Received: 10 May 2023 | Accepted: 22 November 2023

DOI: 10.1111/mve.12703

ORIGINAL ARTICLE

Medical and Veterinary Entomology

Ornithomya biloba, *Pseudolynchia garzettae* and *Pseudolynchia canariensis* (Diptera: Hippoboscidae): three new United Kingdom colonists and potential disease vectors

Denise C. Wawman

Edward Grey Institute, Department of Biology, University of Oxford, Oxford, UK

Correspondence
Denise C. Wawman, Edward Grey Institute, Department of Biology, University of Oxford, South Parks Road, Oxford, OX1 3RB, UK.
Email: denise.wawman@biology.ox.ac.uk

Associate Editor: Karen C. Poh

Abstract

In the northern hemisphere, many species' ranges are shifting northwards with climate change. Here I present evidence, from the first large-scale citizen science study of the Hippoboscidae in the United Kingdom, for the colonisation of the United Kingdom by three species of Diptera in the family Hippoboscidae, which are obligate ectoparasites of birds. The Swallow Louse Fly, *Ornithomya biloba*; the Nightjar Louse Fly, *Pseudolynchia garzettae* and the Pigeon Louse Fly, *Pseudolynchia canariensis* were previously considered to be vagrants from more southerly latitudes but the presence of a pair taken possibly in the act of copulation, gravid females and the increase in numbers of the various species provides good evidence of local breeding activity. I discuss the potential for further northwards range shift and whether the presence of three new species of parasite may have implications for the spread of avian disease within the region. I also include a concise key to the genus *Pseudolynchia* and images of *P. canariensis*, *P. garzettae* and *O. biloba* to aid further identification of these species in the region.

KEYWORDS
avian parasites, citizen science, colonisation, ectoparasites, flat fly, key, louse fly, parasites, range change, range expansion

INTRODUCTION

Colonisation is the establishment of a species where it has not lived previously. Initial colonists generally arrive in small numbers and may fail to reach the numbers required to maintain an established population due to abiotic factors, lack of suitable habitat, the presence of predators and low population density leading to difficulty finding a mate and decreased genetic variability (Chuang & Peterson, 2016; MacArthur & Wilson, 1967). Although the definitions are in many ways artificial (Hoffmann & Courchamp, 2016), species are usually only considered invasive if they were introduced by man and subsequently cause harm. Many insect species have changed their ranges in response to climate change, for example, bumblebees (Soroye et al., 2020) and butterflies (Minter et al., 2020), but changes in parasite ranges, such as ticks, are less often studied and are complicated by their interaction with range changes of their hosts (Nuttall, 2021).

The Hippoboscidae are a neglected taxon of haematophagous ectoparasitic Diptera, which are difficult to study as they are rarely encountered away from their hosts, large mammals and birds. The species found on mammals are known colloquially as keds, whereas those found on birds are known as louse flies in most of the world but as flat flies in the United Kingdom (Hutson, 1984). However, phylogenetic analysis has shown that division by host species is artificial as some of the louse flies found on birds, including *Pseudolynchia canariensis*, are more closely related to the keds on mammals than the other louse flies (Petersen et al., 2007). Here, the terms louse fly and ked will be used to refer to the flies parasitising the different host groups,

birds and mammals, respectively, and Hippoboscidae/Hippoboscids to refer to the whole family.

With the exception of some of the keds in the genus *Melophagus*, the Hippoboscidae spend part of their life cycle away from their hosts as puparia, either in abandoned nests of their bird hosts or on the ground. Such a lifecycle means their range is restricted by abiotic factors such as temperature and levels of precipitation: the emergence of louse flies is temperature dependent, with low winter temperatures proving lethal or causing delayed emergence (Corbet, 1956; Kennedy et al., 1975; Klei & Degiusti, 1975; Walker & Rotherham, 2010b), and louse flies of the genus *Ornithoica* were found to be more prevalent on juvenile North Island Robins, *Petroica australis longipes*, in wetter territories (Berggren, 2005). With climate change, some species of Hippoboscidae have expanded their European range. The ked, *Lipoptena fortisetosa*, originally thought to have been introduced on Sika Deer, *Cervus nippon*, was first recorded in the Czech Republic in 1967 and has now spread as far west as Estonia (Kurina et al., 2019), and the Deer Ked, *Lipoptena cervi*, has also shifted its range further north and is now found on Moose *Alces alces* in Finland as well as on several species of deer (Kaunisto et al., 2011).

While some louse flies have little direct effect on their hosts (Walker & Rotherham, 2010a), *P. canariensis* infestation increases the time pigeons spend preening, using energy and reducing the time available for foraging, predator surveillance and courtship (Waite et al., 2012), and may cause emaciation in heavily infested birds (Reeves & Lloyd, 2019). Some louse flies are known to be competent vectors of avian malaria (Baker, 1967; Cepeda et al., 2019) and a range of other pathogens have been isolated from Hippoboscids, including some with zoonotic potential, although in most cases, their status as a specific vector has not been proven (Bezerra-Santos & Otranto, 2020). While most species of louse fly rarely bite humans, bites from *P. canariensis* can cause skin irritation (Reeves & Lloyd, 2019).

In Europe and North Africa, *Ornithomya biloba* (Diptera: Hippoboscidae) is usually found on the Barn Swallow *Hirundo rustica*, rarely on bird eating raptors and occasionally on other Hirundines: House Martin *Delichon urbica*, Sand Martin *Riparia riparia* and Crag Martin *Ptyonoprogne rupestris* (Hill et al., 1964; Hutson, 1981, 1984). It has been found as far north as Skane in Sweden (Hill et al., 1964). This species was recorded in the United Kingdom on four occasions prior to 2020 (Table 1) and was considered a vagrant by Hutson, as it had only been found on early Swallows despite being common on Swallows in France, including at Cap Gris Nez on the English Channel coast (Hutson, 1984), and being recorded on Guernsey in the Channel Islands in 1968 (Guernsey Biological Records Centre, pers. comm.). In one study of *O. biloba* in Czechia, 18.7% were found to contain trypanosomes and were considered to be competent vectors by the authors, although this was not proven (Santolíková et al., 2022).

Despite *P. canariensis* having an almost worldwide distribution in tropical and temperate regions, in association with its main host, the feral or domestic pigeon *Columba livia domestica*, and some of the raptors that prey on them (Haeselbarth et al., 1966; Maa, 1969; Sychra et al., 2020), the first and only previously published record in the United Kingdom was of a fly in Isleworth, London on the 6 October 2020 (Harrow, 2021). This is despite large numbers of feral pigeons living in UK cities, with the most recent reliable estimate suggesting a population of c0.85 million +/−0.2 million in London alone (Taylor, 2013) and there being 42,000 people across the United Kingdom, including in London, who keep and race pigeons (Pigeon Racing UK & Ireland, 2023). *Pseudolynchia canariensis* is a proven vector of *Haemoproteus columbae* (Cepeda et al., 2019).

