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Mosquito nuisance and control in the UK – A questionnaire-based survey of local authorities

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Abstract

As part of ongoing UK surveillance for invasive mosquitoes, and to understand better the incidence of mosquito nuisance in the UK, a questionnaire survey was carried out in 2009 across all UK local authority (LA) environmental health departments (responsible for mosquito control). Two-hundred and twenty-one LAs (64% return) completed the questionnaire and 57 LAs reported evidence of mosquito nuisance incidence in the last 10 years and 29 during the last 12 months. The most common mosquito species implicated were *Culiseta annulata, Ochlerotatus detritus, Culex pipiens* s.l., *Ochlerotatus cantans* and *Anopheles maculipennis* s.l. There was no evidence of nuisance biting attributable to invasive species. Data are compared with previous similar surveys during the 1980s and 1990s, with evidence of more than a two-fold increase in nuisance reports to LAs over the last 10 years, compared to the same period prior to the 1996 survey. Data on mosquito submissions to a nationwide LA recording scheme (Mosquito Watch) are also presented. Despite the lack of evidence of invasive mosquitoes in the UK, endemic species remain a nuisance locally and LAs are encouraged to continue to retain mosquito control expertise and be alerted to the possible incursion of invasive mosquito species, as has occurred in other parts of Europe.

Key words: Mosquito nuisance, mosquito control, survey, UK

Introduction

To date 34 different species of mosquito have been recorded in the British Isles, including two which have been identified in the last five years (Medlock & Vaux, 2010). The British list includes six species in the sub-family Anophelinae, all in the genus *Anopheles*, and 28 in the sub-family Culicinae in seven genera:*, Aedes* (3), *Coquillettidia* (1), *Culex* (4), *Culiseta* (7), *Dahliana* (1), *Ochlerotatus* (11) and *Orthopodomyia* (1). The aquatic breeding sites adopted by mosquitoes vary considerably. Some species develop in permanent waterbodies such as ditches and ponds, while others occupy temporary freshwater pools in woodlands and flooded meadows or saline pools in saltmarshes. A few species are dendrolimnic, occupying the water that collects in tree-holes, while yet others are found in abundance in containers such as rainwater butts in urban areas. One British mosquito selects underground water that collects in flooded basements, the foundations of dwellings, drains and underground railway tunnels (Medlock & Snow, 2008).

The majority of the British species will bite humans, and at least a dozen species can be associated with nuisance biting. Potential nuisance species are found associated with a range of aquatic habitats in rural, urban and coastal habitats (Snow, 1990; Medlock *et al.*, 2005).

Fens, ditches and ponds are some of the most common aquatic habitats for mosquitoes. Mosquito species, such as *Anopheles messeae* (part of the *Anopheles maculipennis* complex)*, An. claviger* and *Coquillettidia richiardii* are all typically associated with these wetland types, together with several others that are known to exploit a range of habitats (e.g. *Culex pipiens/torrentium, Culiseta morsitans*, *Cs. annulata*) (Snow, 1990). Species such as *Cq. richiardii* are associated with nuisance biting specifically inside neighbouring dwellings during July/August (Medlock & Vaux, 2011), and *Cs. annulata* can cause nuisance biting throughout the year. The anopheline species do bite humans, although it is questionable whether they are truly nuisance species as there is no evidence currently that they constitute a significant biting risk (Lindsay & Willis, 2006). The remaining two *Culex* species and *Cs. morsitans* are predominantly ornithophagic.

There are four main species (*Ochlerotatus cantans, Oc. annulipes, Oc. punctor, Oc. rusticus*) associated with wet woodland, woodland carr or woodland pools, and all four are generally associated with nuisance biting, particularly *Oc. cantans* and *Oc. punctor* (*Cs. annulata* may also be a nuisance species in this habitat) (Service, 1977). There is evidence that some of the species forage away from their habitat to find blood-meals and therefore dispersal to neighbouring dwellings is very likely and is indeed reported. In the habitat itself the level of daytime biting can be intolerable, making visits to these wetland habitats unpleasant at certain times in late spring and summer (Medlock & Vaux, 2011).

The primary nuisance species associated with brackish habitats are *Ochlerotatus detritus* (Service, 1968) and to a lesser extent *An. atroparvus* (part of the *Anopheles maculipennis* complex) and *Oc. caspius*. *Ochlerotatus detritus* is currently associated with nuisance activity and control programmes in certain sites in the UK (e.g. Dee estuary on the Wirral). It is unclear whether the other two species, the former of which was the principal vector of malaria in 18th/19th century Britain, are significant nuisance species. It is probable though that salt-marsh and saline lagoons that hold water following a retreating tide, or have pooling of brackish water due to leaking sea defences constitute a nuisance risk to nearby dwellings (Ramsdale & Gunn, 2005). More recently *Culex modestus* has been found in a number of grazing marsh sites in the Thames estuary (Golding *et al.*, 2012), and although there is no current evidence of persistent human biting, it could become a nuisance locally.

