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The mosquitoes of Epping Forest, Essex, UK

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Abstract

In a survey of mosquitoes conducted in Epping Forest, Essex and the adjoining urban area of Stratford, East London between March 2007 and April 2008, seventeen species of mosquito (Diptera: Culicidae) were recorded. These included typical woodland species such as *Ochlerotatus cantans* and *Ochlerotatus punctor*, which were widely distributed and present in the greatest numbers, as well as more domestic species like *Culex pipiens* and *Culiseta annulata*. All three species of tree-hole-breeding mosquitoes were recorded, including the rare *Orthopodomyia pulcripalpis*. These findings are discussed from an ecological perspective, and mention is made of how habitat management within an ancient forest landscape, such as occurs in Epping Forest, impact on the survival and diversity of British mosquitoes.

Introduction

Epping Forest forms a crescent-shaped belt, about 20km in length, between Epping in Essex in the north and Forest Gate in metropolitan London in the south. The Forest, lying to the north-east of London, covers an area of 2400 hectares, and is largely composed of ancient semi-natural woodland and wood-pasture, as well as old grassland plains and scattered wetlands. It is internationally important, having been one of the first areas of land in Europe attributed conservation status following the Epping Forest Act 1878. Historically it was a hunting ground for British monarchs as far back as Henry VIII (mid-16th century), and has been used for grazing livestock by locals for more than ten centuries. More recently it is a playground for millions of visitors from London and Essex. Its habitats and wild fauna are nationally important, with almost the whole site designated as a Site of Special Scientific Interest, along with evidence of ancient Roman camps designated as Scheduled Ancient Monuments. In total the forest supports 360 Red Data Book (highest British classification for conservation) and nationally notable invertebrate species, one of which is the rare mosquito *Orthopodomyia pulcripalpis*. It also supports nine of the twelve endemic amphibians and reptiles, more than 700 species of fungi, 177 bryophytes and 48 species of breeding bird. It is a relic of the Britain of yester-year, lying less than 10 kilometres from the centre of London.

The dominant habitat within the forest is ancient semi-natural woodland, characterised by groves of over-mature pollards, exemplifying all three wood-pasture types found in Britain: combinations of pedunculate oak (*Quercus robur*) with beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*) and birch (*Betula pendula*). Epping Forest is home to more than 50,000 veteran pollarded trees, many of which are more than 400 years old. The ancient tradition of pollarding involves cutting off branches at a height at which grazing animals underneath are unable to browse the new growth; the tree's life sustained within the ancient trunk known as the bolling. It was a fool proof system that allowed grazing, whilst permitting un-browsed wood to be harvested for fuel and fodder. It left behind a distinctive woodland habitat, with many very old trees that eventually, over time and through decay, produce numerous rot holes and pans. These are, in turn, exploited by many rare invertebrates, which support a diversity of breeding birds.

More recently this ancient system has gone into decline, and the consequent shaded habitat has led to an understorey dominated by holly (*Ilex aquifolium*). Elsewhere in the forest there are lesser numbers of maple (*Acer campestre*), crab apple (*Malus sylvestris*), London plane (*Platanus x hispanica*), wild cherry (*Prunus avium*), ash (*Fraxinus excelsior*), elm (*Ulmus* spp.), horse chestnut (*Aesculus hippocastanum*), sycamore (*Acer pseudoplatanus*), hazel (*Corylus avellana*) and wild service (*Sorbus domestica*); the last named a species indicative of ancient woodland. The undulating and pitted woodland floor, coupled with the varied canopy and nature of the soil, has generated many shaded and partially shaded permanent and temporary woodland pools, further exploited by a different range of invertebrates.

Other habitats within the forest include the open plains comprising acid grassland with areas of heathland, with marshy areas dominated by purple moor-grass (*Molinia caerulea*). There are also areas of mown neutral grassland and open spaces used for recreation. Certain low-lying parts of these grasslands are prone to seasonal flooding, evidenced by the existence of rushes (*Juncus* sp.). The main aquatic habitats are represented

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by numerous bogs, pools and ponds, dotted across the forest with many of the ponds dominated by sweet flag (*Acorus* sp.) and bulrush (*Typha* sp.) and renowned for their considerable botanical and entomological interest.