The main range of *Pseudolynchia garzettae* is central and east Africa, but it has been previously recorded in France, Switzerland, Cyprus, Thailand, Taiwan and the Philippines (Maa, 1969; Nartshuk et al., 2019). It is usually found on nightjars, including the species *Caprimulgus europaeus* (Nightjar) found in the United Kingdom, but has also been found on a range of other species, including owls and buzzards (Haeselbarth et al., 1966). The only previous UK record of *P. garzettae* is that of a specimen found in a museum in Coventry, labelled '31.5.1912, off Nightjar, Hants', which had previously been misidentified as *Ornithomya fringillina* (Palmer, 1987).

Here I provide evidence for colonisation of the United Kingdom by these three species of avian ectoparasites, two of which were collected as part of the Mapping the UK's Flat Flies Project, a study involving British Trust for Ornithology licensed bird ringers, and the third identified from photographs on the internet. I discuss the potential for further range expansion by these species and how this may lead to an increase in avian diseases. I also include photographs of all three species and a simple key to the genus *Pseudolynchia* in the region, as, although these species are included in a recent key to species in Europe (Oboňa et al., 2022), the genus is not comprehensively covered in the commonly used guide to Hippoboscidae in the United Kingdom (Hutson, 1984).

MATERIALS AND METHODS

In 2021 and 2022, following a pilot study in 2020, British Trust for Ornithology (BTO) licensed bird ringers were recruited as expert

TABLE 1 Previous records of *Ornithomya biloba* in the United Kingdom.

Date	Place	Host	References
6 June 1964	Rye Meads, Hertfordshire	Swallow	Lloyd-Evans (1967)
25 May 1970	Spurn, Yorkshire	Swallow	Hutson (1984) Harry E. Beaumont pers. comm.
June 1972	Connel, Argyll	Swallow	Hutson (1984) Hugh Insley pers. comm.
7 October 2007	Icklesham, East Sussex	Paddyfield Warbler *Acrocephalus agricola*	Mark Grantham, pers. comm.

citizen scientists to take part in the Mapping the United Kingdom's Flat Fly Project, via appeals the BTO's publication 'Lifecycle' and on the social media sites Twitter (www.twitter.com, last accessed 25 September 2023) and Facebook (www.facebook.com, last accessed 25 September 2023), as well as direct approaches to bird observatories, ringing groups and individual bird ringers.

Each volunteer was sent a collecting kit containing pots for catching flies, uniquely numbered 2 mL tubes, 70% ethanol (diluted with distilled water and containing no other excipients), pipettes, instructions, recording sheets, a data consent form, a risk assessment for the ethanol and a stamped addressed envelope to return samples. Further supplies were posted to participants as required. Other bird ringers who were not part of the project, including those in Ireland, were also able to submit flies for inclusion in the study.

Collecting was limited to those flies that left birds during normal bird processing due to UK ringing licensing conditions (animal welfare considerations). Ringers were asked to collect all possible flies and return them at the end of the season with the following metadata: site name, Ordnance Survey Grid Reference, altitude and, if known, the species, age, sex and moult status of the host bird, using BTO codes (Redfern & Clark, 2001), and the number of flies seen on and collected from each host.

Louse flies were identified to species level, using a binocular microscope, following a key (Hutson, 1984) with additional information as required (Hutson, 1981; Maa, 1964, 1966; Maa & Petersen, 1987).

Additional records were collected in the author's role as national recorder for the Hippoboscidae as part of a new recording scheme which started in November 2020. The recording scheme uses the website iRecord (https://irecord.org.uk last accessed 25 September 2023) but also receives data from iNaturalist (https://www.inaturalist.org last accessed 25 September 2023). Some records were found on Twitter. The total numbers of Swallows and Nightjars ringed were obtained from the 'BTO online ringing report' (Robinson et al., 2022).

Grid references were checked on the website Curaera (www.cucaera.co.uk/grp last accessed 25 September 2023), and Ordnance Survey Grid References were converted to latitude and longitude using the website Batch Convert Tool (https://gridreferencefinder.com/batchConvert/batchConvert.php, last accessed 25 September 2023), for Great Britain and the Isle of Man and Batch Coordinate Converter (http://ww2.scenictours.co.uk/serve.php?t=WoNlbJvoVlhuJL5405objaa8jVO8atNuwZV, last accessed 25 July 2022) for Ireland.

Graphs and maps were plotted in R version 4.2.1 (R Development Core Team, 2022) with the packages maps (Becker et al., 2022), mapdata (Becker et al., 2018) and scales (Wickham & Seidel, 2022). Kernel densities were calculated and plotted using the package adehabitatHR (Calenge, 2006).

To determine the exact status of the species in the United Kingdom, a literature search, including peer reviewed and grey literature and websites, was performed using each of the terms, '*Ornithomya biloba*', '*Ornithomyia biloba*' (*Ornithomyia* being a previously used spelling for the genus [Maa, 1965]), '*Pseudolynchia*', '*Pseudolynchia canariensis*' or '*Pseudolynchia garzettae*', in combination with each of the following 'United Kingdom', 'Great Britain', 'Ireland', 'England', 'Wales', 'Scotland', 'Northern', 'Ireland', 'British', 'Irish', 'English', 'Scottish' and 'Welsh', using the search engines Google (www.google.com, last accessed 25 March 2023), Google Scholar (https://scholar.google.com, last accessed 25 March 2023) and Bodleian Solo (https://solo.bodleian.ox.ac.uk, last accessed 25 March 2023). Historical data were obtained from Local Environmental Records Centres, museums, GBIF, iRecord, iNaturalist, bird observatory and bird ringing groups' reports. Contact was also made with authors of previous studies to check their current understanding of the status of these species (A.M. Hutson, Harry E. Beaumont, pers. comms.).

RESULTS

A total of 2597 louse flies from 104 species of bird were received from over 140 bird ringers, ringing groups and bird observatories, at sites in 279 unique 10 km squares (Figure 1), across the United Kingdom, Isle of Man and Ireland (the region) as the BTO ringing scheme covers the whole region, and bird ringers in Ireland were keen to take part. This article focuses only on the new breeding species recorded in the region, and the results of the main study will be published in due course.

Ornithomya biloba (Dufour, 1827)

The mapping project yielded 13 new specimens (Table 2 and Figure 2a,b). Unlike the previous records from Hirundines, these all occurred within their hosts' breeding seasons or autumn migrations. Although reverse migration (López-Calderón et al., 2021) of birds from Continental Europe cannot be completely ruled out, it is unusual and most of the bird ringers who caught the specimens at coastal sites were sure, from a combination of weather conditions, local knowledge and the recovery histories of birds controlled on the same day as those caught with ectoparasites, that these were mostly local or UK breeding birds (Clare Buckle, Tony Cross and Phil Jones, pers. comms.). One pair of flies was taken 'tangled together' (Clare Buckle, pers. comms.) possibly in the act of copulation.