Reed-beds and flooded grasslands (that are subject to wet and dry cycling) provide an aquatic habitat for species such as *Aedes cinereus/geminus* as well as the common species *Cs. annulata* and *Cx. pipiens/torrentium*. *Aedes cinereus* can be a nuisance biter usually in the vicinity of its habitat (Medlock & Vaux, 2011), although it is not typically a significant nuisance species. In continental Europe the main species of mosquito associated with flooded river valleys is *Aedes vexans*. Although this species does occur in the UK, it appears to have a limited geographic range, and therefore is currently unlikely to be a significant nuisance species (Snow, 1990). Two additional separate populations of this species have been found recently in Essex and Kent following HPA mosquito surveillance activities (Vaux & Medlock, unpublished), so this species may be more common than previously thought.

In urban areas there are a number of species, such as *Culex pipiens* typical biotype and *Culiseta annulata*, which exploit a range of container habitats. Both of these species are commonly encountered around the home. The latter can be a significant nuisance species, particularly during early spring and late autumn, when no other species are on the wing. Although the former feeds almost exclusively on birds, it enters buildings to hibernate in late summer/early autumn, and many people incorrectly attribute biting to this species at that time. On the other hand, *Culex pipiens* biotype *molestus* is a notorious pest, particularly in parts of west and east London where it is associated with sewage works. It also breeds in underground, cloistered aquatic habitats, including the London Underground (Snow, 1990).

Invasive mosquitoes in Europe

In addition to our native species, the potential exists for invasive mosquito species to establish in the UK and become nuisance and vector species. Since its first appearance in Albania in 1979 and Italy in 1990, the invasive Asian Tiger mosquito, *Aedes albopictus* [*Stegomyia albopicta*] has been reported in 19 European countries: from the following European countries: Albania, Belgium, Bosnia & Herzegovina, Bulgaria, Croatia, France (inc. Corsica), Germany, Greece, Italy (inc. Sardinia and Sicily), Malta, Monaco, Montenegro, The Netherlands, San Marino, Slovenia, Serbia, Spain, Switzerland and the Vatican City (ECDC, 2009; Medlock *et al.*, 2012). It is now widely established and reportedly a nuisance species in Italy (Scholte *et al*., 2007; Genchi *et al.,* 2009), parts of France (Vazeille *et al*., 2008), Spain (Aranda *et al*., 2006) and other locations in the Mediterranean. In 2007, it became involved in the transmission of chikungunya virus in Italy, leading to more than 200 human cases (Rezza *et al*., 2007), and during 2010 it was linked to a case of dengue virus (La Ruche *et al*., 2010) and chikungunya virus in southern France (La Ruche *et al*., 2010), both of which had been acquired locally with suggestions that *Aedes albopictus* was responsible for transmission. The routes of importation of this mosquito are now well established; the global trade in used tyres, and imports of the wet-footed plant, Lucky Bamboo (Schaffner *et al*., 2009). The latter has been shown to be responsible for imports into greenhouses in The Netherlands (Scholte *et al*., 2007).

Recently there have been reports of at least five other invasive mosquito species imported into Europe, mostly associated with the used-tyre trade (ECDC, 2009; Medlock *et al*., 2012). *Aedes aegypti* [*Stegomyia aegypti*] was historically found throughout the Mediterranean region (as recently as 1950s [Almeida *et al*., 2007]), where it was responsible for transmission of dengue virus. Globally it is also the main vector of yellow fever virus. The reasons for its disappearance from Europe are unknown (Reiter, 2010), but it has since re-appeared in western Europe and is now established in Madeira (Almeida *et al*., 2007). During 2010, two larvae of *Ae. aegypti* were found at a used-tyre company in The Netherlands, along with another species, *Ochlerotatus atropalpus* (Scholte *et al*., 2009; 2010). This species had been reported previously in Italy (Romi *et al*., 1997) and France (Chouin & Schaffner, unpublished), and it is generally considered that the climate is suitable for its expansion in Europe, but so far there appears to be little spread in The Netherlands. Although this species shows vector competence for West Nile virus (Turell *et al*., 2001) and La Crosse virus (Freier & Beier, 1984), its vector status is still unclear.