The main part of the forest lies on high ground between the valleys of the rivers Lea and Roding. Geologically, Epping Forest is dominated by glacial clays consisting largely of London Clay overlaid in places by Claygate Beds, Pebble Gravel, and Boulder Clay, with areas of Bagshot Sands. This provides a mosaic of soil types from neutral soils to acid loams and from impervious clays to well-drained gravels. Because of its proximity to London and the 2012 Olympic site at Stratford, and its popularity for recreational purposes, it was considered important to determine which mosquitoes occur in Epping Forest and to obtain information on their distribution, abundance and life-histories. Snow & Fallis (1982) made the first published survey of the mosquitoes of Epping Forest and a few records are reported by Ross (1913), Lang (1920), Marshall (1938) and Nye (1954).

Methods

Due to the size of the Forest it was not possible to survey it throughout. Instead ten survey areas, each approximately ½km^2, were selected. These are described below and shown in Figure 1.

1. Lower Forest
The most northerly area of Epping Forest consisting of a triangular-shaped woodland together with an adjacent strip of woodland to the south. It is largely dense broadleaved woodland, dominated by hornbeam, ash, oak, birch and holly. There is a permanent pond and a number of temporary pools.

2. 'Wake Arms' area
The site surveyed lies between the London-Epping Road and the road to High Beach. It is wooded throughout and dominated by beech, with examples of oak, birch and holly. No permanent ponds are present but there are numerous shallow temporary pools.

3. High Beach/Rushey Plain
The survey area incorporated Rushey Plain, a large open grassy area and adjoining woodland characterised by large pollarded beech trees and little ground vegetation. There are no permanent ponds, but temporary pools occur along the edges of the wooded area.

4. 'Robin Hood' area
A triangular area extending from the 'Robin Hood' roundabout and delimited by the London-Epping Road and the Loughton Road. There are large temporary pools but no permanent water present. The area is wooded throughout with beech being common and with lesser numbers of oak, hornbeam and birch.

5. Fairmead
A large open area surrounded by woodland characterised by oak, hornbeam and holly. There is one permanent pond and a number of areas liable to winter flooding.

6. Chingford Plain
The area surveyed contains one permanent and one semi-permanent pond. Much of the area is grassland but this adjoins woodland composed mainly of pollarded beech and oak.

7. Lords Bushes
Also called Knighton Wood, this area is isolated from the rest of Epping Forest by residential areas. It is densely wooded with beech, oak and holly mainly. There is a small permanent pond and a number of temporary pools occur in the autumn.

8. Oakhill
The survey area includes open grassland and woodland. Trees present include oak, ash and holly. The prominent feature is a small permanent pond, the surrounding area of which is subject to periodic flooding.

9. Leyton Flats
This area is diverse in its character and includes grassland and open wooded areas (mainly oak), two permanent ponds, several temporary pools and areas subject to flooding.

10. Wanstead Flats
Situated adjoining Forest Gate, this is the southern-most part of Epping Forest. It is a flat grassy area with small numbers of trees, mostly oak, London plane and horse chestnut. There are two permanent ponds but no temporary pools.

In addition a further site was selected in the urban area of Stratford surrounding the University of East London. This area comprised dwellings, a few commercial buildings and some small shops.

The collections and observations reported in this paper were made from 31 March 2007 - 1 April 2008, using the following survey methods:

(a) collection of larvae and pupae by dipping and netting from ponds, ditches, woodland pools, artificial containers and tree-holes (and flooded basements in the urban area)

