Mosquito-borne diseases in Belgium: a real threat or just a hype?

Authors. Wim Van Bortel[1,2], Isra Deblauwe[1], Javiera Rebolledo[3], Nathalie Smitz[4], Ruth Müller[1]

Affiliations

[1]Unit Entomology, Institute of Tropical Medicine, Antwerp, Belgium

[2]Outbreak Research Team, Institute of Tropical Medicine, Antwerp, Belgium

[3]Department of epidemiology and infectious diseases, Sciensano, Brussels, Belgium

[4]Royal Museum for Central Africa (Barcoding Facility for Organisms and Tissues of Policy Concern), Tervuren, Belgium

ORCID

- WVB. 0000-0002-6644-518X
- ID. 0000-0001-7268-8965
- NS. 0000-0001-5155-0801

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Abstract.

In Europe several local transmission events of mosquito-borne diseases were reported recently. Similarly, in Belgium mosquito-borne transmission events are likely to occur in the near future. Hence, this paper aims to assess the mosquito-borne disease threats in Belgium focussing on three scenarios assessing the risk of autochthonous transmission of (1) arboviruses by exotic *Aedes* mosquitoes, (2) malaria, and (3) West Nile virus. Based on our assessment it is clear that the situation regarding mosquito-borne disease risk is changing in Belgium and that mosquito-borne diseases need to be considered as a public health threat.

Samenvatting

In Europa werden recent verschillende lokale gevallen van door muggen overgebrachte ziekten gemeld. Ook in België is het waarschijnlijk dat er in de nabije toekomst door muggen overgedragen ziekten zullen voorkomen. Deze studie heeft dan ook tot doel de bedreigingen van door muggen overgedragen ziekten in België te evalueren, met de nadruk op drie scenario's die het risico van autochtone overdracht van (1) arbovirussen door exotische *Aedes* muggen, (2) malaria, en (3) West-Nijl virus evalueren. Op basis van onze evaluatie is het duidelijk dat de situatie met betrekking tot het risico op door muggen overgedragen ziekten aan het veranderen is in België en dat door muggen overgedragen ziekten als een volksgezondheidsprobleem beschouwd moet worden.

Résumé

En Europe, plusieurs événements de transmission locale de maladies transmises par les moustiques ont été signalés récemment. De même, en Belgique, il est fort probable que des maladies transmises par des moustiques surviennent dans un avenir proche. Cet article vise donc à évaluer les menaces de possible transmission de maladies par les moustiques en Belgique. Trois scénarios sont évalué, le risque de transmission autochtone (1) d'arbovirus par des moustiques *Aedes* exotiques, (2) du paludisme, et (3) du virus du Nil occidental. Sur base de notre évaluation, il est clair que la situation concernant ces trois points susmentionnés est en train de changer en Belgique et que les maladies transmises par les moustiques doivent être considérées comme un problème de santé publique.

INTRODUCTION

The year 2007 marked a turning point in Europe when the first local outbreak of chikungunya happened in Italy with more than 200 confirmed autochthonous cases (Rezza et al., 2007). This event made the EU to realise that it was not free of mosquito-borne diseases transmission risk. In the 1970s Europe was freed from malaria and for a long period mosquito-borne diseases were not considered as a major public health concern (World Health Organization. Regional Office for Europe, 2016). Though, West Nile virus (WNV) circulated with for example a large outbreak in Bucharest in 1996 (Zeller & Schuffenecker, 2004). Yet, from 2007 onwards several local dengue, chikungunya and Zika transmission events were reported from countries around the Mediterranean Sea (European Centre for Disease Prevention and Control, 2018b; Giron et al., 2019; La Ruche et al., 2010), malaria re-appeared in Greece in 2009 (Danis et al., 2011), and more recently sporadic cases of airport malaria were reported from several countries in Europe (European Centre for Disease Prevention and Control, 2017; Van Bortel et al., 2022). Further, in 2010 a large outbreak of WNV occurred in Greece, which marked the start of a systematic EU-wide follow-up of WNV infection by the ECDC during the transmission season (European Centre for Disease Prevention and Control, 2019; Papa et al., 2011).

