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SURVEILLANCE AND DETECTION OF INVASIVE MOSQUITO SPECIES IN THE UNITED KINGDOM

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Abstract The UK employs a multi-faceted approach to surveillance for invasive *Aedes* species, including active methods, designed to target particular, potentially higher locations, and passive methods, providing a means for the general public and relevant professional groups to submit mosquito samples for identification. Mosquito surveillance is led by Public Health England's (PHE) Medical Entomology and Zoonoses Ecology (MEZE) group, whose role is to provide advice to PHE and the Department of Health and other government advisory groups, on the risk to public health from vector borne disease. MEZE, and colleagues at Edge Hill University, work with environmental health and port health officers across the country to run mosquito traps to target the detection of potential introduction of invasive species. Surveillance is also conducted at motorway service stations; key locations that target other potential routes by which invasive mosquitoes might enter the UK. Two species native to the UK, *Culex pipiens* and *Anopheles maculipennis* s.l., were found at seaports and airports, and two native species, *Cx. pipiens* s.l. and *Culiseta annulata*, were found at used tyre importers. Eggs of the invasive mosquito *Aedes albopictus* were found at a service station in the South-East of England and a control program was implemented. To enhance our ability to detect the introduction/presence of unusual species PHE works with the Chartered Institute for Environmental Health to promote passive surveillance; the Mosquito Watch and the Mosquito Recording Schemes. These are useful tools to develop better understanding of the presence oand distribution of the potentially changing distribution of different mosquito species in the UK and an important component of surveillance strategies for the early detection of invasive mosquito species.

Key words *Aedes albopictus, Aedes aegypti,* Culicidae

INTRODUCTION

Invasive *Aedes* mosquitoes have in recent decades spread throughout many regions of the world, where they have been responsible for outbreaks of mosquito borne disease. Globalisation, particularly increase in trade and travel, has enabled the importation of vectors and pathogens into Europe. Particular goods, such as used tyres and wet-footed plants, have facilitated movement of invasive mosquitoes, and together with climate and land-use change, importation of vectors and pathogens increase the potential for the establishment of invasive mosquitoes and vector borne disease (Reiter 1998; Scholte et al., 2007; Scholte and Schaffner, 2007). In Europe *Aedes albopictus* has now been reported from 28 European countries (Medlock et al, 2015), and there have been associated cases of chikungunya (CHIKV) in France and Italy, and dengue (DENV) in Croatia and France (Medlock et al, 2012; Schaffner et al, 2013). *Aedes aegypti* is established in Madeira (Portugal), and around the Black Sea (Akiner et al, 2016), and there have been over 2000 cases of DENV in Madeira as a result (Sousa et al, 2012). The rapid emergence of Zika virus in recent months captivated media around the world, and brought home the importance of a strong surveillance network for invasive mosquitoes.

Active surveillance for invasive mosquitoes in the UK focusses on high risk goods and points of entry as detailed in Vaux and Medlock (2015). PHE and Edge Hill University work with seaports and airports as part of the Port Invasive Mosquito Surveillance project in order to conduct surveillance at these ports of entry. Surveillance is conducted at used tyre importers to address the importation of used tyres, as the movement and trade of this commodity has inadvertently provided transport for *Aedes* eggs into new regions across the globe. Service stations providing rest areas to vehicular traffic arriving from continental Europe are also targeted, motorways having been identified as one of the main routes aiding the spread of invasive mosquitoes through Europe (Becker et al, 2012; Werner et al, 2012; Flacio et al, 2016). In 2016 this has been expanded to further locations, and the results of these surveillance efforts are described in this paper.

