European Mosquito Bulletin 29 (2011), 133-140
Journal of the European Mosquito Control Association
ISSN 1460-6127; www.e-m-b.org
First published online 11th November 2011

Monitoring for invasive and endemic mosquitoes at UK ports

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Keywords: Invasive mosquitoes, Culicidae, surveillance, ecology, port, airport

ABSTRACT

Eleven air- and sea-ports in the United Kingdom (UK) were surveyed over two years (2009-2010) for immature and adult mosquitoes using standard survey methodologies. Six species of mosquito were found associated with the ports; all were endemic and locally common to the UK. This paper describes the monitoring activities employed at each port, the aquatic habitats present at each site, and identifies common mosquito issues across UK air- and sea-ports to guide future mosquito monitoring projects. A range of aquatic habitats for mosquitoes at airports included wet ditches, secondary containment bunds, lagoons and reedbeds, and at seaports, open drains, tyres, estuarine habitats, and container habitats. Despite considerable sampling effort over the two years, no exotic imported mosquitoes were found. We should not however become complacent regarding the potential for importation of exotic mosquitoes in the future. The survey provides baseline information on mosquito populations at UK ports and identifies habitat types at these sites that may require additional survey or control measures in the future.

INTRODUCTION

In recent years, the rate of introductions of invasive mosquito species to new geographic locations has increased rapidly in step with increased international travel and trade and this has had adverse consequences for public health (Lounibos, 2002; Tatem *et al.*, 2006; Gratz *et al.*, 2000; Medlock *et al.*, in press). Many species of mosquito have become established in new countries, regions, and continents, as a result of anthropogenic transport (Lounibos, 2002). Transport of mosquitoes beyond their native range via shipping and aircraft has been well documented, particularly the expansion of *Aedes albopictus (Stegomyia albopicta)* via shipping of used tyres (Enserink, 2008; Scholte & Schaffner, 2007), and the occurrence of vectors for yellow fever, dengue, and malaria on aircraft (DeHart, 2003).

Air traffic has been shown to be an important pathway for facilitating movement of mosquitoes globally, with their ability to survive longhaul flights between tropical and temperate climates (Russell, 1987; Russell, 1989), with surveys of incoming flights having found a number of non-native species including *Aedes aegypti (Stegomyia aegypti)* and *Culex quinquefasciatus* (Gratz *et al.*, 2000; Hutchinson *et al.*, 2005; Scholte *et al.*, 2010). Airline baggage has also been implicated as a pathway for entry of non-native diptera into new territories (Liebhold *et al.*, 2006), and the occurrence of airport malaria is well documented with cases having been identified at or near many European airports as a result of incursion of *Anopheles* mosquitoes (Gratz *et al.*, 2000). Air transport has been reported as directly responsible for the establishment of mosquitoes in new locations including the rapid colonisation of the islands of French Polynesia by *Ae. aegypti* shortly following the completion of the airport there. Similarly, *Cx. quinquefasciatus* has become established on the Galapagos Islands (Bataille *et al.*, 2009; Mouchet *et al.*, 1995).

International shipping has resulted in incursion of exotic mosquitoes into new territories, particularly through the movement of used tyres. Shipping containers themselves provide considerable opportunity for stowaway mosquitoes and are difficult to inspect adequately (Wittenberg & Cock, 2001). There are many cases of successful introductions of exotic mosquitoes into Europe via eggs present on used tyres transported in shipping containers (Reiter, 1998; Medlock *et al.*, in press), including *Ae. albopictus* into Italy (Enserink, 2008), *Aedes japonicus (Hulecoe*teomyia *japonica)* into France (Schaffner *et al.*, 2003) and Belgium (Versteirt *et al.*, 2009), and *Aedes atropalpus (Georgecraigius atropalpus)* into the Netherlands (Scholte *et al.*, 2009). A review of 171 interceptions of exotic mosquitoes recorded entering New Zealand since 1929 found that aircraft accounted for 62% of records, but for the period 1990 to 2004 shipping accounted for 51 (82%) of 62 interceptions (Derraik, 2004).