A mosquito-borne disease is characterised by the fact that the pathogen is transmitted from one host to another by a mosquito vector. Transmission can only occur when the pathogen, the vector and a susceptible host are present (Braks et al., 2011). However, the presence of these three factors is not sufficient for transmission to occur. Transmission is also influenced by environmental and socio-economic factors, vector control and access to health structures which are highly interconnected in positive and negative feedback loops (Franklinos et al., 2019; Van Bortel et al., 2009). Changes in land use, urbanisation, global transport of people and goods, socio-economic factors and climate change are altering transmission patterns of vector-borne diseases in both endemic and non-endemic areas (Franklinos et al., 2019; Mora et al., 2022; Semenza & Suk, 2018). As a consequence, the current situation of mosquito-borne disease events in Europe is not only a consequence of increased awareness and surveillance, but also of a changing epidemiology.

In Belgium 33 native mosquito species are inventoried (Boukraa et al., 2015; Deblauwe et al., 2020; Versteirt et al., 2013) some of which are potential vectors of viruses or parasites (Versteirt et al., 2013). Additionally the introduction of exotic *Aedes* mosquitoes is regularly reported and could potentially change the epidemiology of the pathogen transmission in Belgium (Deblauwe et al., 2022). Also pathogens that can be transmitted by native and exotic mosquitoes are regularly introduced in Belgium by travellers (Lernhout et al., 2018). Hence local mosquito-borne transmission events are also likely to occur in the near future in Belgium. Therefore, this paper aims to assess the mosquito-borne disease threats in Belgium focussing on three scenarios: (1) the import of an exotic pathogen transmitted by an exotic established *Aedes* mosquito addressing the question whether local transmission of exotic *Aedes*-borne pathogens can occur in Belgium (Figure 1A); (2) a local transmission event caused by an imported infectious exotic mosquito species that transmits the pathogen it carries focussing on the transmission risk of malaria in Belgium (Figure 1B); and (3) the import of a pathogen through wildlife that is transmitted by a native mosquito species exploring the risk for local transmission of WNV in Belgium (Figure 1C). Per scenario we discuss the current occurrence of potential mosquito vectors in Belgium after which we focus on the actual threat of the vector-borne disease transmission.

SCENARIO A. LOCAL TRANSMISSION OF EXOTIC *AEDES*-BORNE PATHOGENS IN BELGIUM?

The introduction, establishment and spread of exotic *Aedes* mosquito species is a threat to human health in several European countries. Some exotic *Aedes* species display high invasion potential and are vectors of several arboviruses. As these species are not native to Europe, their introduction, establishment and further spread is a first step before an exotic *Aedes*-borne virus transmission can occur.

Current situation of exotic *Aedes* species in Europe and Belgium.

In Europe, six exotic *Aedes* mosquitoes have been found at least once since 1979 i.e., *Aedes triseriatus, Ae. atropalpus*, *Ae. japonicus, Ae. koreicus*, *Ae. aegypti* and *Ae. albopictus. Aedes triseriatus*, a North American species, has been found introduced once in France (Medlock et al., 2012). *Aedes atropalpus*, also known as the American rock pool mosquito, has been imported via used tyres into Veneto Province in Italy in 1996 and 1997. In France, two introductions are known: one in 2003 in a used tyre yard in Poitou-Charentes (Vienne); and a second in Normandy (Orne) in 2005. Also the species has been imported into the Netherlands in 2009 (Scholte et al., 2009). None of these introductions led to establishment, hence currently no population of *Ae. atropalpus* is known in Europe (European Centre for Disease Prevention and Control, 2022c; Medlock et al., 2015). *Aedes japonicus* and *Ae. koreicus* have established populations in several European countries, including Belgium, and are both spreading (European Centre for Disease Prevention and Control, 2022d, 2022e). *Aedes aegypti* is present in Europe around the Black sea, in Cyprus and in Madeira (European Centre for Disease Prevention and Control, 2022a; Vasquez et al., 2023). It has been introduced in the Netherlands through the tyre trade in 2010 (Brown et al., 2011) and through air traffic since 2016 (Ibanez-Justicia et al., 2020; Nederlandse Voedsel en Warenautoriteit, 2022), once in Germany through exotic plant seedling importation in 2016 (Kampen et al., 2016a) and in 2018 in the port of Marseille, France (Jeannin et al., 2019). Its establishment is Belgium is currently unlikely (Trajer, 2021). *Aedes albopictus* was first detected in Albania in 1979, probably introduced via their exclusive exchanges of goods with People's Republic of

