Alien species in Belgium: a fact sheet for

Aedes japonicus

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This fact sheet was created as part of the project *Alien Alert*, which aims at developing an integrated quick-screening tool for emerging pests and invasive species in Belgium. This BELSPO-funded project involves eight scientific institutions. Coordination is provided through the Belgian Biodiversity Platform.

The objective of this fact sheet is to support the identification of potentially invasive non-native species for Belgium and neighbouring areas. Organisms that qualify for this fact sheet are species that are not present in Belgium but likely to become so in the near future, or that are present but not widely distributed, and are likely to cause environmental and/or socio-economic harm.

The scheme of this risk assessment is based upon the International Standards for Phytosanitary Measures, which are endorsed by the Food and Agriculture Organization of the United Nations (FAO 2004). It consecutively assesses the stages of entry, establishment, spread & ecological and/or economic impacts.

(Reference: FAO (2004) International Standard for Phytosanitary Measures No. 11: *Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms.*)

(Cover picture taken from http://commons.wikimedia.org.)

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1 ORGANISM IDENTITY AND DISTRIBUTION

1.1 ORGANISM IDENTITY

Scientific name:	*Aedes japonicus japonicus* (Theobald 1901)
Synonyms:	*Ochlerotatus japonicus japonicus* (see Reinert 2000), *Hulecoeteomyia japonica japonica* (see Reinert et al. 2006)
Common names:	East Asian bush mosquito, rock pool mosquito (Schaffner et al. 2009)
Taxonomic position:	Arthropoda > Insecta > Diptera > Culicidae

Note : Reinert (2000) divided the genus *Aedes* Meigen into genera *Aedes* and *Ochlerotatus* (Lynch Arribalizaga) on the basis of **"**consistent primary characters**"** and supplemental features. *Ochlerotatus* was elevated to generic rank and was further divided into two sections based on features of the fourth-instar larvae and pupae. In subsequent publications the genus *Aedes* was further divided and more subgenera were raised to genus level. Although recent molecular studies support the initial elevation of *Ochlerotatus* to generic rank, the controversy surrounding these separations has left non-taxonomists in doubt and currently no consensus has been reached within the scientific community. Most often *Aedes japonicus* or *Ochlerotatus japonicus* are been used.

1.2 SHORT DESCRIPTION

Adults of *A. japonicus* are relatively large and show a black and white pattern due to the presence of white scale patches on a black background on the legs and other parts of the body. Some indigenous mosquitoes also show such contrasts (more brownish and yellowish) but in that case less obvious. However, *A. japonicus* could be confused with other invasive (*A. aegypti, A. albopictus*) or indigenous species (*A. cretinus*, restricted to Greece and Turkey), and the main diagnostic character is the presence of several lines of yellowish scales on a black background on the scutum (dorsal part of the thorax). The three other described subspecies differ in tibia ornamentation and are restricted to parts of South-eastern Asia (Tanaka et al. 1979).

1.3 ORGANISM DISTRIBUTION

A/ Native range

This species originated from Japan, Korea, Taiwan, and eastern China but has also been detected in Russia (Tanaka et al. 1979).

B/ Introduced range

Three specific surveillance programmes in Europe have been associated with *A. japonicus*. Firstly a survey of used tyres importers in France and Belgium led to the discovery of this species in both countries, and appears a useful method of determining the introduction and presence in the country. Then in Belgium, a 'nationwide' survey (MODIRISK) has completed the knowledge of it distribution and relative abundance. Finally an extensive specific study in Switzerland has mapped the distribution and spread throughout and around the colonised region.

Belgium

The species was introduced and locally established in Belgium (Natoye, Namur); see below. No clear evidence of spread was observed.

Rest of Europe

The species is established and spreading in Switzerland, Germany, Austria and Slovenia (Medlock et al. 2012); see below. It was intercepted in France.