Following reports of nuisance biting in northern Switzerland, centred on the city of Zurich, field-based surveys found populations of another invasive mosquito, possibly imported from North America, *Ochlerotatus japonicus*. Previous imports of this mosquito to Normandy (Schaffner *et al*., 2003) were eradicated (Schaffner *et al*., 2009). It was also reported in

Belgium in 2002, and later surveys in 2007-2008 confirmed the presence of an established population, with little evidence of wider dispersal (Versteirt *et al*., 2009). In Switzerland however, it was found to have established itself over 1600 km^2, and continues to increase in range, including populations in southern Germany (Becker *et al*., 2011). Its movement follows the main highway systems and its favoured aquatic sites, like all the invasive species mentioned, are container habitats. However *Oc. japonicus* appears to exploit cemetery flower vases, where it out-competes the local mosquito fauna. This species swiftly colonises urban areas and readily bites humans and is likely to continue to be a nuisance species in Switzerland (Schaffner *et al*., 2009). Its role as a potential disease vector in Europe is still debatable, although it is thought to be involved in transmission of West Nile virus in North America (Sardelis & Turell, 2001).

Finally, *Aedes triseriatus* was imported in used tyres into France from Louisiana in 2004, but was subsequently eradicated (Chouin & Schaffner unpublished). In North America it is the primary vector of La Crosse virus (Borucki *et al*., 2002). During 2008 and in subsequent years, *Aedes koreicus* was reported in Belgium, a species native to Japan, China, Korea and Russia (Versteirt, unpublished). It is likely that further invasive species will continue to be reported in parts of Europe. Their ability to spread from imported foci, establish themselves in domestic urban environments, develop nuisance status, and become involved in the transmission of previously exotic, tropical pathogens (principally viruses), is now well established.

Surprisingly there have been no reports so far of any of these invasive mosquito species occurring in the UK, although there are historical records of *Ae. aegypti* in Swansea. Following the arrival of a boat from Cuba carrying crew members infected with yellow fever virus and drinking water tanks on deck infested with *Ae. aegypti*, there was a subsequent outbreak of yellow fever in Swansea which led to nearly 30 cases in local residents, and only abated once the cold winter weather led to the demise of the mosquito population (Buchanan, 1865). The UK imports up to one million used-tyre cases every year, and therefore the potential for importation by this route remains. It is also likely that many of these species could survive in a British climate, and models for *Ae. albopictus* detail the possible areas of the UK where this could occur (Medlock *et al*., 2006).

Previous mosquito nuisance surveys in the UK

In light of the events in Europe, the UK established a mosquito nuisance reporting scheme in 2005 for environmental health officers (EHOs) as a result of collaboration between the Health Protection Agency (HPA), the Chartered Institute of Environmental Health (CIEH) and Killgerm Chemicals. During 2009 the HPA, in collaboration with the University of East London and the CIEH, conducted a questionnaire survey of all UK local authority environmental health departments. It is likely that in the event of an invasive mosquito causing nuisance biting that EHOs will be first to identify an issue.

Three previous surveys have been carried out in the UK to gather information on the extent of mosquito nuisance and the methods employed in mosquito control. These were in 1969-1970 (Service, 1970), 1985-1986 (Snow, 1986) and 1996 (Snow, 1996), and the results of the two most recent surveys are summarised here.

During 1985-6 (Snow, 1986), EHOs at 482 local authorities (LAs) across the UK were consulted, with 328 replies (68%). Eighty-one (25%) LAs indicated that they had received

complaints of mosquito nuisance during the previous 25 years, with 40 (12%) reporting incidences during 1985. The number of cases reported to LAs ranged from 1 to greater than 100, with a mean of seven. Twenty-one LAs had identified the mosquitoes to species, with *Culex pipiens* (including biotype *molestus*) [10] and *Ochlerotatus detritus* [9] considered the main nuisance species. Other species implicated were *Culiseta annulata* [4], *Ochlerotatus cantans* [3], *Anopheles claviger* [2], *Ochlerotatus caspius* [1] and *Ochlerotatus rusticus* [1]. With regard to control, 47 LAs had implemented control programmes against mosquitoes within the last 25 years, with 22 (6.7%) having controlled mosquitoes during 1985. The majority (35/38) considered control successful, basing their success criteria on no further complaints received from the public, a satisfied complainant, and no further mosquitoes apparent to EHOs. Annual costs were only declared in 6 LAs, and ranged from £10 - £4000 (mean £760), with individual treatments costing £11-£40. Only three LAs had specific budgets for mosquito control.

These data showed great similarity to the survey conducted by Service (1970), with 15.2% of LAs indicating nuisance in the last twelve months. Surprisingly 11.2% of LAs indicated nuisance issues and control compared to the much lower 6.7% by Snow (1986). In 1970 the favoured insecticide was DDT, whereas in 1986 it was *Bacillus thuringiensis* var. *israelensis* (Bti) and lecithins.