China. In 1990, the species spread to Italy and to France in 2000 and has now colonised most of southern Europe and is heading north (European Centre for Disease Prevention and Control, 2022b; Medlock et al., 2015). It is fast spreading in Europe with an estimated rate of spread of about 100 km per year, rising to about 150 km per year in the period 2014—2019 (Kraemer et al., 2019). Since 2005, it has been repeatedly introduced into the Netherlands through the import of used tyres, lucky bamboo and air traffic, but each time it was successfully eliminated (Ibáñez-Justicia, 2019). In 2007 the species was detected for the first time in Germany and in 2016 the first overwintering population in Freiburg was a fact (Pluskota et al., 2016). It was also detected in south-eastern U.K. in 2016, 2017 and 2018 (Vaux et al., 2019).

In Belgium, three exotic *Aedes* species, viz. *Ae. albopictus*, *Ae. japonicus* and *Ae. koreicus,* were detected between 2000—2020. The first introduction of *Ae. albopictus* in Belgium was linked to tyre trade and dates back to the year 2000 (Schaffner et al., 2004). Between 2007—2020, which marked a period with more regular project-based mosquito surveillance, this species was intercepted at ten points-of-entry throughout Belgium (Figure 2) (Deblauwe et al., 2022). *Aedes albopictus* was found at three used-tyre import companies, at one lucky bamboo import company, and since 2018 also at five parking lots along highways coming from France and Germany, countries where the species has established populations (Figure 2). In Belgium, overwintering populations were not yet detected up to 2020. Summer reproduction, as indicated by detection of different life stages including larvae and nymphs, occurred at some points-of-entry where control was not implemented, or implemented too late (Deblauwe et al., 2022) (Figure 2). During the surveillance period 2007—2020 the percentage of positive points-of-entry for *Ae. albopictus* increased whereby parking lots significantly contributed to the raise (Deblauwe et al., 2022). In 2022 a citizen science surveillance approach was initiated in Belgium and since then the species has been detected at multiple locations outside the known points-of-entry. Also overwintering at two locations occurred (Institute of Tropical Medicine, 2023a, 2023b). *Aedes japonicus* has been detected for the first time in Belgium (Natoye, Namur) in 2002 (Versteirt et al., 2009). This introduction was linked to used tyre trade from Japan and the USA. Since then *Ae. japonicus* is known to be established at this locality. Between 2012 and 2015 a vector control programme was executed to eliminate the species from Natoye. Initially this seemed successful, but in 2017 *Ae. japonicus* was found again. Based on a genetic investigation, the current *Ae. japonicus* population at Natoye (2017-2019) results from an admixture between specimen from the initial established population (before the control programme) and from new introduction(s), possibly from Germany via the used tyre trade (Smitz et al., 2021a). The species has also been detected multiple times in an allotment garden along the border with Germany. Both monitoring and genetic results point to the phenomenon of multiple introductions of *Ae. japonicus* in Belgium from the nearby West

German spreading population (Deblauwe et al., 2022; Kampen et al., 2016b; Smitz et al., 2021a). Further *Ae. japonicus*, has been detected once at the industrial area in Maasmechelen in 2018, but its origin could not be determined (Figure 2). *Aedes koreicus* is known to be established at the industrial area in Maasmechelen since 2008. It has also been found as larvae (2014) and as adults (2017—2019) at a used tyre import company in Dilsen-Stokkem at about 5.6 km from the locality where the species is established (Deblauwe et al., 2022) (Figure 2).

Future threat of *Aedes*-borne diseases in Belgium.

Aedes albopictus is an important vector of chikungunya virus (CHIKV), dengue virus (DENV) and Zika virus (ZIKV). Further, the species is a competent experimental vector for at least 22 other arboviruses including WNV, Rift Valley fever virus, and Sindbis virus (Gratz, 2004; Medlock et al., 2015; Schaffner et al., 2013). The species was involved in local transmission of CHIKV in Italy in 2007 and 2017 and in France in 2010 and 2014 (European Centre for Disease Prevention and Control, 2018b). Autochthonous DENV transmitted by *Ae. albopictus* have occurred in France (2010, 2013—2015, and 2018—2023), Croatia (2010), Spain (2018, 2019, 2022, 2023), and Italy (2020, 2023) (Cochet et al., 2022; European Centre for Disease Prevention and Control, 2018b, 2023). Also the first local transmission of ZIKV in Europe occurred in France in 2019 during which *Ae. albopictus* was incriminated as vector (Giron et al., 2019).

