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SHORT COMMUNICATION

Mosquito Magnet® traps as a potential means of monitoring blackflies of medical and veterinary importance

D. LÓPEZ-PEÑA[1], F. M. HAWKES[2], G. I. GIBSON[2], C. JOHNSTON[3], A. G. C. VAUX[3], Á. LIS-CANTÍN[1], J. M. MEDLOCK[3] and R. A. CHEKE[2]

[1]Entomology and Pest Control Laboratory, Cavanilles Institute for Biodiversity and Evolutionary Biology, University of Valencia (General Studies), Valencia, Spain, [2]Natural Resources Institute, University of Greenwich at Medway, Kent, U.K. and [3]Medical Entomology Group, Emergency Response Department, Public Health England, Salisbury, U.K.

Abstract. Mosquito Magnet® traps, deployed in widespread parts of England as part of nationwide mosquito surveillance projects, also caught blackflies. As many as 1242 blackflies were caught in a trapping session lasting 4 days. Principal among the species caught were *Simulium equinum*, *Simulium lineatum* and *Simulium ornatum s.l.* As *S. ornatum s.l.* is a vector that transmits *Onchocerca linealis* to cattle and *S. equinum* is responsible for dermatitis ('sweet itch') in cattle and horses, it is suggested that Mosquito Magnet® traps could be used to monitor and partially control these pests, as well as nuisance anthropophilic blackflies such as *Simulium posticatum* that can cause simuliidosis in southern England.

Key words. Haematophagous blackflies, traps, *Simulium equinum*, *Simulium lineatum*, *Simulium ornatum*, sweet itch.

There are at least 2331 extant species of blackflies (Diptera: Simuliidae) (Adler, 2020), some of which are vectors of human diseases such as onchocerciasis. In Africa this infection, caused by the filarial worm *Onchocerca volvulus* (Spirurida: Onchocercidae) (Leuckart 1893), is transmitted by members of the *Simulium damnosum* Theobald 1903 complex and by some other blackfly groups, while in Latin America onchocerciasis is spread by numerous other simuliids. In Brazil, Colombia and Guyana, members of the *Simulium amazonicum* Goeldi 1905 group are vectors of mansonellosis caused by *Mansonella ozzardi* (Spirurida: Onchocercidae) Manson 1897. Blackflies also have veterinary importance as vectors of *Onchocerca* spp. to cattle, dogs and wild ungulates, of *Dirofilaria ursi* (Spirurida: Onchocercidae) Yamaguti 1941 to black bears (*Ursus americanus* Pallas 1780 and *Ursus thibetanus japonicus* G. Cuvier 1823), of *Splendidofilaria fallisensis* (Anderson 1954) to ducks and other aquatic birds and of protozoa such as trypanosomes and *Leucocytozoon* spp. (Apicomplexa: Plasmodiidae) to poultry and wild birds (Crosskey, 1990).

Blackflies are not known to transmit any human diseases in the U.K., but 14 species have been recorded biting or molesting people in Britain (Crosskey, 2005). The most notorious of these is the Blandford fly, *Simulium posticatum* Meigen 1838 that is responsible for severe hypersensitive allergic reactions to its bites (simuliidosis) in the valley of the River Stour in Dorset, where its nuisance has required insecticidal control (Ladle & Welton, 1996). *S. posticatum* is also an anthropophilic nuisance in Oxfordshire (McRae & Hill, 1994) and has been recorded from 15 English counties in addition to Dorset and Oxfordshire, as well as in Monmouthshire in Wales (Crosskey *et al.*, 2007). *S. posticatum* has also been implicated in causing simuliidosis in France (Beaucournu-Saguez *et al.*, 1990). Of veterinary significance are members of the *S.* (*Simulium*) *ornatum* Meigen 1818 complex and *S.* (*Simulium*) *reptans* (Linnaeus 1758), which transmit *Onchocerca linealis* (Stiles 1892) to cattle in Wales and elsewhere (McCall & Trees, 1993) and *S.* (*Wilhelmia*) *equinum* (Linnaeus 1758), which also affects cattle and horses by causing a pruritic dermatitis known as 'sweet itch'. Although

Correspondence: R. A. Cheke, Natural Resources Institute, University of Greenwich at Medway, Chatham Maritime, ME4 4TB, UK. E-mail: r.a.cheke@greenwich.ac.uk

this affliction is usually ascribed to biting midges (*Culicoides* spp.; Diptera: Ceratopogonidae), it is known that blackflies are also responsible (Rees, 2004) with *S. equinum* principal among these in the U.K. (Chapman, 2019; and see https://www.centralequinevets.co.uk/FlyControl1535.html) and elsewhere (Pekmezci *et al.*, 2013; Wilkołek *et al.*, 2019). The biting midges tend to target the body, whereas *S. equinum* aims for horses' ears (https://www.sweetitch.co.uk/cause/).

