonicus* mosquitoes are active from May to November (Andreadis et al. 2001). Adult mosquitoes of both sexes feed on sugars and plant nectars as a food source, while only females take blood meals to fully develop eggs. Adult females have been documented primarily taking blood meals from mammals, including humans, but are also known to bite birds (Molaei et al. 2009, Schönenberger et al. 2016). As container-inhabiting mosquitoes, adult females lay their eggs in natural and artificial water-holding containers. Tree holes, rock pools, and bamboo plants are examples of natural containers. Artificial containers include debris, used tires, flowerpots, rainwater collection basins, and concrete structures.

As an adult, *Aedes japonicus* is medium-sized (Burkett-Cadena 2013). Female mosquitoes are typically larger in size and lack the plumose (feather-like) antennae found on males. *Aedes japonicus* can be easily distinguished from many native mosquito species in North America by the presence of golden stripes on its scutum, black and white scales on the sides of the thorax, and black and white banding on the legs (Figure 6).

Similar in appearance to other invasive but now established *Aedes* container-inhabiting mosquitoes in the United States, *Aedes japonicus* is diagnosable by the golden lyre-like pattern on its scutum. In contrast, the yellow fever mosquito, *Aedes aegypti* (Linnaeus), has a silver lyre on the scutum, and the Asian tiger mosquito, *Aedes albopictus*, has a silver line down the middle of the scutum (Figure 7).

Figure 6. In addition to the golden stripes on the scutum, black and white scales on the sides of the thorax, and black and white banding on the legs, are useful in distinguishing *Aedes japonicas* (Theobald) from native mosquito species in North America.
Credits: Lyle J. Buss, UF/IFAS

Figure 7. Although similar in appearance to other container-inhabiting species found in Florida, the gold lyre-like pattern on the scutum easily distinguishes *Aedes japonicus* (Theobald) (left), from *Aedes aegypti* (center), and *Aedes albopictus* (right).
Credits: Lyle J. Buss, UF/IFAS

Medical Importance

Aedes japonicus can transmit Japanese encephalitis virus (JEV; an important arbovirus in its native range) both horizontally and vertically in the laboratory (Takashima and Rosen 1989). However, its role in the JEV transmission cycle is unknown (Kampen and Werner 2013). Under laboratory conditions, *Aedes japonicus* is also a competent vector of a range of other arboviruses, including chikungunya, dengue virus, eastern equine encephalitis, Saint Louis encephalitis, Rift Valley fever, West Nile, and Zika (Turell et al. 2001 and 2013, Sardelis et al. 2002 and 2003, Schaffner et al. 2011, Kaufman and Fonseca 2014, Jansen et al. 2018).

In North America and Europe, wild-caught *Aedes japonicus* mosquitoes have tested positive for West Nile and La Crosse viruses. As a result, *Aedes japonicus* has been suggested as a potential bridge vector of West Nile and La Crosse viruses to humans (Turell et al. 2005, Versteirt et al. 2009). However, more field-collected evidence is needed to determine the role it plays within these transmission cycles (Schaffner et al. 2013).

Regardless, *Aedes japonicus* has been noted as a mosquito pest in areas where it has become established. Although not particularly aggressive, its willingness to take human blood meals (Figure 8) and its reproductive success in areas of human habitation make this species a potential nuisance (Schaffner et al. 2003).

Figure 8. An adult female *Aedes japonicus* (Theobald) taking a blood meal from a human.
Credits: James Gathany, CDC Public Health Image Library

For more information on medically important mosquitoes in Florida, visit the UF/IFAS Florida Medical Entomology Laboratory website at https://fmel.ifas.ufl.edu/.

For more information on mosquito-borne pathogens in Florida, visit the UF/IFAS Extension website at http://edis.ifas.ufl.edu/topic_mosquito-borne_diseases.

Surveillance and Management

As an invasive species, *Aedes japonicus* is often first detected through routine surveillance activities for other mosquitoes of public health importance (Connelly 2004). While common surveillance traps like the Centers for Disease Control and Prevention (CDC) miniature light trap, New Jersey light trap, and BG-Sentinel trap adult mosquitoes can be used to detect adults, they are likely to underestimate *Aedes japonicus* population size (Kaufman and Fonseca 2014). However, baiting a CDC miniature light trap with an octenol lure and carbon dioxide has been shown to significantly increase *Aedes japonicus* adult catch rates (Anderson et al. 2012).

Larval surveillance is likely to be more successful than adult surveillance and can be conducted using dark-colored, five-gallon buckets containing leaf infusion (Johnson et al. 2010, Kaufman et al. 2012). An integrated pest management strategy that includes source reduction (Figure 9) and selective use of chemical controls like larvicides can be used to reduce container-inhabiting mosquito populations. Eliminating larval mosquito habitats around homes, particularly water-holding artificial containers (Figure 10), reduces the number of mosquitoes potentially produced around households. Supplementing container elimination with targeted larvicidal treatments of developmental habitats has been demonstrated to successfully reduce the abundance of *Aedes japonicus* (Ibañez-Justicia et al. 2018).

Figure 9. Emptying containers of standing water helps eliminate developmental sites for *Aedes japonicus* and other container-inhabiting mosquitoes.
Credits: Lauren Bishop, CDC Public Health Image Library

Figure 10. Artificial containers that collect water, such as an uncovered garbage can, may provide developmental habitats for container-inhabiting *Aedes* mosquitoes like *Aedes japonicus*.
Credits: Catherine Lippi, University of Florida

Personal protective measures can reduce the risk of exposure to mosquito bites. These personal protective measures include applying an insect repellant and wearing long pants and a long-sleeved shirt when engaging in outdoor activities as well as limiting outdoor activity during times of peak mosquito activity (Rutledge and Day 2002).

For more information on managing mosquitoes and personal protective measures, please visit the UF/IFAS Extension Mosquito Control website at http://edis.ifas.ufl.edu/topic_mosquito_control.

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