For an autochthonous virus transmission by *Ae. albopictus* to occur, three steps are necessary (Figure 1A). The first step implies the introduction and establishment of the exotic competent vector species. The second step comprises the introduction of the virus through for example an infectious traveller. In the third step the established mosquito bites the viraemic person and can infect another person after the completion of the extrinsic incubation period. In Europe, autochthonous outbreaks of arboviruses transmitted by *Ae. albopictus* typically follow 5-15 years after the introduction of the species (Kraemer et al., 2019). In Belgium, *Ae. albopictus* has been detected at ten points-of-entry between 2007 and 2020, with no evidence that the species is established in Belgium (Deblauwe et al., 2022). Until 2020 there was no eminent threat of local transmission of arboviruses. Yet, this is changing as Belgium is currently at the invasion front of this exotic *Aedes* species. Since 2018, the species enters the country via ground transport and not only via trade of tyres and lucky bamboo. *Aedes albopictus* is in the first stage of its invasion process i.e., the introduction phase, although recent evidence indicates that establishment has started as overwintering at two locations probably occurred. Hence, it is very likely that the species will become established in Belgium in the near future, which will change the epidemiological context of possible arbovirus transmission in Belgium.

Laboratory studies showed that *Ae. japonicus* is a competent vector of several arboviruses including WNV, CHIKV and DENV. However, *Ae. japonicus* has never been incriminated as vector of arboviral outbreaks (Schaffner et al., 2013). The vector status of *Ae. koreicus* is unclear. In Russia *Ae. koreicus* has been suspected to be the vector of Japanese encephalitis virus but this has never been confirmed. Further *Ae. koreicus* is a possible vector of *Dirofilaria immitis* to dogs (Schaffner et al., 2013). *Aedes japonicus* and *Ae. koreicus* are locally established, but because their role as vector is currently questionable, the risk of vector-borne autochthonous transmission by these species seems to be limited at this moment.

SCENARIO B. LOCAL TRANSMISSION OF MALARIA IN BELGIUM?

In September 2020 two fatal cases of autochthonous *Plasmodium falciparum* malaria occurred in Belgium (Van Bortel et al., 2022). Following the outbreak investigation, the most likely route of transmission was through an infectious exotic *Anopheles* mosquito that was imported via the international airport of Brussels or the military airport Melsbroek and that infected the cases who lived near the airports (Van Bortel et al., 2022) (Figure 1B). Arising questions were to determine whether more such events could be expected and whether malaria transmission could occur via local *Anopheles* mosquitoes.

Current situation of *Anopheles* species in Europe and Belgium.

In Europe, malaria was historically associated with several *Anopheles* species primarily *Anopheles atroparvus, An. labranchiae, An. sacharovi, An. messeae* and *An. superpictus* (Sinka et al., 2010). Other species such as *An. claviger* played a much more local secondary role in *Plasmodium* transmission (Mouchet et al., 2004). Currently, *An. atroparvus* has a wide distribution in Europe from Portugal to Ukraine. The larvae of this species are tolerant to salinity and are associated with brackish water. It is still abundant on the Iberian Peninsula, but in other areas of its historical distribution it has become sporadic and localised. Factors that might have contributed to its decline are land-use changes, pollution, lack of suitable larval habitats, and lack of adult feeding and resting sites (Bertola et al., 2022). *Anopheles labranchiae, An. sacharovi* and *An. superpictus* are species distributed in southern and eastern Europe. *Anopheles labranchiae* is known to occur in Central Italy, Sardinia and Corsica. *Anopheles sacharovi* is frequently found in Greece and Turkey (Bertola et al., 2022) and *An. superpictus* occurs from the Mediterranean region to Southeast Asia. Yet, its current distribution in Europe is not well known (Bertola et al., 2022).