At the current time, no invasive species have been found established in the United Kingdom (UK) (Medlock *et al.* unpublished), despite the UK importing large numbers of shipping containers and having some of the world's busiest airports. Despite millions of used tyres imported into the country each year, it seems surprising that *Ae. alpopictus* in particular has not been found in the UK, although so far targeted surveillance has been limited. Given the scale of commercial activities at UK seaports and airports and their potential to provide suitable habitats for exotic mosquitoes this study aims to identify and characterise suitable habitats available for mosquitoes and detail the mosquito species currently exploiting such port-associated habitats.

A pilot study was conducted at 11 ports (seaports and airports) in the UK, with the aims of testing surveillance techniques suitable for monitoring mosquitoes at ports and describing and assessing suitability of the aquatic mosquito habitats present at airports and seaports in the UK. Port Health Officers (PHOs) at the following ports participated in the study: Belfast City airport; Belfast International airport; Belfast seaport; Bristol seaport; Felixstowe seaport; Hull and Goole seaport; Liverpool seaport; London Gatwick airport; London Heathrow airport; Manchester seaport; Southampton seaport (Figure 1).

MATERIALS AND METHODS

At each port, aquatic sites were identified through ground survey, and also through the use of maps and aerial photographs. Qualitative larval sampling (using a standard dipper) was conducted from April to October at permanent aquatic habitats and also at transient waterbodies such as containers or temporary pools. Quantitative sampling was not possible as the resources available to each PHO varied. Larvae were either reared through to imago or preserved as larvae in alcohol, with all samples sent to the Health Protection Agency for identification. BG Sentinel traps (Biogents), and sticky traps were trialled, and in 2010, ovitraps and Mosquito Magnet traps (Midgetech) were also used at some ports / airports. Where it was possible to use a Mosquito Magnet trap, these were run from Monday-Friday every other week, starting on the 3rd week of April and ending with the 3rd week of October. Ovitraps were set out in early June, and checked weekly until late September. This paper describes results from 2009 and 2010, and the project is ongoing with PHOs continuing to participate in mosquito surveillance.

Study sites: Airport and Seaports

Belfast City Airport (Latitude: 54.631603; Longitude: -5.856982) is located on reclaimed land in Belfast harbour and is surrounded by the seaport and industrial zones to the south, residential housing to the east and Belfast Lough to the north. Much of Belfast Lough is designated as a Special Protection Area for its habitats of intertidal mudflats and lagoons which support significant numbers of wintering waders and wildfowl. Belfast City Airport caters for 2.5 million passengers per year, accounting for 40% of Northern Ireland domestic flights.

Belfast Port (Latitude: 54.623607; Longitude: -5.90293) is located next to Belfast City Airport and operate passenger, container, and bulk carrying vessels.

Belfast International Airport (Latitude: 54.659493; Longitude: -6.225064), located approximately 20km west of Belfast, is surrounded by agricultural land, and is approximately 3km east of Lough Neagh; the largest lake in the British Isles. The airport handles 48,000 tonnes of cargo and serves approximately 6 million passengers a year; 40% of which are from international flights.

Bristol Port (Latitude: 51.5036; Longitude: -2.7041) includes the Avonmouth Docks and the Royal Portbury Dock, on either side of the River Avon. The port is located on the southern bank of the mouth of the River Severn, and is adjacent to agricultural land in the north and south, and the city of Bristol to the east. The Severn estuary is known particularly for its large tidal range, which exposes large areas of mudflat at low tide,

supporting internationally important populations of migratory birds. The port handles imports and exports of vehicles and containerised freight (called twenty foot equivalent units or TEUs) and bulk goods, including coal, orange juice, metal, glass, animal feed stuffs, and timber. The port is arranged around the ship's berths, with large areas of hardstanding for goods storage.

Felixstowe Port (Latitude: 51.954997; Longitude: -1.320140) is located at the mouth of the River Orwell, Suffolk. The port is bounded by the town of Felixstowe and a large area of saltmarsh, Trimley Marshes. Felixstowe Port handles 40% of the UK's imports and exports, approximately 3.5 million TEUs, with 4000 ships a year calling at 365 ports around the world. It is the largest container port in the UK and the third largest in Europe.