MATERIALS AND METHODS

Surveillance at Ports and Airports

Port health officers (PHOs) at ports and airports across the UK were contacted and subsequently engaged between March and October 2016 in order to increase the number of sites participating in the survey for potentially imported invasive mosquitoes. The Gravid *Aedes* trap (GAT; Biogents, Regensburg, Germany, http://www.biogents.com) was chosen as the preferred trap type, due to its effective targeting of invasive *Aedes* species, ease of use, low cost, and after an appraisal of other trap types in previous work at UK ports and airports (Johnson et al., 2016; Murphy et al., 2012; Vaux et al., 2011). Many PHOs had difficulty regularly accessing traps that were placed airside within the secure area, and the simple unpowered trap design aided their ability to access these areas regularly. Five GATs were used at each seaport/airport, were filled with water and sited close to key areas within the port: cargo inspection warehouses, aircraft gates, and dockside. Heathrow, Gatwick, and Stansted airports each employed ten GATs each. Three GATs were also used at Eurostar St Pancras as fewer locations were available here for traps. GATs were placed within small dog cages, to ensure the traps were not tampered with or disturbed by aircraft engines. Wherever possible, a powered electrical trap (BG Mosquitaire, Biogents, Regensburg, Germany) was used together with Sweetscent® lures (Biogents, Germany). Four ports were able to run this trap (Heathrow airport, Stansted airport, Felixstowe seaport, and Gatwick airport). Traps were checked once per fortnight from March to October 2016 for adult insects and larvae, and all samples sent to PHE or Edge Hill University for identification, and the results reported here. PHOs continue to check traps at monthly intervals for the winter season (Nov-Mar), and will begin fortnightly checks thereafter.

Surveillance At Service Stations And Used Tyre Importers

PHE's Medical Entomology team identified the main service stations of potential relevance to be along the M20, M2, M25, M3, and M27 motorways; servicing traffic leaving ports at Dover, Folkestone, Southampton and Portsmouth. Seven service stations on these routes were visited in early 2016, and locations for traps identified. Ten ovitraps were set up within the vegetation around the carparks at each site – each trap was filled with water and fixed to the ground with a tent peg to prevent disturbance. A polystyrene block was placed in each ovitrap. Two GATs were also set up, as described above for ports and airports. Where access, security and power constraints could be overcome, one BG Mosquitaire adult trap (Biogents, Regensburg, Germany) baited with Sweetscent® lures (Biogents, Germany), was set up at a service station.

The team also undertook three visits to the two largest importers of used tyres during August and September. Two visits were made to a company in Devon, and one visit to a company in Lincolnshire; during each, searches for larvae in the tyres were made dippers, torches, and nets. In these used tyre locations it was not possible to place adult traps, GATs or ovitraps due to a lack of electrical power, and the very high number of alternative ovipositing sites provided by the tyres.

RESULTS AND DISCUSSION

Surveillance At Ports and Airports

Thirty-six seaports, airports, and Eurostar St Pancras conducted surveillance for invasive mosquitoes (Table 1). Each location submitted the catch from each trap every fortnight and these were examined for adult mosquitoes. Mosquitoes were found at eight locations, all were identified as *Culex pipiens* s.l. or *Anopheles maculipennis* s.l. (Cardiff Airport 2 *Cx. pipiens* s.l.; Glasgow Prestwick airport 5 *Cx. pipiens* s.l. at GAT, 25 *Cx. pipiens* s.l. from warehouse walls; Heathrow airport 20 *Cx. pipiens* s.l.; Heysham and Glasson Docks 4 *Cx. pipiens* s.l.; Felixstowe seaport 15 *Cx. pipiens* s.l. and 1 *An. maculipennis* s.l.; Liverpool seaport 8 *Cx. pipiens* s.l.; Stansted airport 2 *Cx. pipiens* s.l.; Teesport 9 *Cx. pipiens* s.l.). The *An. maculipennis* s.l. was found in the BG Mosquitaire trap, and all the *Cx. pipiens* were found in the GATs. Both of these species are common British mosquitoes. *Anopheles maculipennis* s.l. is a species complex which in the UK includes *An. atroparvus, An. messae,* and *An. daciae.* These species bite a range of hosts including humans, and occupy a range of permanent aquatic habitats including brackish saltmarshes, coastal ditches, and freshwater ditches and lake margins. The species cannot be separated morphologically hence the result reported here as the species complex *An. maculipennis*. *Culex pipiens* s.l. is found in a wide range of aquatic habitats in urban and rural landscapes, and is known for utilising container habitats. In the UK, the typical form, found in above ground habitats, and likely to be the form collected at the ports, bites birds exclusively.

Table 1. Ports and airports taking part in mosquito surveillance.