In Belgium, six *Anopheles* species are reported. Four species of the Maculipennis complex were identified in Belgium, viz. *An. maculipennis* s.s., *An. daciae* sp. Inq., *An. messeae* and *An. atroparvus*

(Smitz et al., 2021b). Based on the currently available evidence, *An. maculipennis* s.s. is the most widespread species of the complex in the country as it was found at 21 out of 25 sampled localities (Smitz et al., 2021b). In contrast, *An. atroparvus* was only found at two localities in the same study, namely in the port of Antwerp and Vrasene (Oost-Vlaanderen) (Smitz et al., 2021b). *Anopheles claviger* was among the top five most abundant species in the inventory study between 2007—2010 (Versteirt et al., 2013). In that study it was found at 185 localities (i.e., in 18.5 % of the sampled sites) and was the species that was found at most localities after *Culex pipiens*, the latter being found in almost 70 % of the sampled localities (Versteirt et al., 2013). The first record of *An. plumbeus* in Belgium goes back to 1938 when Goetghebuer collected this species in Rouvroy near Torgny (Dekoninck et al., 2011). *Anopheles plumbeus* was only collected sporadically and linked to forested areas. In recent years, *An. plumbeus* exploits artificial breeding habitats such as tyres and large abandoned manure collecting pits of uncleaned pig stables and was found in 114 localities (i.e., in 11.4 % of the sampled sites) spread over Belgium during the large inventory between 2007—2010 (Dekoninck et al., 2011; Versteirt et al., 2013). Locally *An. plumbeus* can cause high biting nuisance.

Future threat of local malaria transmission in Belgium.

Historically, malaria in Belgium due to *P. vivax* was associated with wetlands in the north of the country (Flanders) and the presence of *An. atroparvus* (Rodhain & Van Hoof, 1939, 1942, 1943). Yet, the current vector status of *An. atroparvus* in Belgium is not known. In a recent review, Bertola (2022) only considered *An. plumbeus* as an important potential malaria vector of *P. falciparum* and *P. vivax* in Europe nowadays. Yet, this species has never been implicated in historical *Plasmodium* transmission. In the same review, *An. atroparvus* was labelled as a vector of low importance and *An. maculipennis* s.s., *An. daciae* sp. Inq. and *An. messeae* as moderate important potential vectors of *P. vivax* (Bertola et al., 2022).

Currently, malaria is a travel associated disease in Belgium and local transmission is only sporadically reported. Events of local transmission occurred in 1995 associated with Brussels international airport (Van den Ende et al., 1998); in 1997 a possible case associated with the port of Ghent (Peleman et al., 2000); in 1998 a case linked to the regional airport of Oostende (De Schrijver, 1998); in 2008 a case notified in Brussels and labelled as suitcase malaria (Theunissen et al., 2009); and in 2015 a *P. falciparum* case detected near Antwerp, suitcase malaria was suspected (Vermeulen et al., 2016). More recently four events of autochthonous malaria transmissions in four consecutive years (September 2020, June 2021, June 2022 and September 2023) were reported in Belgium (Van Bortel et al., 2022) (Rebolledo & Van Bortel, personal communication). All events were labelled as malaria acquired through an “imported infectious exotic *Anopheles* mosquito” (Figure 1B). Of note, the four events occurred after Belgium experienced temperatures above the long-term mean at the time the transmission event most likely occurred (Koninklijk Meteorologisch Instituut van België, 2023). These weather conditions could have favoured the survival of introduced exotic *Anopheles* mosquitoes. The question raises whether more such transmission events can be expected if such hot spells become more regular in the future. Additionally, it is not clear whether we are confronted with an increased introduction of the exotic *Anopheles* species at airports or only a better survival of the introduced species due to the climate conditions. Exotic *Anopheles* species were in fact detected in Belgium. For example, we found *An. pharoensis*, a malaria vector from Africa, at the airport of Liège in 2017 (Ibanez-Justicia et al., 2020). Likewise, in the Netherlands exotic *Anopheles* species are occasionally trapped at airports (Ibanez-Justicia et al., 2020). The local transmission event of 2020 in Belgium occurred during the second COVID-19 wave. We observed a reduction of 65 % of flights from Africa, the most likely continent of origin of the infection based on a genomic analysis, over the period 1 August to 15 September 2020 compared to the same period in 2019 (Van Bortel et al., 2022). Also in France three cases of airport malaria were reported in 2020 (European Centre for Disease Prevention and Control, 2020). These elements points to the possible importance of the weather conditions when an exotic *Anopheles* species enters the country for their survival.