Hull Port (Latitude: 53.743344; Longitude: -0.277384) is located in the north-east of England, on the north bank of the Humber Estuary. The port handles over 1.5 million m^3 of softwood timber, around 300,000 TEUs, as well as dry bulk goods including aggregates, cement, agribulks, coal, cocoa, and grain. The port is surrounded by residential, industrial, and agricultural land.

Liverpool Port (Latitude: 53.4628; Longitude: -2.9977) incorporates a large area, including the Royal Seaforth Container Terminal, John Lennon Airport, Mersey Docks, and 53 miles of coastline including the River Mersey. As with many ports the local surroundings incorporate urban areas of residential, commercial, and industrial uses, as well a nature reserve and vacant land. These areas include grassland, scrubland, and freshwater and brackish wetlands. The seaport's main business is handling containers and supporting shipping movements to oil refineries.

London Gatwick Airport (Latitude: 51.1509; Longitude: -0.1760) is situated in a rural area approximately 40km south of the centre of London and is surrounded by agricultural land, and the towns of Horley and Crawley. The airport handles 33 million passengers a year, flying to over 200 destinations. Habitats found near the airport's boundary include farmland and woodland, many of these areas with wet ditches throughout.

London Heathrow Airport (Latitude: 51.4709; Longitude: -0.4525) is the busiest international airport in the world, serving 67 million passengers a year and 187 destinations. The airport has two runways in an east-west direction and extensive areas supporting airport infrastructure and associated businesses. It also has a number of constructed wetlands adjacent to the site.

Manchester Port (Latitude: 53.282305; Longitude: -2.876851) covers the 58km length of the Manchester Ship Canal, and includes 24 docks in 18 locations from Eastham to Manchester city centre. The port deals predominately with bulk goods, with regular shipping arriving at the oil terminals at Eastham and Stanlow, and chemicals, coal, and other bulk cargos at Runcorn and Ellesmere Port. The ship canal and adjacent land includes estuarine and grassland habitats, as well as urban, industrial, and agricultural land.

Southampton Port (Latidude: 50.8892; Longitude: -0.4525) handles large numbers of vehicle imports, cruise ships, bulk goods, and containers. The port is located in Southampton Water, between the River Test and the River Itchen, and is surrounded by the city of Southampton including residential, commercial, and industrial land, and the estuary of Southampton Water.

RESULTS

Details of suitable habitat and local mosquito fauna

Belfast

Port Health Officers at Belfast City Airport conducted larval surveys of habitats at the airport, and ran a Mosquito Magnet adult trap. A large area of rough grassland surrounds the runway drained by vegetated ditches. The airport is bounded to the north and east by the estuarine habitats of Belfast Lough and the south by the wetland nature reserve in Victoria Park. The aquatic habitats identified and surveyed were drainage ditches, tyre ruts, and a lake. *Culex pipiens* s.l. species was identified through larval sampling and three other species (*Coquilletidia richiardii, Anopheles maculipennis* s.l., and *Culiseta annulata*) were caught in the Mosquito Magnet (Table 1).

At Belfast Port, there were no natural vegetated aquatic habitats, as the port predominately consists of concrete areas designed for large vehicle movements. Mosquito larval habitats include used tyres, puddles, and

miscellaneous collections of water in storage and maintenance areas. *Culex pipiens* s.l. was the only species identified in larval samples and one adult *Cx. pipiens* s.l. was collected in the Mosquito Magnet.

The survey at Belfast International Airport identified the following potential aquatic habitats: an airside lagoon, a temporary water reservoir covered in plastic balls, secondary containment under fuel storage tanks, open overflow pipes and drains, and water-filled road barriers. The Mosquito Magnet was placed near an airside lagoon and reedbed dominated by *Phragmites australis* and *Typha latifolia* (Table 1). Four species were identified through larval and adult sampling (*An. maculipennis* s.l., *Cx. pipiens* s.l., *Cs. annulata* and *Cq. richiardii*).