Other continents

Aedes japonicus is established in the United States since the 1990s (Andreadis & Wolfe 2010) after which it rapidly spread throughout eastern and northern America and southern Canada (Molaei et al. 2009). It was reported in New York state, New Jersey and Connecticut in 1998; Connecticut, Ohio and Pennsylvania in 1999; Maryland, Massachusetts and Virginia in 2000; and Quebec, Canada in 2000 (Schaffner et al. 2003). It has since spread to 30 states including Hawaii, Iowa, Wisconsin and Minnesota to name a few (Dunphy et al. 2009; Versteirt et al. *2*009).

The species was intercepted at several occasions in ports of New Zealand (1993, 1998, 1999) through the importation of used tyres from Japan (Laird et al. 1994, Versteirt et al. 2009).

2 RISK ASSESSMENT

2.1 PROBABILITY OF ESTABLISHMENT AND SPREAD

2.1.1 Present status in Belgium

Prior to the elimination campaign of the species in spring 2012, *A. japonicus* was well-established and had a viable population on a local scale (Natoye, Province de Namur) where it was first detected in 2002 (Versteirt et al. 2009). There are currently no indications that the species, which has been present for at least ten years in Belgium, has spread far from the surroundings of the import site. However, a follow-up study after the first treatment (2012) has revealed a positive site about 1 km from the initial pest site indicating the need for continued surveillance.

2.1.2 Present status in neighbouring countries

Populations are now widely established in northern Switzerland and southern Germany, (Schaffner et al. 2009, Becker et al. 2011). The range of *Aedes japonicus* in Switzerland has expanded in all directions. It can also be found widespread in southwest Germany, where large areas in the state of Baden-Württemberg are now infested (e.g., around the Stuttgart area; Becker et al. 2011, Huber et al. 2011, Schneider 2011). Recently it has been found established in a wide area of southeastern Austria and neighboring Slovenia, from Graz to Maribor (B. Seidel, pers. comm.).