Besides the autochthonous malaria transmissions linked to the import of infectious exotic *Anopheles* mosquitoes, it is very unlikely that malaria gain a foothold in Belgium as the contact between native *Anopheles* species and humans is low due to the primarily zoophilic nature of most Belgian *Anopheles* species, the low vector status of the native *Anopheles* mosquitoes (Bertola et al., 2022), and the health system that should be able to early detect cases so that establishment of an infectious human reservoir is unlikely.

LOCAL TRANSMISSION OF WEST NILE VIRUS IN BELGIUM?

Since 2010, ECDC systematically follows the human WNV infections during the transmission season (usually between June and November) to inform public health authorities, especially the competent authorities responsible for blood safety in the implementation of the EU blood safety directives (European Union, 2004, 2014). In 2018 the total number of reported autochthonous WNV infections in the EU surpassed the total number of reported cases during the previous seven years and marked one of the highest WNV seasons (European Centre for Disease Prevention and Control, 2018a). Yet, the epidemiological situation of WNV in Europe is heterogeneous with countries reporting regular outbreaks in humans and animals and others that never reported any autochthonous case (Gossner et al., 2017). Hence the question raises whether Belgium is at risk for human WNV infections.

Vector species in Europe and Belgium.

WNV circulates in a complex bird-mosquito-bird cycle with humans and horses considered as dead-end host as the viraemia in humans is not high enough to infect mosquitoes. In Europe, *Cx. pipiens* s.s. is the most efficient vector for transmitting the virus among birds and from birds to humans and other mammalian dead-end hosts (Vogels et al., 2017a). Birds are important amplifying hosts and they play an important role in the spread of the virus (Mancuso et al., 2022) (Figure 1C).

Culex pipiens s.s., also known as the northern house mosquito, is a widespread mosquito species in Europe (European Centre for Disease Prevention and Control, 2022f; Haba & McBride, 2022). *Culex pipiens* s.s. belongs to the *Cx. pipiens* complex comprising three species i.e., *Cx. australicus*, *Cx. pipiens* s.s., and *Cx. quinquefasciatus*. Within *Cx. pipiens* s.s., two biotypes are recognized namely *Cx. pipiens* biotype *pipiens*, and *Cx. pipiens* biotype *molestus*. The biotypes are morphologically indistinguishable, but they show a number of behavioural differences on which they were initially described and which impact their distribution and potential role as vectors (Haba & McBride, 2022). Females of the biotype *pipiens* need a bloodmeal to produce a first batch of viable eggs, prefer feeding on birds, breed in open spaces, and overwinter in a state of diapause. In contrast, females of the biotype *molestus* can produce a first batch of viable eggs without a bloodmeal, prefer feeding on mammals, can breed in confined mating spaces, and do not overwinter in a state of diapause (Haba & McBride, 2022).

In Belgium, *Cx pipiens* s.s. is a very common mosquito which can be found in different types of habitats (Vanderheyden et al., 2022; Versteirt et al., 2013). Between 2007—2010, during the nationwide inventory, it was found in almost 70 % of the 936 sampled locations (Versteirt et al., 2013). *Culex pipiens* biotype *pipiens* seems to be more common and widespread in Belgium than *Cx. pipiens* biotype *molestus*, although in that study the sample strategy might have been biased towards the collection of the biotype *pipiens* (Vanderheyden et al., 2022). Both biotypes co-occur in urban, agricultural, forest and seminatural habitats. Despite the sympatric occurrence of both biotypes, only few hybrid specimens were found (Vanderheyden et al., 2022).

Culex modestus, a bridge-vector of WNV, has also been detected in Belgium, yet it's distribution is currently unknown (De Wolf et al., 2021; Wang et al., 2021).

Future threats of local WNV transmission in Belgium.

WNV is not new to Europe: in the 1960–1980s the circulation of WNV in humans was suspected based on serological studies conducted in Albania, Portugal, Spain, Romania, and Slovakia (Zeller & Schuffenecker, 2004). Between 1962-1963 WNV encephalitis cases occurred in France in humans and horses and in 1996 a large outbreak occurred in Romania with more than 390 confirmed cases. Currently, WNV primarily circulates around the Mediterranean Sea and in Eastern Europe but a more northern spread happened recently with human cases detected in Germany in 2019–2022 and the

Netherlands in 2020 (Bakonyi & Haussig, 2020; European Centre for Disease Prevention and Control, 2022g).