Belfast City Airport	Heathrow Airport	Newport Port
Belfast International Airport	Heysham Port and Glasson Dock	Port Talbot Port
Belfast Port	Hull Port	Portsmouth Port
Bristol Airport	Ipswich Port	RAF Akrotiri Airport
Cardiff Airport	John Lennon Airport	River Tees Port
Cardiff Port	JSPU Limmasol Port	RN Davenport
Dover Port	Liverpool Port	RN Portsmouth
Falmouth Port	Luton Airport	Robin Hood Airport
Felixstowe Port	Manchester Airport	Eurostar St Pancras
Gatwick Airport	Manchester Port	Stansted Airport

The lack of mosquito species collected during this extensive surveillance program is not unexpected. The Gravid *Aedes* traps are designed to target *Aedes* mosquito species, specifically those which utilise container habitats, and therefore it is unsurprising that only native container breeding *Cx. pipiens* was found at this trap. The record of *An. maculipennis* s.l. found at the powered adult trap at Felixstowe is also unsurprising, given the proximity of suitable aquatic habitats near the port, and the propensity of this species to bite humans, hence its attraction to the mammal lure baited adult trap.

Surveillance At Service Stations And Used Tyre Importers

Service stations in the south and south-east of England were targeted for surveillance for invasive mosquitoes (Table 2). Four service stations (Winchester, Folkestone, Southampton, and Maidstone), were able to run BG Mosquitaire adult traps. One mosquito species (*Culex pipiens* s.l.) was recorded present at all of the BG Mosquitaires (Winchester, Folkestone, Southampton, and Maidstone). Two *Culiseta annulata* females were found at a GAT at Southampton service station. *Culex pipiens* s.l. larvae were found at two ovitraps in Southampton, and at one ovitrap at Maidstone. No other larvae were recorded. Thirty-seven *Aedes* eggs were detected in an ovitrap at Folkestone services in late September, and these were identified by MALDI-TOF mass spectrometry and morphological identification of reared

larvae and adults as *Aedes albopictus* (Medlock et al., 2017). This is the first recorded incursion of *Aedes albopictus* into the UK, and is likely to have resulted from the vehicular importation of a single female. Additional surveillance was undertaken, and the local authority conducted control of aquatic habitats within a 300-meter radius of the finding (Medlock et al., 2017). No further specimens of this species were found, and surveillance in this area will be conducted in April 2017.

Two species were recorded during the used tyre surveys: *Cx. pipiens* s.l. and *Culiseta annulata*. Both species are native species typical of container habitats in the UK. The larvae were found in tyres closest to the margins of the yards, in close proximity to vegetation. Discussions with the yard managers revealed that tyres were processed within 3-4 weeks of arrival, and thereafter kept in an indoor warehouse unsuitable for mosquitoes. It may be this relatively fast turnaround time that has meant that to date invasive mosquitoes have not been found at tyre yards in the UK.

Table 2. Location and motorway of service stations taking part in mosquito surveillance.

Location	**Motorway**
Medway, Kent	M2
Sevenoaks, Kent	M25
Maidstone, Kent	M20
Folkestone, Kent	M20
Ashford, Kent	M20
Winchester, Hampshire	M3
Southampton, Hampshire	M27

Incursions of invasive mosquitoes are likely to increase in number over the coming years, as *Ae. albopictus* increases its northward march through Europe. Another species of concern is *Ae. japonicus,* an invasive mosquito that has recently established in central European countries, including France, Belgium, the Netherlands, Germany and Switzerland, following introduction and spread through similar routes to *Ae. albopictus* (Kampen and Werner, 2014). As densities of these mosquitoes increase in areas within a few hours driving distance of the English Channel, it can be expected that adult mosquitoes will be more frequently transported into the country. Surveillance at key points of entry is therefore vital, as is a defined and actionable control strategy to ensure populations are eradicated swiftly upon detection. An important factor here is the ability for environmental health officers, pest controllers, and the public to be able to submit mosquitoes they find to a central point for identification. Passive schemes have been used to great effect in Europe (Kampen et al 2015), and the Mosquito Recording Scheme, run by PHE and the Biological Records Centre, undertakes this important work (Vaux and Medlock, 2015). Further development of this citizen science element of surveillance is necessary to strengthen our ability to detect new mosquito species. Nevertheless, an active surveillance network, including working with professionals at major ports of entry across the country, remains a vital component of the UK's preparedness for incursions of key mosquito vectors.

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