Snow's second survey in the mid 1990s (Snow, 1996) was circulated to 540 LAs across the UK, with 393 replies (72.7%). Thirty-nine (9.9%) LAs reported mosquito biting nuisance since his last survey (1986-1995), with only 17 (4.3%) during the last year. Twenty LAs identified their nuisance species, with *Oc. detritus* [8] again the main pest species, followed by *Oc. cantans* [4], *Cx. pipiens* form *molestus* [3], *An. claviger* [2], *Cs. annulata, Oc. rusticus, Oc. caspius* [all 1]. Twenty-nine LAs had implemented control in the last 10 years, with 10 (2.5%) controlling mosquitoes in the last year. Bti had been used by 15 LAs, and although mosquito control activities were less than during the 1985 study, annual costs in some cases had increased to a maximum of £20K.

2009 Survey

In order to ascertain the nuisance caused by mosquitoes in the UK, methods of control and the level of activities, a questionnaire was designed and circulated to EHOs within all 347 local authorities in the UK. Each environmental health department, which are responsible for pest control in the UK, was asked a number of questions relating to the incidence of nuisance biting by mosquitoes in the last 12 months (during 2009), and in the last ten years. Additional information was requested on which species were implicated (with details of the source of confirmation), whether aquatic breeding sites for mosquitoes were identified and which sites in their locality were the most likely to support mosquito development. Those reporting mosquito nuisance were also encouraged to answer questions on whether control strategies were employed, which methods were used, whether control was effective, how success was measured and whether the local authority had a specific budget for mosquito control.

Mosquito nuisance incidence

Completed questionnaires were returned from 221 local authorities (64% return) across the UK (194 in England [15 in London, 53 in Midlands, 22 in North East, 33 in North West, 53 in South East, 18 in South West], 9 in Wales, 2 in Scotland, 14 in Northern Ireland and 2 from crown dependencies [Channel Isles, Isle of Man]). Fifty seven (26%) local authorities

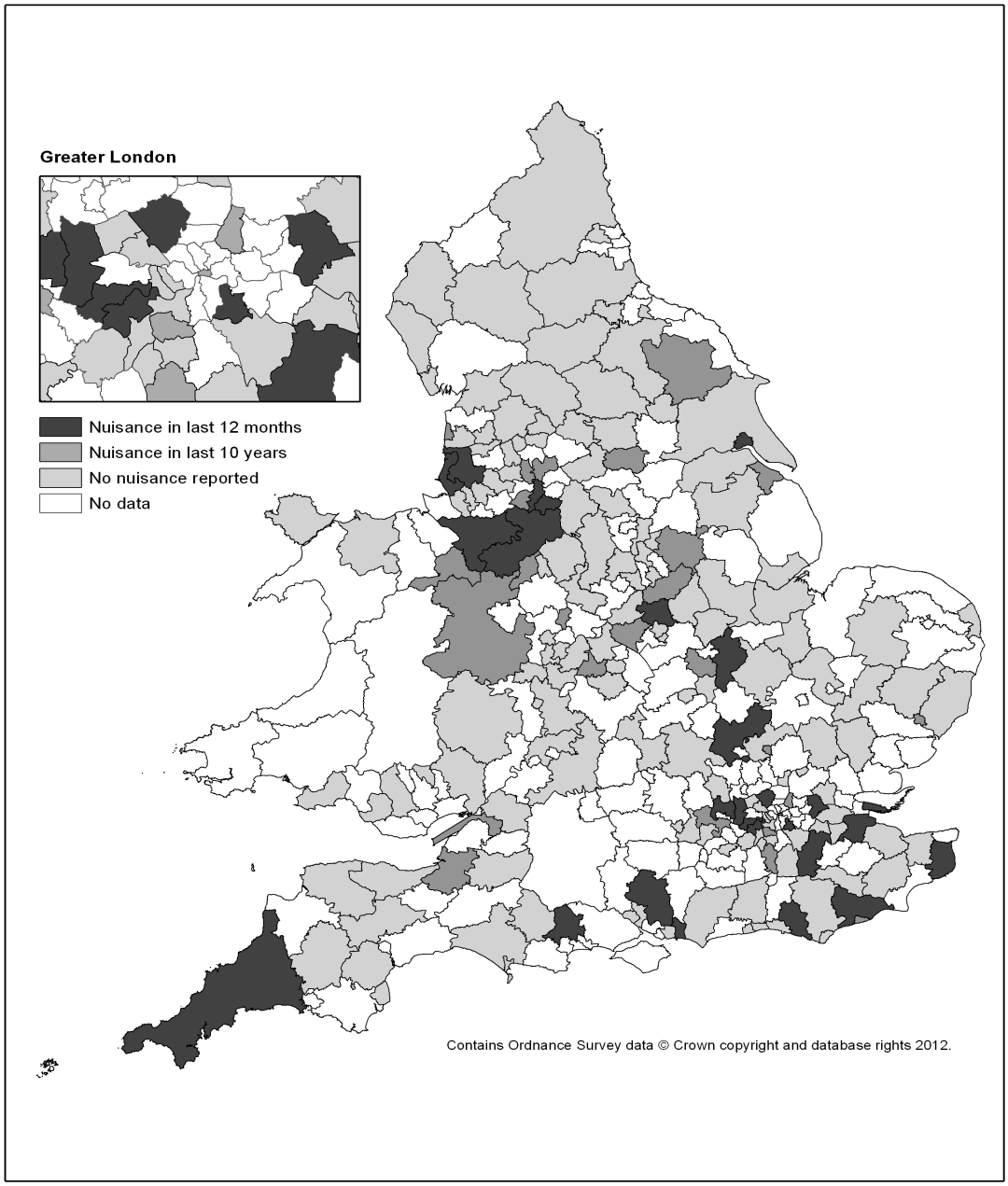
reported evidence of mosquito nuisance incidence having been reported to the environmental health office in the last 10 years (Table 1); 160 reported no issues. Four authorities either provided no response to this question or did not have records that covered the last 10 years.