In Belgium, no autochthonous mosquito-borne transmission of the WNV is known so far. Migratory birds might play an important role in the introduction of this virus in new areas along their major routes between Africa and Europe, but also within Europe, although the exact introduction events are difficult to determine (García-Carrasco et al., 2023; Mancuso et al., 2022; Seidowski et al., 2010; Ziegler et al., 2022; Ziegler et al., 2020). Vogels et al. (2017b) did not find any difference in vector competence between *Cx. pipiens* biotype *pipiens* from Italy and from the Netherlands, and concluded that the vector competence of *Cx. pipiens* s.s. is not a limiting factor for the northward spread of the virus. Furthermore, the autochthonous vector-borne related cases reported in the Netherlands and Germany indicate that virus transmission is possible at more northern latitudes including Belgium. Additionally, in the summer of 2016, a widespread circulation of Usutu virus (USUV) in birds was reported from Belgium, France, Germany and the Netherlands (Cadar et al., 2017). USUV is a virus closely related to the WNV and circulates in a similar bird-mosquito-bird cycle. The circulation of USUV is an additional indication that the environment and climate in Belgium is permissive for these arboviruses. All these elements points to one major conclusion: the question is not whether autochthonous mosquito-borne transmission of WNV can happen in Belgium, but rather when.

CONCLUSION.

We reviewed the three plausible scenarios of mosquito-borne disease transmission in Belgium. First, we find *Ae. albopictus* regularly introduced in Belgium. It is very likely that the species will become established in Belgium in the near future as we observe regular introductions and possible overwintering in the recent years. This will change the epidemiological context of *Aedes*-borne arbovirus transmission in Belgium i.e., one of the prerequisites for local arbovirus transmission, being the presence of the vector, will become fulfilled in Belgium. Second, transmission of *Plasmodium* through imported infectious exotic *Anopheles* does occur in Belgium with recently four transmission events in four years. Despite these events, it is very unlikely that malaria will get established in Belgium again because of the socio-economic situation and health-system ensuring the early detection and treatment of cases and the vectors being primary zoophilic and having a low vector potential. Third, based on the geographical spread of WNV infections to the Netherland and Germany and the recent occurrence of USUV in Belgium, it is clear that Belgium is environmentally suitable for WNV and that mosquito-borne human WNV infections will occur in the near future in Belgium.

As in Europe, mosquito-borne diseases were not considered a public health problem in the past in Belgium. Based on our assessment it is clear that the situation is changing and that mosquito-borne diseases need to be recognised as a public health threat. In order to improve the risk assessment and preparedness for mosquito-borne diseases, several steps need to be taken. First, an improved knowledge of the occurrence and distribution of vectors is a first step to better assess the risk of mosquito-borne disease transmission. This not only refers to exotic *Aedes* mosquitoes but also to native mosquito species such as *Anopheles* spp*.* and *Culex* spp. Currently the monitoring of exotic *Aedes* mosquitoes is done on a project-based approach which hampers the establishment of a long term surveillance strategy. Second, the integration of entomological, epidemiological, and veterinary and wildlife surveillance data could enhance our understanding of the epidemiology of mosquito-borne diseases and improve the early detection of possible local transmission events. A first step is taken by the recent set-up of the MEMO+ project where Sciensano (https://www.sciensano.be) and the Institute of Tropical Medicine (https://www.itg.be) collaborate to follow the risk of *Aedes*-borne diseases and their vectors in Belgium. Third, research on vector competence and environmental or climatic suitability of mosquito species and mosquito-borne diseases could help to identify target areas for surveillance and control. Fourth, the development of an overall preparedness plan integrating the different aspects of disease and vector surveillance and their control will be essential to ensure that surveillance will result in the necessary control actions to safeguard the health of humans in Belgium.

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Figure 1. Overview the three possible scenario's related to mosquito-borne disease risk for Belgium. Red coloured icon indicates an infectious individual i.e., mosquito, bird, or human. The red circle indicates a transmission event from the infectious individual (bird or human) to a established-exotic (scenario A) or a native (scenario C) non-infected mosquito species.