(b) collection of resting adults using aspirators and sweep-nets

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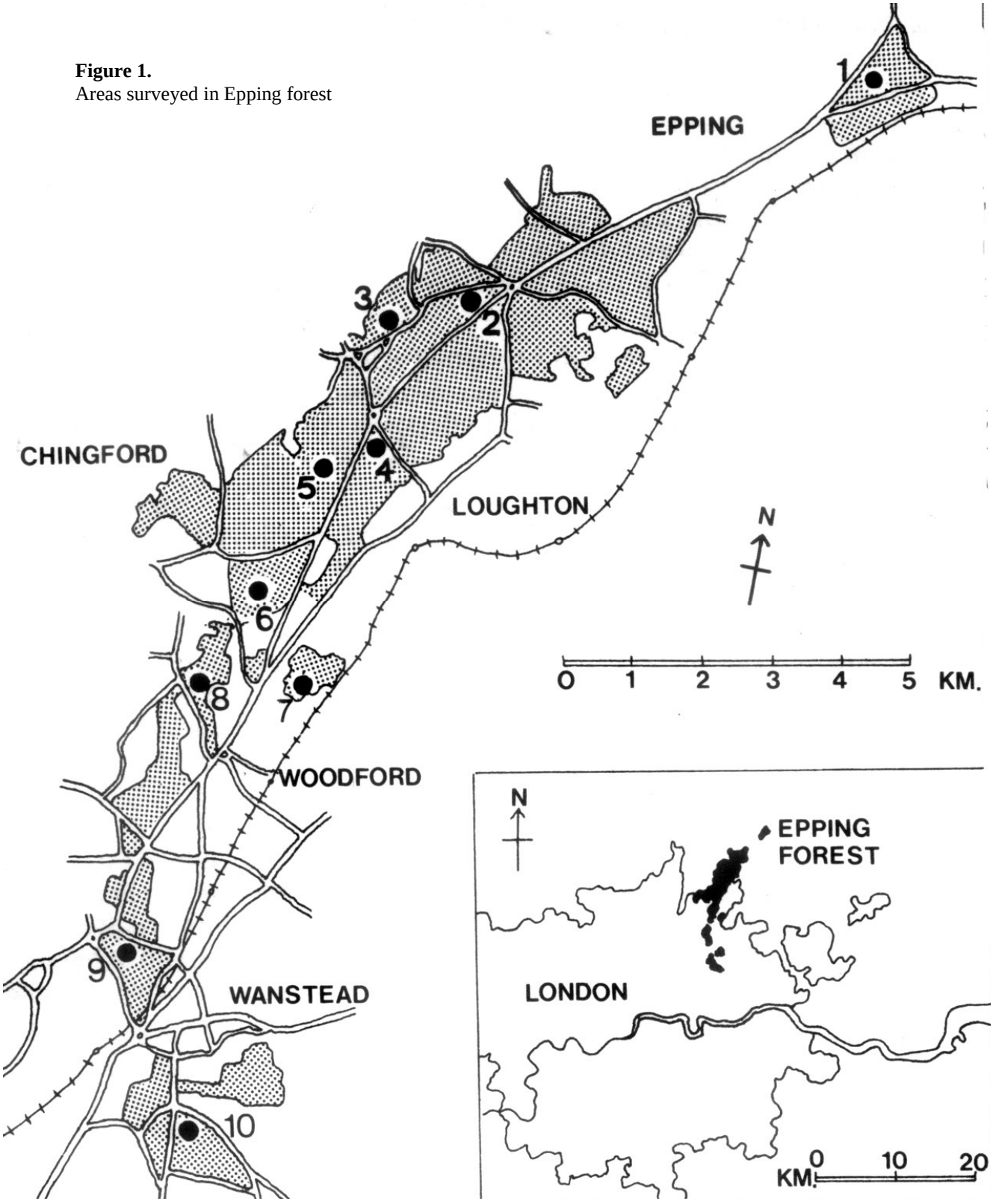
(c) trapping of adult females using carbon dioxide suction traps

(d) netting of females attracted to humans.

Identification was performed on morphological features using the keys of Snow (1990). Differentiation of members of the *Anopheles maculipennis* complex, *An. messeae* and *An. daciae*, and the biotypes of *Culex pipiens*, namely *pipiens* and *molestus*, was not attempted on morphological grounds but was based on behaviour and habitat preference.