Table 1. Local authorities reporting nuisance biting by mosquitoes in the last ten years and in the last 12 months (bold, underlined). Reports are arranged by geographic region. The numbers in parentheses indicate numbers of LAs reporting nuisance.

Region	**Local Authorities**
London (9):	LB Merton, **LB Hounslow**, **LB Lewisham**, **LB Hillingdon**, **LB Havering**, City of London, **LB Barnet**, **LB Richmond**, LB Waltham Forest
South East (14):	**Havant**, **Sevenoaks**, **Medway**, **Rother**, Hastings, **Southend**, Windsor & Maidenhead, Reigate & Banstead, Ipswich, Stevenage, **South Buckinghamshire**, **Dover**, **Winchester**, **Mid Bedfordshire**
South West (4):	**Penzance**, **East Dorset**, Bristol, Sedgemoor
Midlands (10):	Kettering, **East Northampton**, Newcastle-under-Lyme, Solihull, **Charnwood**, Rushcliffe, Shropshire, Newark & Sherwood, Hinckley & Bosworth, Cannock Chase
North West (10):	**West Lancashire**, **Manchester**, Bury, **Cheshire East**, Trafford, **Stockport**, Rochdale, **Sefton**, **Ellesmere & Neston**, **Vale Royal**, Blackpool
North East (5):	Ryedale, Wakefield, Northeast Lincolnshire, **Hull**, **Leeds**
Scotland (0):	None
Wales (1):	Wrexham
Northern Ireland (2):	Ards, Limavady
Channel Islands (1):	**Jersey**

Twenty-nine local authorities (13.7%) (Table 1; Figure 1) reported incidence of nuisance biting reported to their environmental health office in the last 12 months. The highest rates of mosquito biting incidence (between 10-99 reports) were reported by four local authorities: London Borough (LB) of Hounslow, Ellesmere & Neston, Hull and Vale Royal. Thirteen LAs reported 2-9 incidences of nuisance biting (Manchester, Havant, Penzance, Cheshire East, Medway, LB Hillingdon, Stockport, Rother, LB Havering, LB Barnet, Dover, Leeds and LB Richmond). Only one incident was reported by 8 LAs (West Lancashire, Jersey, East Northampton, Charnwood, Sefton, East Dorset, Mid Bedfordshire, Winchester). No information on incidence was provided for the remaining four LAs (Sevenoaks, LB Lewisham, South Bucks, Southend).

Figure 1. Local authorities reporting mosquito nuisance. Note: this map is based on post-2009 LA boundaries, so some LAs have been amalgamated since the survey.



Mosquito species implicated

Fourteen LAs reported having sent their mosquito specimens for identification, with seven having had their specimen identifications confirmed by the Mosquito Watch programme (see below). The most common mosquito species implicated were *Cs. annulata, Oc. detritus, Cx. pipiens* (including biotype *molestus*), *Oc. cantans* and *An. maculipennis* s.l.. Details of the LA, mosquito species, and method of confirmation are given in Table 2.

Table 2. Nuisance species identified in 2009 survey.