Traps can be used for monitoring and controlling insect populations and their uses for catching blackflies were reviewed by Service (1977). In onchocerciasis-endemic areas, human landing catches have been used extensively (Walsh *et al.*, 1978) but their ethical disadvantages have led to efforts to replace them with traps, with some success using plate traps (Bellec,1976; Cheke *et al.*, 1982), Esperanza window traps (Rodríguez-Pérez *et al.*, 2013; Toé *et al.*, 2014; Hendy *et al.*, 2017) and human decoy traps (B. A. D. Talom, P. Enyong, R. A. Cheke, R. Djouaka & F.M. Hawkes, unpublished data). In contrast, results have been varied with light traps (Walsh, 1978; Service, 1979; Lamberton *et al.*, 2015) and CDC traps (McCall & Trees, 1993; Lamberton *et al.*, 2015). Although it is known that Mosquito Magnet® traps can catch blackflies (Pucci *et al.*, 2003; and see video evidence at https://www.youtube.com/watch?v=sUqRtYVE6-M), no systematic study of these traps' ability to capture blackflies has been conducted to the best of our knowledge. During the course of surveys throughout England as part of a continuing nationwide mosquito surveillance programme for monitoring for invasive and native mosquitoes organized by Public Health England (PHE) (Vaux & Medlock, 2015) and related ecological studies as part of the WetlandLIFE project (Hawkes *et al.*, 2020), Mosquito Magnet® traps were deployed to trap adult mosquitoes. When examining some of the catches it was noticed that numerous blackflies, initially identified as being mostly *S. equinum*, were being trapped (Cheke *et al.*, 2018). Here we document identifications of the blackflies caught during these surveys and suggest that Mosquito Magnet® traps could be used to reduce blackfly populations in discrete areas where they are causing severe problems such as simuliidosis or sweet itch.

Single, or occasionally two, Mosquito Magnet® traps (Executive model; see https://www.midgeguard.co.uk/product/executive/) were deployed at various sites in spring to autumn in 2013 and 2017–2020 inclusive [Table 1; Fig. 1; locations data file (Table S1) and sample data file (Table S2)]. Initial studies were part of surveys on the distribution of *Culex modestus* Ficalbi, 1889 (Vaux *et al.*, 2015), followed by surveys for the WetlandLIFE project in 2017 and 2018 with the concurrent PHE mosquito surveillance programme sampling up to and including 2020. Each trap released carbon dioxide as an attractant by catalytic conversion of butane or propane gas and was additionally baited with an octenol tablet and run continuously for one or more periods of 4 days. After each such catch, the contents of the collection receptacles were taken to a laboratory for sorting. Any adult blackflies found were stored, dry, in refrigerators before being identified using the keys of Davies (1966) and Crosskey (2005), supplemented by information published by Rivosecchi *et al.* (2007). Most species were identifiable by adult external characters, but this cannot be done to separate *S. equinum* from *S.* (*Wilhelmia*) *lineatum* (Meigen 1804). So, this was achieved by examination of the size and shape of a specimen's spermatheca (Crosskey, 2005) after softening for 5–10 min in hot 10% potassium hydroxide (KOH), washing in deionized water (5–10 min), dehydrating in two washes of 80% ethanol (5–10 min each), dissection in 96% ethanol and mounting in Euparal®. It was not possible to do this on all specimens of *S. equinum*/*S. lineatum*, so when numerous such flies were caught sub-samples were dissected and the proportions of each species found were used to estimate the relative abundances of the two species. Even examination of spermathecae does not exclude the possibility of *S.* (*Wilhelmia*) *pseudequinum* Seguy 1921, but we have discounted its presence in our collections since it is rare in England, having only been recorded in one of the rivers close to our traps (the Great Ouse) with other records only from the Stour (Dorset), Kennet (Wiltshire or Berkshire), and various tributaries of the Thames including the Cherwell and the Thame in Oxfordshire (Crosskey, 1981; Williams, 1991; Bass, 1998). Furthermore, during a related study in 2020 involving examinations of aquatic stages of Simuliidae collected close to many of our study sites, no pupae or last-instar larvae of *S. pseudequinum*, which are distinguishable from those of *S. equinum* and *S. lineatum* (Bass, 1998), were found (D. López-Peña & R. A. Cheke, unpublished data). Some of the trapped specimens (Table 1) could not be identified, mostly because they were badly damaged. Figure 1 was created in ArcMap 10.5 (www.esri.com).