Figure 1.
Areas surveyed in Epping forest



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Mosquitoes Recorded in the Present Survey

The species recorded in the present investigation were found in the following locations:

1. Ditches and temporary pools
Ochlerotatus annulipes (Meigen), *Ochlerotatus cantans* (Meigen), *Aedes cinereus* (Meigen), *Ochlerotatus punctor* (Kirby), *Ochlerotatus rusticus* Rossi, *Aedes vexans* (Meigen), *Culex pipiens* biotype *pipiens* (L.), *Culiseta annulata* (Shrank), *Culiseta morsitans* (Theobald), *Culiseta subochrea* (Edwards)

2. Water-filled cavities in trees
Anopheles plumbeus Stephens, *Ochlerotatus geniculatus* (Olivier), *Orthopodomyia pulcripalpis* (Rondani)

3. Water in artificial containers (in rural and urban areas)
Culex pipiens biotype *pipiens*, *Culex torrentium* Martini, *Culiseta annulata*, *Culiseta subochrea*

4. Permanent pools
Anopheles claviger (Meigen), *Anopheles messeae* Falleroni, *Coquillettidia richiardii* (Ficalbi), *Culex pipiens* biotype *pipiens*, *Culex torrentium*, *Culiseta morsitans* (Theobald)

5. Flooded subterranean areas in dwellings in East London
Culex pipiens biotype *molestus* Forskål, *Culiseta annulata*.

Notes on the species with details of their typical ecology and habitat requirements

The general distribution of the mosquitoes recorded in the forest survey can be seen in Table 1. The following notes give information on the location of the species and some details of their life-histories.

Aedes cinereus
The only recorded breeding sites of this uncommon mosquito were the flooded margins of permanent ponds at Oakhill, Leyton Flats and Wanstead Flats. Small populations were found in April to June. These observations agree with those of Marshall (1938) who reports that the winter (and indeed six months of the year) is passed in the egg stage and that larvae appear from April to June. Adults are said to be on the wing from June to August but the only females found in the present survey were all in August. Female *Ae. cinereus* are known to be troublesome biters of humans.

Aedes vexans
This species was found only at Leyton Flats close to the metropolitan London end of the Forest but not in the urban area. Immature stages occupied open, unshaded collections of temporary water and were found only in May and June. Only small numbers of adults were collected, but were causing annoyance among the local residents from May to August. They were found feeding on people up to 3km from the identified development sites.

Anopheles claviger
The Oakhill and 'Wake Arms' areas were the only recorded breeding site for this species. Larvae were found in March and May, and adults were captured in June and July. According to Marshall (1938), unlike *An. maculipennis s.l.*, this species does not hibernate as adults, and as their eggs cannot survive desiccation, they overwinter as larvae, with those surviving hatching from March. Several subsequent populations are typically produced through to late autumn, with aquatic sites chosen where water is more permanent and mostly in shaded situations, such as the margins of lakes and ponds sheltered by trees and among reeds and surface pond weed (*Lemna* sp.).

Anopheles messeae
This species was encountered commonly as resting and overwintering forms in stables in the Leyton Flats area in all months of the year. It was also recorded as females attracted to people in the vicinity of Oakhill from May to September. Eggs and larvae were not found in permanent ponds or other water masses adjacent to these areas. Marshall (1938) states that larvae may be found between April and October, with adults entering complete hibernation, seeking refuge in cool outhouses, cellars and lofts.

Recently another member of the *An. maculipennis* complex has been reported in Britain, namely *An. daciae*, which, like *An. atroparvus* is morphologically indistinguishable from *An. messeae*. As brackish waters, the favoured development sites for *An. atroparvus*, do not occur in the Epping Forest area it was assumed that this species was not present. Although the tentative identification of the specimens recorded is given as *An. messeae*, it is possible that *An. daciae* exists in the area.

Anopheles plumbeus
This tree-hole-breeding mosquito was far less abundant than *Oc. geniculatus* in Epping Forest. Although it was recorded at all sites, including the urban site, it was found in very low numbers as both larvae and adults. In the 'Wake Arms' area it was recorded from only three of the ten tree-holes surveyed and in the High Beach area in only one of the three tree-holes. In Stratford it was found in 5 tree-holes in London plane trees. *Anopheles plumbeus* was recorded as larvae in all months of the year, while adults were found from late April to early October. Unlike *Oc. geniculatus*, the eggs of this mosquito are very

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Table 1.: The mosquitoes recorded in Epping Forest.
An asterisk denotes the presence of the species at that site. The sites are described in the text and their location shown in Figure 1.