Local Authority	**Species implicated**	**How identified**
Bristol	*Cs. annulata*	Mosquito Watch
LB Hounslow	*Cs. annulata, Cx. pipiens* s.l. *(*presumably *molestus), An. maculipennis* s.l.	Environmental Health Officer
Manchester	*Cs. annulata, Cx. pipiens* s.l.*, An. maculipennis* s.l.	Mosquito Watch
Wrexham	*Oc. cantans, Cx. pipiens* s.l.*, Cs. annulata, Anopheles* sp.	Mosquito Watch
Havant	*Oc. detritus.* Field studies also found: *An. claviger, An. maculipennis s.l., Da. geniculata, Oc. cantans, Oc. caspius, Oc. rusticus, Cx. pipiens* s.l.*, Cs. annulata, Cs. subochrea*	No details
City of London	*Cx. pipiens* s.l.	Mosquito Watch
Stockport	*Cx. pipiens* s.l.	Mosquito Watch
Rother	Field studies: *Cx. pipiens* s.l.*, Cq. richiardii, Oc. detritus, Cs. annulata, An. maculipennis* s.l.*, Oc. cantans, Oc. annulipes*	Environmental Health Officer/ Health Protection Agency
Ards	Un-named salt-marsh species	Government agency
Blackpool	*Cx. pipiens* s.l.	Consultant epidemiologist
Dover	*Oc. detritus* – considerable nuisance biting associated with species around Sandwich area	Expert medical entomologist
Ellesmere & Neston	*Cx. pipiens* s.l.*, Oc. punctor, Oc. cantans, Oc. detritus*	Local university
Mid Bedfordshire	*Cs. annulata*	Mosquito Watch
LB Richmond	*Cx. pipiens* s.l.	Mosquito Watch

Note: the biotypes of *Cx. pipiens* s.l. were not separated, as they cannot be distinguished morphologically, and no molecular techniques were available for use.

Details of confirmed or probable aquatic habitats for mosquitoes

Twenty-four LAs reported aquatic breeding sites that were considered (but not always confirmed) to be implicated as the source for nuisance mosquitoes. The most common habitats implicated were ponds (7; including urban ornamental and garden ponds), salt-marsh (4) and blocked drainage ditches (4). Other more natural aquatic habitats implicated were areas of standing water (3), woodland pools (2), estuary/river basin (2), marshland, cultivated stream, and urban flooding (all 1). The latter related to large floods in the City of Hull. Local premises/sites were implicated on three occasions: a local water park, a sewage works and an airport. The remaining aquatic habitats were associated with synanthropic settings (each reported once): pot holes, planters, water butts, tyres, gulleys, swimming pools and underground flooded premises.

In order to gauge understanding on the likely aquatic habitats associated with nuisance mosquitoes, each LA was also asked to provide information on possible aquatic habitats within their district (Table 3). 74 LAs responded.

Table 3. Aquatic habitats in which EHOs considered as most likely to support mosquitoes.

Potential aquatic habitats	**Frequency of report**	**Specific comments**
Ponds	17	Included natural ponds as well as garden and ornamental ponds, and duck ponds in parks
Lakes	12	Included meres (there is perhaps little distinction between ponds and lakes)
Marsh/reedbeds	11	Included sites defined as wetland areas.
Wet woodlands	10	Included forestry sites
Watercourses	10	Included rivers, canals (inc. disused) and river basins
Ditches	8	Included drainage ditches and farmland ditches
Bog/Heaths	7	In addition to boggy areas, also included heather peat moorland, heathland and bracken covered fell
Flooded areas	5	Included flooded farmland where farmers seasonally flood the land to kill off insect pests, thus potentially exacerbating mosquito problems
Waterbutts	5	Situated around the home and in allotments
Salt-marshes	4	
Sewage treatments	4	Included water treatment works
Tyres	4	
Other	21	Fishing lakes (3), reservoirs (2), marina/docks (2), sand/gravel pits (2), green urban areas (2), road gulleys (2), estuary/tidal (2), industrial sites (1), scrap metal (1), standing water non ships/vessels from overseas (1), allotments (1), airport (1), buckets in gardens (1)

Mosquito control activities

Despite 57 LAs reporting incidence of nuisance biting in the last 10 years, only 11 LAs have been actively engaged in mosquito control. These were: LB Hounslow, LB Richmond, Manchester, Cheshire East, Bradford, Medway, South Buckinghamshire, Dover, Ellesmere & Neston, Ryedale and Havant. Two LAs (Jersey, Sefton) have engaged in providing advice to residents.

Much of the mosquito control was conducted at sites that are well known or long established as supporting nuisance biting. These include sewage works in SW London (LB Hounslow, LB Richmond), water treatment works in Yorkshire (Bradford), salt-marsh and coastal wetlands in Cheshire (Ellesmere & Neston), Kent (Dover, Medway) and Hampshire (Havant). These coastal wetlands are often protected sites for nature with UK (Site of Special Scientific Interest [SSSI]), European (Special Area of Conservation [SAC], Special Protection Area for Birds [SPA]) and International (i.e. RAMSAR) status. This poses the additional problem of balancing mosquito control with nature conservation. In one case mosquito control was temporarily halted owing to nature conservation concerns. In another case the seasonality of larviciding is limited to the winter months. In some cases local mosquito control has been ongoing for 90 years, and on Hayling Island, this is a legacy of intense mosquito control efforts in the 1920s and 1930s initiated by John Marshall.