The sites and dates of where and when the traps were run at 23 sites, from which non-mosquito catches were examined for blackflies, are listed in the locations file (Table S1). Forty-nine of the 100 catches did not contain any blackflies [for full details of the catches see the sample data file (Table S2)]. Details of the identifications of those that were caught (total 5165) in the remaining catches are given in Table 1. Between 1 and 1242 blackflies were caught per sample (for each sample the traps were run for 4 days), including a few males (Table S2). The highest catch, at Bedford Priory Country Park in May 2017, included all three of the most common species: *S. equinum* (989 caught), *S. lineatum* (247) and *S. ornatum* (4), but even more *S. equinum* (1048) were caught at Gamston in June 2020, in the absence of *S. lineatum*. The highest catch of *S. ornatum* (103) was at the same site in May 2020, and the maximum catch of *S. lineatum* (419) was at Ringwood in October 2018.

The results showed that more than a thousand *S. equinum*, the species incriminated with causing sweet itch, can be caught in Mosquito Magnet traps in a 4 day period and that more than a hundred *S. ornatum s.l.*, a vector of *Onchocerca linealis* to British cattle, can be trapped in the same way. Given that these totals were secured at sites where the traps were targeting mosquitoes, it is likely that they could be much higher if the traps were deployed where blackflies are abundant. Thus, it would be instructive to test their efficacy in trapping the highly anthropophilic 'Blandford fly' *S. posticatum* along the banks of the River Stour, Dorset, in April to June when its adults are most active, or at sites where *S. equinum*, *S. ornatum* or other mammalophilic species were troubling livestock. Under such circumstances, it is possible that the traps could serve as partial control agents, at least by reducing blackfly biting to tolerable levels.

Table 1. Numbers of different species of blackflies identified according to sample location and dates

Location codes (Fig. 1)	Sample numbers (Table S1)	Location	Dates	*S. equinum*/ *S. lineatum*		Estimated *S. equinum*	Estimated *S. lineatum*	*S. ornatum*	Other species	Total
				M	F	F	F	F		
2	2–6, 9, 11	Bedford Fenlake Meadows	15/05–3/11/2017		246 (41)	222	24	18	3 *Simulium* sp. 2 *S. noelleri*	269
3	12	Bedford Millennium Country Park	6–10/08/2018					1		1
4	15–21, 23, 24	Bedford Priory Country Park	15/05–22/09/2017	9	1645 (55)	1315	330	4	1 *Simulium* sp.	1659
6	28	Brandon Marsh (near Coventry)	03–06/04/2018		28 (10)	28			1 *Simulium* sp.	29
8	30	Chippenham Fen	03–06/04/2018		2 (2)	1	1	16		18
10	32	Gamston	06–10/08/2018		425 (10)	425		25	5*S. aureum*, 26 *Simulium* sp.	481
10	33, 34	Gamston	18/05–5/6/2020	9	1159 (40)	1159		139	8 *Simulium* sp.	1315
11	36, 37, 39, 40, 43, 44	Greywell (back trap)	29/5–21/09/2018		9 (9)	6	3	34		43
12	46–49, 55	Greywell (Front Trap)	14/05–21/092018		52 (20)	42	10	11		63
13	57, 59–61	Hurcott middle dam	16/05–15/06/2018		48 (20)	8	40	67		115
14	63, 65	Hurcott Perriford Lane	16/05–15/06/2018		11 (5)	8	3	7		18
16	73, 75, 78, 81	Northward Hill 1	12/05–13/10/2017		2 (2)	2		12		14
17	83	Northward Hill 2	17–21/07/2017					1		1
18	88, 89	Norwich	18/05–19/06/2020		57 (22)	57		42	25 *Simulium* sp.	124
20	91, 92	Ringwood	29/05–19/10/2018	11	918 (20)	100	818		1 *Simulium* sp.	930
23	95, 96, 99	Weymouth Radipole Lake	05/06–16/08/2018		85 (21)	85				85