Species	Site number									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Aedes cinereus								*	*	*
Aedes vexans									*	
Anopheles claviger		*						*		
Anopheles messeae								*	*	
Anopheles plumbeus	*	*	*	*	*	*	*	*	*	*
Coquillettidia richiardii					*		*			
Culex pipiens	*	*	*	*	*	*	*	*	*	*
Culex torrentium	*	*	*	*	*	*		*		
Culiseta annulata	*	*	*	*	*	*	*	*	*	*
Culiseta morsitans	*							*	*	
Culiseta subochrea		*		*	*		*	*	*	
Ochlerotatus annulipes	*	*	*	*	*	*				
Ochlerotatus cantans	*	*	*	*	*	*	*	*	*	
Ochlerotatus geniculatus	*	*	*	*	*	*	*	*	*	*
Ochlerotatus punctor	*	*	*	*	*	*	*	*	*	
Ochlerotatus rusticus	*	*	*	*	*					
Orthopodomyia pulcripalpis		*	*							

susceptible to desiccation and this species does not do well during periods of protracted drought, with, according to Marshall (1938), particularly dry winters resulting in low population numbers the following year.

Coquillettidia richiardii
This mosquito species develops in permanent pools and the larvae and pupae remain submerged, obtaining their oxygen by penetrating the roots and stems of certain aquatic plants. Larvae were found in two locations only, Fairmead and Lords Bushes in April-June in permanent ponds with reed mace (*Typha* sp.) and sweet flag (*Acorus* sp.), to which the larvae and pupae were attached. In addition this species has been reported elsewhere associated with *Ranunculus* and *Glyceria*. Adults were collected during the survey in July only, and according to Shute (1930) and Service (1968), are seldom on the wing until it is very dark, with males swarming an hour after sunset.

Culex pipiens* biotype *pipiens
Females of this biotype feed on birds and so are not attracted to humans. Eggs, larvae and pupae were collected from shallow collections of ground water as well as from water troughs and other artificial containers. The duration of the larval stages was from April until November. Adults were located in all months of the year, both as active flies from April to October, and as overwintering forms from September to May. *Culex pipiens* is thought to be the most common mosquito in Great Britain and is one of the most widespread in Epping Forest, being found at all sampling sites. It was also recorded in the urban area in Stratford.

Culex pipiens* biotype *molestus
Females of this biotype feed on humans as well as birds, and develop in underground water. It was located in 8 domestic and commercial dwellings in Stratford in basements containing standing water. Larvae, pupae and adults were found in every month of the year. The inhabitants of the dwellings and near neighbours reported biting nuisance all year round, but especially in the summer and autumn.

Culex torrentium
This species is similar to *Cx. pipiens* in almost every respect and occupies the same larval sites, but was found more often in container-water and less commonly in ground water. It has also been reported from tree-holes, but not in the current survey. Larvae were recorded from April until September and adults from May to October in all sites except Lords Bushes, Leyton Flats and Wanstead Flats.

Culiseta annulata
This mosquito was located in all of the areas surveyed, including the urban site. It is a troublesome biter, particularly at dusk, and was found breeding in a variety of habitats including flooded grassland, woodland depressions, artificial accumulations of

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water and flooded basements. Larvae were recorded from May to September only; although Marshall (1938) states that they have been collected in every month of the year. The first adults of the season were on the wing in April and could still be trapped as late as September. Blood-fed females were taken from a number of stables and outbuildings in the High Beach and Leyton Flats areas and houses in the Stratford area in July, September, December and March, verifying that the female is an overwintering stage.