Pseudolynchia sp.

There is one UK record of '*Pseudolynchia*' in the records supplied by the Warwickshire Biological Records Centre, from a rural area adjacent to Solihull, from May 2014 to September 2014. Unfortunately, there is no further information, which would allow this record to be verified or determined to species level.

Pseudolynchia canariensis (Macquart, 1839)

Three new records have been added. All were found as misidentified flies on Twitter (one) and iNaturalist (two; Table 3 and Figure 2c). The

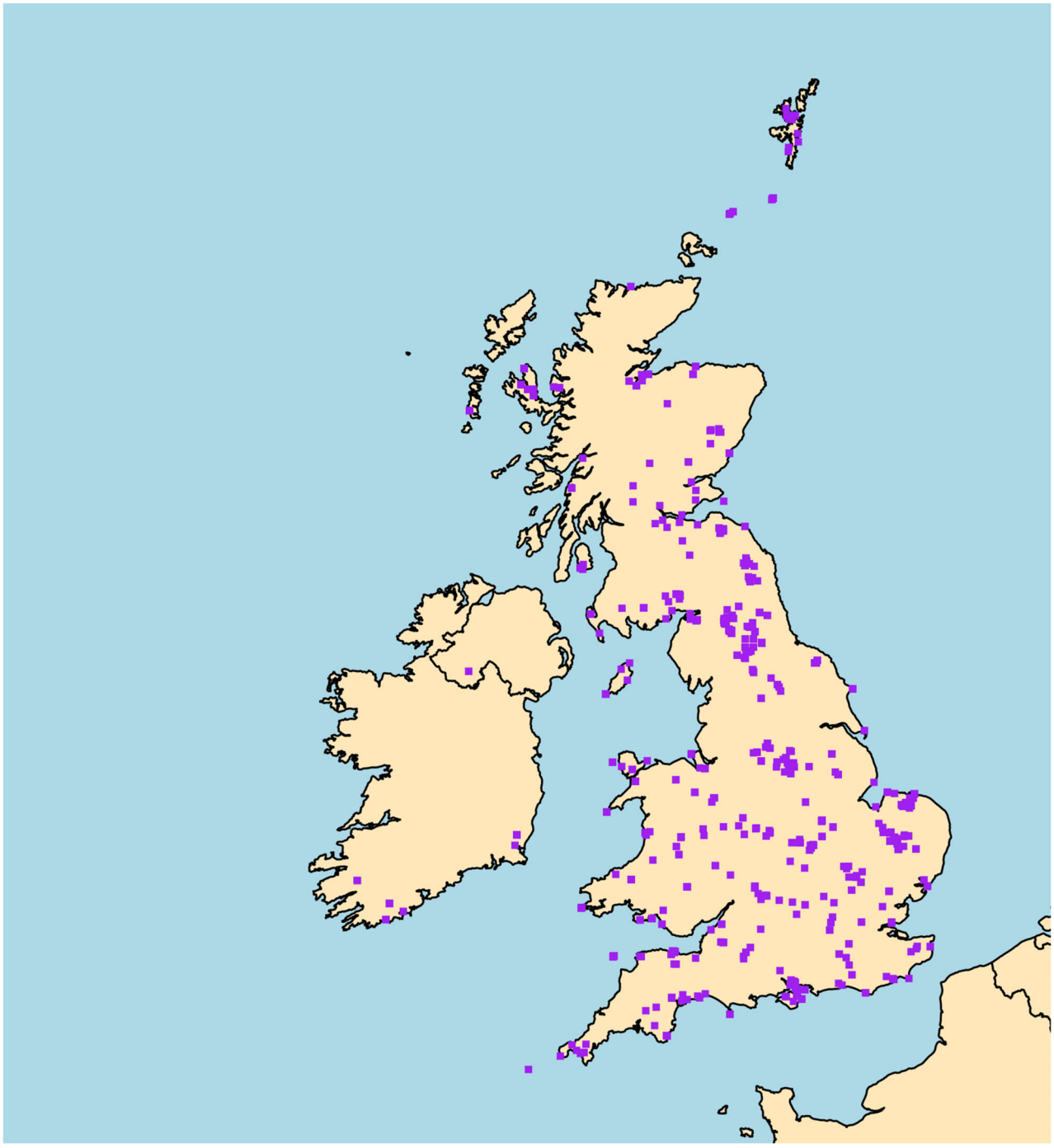

FIGURE 1 Sites at which ectoparasites were collected for the Mapping the UK's flat fly project.

fly found by D.F. Huerta (Figure 6b) has a very rounded, pale abdomen, which may indicate that it is a gravid female but this is impossible to confirm from the photograph.

All records of this species have been of free-flying individuals in the London area, the new records falling within a relatively small area of Inner London. There are no records of flies found in association with a host, usually the feral pigeon or domestic pigeon *Columba livia domestica*. This is not unexpected as pigeon fanciers treat their birds for parasites and feral pigeons are not included in the BTO ringing scheme.

Pseudolynchia garzettae (Rondani, 1879)

The mapping project found three more specimens of *P. garzettae*, all female, two of which were gravid (Table 4 and Figure 2d).

TABLE 2 New records of *Ornithomya biloba* in the United Kingdom.

Date	Place	Host	Finder	Sex/breeding status
8 July 2021	Culverwell, Portland Bill, Dorset	Swallow	Mark Cutts	Female
3 August 2021	Cors Ddyga, Anglesey	Swallow	Rachel Taylor	Female
23 August 2022	Icklesham, East Sussex	Sand Martin	Rye Bay Ringing Group	Male
24 August 2022	Icklesham, East Sussex	Sand Martin	Rye Bay Ringing Group	Female
25 August 2022	Icklesham, East Sussex	Swallow	Rye Bay Ringing Group	Two females on same bird
25 August 2022	Borth Bog, Ynyslas, Dyfed	Swallow	Mid-Wales Ringing Group	Male
26 August 2022	Icklesham, East Sussex	Unknown	Rye Bay Ringing Group	Female
1 September 2022	Avenue Washlands Nature Reserve, Derbyshire	Swallow	Bryn Roberts	Female
19 September 2022	Stanford Reservoir, Northamptonshire	Swallow	Stanford Ringing Group	Female
19 September 2022	Lundy Island, Devon	Swallow	Lundy Field Society	Male
3 October 2022	Hope Bottom, East Sussex	Swallow	Clare Buckle	Male and female? in copula

DISCUSSION

A 2-year study, in which volunteer BTO licensed bird ringers collected bird ectoparasites, found evidence that three species of louse fly, which were previously considered to be vagrants in the United Kingdom, are now breeding in the region. The study added 13 new records of *O. biloba*, including a possible mating pair, to the previous UK total of four. Three new specimens of *P. garzettae*, including two gravid females, were found in Wales, this being a species which had only been recorded once before in southern England. In addition, records from the internet added three new records of *P. canariensis*, from the Inner London area, bringing the UK total to four.