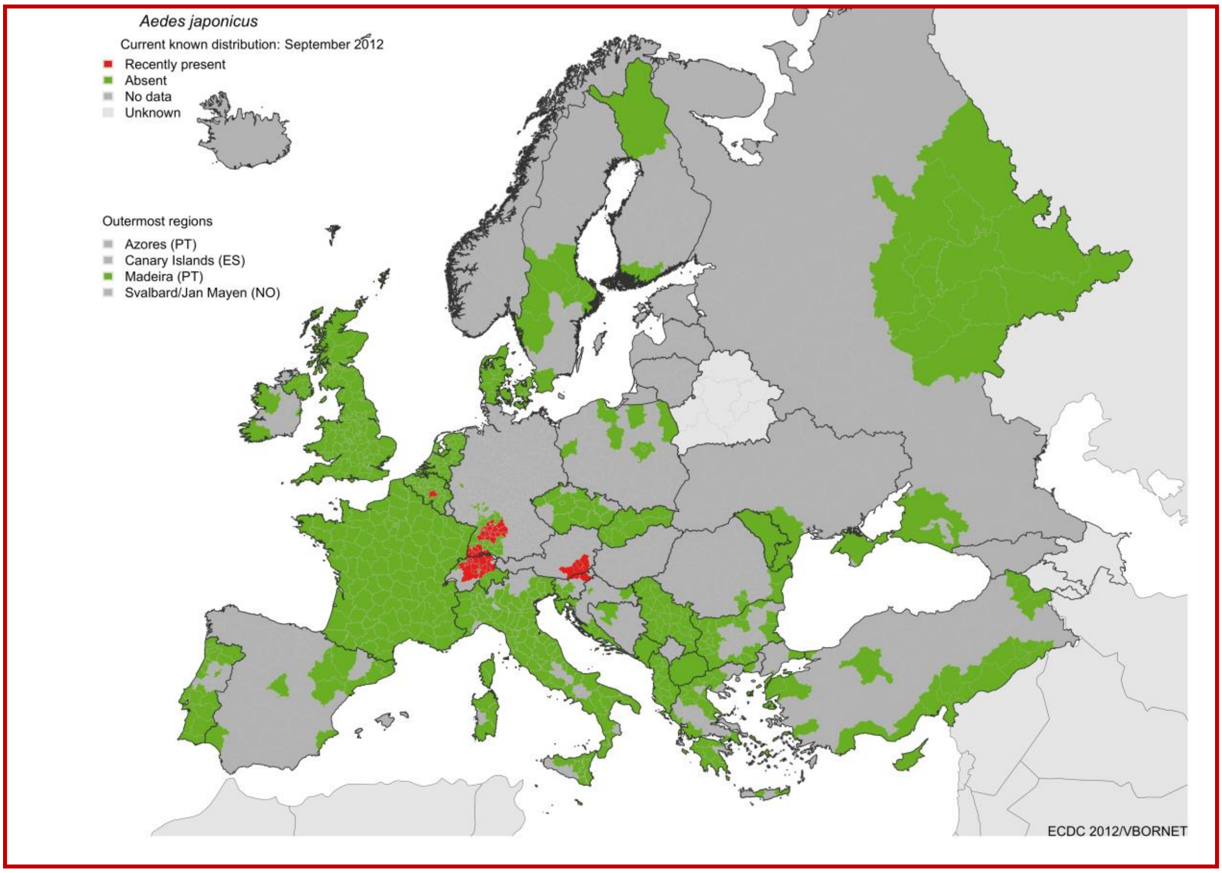


Figure - The current distribution of the established populations of *Aedes japonicus* in Europe (source: VBORNET).

2.1.3 Introduction in Belgium

The primary dispersal mode of *A. japonicus* by human activity has been through transport of desiccation-resistant eggs in cargo that previously contained stagnant water. The most important type of cargo is used tyres that have been stored outdoors (Knudsen 1995). Businesses processing or trading used tyres should be given high priority for monitoring of exotic fauna and flora. Due to high humidity and cool air temperature, the refrigerated transoceanic containers offer ideal conditions suitable for the transport of living insects (Reiter & Darsie 1984). In the USA and France, the used tyre trade was the main importation pathway. However, both in Switzerland and Germany the sites of initial importation are not clear, as no evidence of importation of used tyres has been reported within the colonized area (Schaffner et al. 2009, Becker et al. 2011). For Germany, one hypothesis is that this species was introduced via used tyres or by airfreight through Zürich. However, since the species is most abundant in flower vases in cemeteries, used tyres may not be the only pathway of introduction. Another possibility is that *A. japonicus* was, introduced together with ornamental plants (e.g. the box tree *Buxus* spp.) in transoceanic containers originating from Asia (Becker et al. 2011).

An introduction route that is similar to that of *A. albopictus* to the Netherlands (Lucky Bamboo trade). However there is still no clear evidence to support this theory.

Indeed, the most likely route of importation into Belgium seems the international used tyre trade. First, the primary infested site belongs to a company importing used tyres from various countries including countries colonized by the species (Japan, United States). Secondly, the site is isolated from motorways and airports and thirdly the species has so far not been observed in other surrounding sites. In general, the international movement of tyres is known to be the primary pathway of introduction of container breeding species (Sardelis and Turell 2001, Schaffner et al. 2003).

2.1.4 Establishment capacity and endangered area

A/ Life-cycle and reproduction

Life history

Aedes japonicus can produce freeze- and desiccation-resistant eggs (Andreadis & Wolfe 2010) that can remain dormant over winter and hatch once environmental conditions become favourable. This allows for the species to be transported in infested containers (Medlock et al. 2005). During studies in Belgium in 2008, larval sampling during early spring confirmed that this species can overwinter as diapausing eggs in Northern Europe (Versteirt et al. 2009). In parts of Asia, *A. japonicus* overwinters as eggs in north eastern Japan but as larvae in south western Japan (Schaffner et al. 2003). However, no larvae were found during winter sampling in Belgium (Versteirt et al. 2009).