Bristol

A survey of the Bristol Port, including Avonmouth Dock and Royal Portbury Dock identified limited aquatic habitats. Occasional designated wildlife habitats and other vegetated areas are found throughout Bristol Port, including a series of linked ponds in the north of the Avonmouth Dock. Vegetated channels are also found around the coal storage yard at Royal Portbury. *Culex pipiens* s.l. larvae were found in the channels around the coal storage yard, and in an open drain at Avonmouth (Table 1). No mosquitoes were collected using the Mosquito Magnet, which was placed near open drains at Avonmouth Dock.

Felixstowe

The large expanse of hardstanding concrete areas at Felixstowe Port is designed to deal predominately with TEUs, and their movements by lorry and forklift. Drainage ditches are found in some areas, but most areas are drained using closed systems. Relatively few aquatic habitats were found at the Port, although *Cx. pipiens* s.l. larvae were found in aquatic habitats in discarded tyres; puddles; vegetated drainage ditch; and a wide, flowing channel, with adult *Cx. pipiens* s.l. found resting inside the food inspection building.

Hull

A survey of Hull Port did not identify many aquatic habitats within the port's boundaries. The port's business is mainly the import of bulk goods, and like other ports, this necessitates large areas of concrete and storage areas. Some used tyres were found on the margins of a storage area but did not contain larvae, and although adults were found in the Mosquito Magnet (*Anopheles claviger, Cs. annulata,* and *Ochlerotatus detritus*) some of these species may have been attracted to the trap from the estuarine habitats adjacent to the port.

Liverpool

Liverpool Port encompasses a large area and incorporates many habitat types, such that many areas of port activity are within metres of estuarine habitats or wetland nature reserves. At Liverpool the survey focused on areas close to the main docks (Huskinson Dock, Spiller's Quay, West Canada Docks, Crosby Marina), the port offices, and Marine Base. Mosquito larvae (*Cx. pipiens* s.l.) were found in small pools, discarded tyres, fly-tipped rubbish, and the margins of a lake. The Mosquito Magnet was run at four locations (Marine base, Huskinson Dock, Seaforth Nature Reserve, and Crosby Marina) and trapped *Cs. annulata* and *An. claviger.*

London Gatwick

London Gatwick Airport is a busy single runway airport, and has all the typical aquatic habitats of airports. Mosquito larvae (*Cx. pipiens* s.l., and *Cs. annulata*) *were* found in vegetated seasonal ditches, ponds, reservoirs, fuel bunds, drains, puddles, discarded tyres, skips, refuse bins, and chemical bunds. Where possible, surveys were also conducted at properties immediately adjacent to the airport, and mosquito larvae (*Cs. annulata*) were found in wet-woodland and open ditches in these areas. The Mosquito Magnet adult trap was operated near an airside ditch, but collected no mosquitoes. Fifteen ovitraps were placed around aircraft aprons, and cargo-handling areas, and were monitored for egg rafts and larvae throughout the summer with no mosquito eggs found.

London Heathrow

London Heathrow Airport airside and landside areas cover a large site (approximately 1300 hectares), which incorporate many different types of aquatic habitats for mosquitoes. In particular, the airport has a number of large reservoirs, waste-water lagoons, water-treatment sites, reedbeds, culverted and non-culverted watercourses, and ditches. These habitats included steep sided waste-water storage lagoons maintained with minimal vegetation; ditches heavily vegetated with *Phragmites australis, Typha latifolia*, *Salix* sp.; a group of lakes with *Salix* species and *Alnus glutinosa* margins; and a series of lagoons, channels, and reedbeds that form the Heathrow Constructed Wetlands water-treatment facility. In addition to these large-scale habitats, many types of container habitats were recorded and mosquitoes collected. Container habitats included fuel bunds, chemical bunds, discarded tyres, wheelie bins, and skips. Mosquito larvae were also found in wheelbarrows, puddles, and

drains. Fuel and chemical tanks with open secondary containment or bunds were probably the most abundant of container types. Three species were found at Heathrow with *Cx. pipiens* s.l. and *Cs. annulata* found in most habitat types surveyed, and *An. maculipennis* s.l. found in lagoons, channels, and reedbeds.