Some of the flies in the genus *Pseudolynchia* have been previously misidentified by recorders, as evidenced by the online records of *P. canariensis* and the historical misidentification of the only previous UK specimen of *P. garzettae* (Palmer, 1987). Misidentification is more likely to occur with flies in the genus *Pseudolynchia* as they are not illustrated in the most widely used identification guide (Hutson, 1984) and this may partially account for some of the recent increase in observations.

As this is the first large-scale study of louse flies in the United Kingdom undertaken at a large number of sites over a short period of time, it is impossible to say whether these species have been present, and have gone undetected, or whether they are recently arrived, although earlier systematic work in the 1950s and 1960s by entomologists and museum curators (see Supplementary Materials), who examined large numbers of louse flies, collected over previous decades, did not find evidence of these species. Neither did smaller more intense studies of single species of flies or single host species nor studies from single sites such as those found in bird observatory annual reports. A list of the important studies reviewed but not cited in this text is included in the Supplementary Materials. It is unlikely that multiple studies in the 1950s and 1960s would have missed species entirely if they were present in significant numbers but small localised populations on infrequently studied species of bird host could have gone undetected, especially as most louse flies are seen by bird ringers who are usually more interested in the host than its parasites.

Pseudolynchia garzettae might easily go unnoticed in the United Kingdom: its main host, the Nightjar, is a crepuscular summer migrant, unlikely to be found near human habitation, and only small numbers are ringed each year (Figure 3), with fewer than 10 ringed in most years before 1965 and recent annual totals of only between 500 and 600 (Robinson et al., 2022). Bird ringers monitoring Nightjars are usually working outdoors, in poor light or in the dark when it would be hard to spot parasites leaving their host and difficult to catch them.

Conversely, *O. biloba* should have been detected if it was present in the United Kingdom. The numbers of its main host, the Swallow, ringed each year are similar now, at roughly 20,000 birds per year, to those ringed during the heyday of UK louse fly studies in the 1960s (Figure 4) and were much higher during the intervening period. *Ornithomya biloba* is relatively easy to distinguish from the other species of *Ornithomya* present in the region (Figures 5a, 6a and 7a) and is illustrated in Hutson's guide (Hutson, 1984), although caution is needed to separate it from other potential vagrants such as *O. roubaudi*, which is yet to be recorded in the United Kingdom. It therefore seems likely that *O. biloba* is a new colonist rather than a previously overlooked species. It also seems unlikely that a major infestation of *P. canariensis* could have gone unreported in domestic pigeons in the United Kingdom for any length of time, but large numbers of ectoparasites could survive undetected on feral pigeons as these are rarely handled. The detection of several free-flying individuals would suggest a much larger population as these flies are rarely seen away from their hosts.

The probability of successful long-term colonisation by a species is proportional to the original population size, birth rate and death rate of the species and carrying capacity of the environment (MacArthur & Wilson, 1967). In the case of parasites, the carrying capacity of the environment is the availability of suitable hosts. Thus further range expansion by *P. garzettae* in the United Kingdom is likely to be limited by the low population density of its main host the Nightjar. In contrast, *P. canariensis* has a readily available supply of its preferred host the feral or domestic pigeon, which is common in urban areas throughout the country, and its wild ancestor, the Rock Dove, found

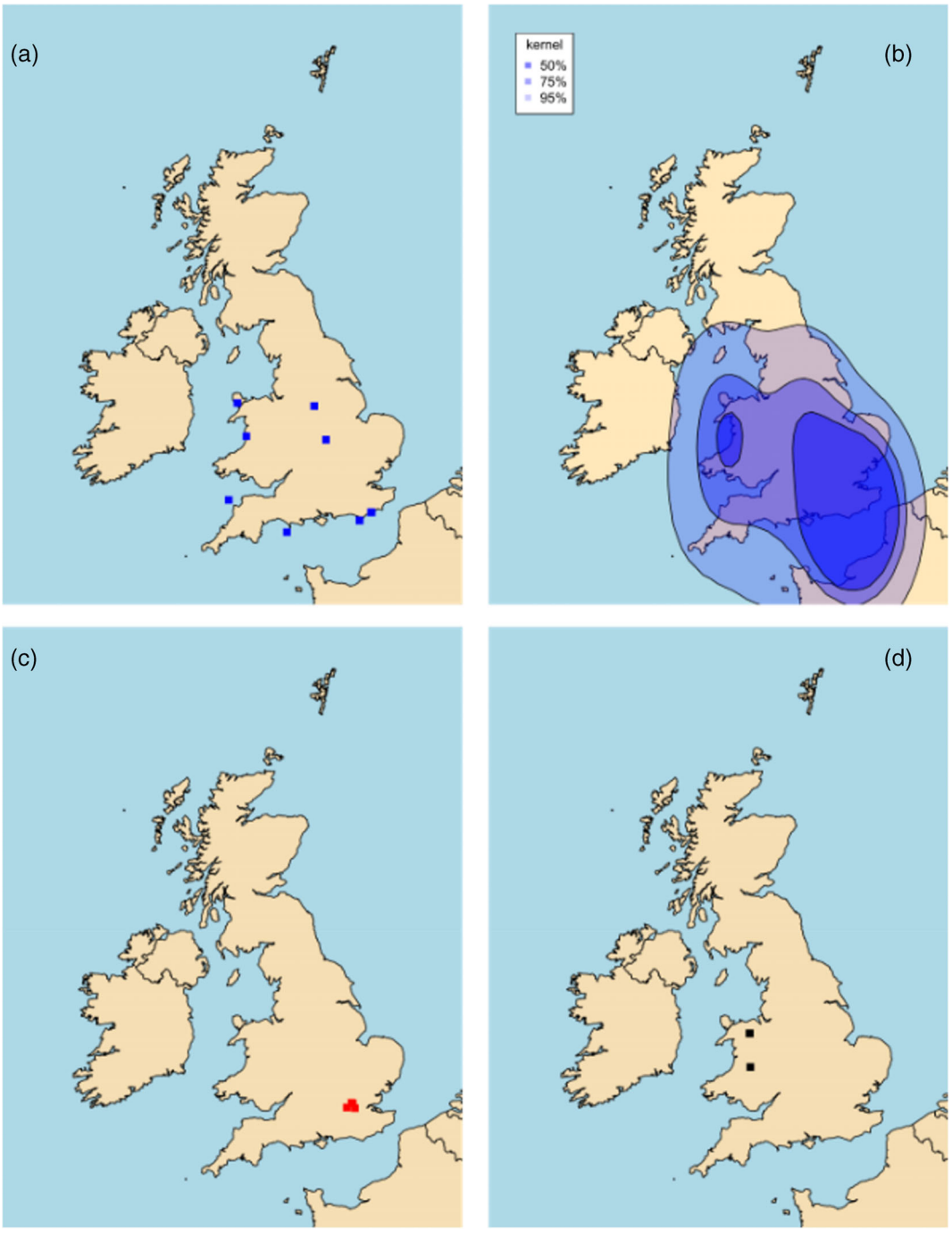

FIGURE 2 Maps showing (a) the locations of new *Ornithomya biloba* specimens and (b) their kernel densities at 50%, 75% and 95% probabilities. (c) Map of new records of *Pseudolynchia canariensis*. (d) Map of the locations of new specimens of *Pseudolynchia garzettae*.