Numbers in brackets after numbers of females of *S. equinum*/*S. lineatum* refer to the numbers of insects in sub-samples which were identified according to the appearance of their spermathecae. The estimated numbers of *S. equinum* and *S. lineatum* are based on the proportions of each found in the sub-samples.
F, female; M, male.

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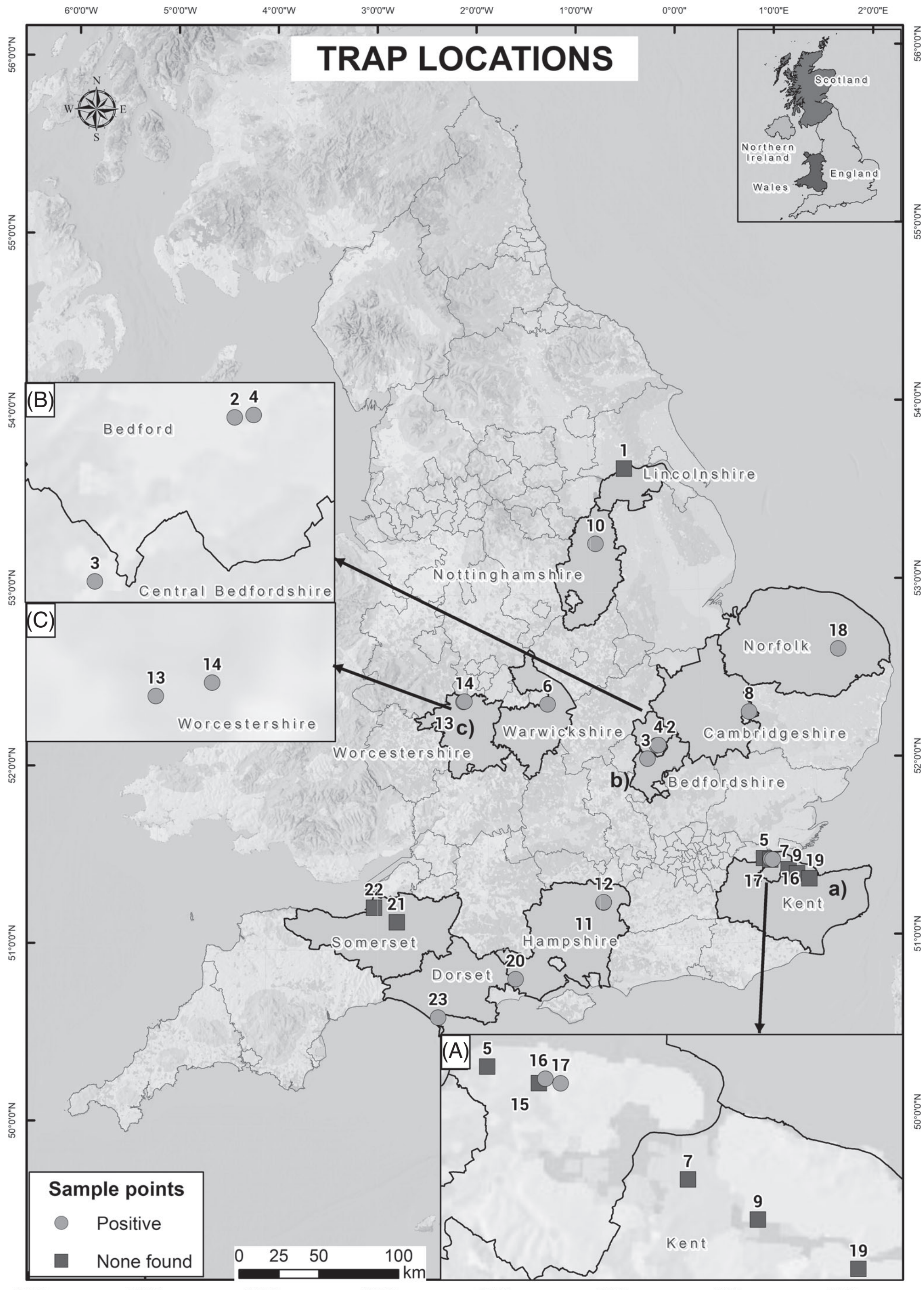