Manchester

As described above, the 60km linear nature of Manchester Port along the Ship Canal, results in a large boundary between the port and neighbouring habitats. Aquatic habitats were found in the form of discarded tyres, fly-tipping sites, large and small ponds, an uncovered water butt, flooded grasslands, road-marking tyres, and miscellaneous containers. Mosquito larvae (*Cx. pipiens* s.l., *Cs. annulata* and *An. claviger*) were found in these habitats on a regular basis throughout May to September during both 2009 and 2010.

Southampton
Southampton Port primarily consists of large areas suited for vehicle movements, container storage, and bulk goods handling, and as such the survey did not identify many aquatic habitats within the main area of the port. Those that were found to support mosquito larvae (*Cx. pipiens* s.l.) were miscellaneous containers, tyres used for road marking, and open drains. The mosquito magnet was run at the boundary of the port close to grassland and woodland habitats, but yielded no mosquitoes.

DISCUSSION

The most common species found during the surveys at the sea- and airports was *Culex pipiens* s.l., and *Culiseta annulata,* reflecting the fact that most aquatic habitats suitable for mosquitoes were found in miscellaneous containers such as fuel bunds, used tyres, barrels, and buckets. Other species found tended to be a result of surveys in or near specific habitat types, for instance, *An. maculipennis* s.l. in Heathrow Wetlands, or *Oc. detritus* and *An. claviger* at Seaforth Nature Reserve, Liverpool. *Coquillettidia richiardii* was found in a reedbed dominated by *Phragmites* and *Typha* at Belfast International Airport (Table 2).

The aquatic habitats found during the surveys at the sea- and airports varied considerably, largely depending on the type of port, its size, and location (Table 3). The activities of seaports requiring passenger and vehicle movements, bulk goods, and container handling, require large areas of hardstanding surfaces, usually with a closed drainage system. Felixstowe Port is typical of this, but unlike Southampton Port, Felixstowe has heavily vegetated drains through and around the perimeter of the port, and it was these habitats that supported mosquitoes. In general though, it was the miscellaneous habitats which supported mosquitoes within the seaport boundaries, in particular, the used tyres either discarded in maintenance areas or used for road-marking. By their very nature, habitats such as salt marshes, floodplains and nature reserves containing ponds and pools which are often adjacent to seaports can support mosquito populations.

As with seaports, airports require large areas of hardstanding for vehicle movements, but that is their only similarity. Apart from Belfast City, all the airports surveyed in this study were inland, and adjacent to farmland or urban areas. Key habitats for mosquitoes at airports were found to relate to the operation and water management of the runway. Many fuel and antifreeze bunds were found to support mosquitoes, and other miscellaneous containers were also found, such as skips and open waste bins. Water management is an environmental process undertaken at airports to minimise antifreeze and other pollutants running directly into watercourses, and so airports usually have a number of pools, lakes, settlement lagoons, and water treatment facilities. Surveys of these habitats found that some of the lagoons (eg: Belfast International Airport) supported abundant vegetation and therefore good mosquito numbers, while other airports (eg: London Heathrow Airport) had concrete-sided lagoons covered in black plastic air-filled balls (approximately 15 cms diameter) and had no mosquitoes. Vegetated ditches were found at all the airports surveyed, and all were found to support mosquitoes at certain times throughout the year.

The use of adult traps, in this case the Mosquito Magnet, certainly enhanced the survey, and recorded species of mosquito (eg: *Cq. richiardii* and *Oc. detritus*) that the PHOs were unlikely to find during their larval surveying. Where possible the PHOs intend to continue running these traps to supplement the other data they collect for their port. It should be noted however that adult trapping at ports should not be used as an exclusive method for mosquito surveillance, as the species trapped will not represent the full complement of species present at that site (e.g.: *Cx. pipiens* s.l.), but more importantly, these sites are big, open sites, and are therefore exceptionally windy which can only affect the success of adult traps. Further efforts will be put towards the use of ovitraps for mosquito monitoring, as they offer a low maintenance method that poses little risk of theft of equipment or a perceived security threat - the two factors limiting the use of adult traps at ports. Larval sampling was by far the

most useful survey technique and allowed the PHO to gain a fuller understanding of the types of aquatic habitat available to mosquitoes at their port which in itself is an important output of the work. Larval sampling required no specialised equipment, and could be carried out at any time through the working week, ideally in co-ordination with other port health activities.