TABLE 3 New records of *Pseudolynchia canariensis*.

Date	Place	Host	Source of data	Finder/Licence
5 September 2022	Waldram Cresent, Forest Hill, Dulwich, Inner London	Free-flying	iNaturalist	David Fernández Huerta CC-BY-NC
28 October 2022	Hampstead, London Borough of Camden, Inner London	Free-flying	Twitter	Rory Dimond
14 November 2022	Camden Square, London Borough of Camden, Inner London	Free-flying	iRecord via iNaturalist	'lamaureen' CC-BY-NC

TABLE 4 New UK records of *Pseudolynchia garzettae*.

Date	Place	Host	Finder	Sex breeding status
11 July 2022	Gors-y-wern. Clocaenog Forest	Nightjar	Mid-Wales Ringing Group	Female
27 July 2022	Clywedog Reservoir, Clocaenog Forest	Nightjar	Mid-Wales Ringing Group	Female Gravid
7 August 2022	Waun Marteg, near Rhayader	Nightjar	Mid-Wales Ringing Group	Female Gravid

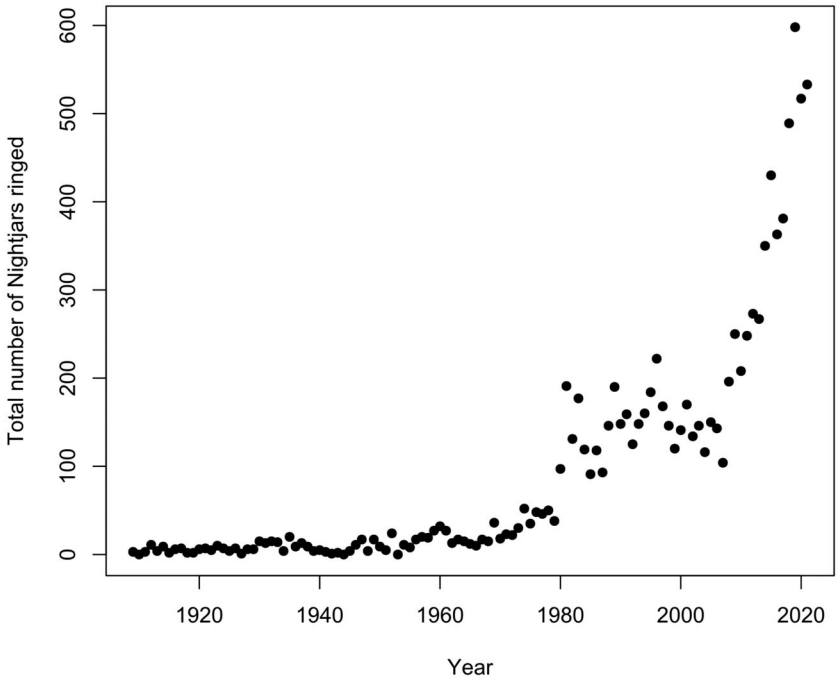

FIGURE 3 Total number of Nightjars ringed in the United Kingdom, Ireland and the Isle of Man, per year. Data from the BTO online ringing and nest recording report (Robinson et al., 2022).

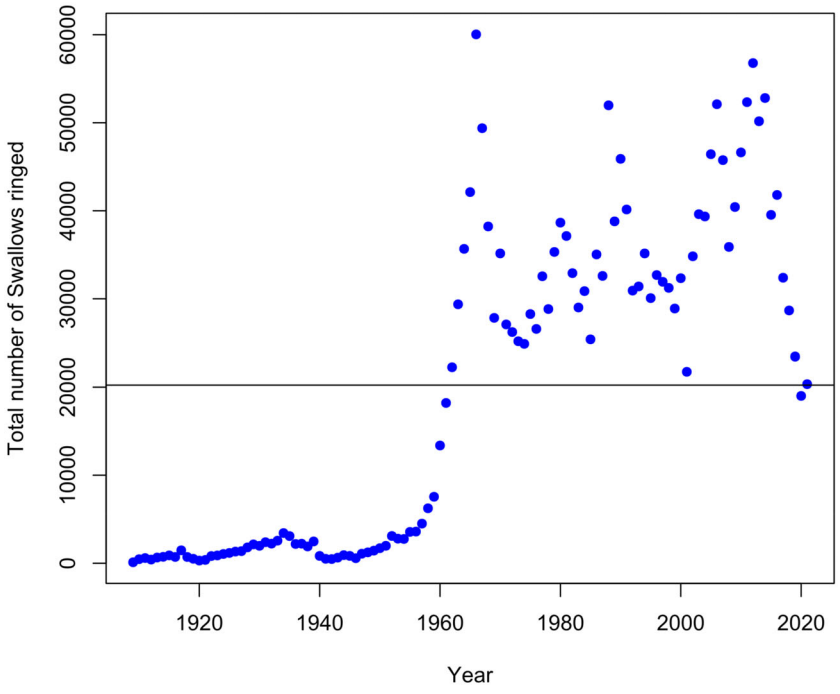

FIGURE 4 Total number of Swallows ringed in the United Kingdom, Ireland and the Isle of Man, per year. The horizontal line represents the total number of Swallows ringed in 2021, the first year of the main study. Data from the BTO online ringing and nest recording report (Robinson et al., 2022).

on remote Scottish Islands (Smith et al., 2022). The Swallow, the main host of *O. biloba*, breeds across the United Kingdom, being absent from only a few areas of central London and northern Scotland (Balmer et al., 2013).