Seasonal abundance

In North America, larvae and biting adults have been collected between May-November in Connecticut (Andreadis et al. 2001) and May-October in New York State (Falco et al. 2002). This is confirmed by data from Belgium (Damien et al 2009); adults and/or larvae were found from May till October and overwintering larvae were detected in January. In Switzerland, eggs were found until October during field studies in 2008 (Schaffner et al. 2009) and data from North American studies suggests *A. japonicus* remains active through early Autumn in northern temperate zones (Dunphy et al. 2009).

Voltinism

Reported to be multivoltine (multiple generations per season) in Connecticut and southern Japan (Andreadis et al. 2001).

B/ Climatic requirements

There is limited information on environmental thresholds constraining their distribution. Although this species is said to be increasing in abundance in some areas of the US compared to native species, it was found that habitats with water temperature over 30 °C did not yield any *A. japonicus* (Andreadis & Wolfe 2010). This could be a limiting factor for future spread outside of, and in southern, Europe.

C/ Habitat preferences

Aedes japonicus can develop in a large range of both natural and artificial aquatic container habitats including rock pools, tyres, bird baths, milk cartons, buckets, tree holes (Andreadis et al. *2*001). In North America their preference is for rock pools (Versteirt et al. *2*009; Juliano & Lounibos 2005) and sampling conducted across a wide area in northern Switzerland showed a preference for plastic vases in cemeteries, but fountains, rain water casks and catch basins were also colonised (Schaffner et al. 2009). Adults are often found in forested areas (Andreadis et al. 2001).

D/ Feeding habits

Adults are active during the daytime and crepuscular hours (Turell et al. *2*005) and will readily bite humans outside and occasionally inside houses (Schaffner et al. *2*003). This species preferentially feeds on mammalian hosts (Turell et al. *2*005). Studies in New York showed *A. japonicus* fed solely on humans and mammals (Apperson et al. *2*004). Analysis of blood meals from specimens collected in Connecticut showed human, deer and eastern chipmunks as hosts (Molaei et al. *2*008). Analyses of blood meals from specimens collected in New Jersey also showed a preference for mammalian blood feeding; 52% were found to have fed on White-tailed deer and 36% were found to have fed on humans. No samples were found positive for avian or reptilian blood (Molaei et al. *2*009), however there is evidence of bird biting under laboratory conditions (Sardelis et al. *2*003).

E/ Control agents

NA

F/ Establishment capacity in Belgium

Generally, It is assumed that most exotic species need a lag period to adapt to the new environment in which they remain at low density. The genetic fingerprint and diversity of the species probably plays an important role in this adaptation process. Studies on the genetic structure of *A. j. japonicus* in the USA (Fonseca et al. 2010) and Belgium (Ayrinhac et al. 2009) reveal that in both countries probably multiple introductions occurred, although in the latter case this still needs further research. Genetic groups therefore appear to be recombining, increasing the species diversity and thus enhancing the invasive capacity of the species and therefore the speed of dispersion (Medlock et al. 2011).

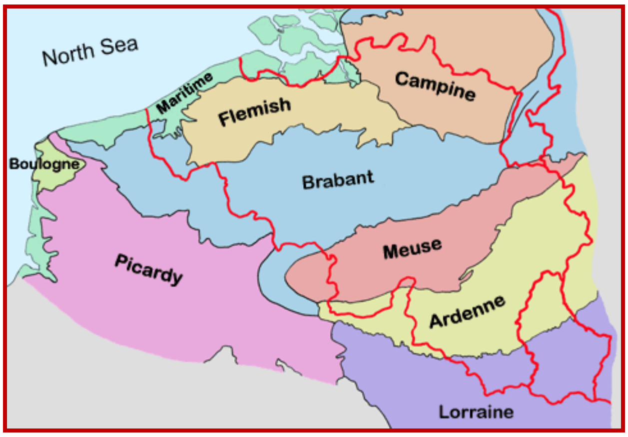
Future establishment is thus not unlikely as the species has strong adaptation capacities and is not limited due to suitable climatic conditions and the availability of suited habitats. The success of the invasion of *A. japonicus*, particularly in the US, has been due to a number of factors including its ability to withstand long distance dispersal and winter temperatures in temperate regions, and its high tolerance to organic concentrations in a number of natural and artificial containers (Versteirt et al. 2009). Its less specialised requirement for aquatic habitats, compared to *A. albopictus*, could facilitate its spread further (Schaffner et al. 2003).