Culiseta morsitans
Only three breeding sites of *Cs. morsitans* were discovered. At Leyton Flats and at Oakhill larvae were recorded from small permanent ponds in April to June of all years. Larvae were also found in a temporary woodland pool at Lower Forest in December to April. According to Marshall (1938) the winter is passed as the larva which may be encountered from September to June. Females are not attracted to humans and were not found by sweeping vegetation. The few adult females that were collected were in June-July 1981 and July 2005. Marshall (1938) records adults from April to August.

Culiseta subochrea
Found at six of the sites surveyed ('Wake Arms', 'Robin Hood', Fairmead, Lords Bushes, Oakhill, Leyton Flats) both as larvae in February to September and adults in April to August. The aquatic habitats are similar to those of *Cs. annulata*, which it resembles very closely.

Ochlerotatus annulipes
This species is typical of the genus with eggs laid in dry ditches and depressions subject to autumn and winter flooding. Typical depressions were in open or partly shaded situations. Larvae were recorded from December to April with adults on the wing from May to August and were readily attracted to people at all times of day, but especially at dusk. It was absent from the urban area and Lords Bushes, Oakhill, Leyton Flats and Wanstead Flats, although suitable sites were present at all but the last of these sites.

Ochlerotatus cantans
This species was found to be one of the most abundant in the woodland areas. Adults were collected at all sites with the exception of Wanstead Flats, where suitable breeding sites were absent. Females were readily attracted to carbon dioxide suction traps and human bait and showed a peak of biting activity around dusk. Males were collected on many occasions by sweeping and were observed resting in low vegetation especially bracken, holly and grass. Larvae and pupae were found, often in high densities, in roadside ditches and temporary woodland pools in partially shaded situations. Marshall (1938) remarked that unlike *Oc. annulipes* which favours open or partly shaded situations, *Oc. cantans* favours densely shaded pools, and that complete removal of bushes around a breeding site can lead to a temporary loss of populations, until the vegetation grows back. In Epping Forest, this distinction in habitat preference between the species was not found. Larval stages of both species were found together, and many of the aquatic sites for *Oc. cantans* were not densely shaded. Certainly the abundance of *Oc. cantans* in the forest might be indicative of the extent of the shaded woodland floor, governed by the maturity of the trees, as well as the profusion of temporary pools. In woodland areas either side of the network of forest roads, the numerous borrow pits excavated to aid road construction, form a myriad of depressions that are subject to winter flooding, providing ideal aquatic sites for all woodland mosquito species. Although less abundant, larvae of *Oc. punctor* and *Oc. rusticus* commonly occurred in the same pools as *Oc. cantans*.

Hatching was normally found to occur from January onwards after autumn and winter rains had filled the ditches and depressions. The first adults emerged in April and larvae were not seen after the middle of May, by which time the pools were drying. The last adults of the season were trapped in mid-September. *Ochlerotatus cantans* is a persistent biter, and was commonly reported biting at ankle height. Its main host in the forest is likely to be rabbit (*Oryctolagus cuniculus*).

Ochlerotatus geniculatus
This species is a troublesome biter in woodland areas and was located at every rural site examined, although in only small numbers. Despite intense searching, breeding sites were found at only seven sites: 'Wake Arms' area, High Beach/Rushey plain, 'Robin Hood' area, Oakhill, Lords Bushes, Wanstead Flats and Chingford Plain. In all but one tree-hole in which mosquitoes were present, *Oc. geniculatus* was the most abundant species. It was found in eight of the ten known water-filled tree-holes in the 'Wake Arms' area and in all three of the tree-holes at High Beach. Females were recorded attempting to bite from April to September and larvae were observed in every month of the year.

Ochlerotatus punctor
This mosquito also breeds in ditches and woodland depressions. At some sites, namely the 'Wake Arms' area, Chingford Plain and at Lords Bushes, *Oc. punctor* was the most numerous species as judged by both larvae and adults. At all the other rural sites, with the exception of Wanstead Flats, it was present, but in lesser numbers. Marshall (1938) reports that aquatic sites are almost exclusively in districts characterised by a sandy or gravelly soil (e.g. water-filled gravel pits), in areas of heath or woods where pine or birch

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predominate (i.e. acid soils). Although much of Epping Forest overlies glacial clays, and therefore exhibits low permeability and a tendency to be acidic, the larvae of other mosquito species were also found in these aquatic sites. Furthermore, in Epping Forest neither pine nor birch predominated in areas where this species was reported. The life-cycle follows a similar pattern to that of *Oc. cantans*, with the eggs, larvae, pupae and adults present at similar times of the year. Females of *Oc. punctor* bite people readily, especially at dusk.