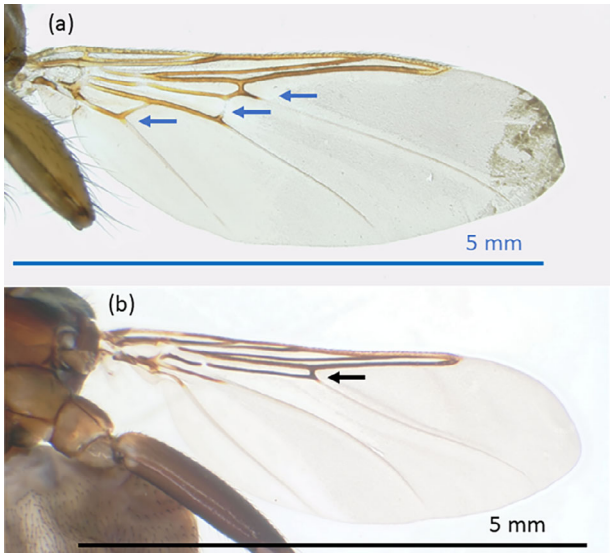

FIGURE 5 (a) Wing of *Ornithomya biloba*: note the three cross-veins, indicated by arrows, one of which rarely fills. This contrasts with the single cross-vein seen in (b) the wing of *Pseudolynchia garzettae*.

However, host ranges place only a partial limitation on the ranges of these species of flies because of their potential to switch host species. Despite its widely used common name suggesting host specificity, the Pigeon Louse Fly *P. canariensis* has been found on many other avian species: Maa reported *P. canariensis* from 33 genera of birds across 13 families (Maa, 1969), and Sychra et al. found it on a further six species of birds in five families in South Africa (Sychra et al., 2020). *Pseudolynchia canariensis* has been found living on urban, but not rural, Woodpigeons *Columba palumbis* in Spain (Gutiérrez-Galán & Martínez-Fernández, 2023) and it is possible that, as Woodpigeons are migrants (Snow, 1953), they could help *P. canariensis* spread across the United Kingdom. Across its range, *P. garzettae* has been found on 14 genera of birds of seven families (Maa, 1969) although it has only been recorded on Nightjar in the United Kingdom. Elsewhere in Europe, *O. biloba* has been recorded on all three species of Hirundine, which breed in the United Kingdom (Hutson, 1981) and on Sparrowhawk *Accipiter nisus* (Hill et al., 1964). In the United Kingdom, it had only previously been recorded on Swallow, with the records presented here from Sand Martin and Paddyfield Warbler *Acrocephalus agricola*, representing new host records for the country.

Although the UK's native species of louse flies undergo a winter diapause (Corbet, 1956; Hill, 1963; Walker & Rotherham, 2010b), which limits them to one generation a year, *O. biloba* has both diapausing and non-diapausing generations (Kennedy et al., 1975), and adult *P. canariensis* emerge after only 25–31 days when kept at laboratory temperature (Coatney, 1931). In good conditions, these shorter

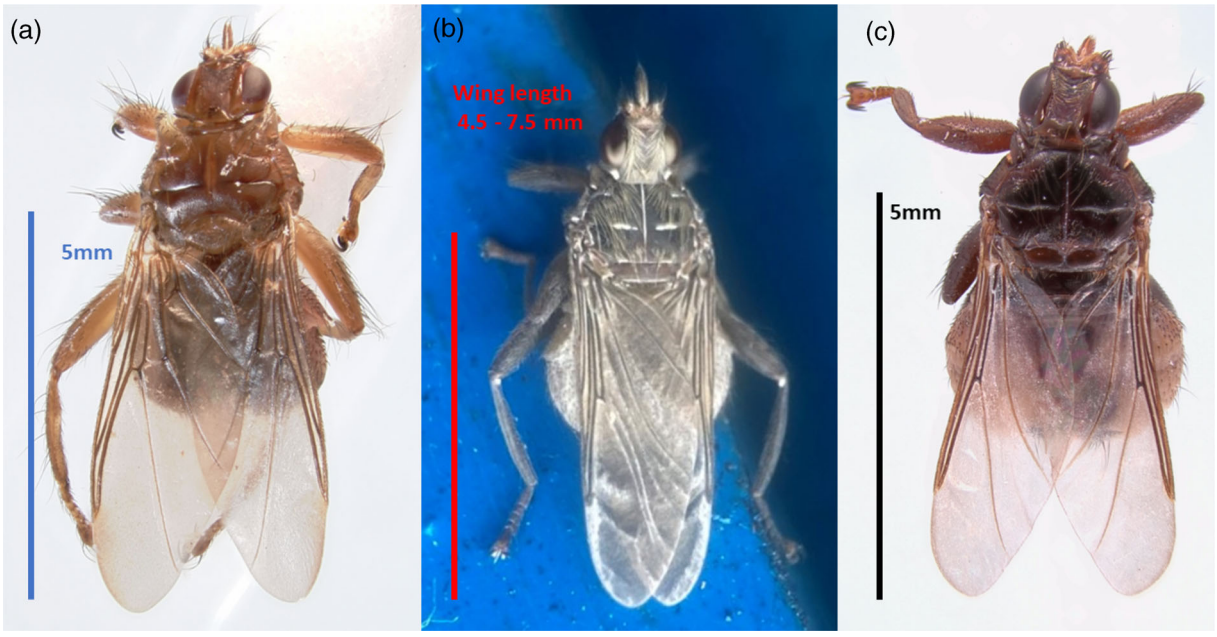

FIGURE 6 (a) *Ornithomya biloba*. Note the presence of multiple bristles on the scutellum, which are not restricted to a single row near the posterior edge as they are in the other species of *Ornithomya* in the region (shown in more detail in Figure 7a). (b) *Pseudolynchia canariensis*. Note the rectangular scutellum and pale bristles on the thorax. The very rounded, pale abdomen suggests that this might be a gravid female, but this cannot be confirmed without a more detailed examination of the specimen. The wing length is indicated as the known range for the species (Maa, 1966) because the specimen was not measured. Image reproduced with permission © David Fernández Huerta, 2022. (c) *Pseudolynchia garzettae*. The scutellum is rounded posteriorly, and the bristles on the thorax appear black in a live fly and are shown in more detail in Figure 7b. All images reproduced with permission.