All 11 LAs reported having engaged in insecticidal control with three specifically mentioning using of the microbial larvicide Bti. The use of this insecticide for control of other biting flies (*Simulium posticatum*) has also been used along the River Stour in Dorset (North Dorset) (Ladle & Welton, 1996). Other control strategies have included habitat reduction, gulley cleansing, drainage of land, manual ditching, netting, trapping, decommissioning of filter beds, and regular flushing of drains.

Nine of these LAs considered their control efforts effective. They measured their success in various ways. Most LAs reported that the most effective method of determining success was the reduction in nuisance biting complaints (including through a public questionnaire), as well as an observed reduction in the numbers of mosquitoes. One LA conducts specific surveys before and after their insecticide intervention to determine the efficacy of treatment. Six LAs reported having a specific budget for mosquito control; this varied from £50 to £50,000.

Mosquito Watch – nuisance biting reporting system

Mosquito watch was established in 2005 to understand better the incidence of mosquitoes biting humans in the UK by encouraging EHOs to record nuisance mosquitoes and submit samples for free identification. EHOs are required to respond to pest issues and it is possible that they will be the first to identify new mosquito biting nuisance issues that could be related to an invasive species. During five years of the scheme, there were 116 confirmed mosquito reports, with an additional 21 reports associated with other insect groups.

The most commonly reported mosquito species were *Cs. annulata* (56 reports), *Cx. pipiens* (42), *Oc. detritus* (7), non-specific *Ae./Oc.* spp. (7), *Cq. richiardii* (1) and *An. maculipennis* s.l. (1). Further information on nuisance issues were recorded for *Cs. annulata* in 45 instances, and for *Cx. pipiens* s.l. in 39 instances. The majority of nuisance biting issues related to *Cs. annulata* were reported in the Midlands [13], Southeast [12], London [9] and

the Southwest [9]. Fewer instances were reported throughout the rest of the UK: Northeast [3], Scotland [2; as far north as Aberdeen], northwest, Northern Ireland and Wales [all 1]. The majority of reports [37/42] were from nuisance biting indoors. Nuisance reports associated with *Cs. annulata* were recorded from February through to November (no records in May), with peak reports in August [19], July [8], September [8] and October [6].

The geographic data for *Culex pipiens* s.l. is similar for many of the regions of the UK (mostly 3-6 reports for each), except the northwest [13], which is perhaps biased by repeated reports from the Dee estuary. Although reports of indoor nuisance is more common [22/35], there were many reports of nuisance outdoors. However, most of the nuisance reports were in October [13] and September [12], much higher than July [5] and August [4], suggesting that perhaps although nuisance biting was occurring the insects collected for identification and implication were perhaps female *Cx. pipiens* typical form entering houses for hibernation.

Conclusion

Four LAs reported between 10-99 nuisance biting reports. Two of these LAs are located neighbouring the Dee estuary in Cheshire where the local salt-marsh species (i.e., *Oc. detritus*) has been the subject of long-term control strategies. This species is a notable pest in specific locations associated with salt-marsh, with *Oc. detritus* also a significant nuisance close to Sandwich Haven in Kent (Dover Council). The other two LAs were in the London Borough of Hounslow and the City of Hull, The former is attributable to nuisance populations of *Culex pipiens* biotype *molestus*, associated with the local sewage works; again a notable control programme has been employed in recent years. Regarding Hull, the city was subject to extensive flooding during 2007, and the period following this extreme event led to a significant number of nuisance reports to the local authority. Interestingly, following the 2007 floods, calls to NHS (National Health Service) direct phone lines for nuisance mosquitoes increased by 25%. Further investigations should be conducted to ascertain which species were responsible for biting nuisance.

There does not appear to be any evidence of invasive mosquitoes in the UK responsible for nuisance biting. Although there have been a number of press reports of the presence of *Ae. albopictus*, these have always been the native *Cs. annulata*. With respect to endemic species, the incidence of mosquito nuisance does not appear to have reduced between the 2009 and 1986 surveys. Indeed, reports over the last 10 years appear to have increased by 2.6 times since the ten years prior to the 1996 survey. The main species still appear to be *Oc. detritus*, *Cs. annulata* and *Cx. pipiens* biotype *molestus*. It is likely that *Cx. pipiens* typical biotype is being incorrectly implicated in some nuisance biting. The seasonality of some of the reporting of *Cx. pipiens* during the Mosquito Watch survey is coincident with when the *pipiens* biotype enters houses to hibernate in early autumn. This species is not known to bite humans, so it is very unlikely that this species actually causes nuisance, but admittedly will be more conspicuous at this time as it enters dwellings.