Ochlerotatus rusticus
This species breeds in ditches and woodland pools in shaded situations. Although reported to be a common mosquito in this country it was encountered in only half of the sites (Lower Forest, 'Wake Arms', High Beach, 'Robin Hood', Fairmead). Larvae were recorded in the months of January to May. According to Marshall (1938) the larval season extends from October to June with all instars normally present before the end of December, with larvae found mostly in ditches or woodland pools which are bordered by deciduous trees and hedges. In agreement with Marshall (1938), the adult season was found to be from April to August.

Orthopodomyia pulcripalpis
This rare mosquito was found breeding in tree-holes in the 'Wake Arms' and High Beach areas in association with both *Oc. geniculatus* and *An. plumbeus*. In common with these other tree-hole breeders, larvae were present throughout the year. Females were not attracted to humans or suction traps and the capture of resting adults was in June and July. This species was found in rot holes and pans on veteran beech pollards. Adults, upon emergence, were noted as always flying straight up to the canopy, presumably to feed on birds.

Species Recorded in Other Investigations but not in the present survey

Culiseta fumipennis Stephens. A species which breeds in either temporary pools or the weedy margins of permanent, pools in open situations. Recorded by Nye (1954).

Culiseta litorea Shute. Normally a coastal mosquito but may breed in open pools. Recorded by Nye (1954).

Discussion

The findings of this survey show the presence of 17 species of mosquito in Epping Forest and the adjacent urban area of East London. *Anopheles plumbeus, Cs. annulata* and *Cx. pipiens* (biotypes *pipiens* and *molestus*) were found in urban areas and, of these, all but *Cx. pipiens* biotype *molestus* found also in rural locations. As specimens were identified using morphological criteria only, it was not possible to determine whether individuals of *Cx. pipiens* were biotype *pipiens* or *molestus* with any certainty unless they were developing in underground water and blood-feeding on humans (biotype *molestus*). Similarly the differentiation between *An. messeae* and *An. daciae* was not attempted.

Compared with the earlier survey carried out by Snow & Fallis (1982), *Ae. vexans, Oc. annulipes, Cq. richiardii, Cx. torrentium* and *Cs. subochrea* were located in Epping Forest. Culex *pipiens* biotype *molestus* has been recorded in East London on several occasions (Ramsdale & Snow, 1995).

The diversity of species occurring in Epping Forest reflects the diversity of habitats and the range of habitat requirements of British mosquitoes. Most significantly, the abundance of old wood pasture and old trees, and their associated rot holes and pans, provides innumerable aquatic habitats for all three of Britain's arboreal species (*An. plumbeus, Oc. geniculatus, Or. pulcripalpis*), with *An. plumbeus* also found within more urban areas. Following the cessation of pollarding, many of the veteran pollards are suffering under the weight of their ever increasing crowns. This has led to the creation of new tree-hole aquatic sites following the loss of large branches, and in some cases, the toppling of ancient trees. Tree-hole mosquitoes were also recorded in pans and depressions on these fallen trees. The current management plan involves the re-instatement of pollarding and it will be interesting to see what effect this has on aquatic breeding sites.

The long history and geographic extent of the forest and the associated variability of shade and sunlight reaching the woodland floor provides a range of habitats suitable for Britain's typical woodland species. Marshall (1938) reported clearly defined habitats for the woodland species, with *Oc. cantans* preferring densely shaded woodland pools, *Oc. annulipes* occurring in pools in open and partially shaded situations, *Oc. rusticus* in pools and ditches with abundant leaf litter, and *Oc. punctor* in pools on acid soils, characteristic of sandy and gravelly soil. In Epping Forest, larvae of all the woodland species were found in the same pools, usually filled with leaf litter, and the distinct difference in aquatic sites was not so apparent. Certainly the presence of impermeable clays and the evidence of previous excavations within the forest make this a good site for these species. Notably the adoption by these species of excavated borrow pits associated with roads is a lesson for future road development.