Fig. 1. Map showing the locations of study sites in England. Circles indicate sites where blackflies were trapped, squares where none were found. Site codes and coordinates are as follows: 1. Alkborough (53°41′42″N, 00°39′39″W); 2. Bedford Fenlake Meadows (52°07′44″N, 00°26′28″W); 3. Bedford Millennium Country Park (52°03′22″N, 00°31′57″W); 4. Bedford Priory Country Park (52°07′49″N, 00°25′41″W); 5. Boatrick House, Cliffe (51°28′09″N, 00°29′18″E); 6. Brandon Marsh, near Coventry (52°22′38″N, 01°26′08″W); 7. Chetney (51°23′56″N, 00°42′19″E); 8. Chippenham Fen (52°17′54″N, 00°25′02″E); 9. Elmley Barn (51°22′25″N, 00°46′51″E); 10. Gamston (53°16′33″N, 00°57′05″W); 11. Greywell (back trap) (51°15′08″N, 00°58′16″W); 12. Greywell (front trap) (51°15′16″N, 00°58′07″W); 13. Hurcott middle dam (52°23′56″N, 02°12′35″W); 14. Hurcott Perriford Lane (52°24′02″N, 02°12′04″W); 15. Northward Hill (51°27′34″N, 00°32′38″E); 16. Northward Hill 1 (51°27′45″N, 00°33′02″E); 17. Northward Hill 2 (51°27′35″N, 00°34′01″E); 18. Norwich (52°37′36″N, 01°16′08″E); 19. Oare Marshes (51°20′34″N, 00°53′20″E); 20. Ringwood (50°49′55″N, 01°46′22″W); 21. Shapwick Heath (51°09′32″N, 02°49′41″W); 22. Steart (52°12′15″N, 03°03′07″W); 23. Weymouth, Radipole Lake (50°37′12″N, 02°27′55″W).

We did not find any unusual species or unexpected species among our catches. However, since Crosskey (2005) remarked that *S. lineatum* is absent from Essex, Hertfordshire, Kent, London, Surrey and Sussex, it is worth noting that we only found *S. equinum* and *S. ornatum* in Kent, consistent with Crosskey's statement. *Simulium ornatum* comprises a species complex with at least four cytoforms occurring in the U.K. (Post, 1980), but they are identifiable only by cytotaxonomy based on larval chromosomes, so we cannot confirm which variety or varieties were among our catches. Of the other species that we caught, only *S. noelleri* Friederichs 1920 is known to be anthropophilic (Crosskey, 2005).

No or very few blackflies were caught at some sites, presumably because the traps at sites such as Bedford Millennium Country Park, Chippenham Fen, Boatrick House and the three Northward Hill localities were located considerable distances away from rivers suitable for blackfly breeding, whereas sites where many blackflies were trapped (e.g. Gamston, Bedford Priory Country Park and Ringwood) were close to such rivers. Nevertheless, much of the variability can also be ascribed to seasonal factors and population dynamics. For instance, in southern England, both *S. equinum* and *S. lineatum* may have four generations a year (Bass, 1998). In addition, some fluctuations were attributable to inclement weather and occasional trap breakdowns.

In addition to their potential value in the U.K., Mosquito Magnet® traps could prove to be useful for monitoring and partial control of nuisance blackflies in many other countries. In addition they could, potentially, be used to target onchocerciasis vectors in Africa and the Yemen, but their cost and the need for supplies of butane or propane gas and octenol tablets, together with transport expenses, may be prohibitive in resource-poor settings.

Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 Locations where traps were deployed and whether any adult Simuliidae were caught or not.

Table S2 Numbers of different species of blackflies identified according to sample location and dates.

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Data availability statement

All data are contained in Table 1 and Supporting Information Tables S1 and S2.

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