G/ Endangered areas in Belgium

Given the recent import events in Europe of several exotic mosquito species and their subsequent spread (Medlock et al. 2012) it is likely that new introductions to Belgium will occur. Moreover, the vulnerability of a country or region for bioinvasions appears generally to be correlated to the extent of international trade it conducts (economic variable) and to its national wealth and human population density (demographic variable) (Pysek et al. 2010). In the last decade, dramatic increase in traffic has been observed between eastern Asia and Europe and North America (Tatem 2009) leading to a gradual augmentation of the number of notifications of new exotic species in Europe.

Areas at risk are those linked to an economic activity that can facilitate the importation of a species such as the second hand tyre trade and trade of certain plant species (Lucky Bamboo, *Buxus*….). Therefore areas with, or near, zones hosting such trade activities are more prone to introductions of exotic mosquito species.

The establishment capacity for the different Belgian geographic districts is deemed as follows:



Map taken from Diederich & Ries, lichenology.info

Districts	**Establishment conditions**
Maritime	Suboptimal
Flandrian	Suboptimal
Brabant	Optimal
Kempen	Optimal
Meuse	Optimal
Ardenne	Optimal
Lorraine	Optimal

2.1.5 Dispersal capacity

A/ Natural spread

Dispersal of adults is dependent on habitat availability, but it is usually within 300m from the emergence site (Tanaka et al. 1979). The maximum flight range is less than 1.6km (Morberly et al. 2005). However, rapid spread can occur from one larval breeding site to the next. In Southwest Germany it has already colonized an area of at least 2200km^2 and of 1400km^2 in northern Switzerland (Becker et al. 2011).

Possible barriers are large, open areas with a limited presence of natural and/or artificial breeding sites. Highly cultivated arable regions will be less suited to be colonized.

B/ Human assistance

The initial introduction of the species is always linked to anthropogenic activities. Moreover, one of the main factors facilitating the spread of *A. japonicus* in the USA was presumably the interstate trade and transit (Fonseca et al. 2001) as was already observed for *A. albopictus*. For the latter species, a similar pattern is observed in Europe, where females hitchhike with cars and trucks and are first detected in new regions around rest areas and parking lots along highways (Pluskota et al. 2008).

2.2 EFFECTS OF ESTABLISHMENT

2.2.1 Environmental impacts

A/ *Competition* [Likely]

It is hypothesized that successful establishment by exotic species occurs due to the competitive advantage of the invasive species over the native species particularly when subject to interspecific conditions. Due to the diversity of oviposition sites used by *A. japonicus*, it can be found alone or co-occurring with other mosquito species (Andreadis et al. 2001, Bevins 2007). The establishment and spread of *A. japonicus* in North America have coincided with a reduction of other container-inhabiting mosquitoes in used tyre and rockhole habitats (Andreadis & Wolfe 2010). In Belgium, a development shift was observed of *C. pipiens* when co-occurring in the same larval site (Damiens et al. 2009). However laboratory experiments did not clearly validate the observed field observations (Damiens et al. 2009) which was also the case in the USA (Hardstone & Andreadis 2012).

B/ *Predation/herbivory* [Likely]

Predation is directly linked to competition: *A. japonicus* larvae predate on other mosquito larvae. Both inter- as intraspecific predation occurs.