Outside the woodland, areas of the grasslands that are subject to seasonal flooding, particularly in low-lying areas and around permanent pools, provide suitable

habitat for the floodwater specialists *Ae. vexans* and *Ae. cinereus*, both species considered uncommon in Britain. The more permanent water in the many ponds and pools support several species including *An. claviger*, *An. messeae*, *Cs. morsitans* and those with *Acorus* and *Typha* supporting *Cq. richiardii*. Forest management strategies that increase the diversity of permanent and temporary pools are designed to increase the diversity of plant, vertebrate and invertebrate species in the forest. Although these also provide habitats and hosts (e.g. birds) for these mosquitoes, they provide a refuge for their natural predators such as fish, newts and predacious invertebrates (Medlock & Snow, 2008).

The remaining species are less specialised in their habitat requirements, and found throughout a variety of habitats both sylvatic and synanthropic: *Cx. pipiens* biotype *pipiens*, *Cx. torrentium* and *Cs. annulata*.

In urban areas mosquito abundance and diversity is often a product of the number of available container breeding habitats and, in the case of *Cx. pipiens* biotype *molestus*, the availability of basements with standing water. However, in rural areas, particularly in Epping Forest, mosquito diversity is the product of the range of available habitats. Management strategies that maintain and re-instate diverse habitats, such as occurs in Epping Forest, will inevitably lead to the survival of a range of mosquitoes with specialist habitat requirements. After all, mosquitoes are part of our natural invertebrate fauna. However from a public health perspective it is hoped that if they exist within healthy ecosystems, their numbers are brought under control through natural cycles of predation.

The challenge for those individuals involved in managing the countryside will be to conserve habitats, maintain habitat diversity and increase biodiversity whilst ensuring that medically important mosquito species do not become a health concern. This requires a united effort from land managers, ecologists and medical entomologists. It also requires an in-depth knowledge of the life-history of mosquito species, and an understanding of their ecology and their role in complex food chains. Epping Forest, unlike many other wooded areas in Britain, has survived for many centuries, and the mosquito populations surviving here have perhaps been extant for many hundreds of years. The management plan is quite rightly focussed on preserving these existing habitats and re-instating traditional management practices that increase biodiversity, and therefore this study not only provides an insight into how a habitat diverse landscape can support a diverse mosquito fauna, but also illustrates the possible impacts of future habitat creation and enhancement in areas currently less diverse.

Although Britain does not currently experience the same involvement of mosquitoes in the transmission of disease as is the case in other parts of Europe, their potential for involvement in enzootic and bridge vector cycles exist (Medlock *et al*., 2005; Medlock *et al*., 2007). Populations of mosquitoes occurring on the edge of a large city in an area used for recreation, and close to an Olympic village, might therefore be a consideration not only for the future, but also during the planning and preparatory phases of the London Olympics. Endemic species that are known vectors globally should be a consideration, particularly with the influx of international travellers to this part of London. For example, the occurrence of *Aedes vexans*, a vector of Rift Valley fever virus in Africa, occurs at Leyton Flats (<5 km from the Olympic village) and is reported to cause nuisance biting up to 3km from the site. However further studies are required to ascertain the sub-species of *Ae. vexans* occurring in Epping Forest. Furthermore the biting nuisance associated with *Culex pipiens* biotype *molestus* and *Culiseta annulata* in urban areas adjacent to the forest may also need to be considered during the planning and operational stages.

However, with respect to the forest and similar habitats, it is crucial that the impact of habitat creation and management on mosquito populations is more fully understood if we are to ensure that, in the event of such a disease outbreak, appropriate and proportional mitigating strategies are in place. It is of paramount importance that these do not impact negatively on either biodiversity or our ancient protected habitats and landscapes. Such impact though can only be assessed following a fuller understanding of the habitat requirements and ecological niches of our native mosquito species.

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