Despite the apparent rise in nuisance reporting, fewer LAs are now engaged in mosquito control. This is due to increasing pressure on LAs to reduce spending, and this may begin to impact on monitoring and control activities. This is a concern, particularly in the face of increased reports of invasive mosquito species in Europe, an increase in urban container habitats, sustainable urban drainage and ecological mitigation which will favour endemic species (particularly *Cs. annulata*), and also the impacts of climate change. What is

encouraging is that the knowledge of environmental health officers of suitable mosquito habitats within their districts in very good. When utilised, the free identification service provided by Mosquito Watch has been very effective. Particularly in the case of dealing with suspected invasive mosquitoes. On several occasions there have been news reports of *Ae. albopictus* having been found in the UK, but on every occasion that samples were submitted to the scheme, they were found to be *Cs. annulata*. This species is much larger than *Ae. albopictus*, but its black and white colouration makes it easily confused. On closer inspection this mosquito has many distinguishing features that separate it from all the invasive species. There were some reports from LAs that malicious complaints were made about neighbouring properties harbouring mosquitoes, and it is useful therefore to ascertain whether such reports are actually attributable to mosquitoes, and that they
do constitute a nuisance.

This study also highlighted that nuisance biting was not regularly reported in rural areas associated with sylvatic mosquitoes. As we discussed previously there are many British species associated with natural wetland habitats that can be a nuisance pest. To test whether mosquitoes were a nuisance in rural areas, or whether they were simply accepted as an aspect of rural life, not requiring reporting to the local authority, we (KS) conducted a preliminary study in the rural village of Ongar in Essex.

A survey of mosquito nuisance by oral questionnaire was carried our between 26 and 30 July 2010 in Ongar, Essex at a time of good weather – clear skies, temperatures in the mid 20s centigrade and no rain. One hundred adjacent houses in an area close to identified aquatic sites of *Dahliana geniculata* were selected. Three-hour catches using Mosquito Magnet CO_2 traps were performed between the hours of 10am and 8pm over the 5 days, a trap being sited in the garden of every fourth house, 10m from the rear entrance to the house.

Dahliana geniculata, together with *An. plumbeus, Oc. punctor* and *Oc. cantans* were collected during the survey. The mean catch/trap was 5.2 mosquitoes with a range of 3 to 11. *Dahliana geniculata* accounted for just over 50% of the specimens collected. Thus there was a biting potential in all gardens and all occupants readily accessed their gardens on a daily basis.

However 93% of householders considered that they did not have a mosquito problem, with only 6% replying that they had. When posed with the same question, but by describing mosquitoes as ‘gnats’, 12% considered they had a gnat problem, presumably not knowing that mosquitoes and gnats are the same. When asked whether there were mosquitoes or biting gnats in their area, 74% replied that there were, the remainder presumed that there probably were, but none replied ‘no’. 88% replied that they do get bitten by insects (12% said no), and 70% said that the biting came from gnats or mosquitoes (6% were not sure, and 12% attributed the biting to cat fleas).

A visual inspection of the people answering the questions and anyone else accompanying them revealed evidence of insect biting, almost certainly due to mosquitoes, in 64% of the houses. This is a minimum figure for mosquito nuisance.

What this simple study shows is that in rural areas of Britain, mosquito biting is common, but accepted. It is questionable that most people living in rural areas would actually report nuisance mosquitoes to their environmental health department. It is inferred that reports of biting may considerably underestimate mosquito populations in rural areas of England. In the

event of invasive mosquitoes appearing, it may take some time before such populations are identified as non-native. Perhaps though in urban areas, where insect biting is less tolerated, more nuisance reports occur. There is every possibility that there will be an accidental introduction of a non-indigenous invasive species of mosquito into the UK in the near future and it will be the responsibility of local authorities to deal with such incidents. In many local authorities there do not appear to be any strategies in place to deal with the arrival and identification of non-indigenous mosquito species. There should be a clear set of actions in place with strategies developed for rapid location of sites where control measure should be introduced.

It is also a concern that the number of pest control individuals who have the expertise to deploy effective control strategies is extremely limited. There is an absolute need for a core of individuals distributed throughout the pest control sections of each local authority to have the skills for reacting quickly and effectively to the arrival of an invasive mosquito species. It is clear from the incidence of non-indigenous species arriving in other European countries that early and rapid responses to the mosquito presence are key to the effective control. Any delay in reacting will only increase the likelihood of the permanent establishment of invasive mosquitoes.

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