C/ *Genetic effects and hybridization* [Medium]

Previous morphological and molecular studies indicate the close relationship between members of the *A. japonicus* complex and another exotic invasive species, *A. koreicus* (Tanaka et al. 1979, Widdel et al. 2005, Cameron et al. 2010), even contesting the current commonly accepted construct for this complex. Tanaka et al. (1979) described overlapping ranges of all differentiating morphological characteristics found in adults of the two species. Recent molecular work with microsatellites as indicators of evolutionary distance between species, confirmed this strong relationship between the species as already seen using only sequence data (Widdel et al. 2005, Cameron et al. 2010).

D/ *Pathogen pollution* [Likely]

In Japan and Korea (its normal native range) *A. japonicus* is not considered an important disease vector (Schaffner et al. 2003). There is a concern however that this species may become a pest problem or be involved in the transmission of North American arboviruses such as West Nile virus (WNV; Sardelis & Turell 2001). In laboratory conditions, this mosquito has been shown to be a competent vector of Eastern encephalitis virus, La Crosse virus, St. Louis encephalitis virus, Chikungunya, Dengue and a highly competent vector for West Nile virus (WNV; Sardelis et al. 2001, 2002a, 2002b and 2003, Schaffner et al. 2011). *Aedes japonicus* colonises urbanised environments (Schaffner et al. 2009) and females are active during the day (Turell et al. 2005), increasing the potential contact this species could have with humans, which in turn may result in disease transmission.

E/ *Effects on ecosystem functions* [Low]

The effect on ecosystem functions is considered to be quite low.

2.2.2 Animal health impacts

Although few studies have been done to assess the veterinary health importance of *A. japonicus*, this species is suspected of being a vector of Japanese encephalitis (JE) virus to swine in northern Japan. Under experimental conditions it has been shown to transmit JE virus to mice and also to transmit the virus to its progeny through the eggs (Takashima & Rosen 1989).

2.2.3 Plant health impacts

Not applicable.

2.2.4 Human health impacts

Females are known to feed on mammals, including humans, in the field (Apperson et al. 2004) and on avian hosts under laboratory conditions (Sardelis et al. 2003) and could therefore act as a zoonotic bridge vector species. In laboratory conditions, this mosquito has been shown to be a competent vector of Eastern encephalitis virus, La Crosse virus, St. Louis encephalitis virus, and a highly competent vector for West Nile virus (Sardelis et al. 2001, 2002a, 2002b, 2003). However, its role as a disease vector species in natural conditions in the United States, where the species has been established for almost a decade, remains unclear.

2.2.5 Other impacts

A/ *Economic impacts*

Economic impacts can be inflicted by *A. japonicus* to human activities such as tourism due to its severe biting nuisance. Moreover, as the species can transmit several virus diseases to humans and/or animals, the burden to human and/or animal healthcare can be high.

B/ *Social impacts*

The species can transmit several arboviral diseases that has an effect on human and/or animal health.

3 SUMMARY: *AEDES JAPONICUS* IN BELGIUM

ENTRY - Seen the importance and magnitude of second hand tyre trade, recurrent import of the species into Belgium cannot be ruled out. Moreover, seen the rapid spread of the species in central Europe the species could eventually arrive in Belgium, through transport (cars, trucks, boats, …) from nearby colonized regions (Southwest Germany,…).

ESTABLISHMENT - As there are no environmental restrictions for the establishment of the species in Belgium, it is likely that the species could establish a self-sustaining population in areas with sufficient larval breeding sites, when no surveillance or control measurements are put into operation.

SPREAD - *Aedes japonicus* has a limited capacity to spread naturally but is easily dispersed from the initial import site through human activities. The species is rapidly spreading in central Europe

IMPACTS - Environmental impacts of this species is considered to be reasonably low; outcompetition of species occupying the same larval habitat could occur but is not clearly proven. The impact on human and/or animal health is however considerably high which could lead to an increased outbreak risk of several viral diseases.

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