The following steps could be taken to reduce mosquito populations at ports: (i) regularly draining fuel/anti-freeze bunds; (ii) removing miscellaneous containers, e.g.: buckets, tyres; (iii) ensuring ditches are clear and free-flowing. Other more permanent habitats required for water management (e.g.: reedbeds, anti-freeze lagoons) may require surveys and subsequent control measures, as it may not be possible to alter these habitats to make them less suitable for mosquitoes. The surveys conducted at the ports have established a baseline knowledge for each of the ports that can be built on through subsequent surveys. The surveys have also identified particular habitat types at seaports and airports which are known to support mosquitoes and which could be targeted during further surveys or in the case of the need for mosquito control.

Despite considerable efforts so far no exotic imported mosquitoes have been found at seaports or airports during this project. However given the rate at which exotic mosquitoes have invaded European countries, we should not be complacent. In addition, many of the habitats identified, particularly those container habitats supporting *Culex* sp., are the kinds of habitats that would be suitable for many potential invasive species such as *Ae. albopictus*. Mosquito surveillance at ports and airports in the United Kingdom is an important tool in our ability to deal swiftly with incursions of exotic mosquitoes in the future.

ACKNOWLEDGEMENTS

This study was conducted under the HPA UKVECTOR project and funded by NIHR Centre for Health Protection Research at the Health Protection Agency. This paper is work commissioned by the UK National Institute of Health Research. The views expressed in this publication are those of the author(s) and not necessarily those of the NHS, the National Institute for Health Research or the Department of Health.

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Table 1: Mosquito species collected at each seaport and airport by larval dipping (L); adult trap (A); and adult collected using handheld aspirators (P).

	Mosquito species					
Port / Airport	*Culex pipiens* s.l.	*Anopheles claviger*	*Culiseta annulata*	*Anopheles maculipennis* s.l.	*Ochlerotatus detritus*	*Coquillettidia richiardii*
Belfast City Airport	L	A	A			A
Belfast Port	LA					
Belfast International Airport	L	A	A			A
Bristol Port	L					
Felixstowe Port	LP					
Hull Port		A	A		A	
Liverpool Port	L	A	A		A	
London Gatwick Airport	L		L			
London Heathrow Airport	L		L	L		
Manchester Port	L	L	L			
Southampton Port	LA					

Table 2: Species surveyed shown by habitat type.

	Mosquito species					
Habitat type	*Anopheles claviger*	*Anopheles maculipennis* s.l.	*Coquilletidia richiardii*	*Culex pipiens* s.l.	*Culiseta annulata*	*Ochlerotatus detritus*
Reservoir (vegetated margins)				■	■	
Container (miscellaneous)				■		
De-icing lagoon					■	
Ditch				■	■	
Drain / culvert				■		
Estuarine nature reserve						■
Fuel / anti-freeze bund				■	■	
Pond	■			■		
Reedbed		■	■	■	■	
Skip / bin				■		
Tyre				■	■	

Table 3: Habitat types found at airports and seaports

	Port / Airport										
Habitat type	Belfast City	Belfast International	London Gatwick	London Heathrow	Belfast Port	Bristol Port	Felixstowe Port	Hull Port	Liverpool Port	Manchester Port	Southampton Port
Reservoir / lake (vegetated margins)	■	■	■	■		■					
Fuel / anti-freeze bund		■	■	■							
Container (miscellaneous)			■	■						■	■
De-icing lagoon		■	■	■							
Ditch	■		■	■		■	■				
Skip / bin			■	■	■						
Tyre			■		■			■	■	■	■
Drain / culvert				■		■	■				■
Estuarine habitat nearby								■			
Pond			■						■	■	
Reedbed		■		■							