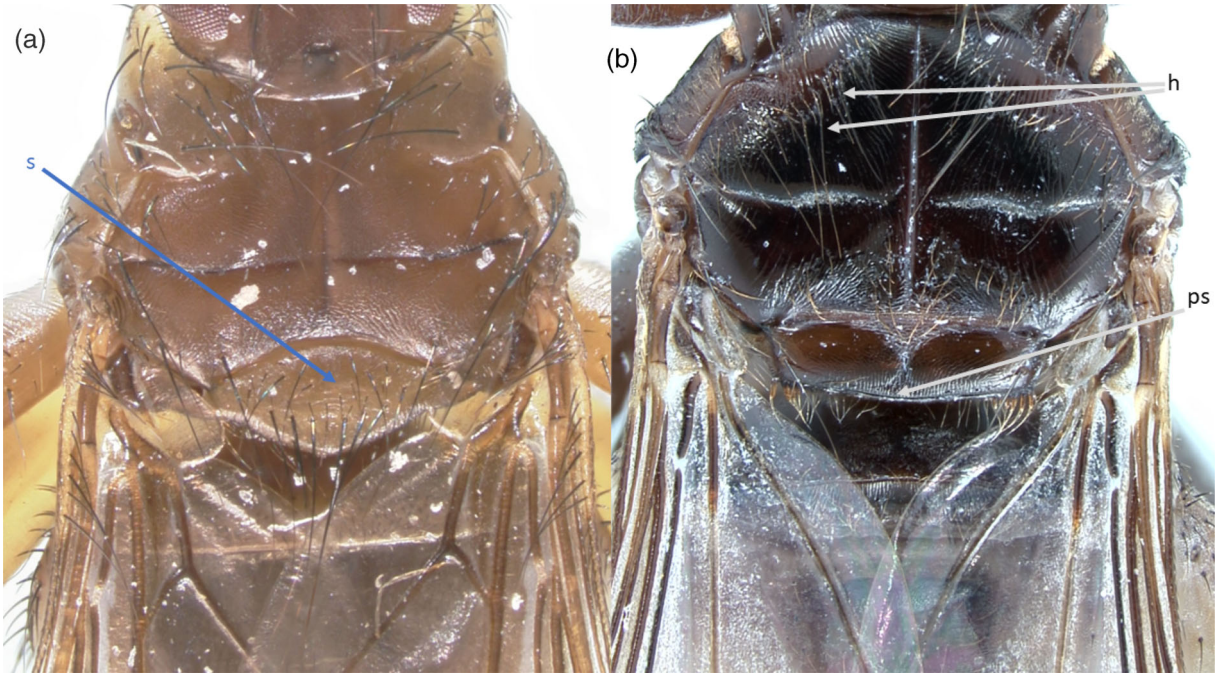

FIGURE 7 Detail of thorax, (a) *Ornithomya biloba* and (b) *Pseudolynchia garzettae* highlighting key identification features. (a) The arrow labelled 's' indicates the scutellum of *O. biloba* with multiple bristles that are not restricted to a single row as they are in the other species of *Ornithomya* in the region. (b) Note the rounded edge to the scutellum of *P. garzettae* indicated by 'ps' and the dark bristles on the anterior thorax 'h'—in real life, these are dark, but the colour has been adjusted to highlight them. Images reproduced with permission.

generation times could allow a rapid increase in numbers, helping these species to establish new populations.

Conversely, factors that decrease survival may prevent further range expansion. *Pseudolynchia canariensis* is likely to be limited by abiotic factors such as winter temperatures in rural areas: the puparia die after more than 20 days at temperatures of 13°C or lower (Klei & Degiusti, 1975), but the puparia could survive in pigeon lofts where pigeon racing enthusiasts keep their birds. Adult flies can survive for up to 86 days, although the mean is only 17 or 18 days (Arcoverde et al., 2009), so it is also possible that small numbers of adult flies could survive cold periods on adult pigeons, either on domestic birds that are not treated for ectoparasites or feral pigeons. The increased temperatures in urban heat islands may help *P. canariensis* to survive in cities, but changes in humidity due to urbanisation (LaDeau et al., 2015) and pollution (Buczek et al., 2014) have been shown to limit the spread of some arthropod vectors within an urban setting and might limit its spread. The puparia of *O. biloba* could survive overwinter in sheltered Swallow nests in buildings, especially as they have been shown to develop most rapidly at 11°C under laboratory conditions (Kennedy et al., 1975).

Combining what is known of these parasites' lifecycles may allow us to predict which of these three species are most likely to successfully expand their ranges in the United Kingdom. The shorter generation times and widespread availability of suitable hosts, that nest in buildings or within urban heat islands, could allow *O. biloba* and *P. canariensis* to rapidly colonise the region, with *O. biloba* having a greater advantage as the puparia survive at lower temperatures. Gaps in our knowledge of the biology of *P. garzettae* make it more difficult to predict the long-term outcome for this species in the United Kingdom, but the lower population density of its hosts that live in rural areas, away from urban heat islands, may limit the spread of this species outside of its main range in Africa.

Even though the Hippoboscidae are unlikely to transfer disease to humans, their role as vectors of avian malaria within bird populations could be important. The presence of additional species of haematophagous ectoparasite might increase the potential for disease transmission, and the risks of emergent avian diseases and zoonoses, especially when their hosts are long distance migrants with large geographical ranges, like Nightjars, Swallows and Sand Martins, or species living in close association with humans such as pigeons. We would do well to continue to monitor the ranges of these ectoparasites carefully and explore their potential as disease vectors, and this will form the basis of future research.

SIMPLIFIED KEY TO THE GENUS PSEUDOLYNCHIA IN THE UNITED KINGDOM

Fully developed wings with one cross-vein (Figure 5b), large eyes. On birds.

> Rectangular scutellum, approximately four times as wide as it is long, with a distinct, straight posterior edge. 20 or more long, pale setae on thorax (Figure 6b). Usually on pigeons.
>
> ***Pseudolynchia canariensis***

Scutellum approximately three times as wide as long, with a slightly curved posterior edge (Figure 7b). Fewer than 20 dark or black setae on thorax (Figure 6c). Usually on Nightjar.

Pseudolynchia garzettae

AUTHOR CONTRIBUTIONS

Denise C. Wawman: Conceptualization; investigation; writing – original draft; methodology; validation; visualization; writing – review and editing; formal analysis; project administration; data curation; resources.

ACKNOWLEDGEMENTS

Thank you to the individual bird ringers, ringing groups and bird observatories (listed in the supplementary information) who collected flat flies for the project, especially those named in the text who provided specimens and records of the three species reported in this paper. David Fernández Huerta for permission to reproduce his photograph of *Pseudolynchia canariensis* and David Brice of Diptera Identification Services for photographing *O. biloba* and *P. garzettae* (whole flies, wings and scutella). Adrian L. Smith and the anonymous reviewers for their helpful comments on the earlier versions of this paper.

FUNDING INFORMATION

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

CONFLICT OF INTEREST STATEMENT

The author declares that there are no conflicts of interest. All records have been correctly attributed. With the exception of the photograph of *Pseudolynchia canariensis* (Figure 6b), all photographs and images have been produced by, or commercially for, the author, who wishes to retain copyright of these images. David Fernández Huerta has agreed to the use of his image of *Pseudolynchia canariensis* but wishes to retain the copyright.

DATA AVAILABILITY STATEMENT

The data for the three species discussed are provided in the tables in the main text. These details will be uploaded to the Hippoboscidae and Nycteribiidae Recording Scheme records in iRecord in due course, and published as part of the full data set for the whole Mapping the UK's Flat Fly Project when all the research has been published.