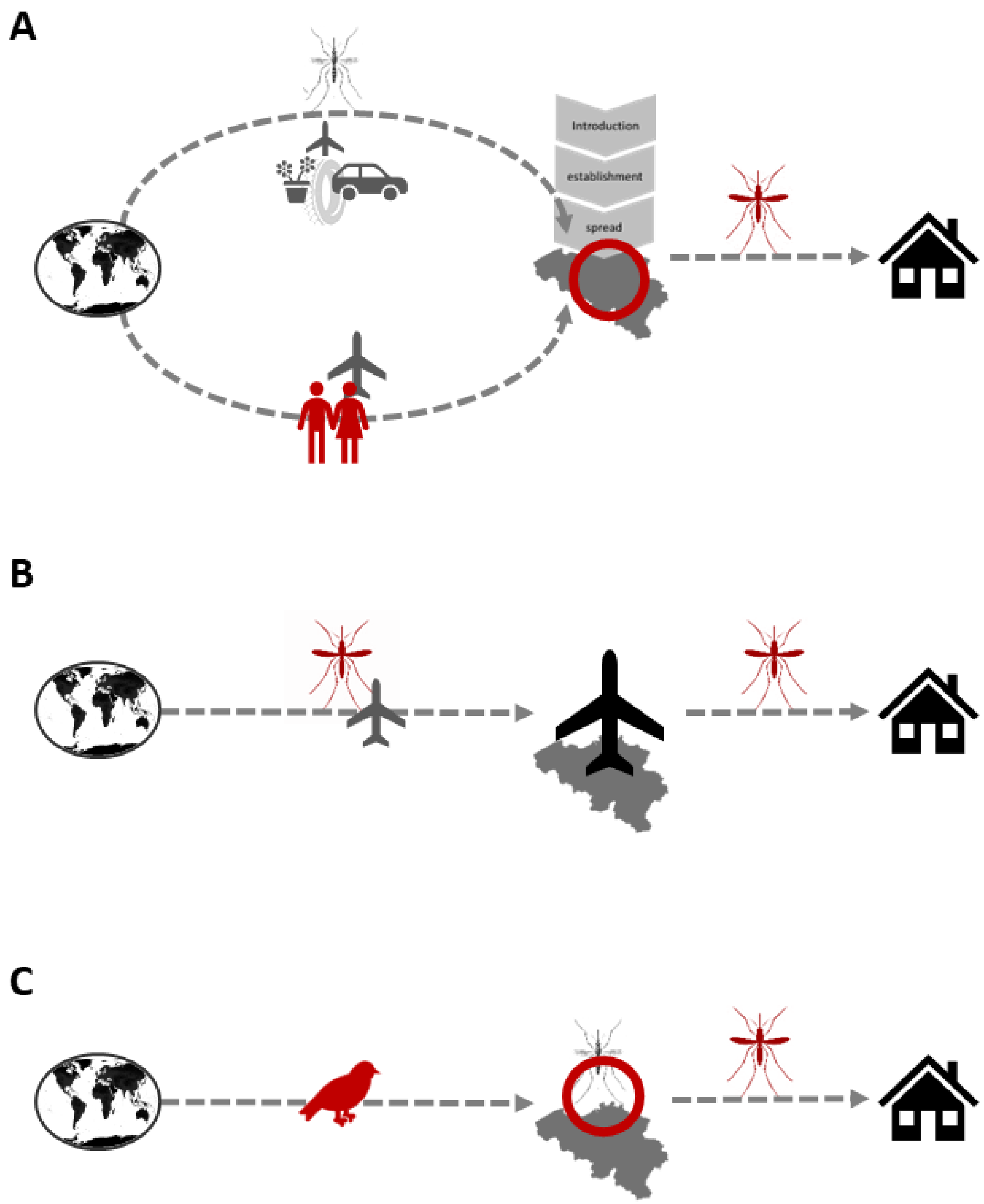

Figure 2. Overview of the current known occurrence of exotic *Aedes* species in Belgium, 2000—2020 adapted from (Deblauwe et al., 2022). The colour code of the icon indicates the species that was found at the Point of Entry. Summer reproduction: outdoor summer reproduction as indicated by the detection of adult and immature stages during at least one mosquito season (May-October).