ORCID

Denise C. Wawman https://orcid.org/0000-0002-8172-4734

TWITTER

Denise C. Wawman *SomEcoWorrier*

REFERENCES

Arcoverde, A.R., Rodrigues, A.F.S.F. & Daemon, E. (2009) Feeding and breeding aspects of Pseudolynchia canariensis (Macquart, 1839) (Diptera, Hippoboscidae) under laboratory conditions. *Parasitology Research*, 104(2), 277–280. Available from: https://doi.org/10.1007/s00436-008-1188-9

Baker, J.R. (1967) A Review of the role played by the Hippoboscidae (Diptera) as vectors of Endoparasites. *Journal of Parasitology*, 53(2), 412–418. Available from: www.jstor.org/stable/3276603

Balmer, D., Gillings, S., Caffrey, B., Swann, B., Downie, I. & Fuller, R. (2013) *Bird atlas 2007–2011 the breeding and wintering birds of Britain and Ireland*, 1st edition. Thetford: British Trust for Ornithology.

Becker, R.A., Wilks, A.R. & Brownrigg, R. (2018) mapdata: Extra Map Databases. https://cran.r-project.org/package=mapdata%0A

Becker, R.A., Wilks, A.R., Brownrigg, R., Minka, T.P. & Deckmyn, A. (2022) *maps: Draw Geographical Maps. R package version 3.4.1*. https://cran.r-project.org/package=maps

Berggren, Å. (2005) Prevalence and impact of the native blood-sucking louse-fly (Ornithoica sp.) on the North Island robin (Petroica australis longipes). *Notornis*, 52(2), 114–116.

Bezerra-Santos, M.A. & Otranto, D. (2020) Keds, the enigmatic flies and their role as vectors of pathogens. *Acta Tropica*, 209, 105521. Available from: https://doi.org/10.1016/j.actatropica.2020.105521

Buczek, A., Ciura, D., Bartosik, K., Zajac, Z. & Kulisz, J. (2014) Threat of attacks of Ixodes ricinus ticks (Ixodida: Ixodidae) and Lyme borreliosis within urban heat islands in South-Western Poland. *Parasites and Vectors*, 7(1), 1–9. Available from: https://doi.org/10.1186/s13071-014-0562-y

Calenge, C. (2006) The package adehabitat for the R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling*, 197, 516–519.

Cepeda, A.S., Lotta-Arévalo, I.A., Pinto-Osorio, D.F., Macías-Zacipa, J., Valkiūnas, G., Barato, P. et al. (2019) Experimental characterization of the complete life cycle of Haemoproteus columbae, with a description of a natural host-parasite system used to study this infection. *International Journal for Parasitology*, 49(12), 975–984. Available from: https://doi.org/10.1016/j.ijpara.2019.07.003

Chuang, A. & Peterson, C.R. (2016) Expanding population edges: theories, traits, and trade-offs. *Global Change Biology*, 22(2), 494–512. Available from: https://doi.org/10.1111/gcb.13107

Coatney, G.R. (1931) On the biology of the Pigeon Fly, Pseudolynchia maura bigot (Diptera, Hippoboscidae). *Parasitology*, 23(4), 525–532. Available from: https://doi.org/10.1017/S0031182000013901

Corbet, G.B. (1956) The life-history and host-relations of a Hippoboscid Fly Ornithomyia fringillina Curtis. *The Journal of Animal Ecology*, 25(2), 403. Available from: https://doi.org/10.2307/1934

Gutiérrez-Galán, A. & Martínez-Fernández, V. (2023) Low parasite infestations in high densities: the paradox of woodpigeons in urban areas. *International Journal for Parasitology*, 53(3), 127–132. Available from: https://doi.org/10.1016/j.ijpara.2022.11.008

Haeselbarth, E., Segerman, J. & Zumpt, P. (1966) In: Zumpt, P. (Ed.) *The arthropod parasites of vertebrates in Africa south of the Sahara (Ethiopian region) volume III (Insecta excl. Phthiraptera)*, 1st edition. Johannesburg: South African Institute for Medical Research.

Harrow, M. (2021) Pseudolynchia canariensis (Macquart in Webb & Berthelot) (Diptera, Hippoboscidae) new to Britain. *Dipterists Digest*, 28(2), 166.

Hill, D.S., Hackman, W. & Lyneborg, L. (1964) The genus Ornithomya (Diptera: Hippoboscidae) in Fennoscandia, Denmark and Iceland. *Notulae Entomologicae*, XLIV, 33–52.

Hill, D.S. (1963) The life history of the British species of Ornithomya (Diptera: Hippoboscidae). *Transactions of the Royal Entomological Society of London*, 115(13), 391–407. Available from: https://doi.org/10.1111/j.1365-2311.1963.tb00812.x

Hoffmann, B.D. & Courchamp, F. (2016) Biological invasions and natural colonisations: are they that different? *NeoBiota*, 29, 1–14. Available from: https://doi.org/10.3897/neobiota.29.6959

Hutson, A.M. (1981) A new species of the Ornithomya biloba-group (Dipt., Hippoboscidae) from Crag Martin (Ptyonoprogne rupestris) (Aves,

Hirundinidae). *Mitteilungen Der Schweiserischen Entomologischen Gesellshaft; Bulletin de La Societe Entomologique Suisse*, 54, 157–162. Available from: https://www.e-periodica.ch/digbib/view?lang=en&pid=seg-001%3A1981%3A54%3A%3A455#166

Hutson, A.M. (1984) Keds, flat-flies and bat-flies: Diptera, Hippoboscidae and Nycteribiidae. *Handbooks for the Identification of British Insects*, 10(7), 40. Available from: https://www.royensoc.co.uk/sites/default/files/Vol10_Part07_Hutson.pdf

Kaunisto, S., Härkönen, L., Niemelä, P., Roininen, H. & Ylönen, H. (2011) Northward invasion of the parasitic deer ked (Lipoptena cervi), is there geographical variation in pupal size and development duration? *Parasitology*, 138(3), 354–363. Available from: https://doi.org/10.1017/S0031182010001332

Kennedy, J.A., Smith, J.R. & Smyth, M. (1975) Diapause in Ornithomya biloba Dufour (Diptera: Hippoboscidae) parasitic on fairy martins in South Australia. *The Journal of Parasitology*, 61(2), 369–372. Available from: https://doi.org/10.2307/3279023

Klei, T.R. & Degiusti, D.L. (1975) Observations on the bionomics of Pseudolynchia canariensis (Diptera: Hippoboscidae). *Parasitology*, 70(2), 195–202. Available from: https://doi.org/10.1017/S0031182000049660

Kurina, O., Kirik, H., Õunap, H. & Õunap, E. (2019) The northernmost record of a blood-sucking ectoparasite, Lipoptena fortisetosa Maa (Diptera: Hippoboscidae), in Estonia. *Biodiversity Data Journal*, 7, 1–14. Available from: https://doi.org/10.3897/BDJ.7.e47857

LaDeau, S.L., Allan, B.F., Leisnham, P.T. & Levy, M.Z. (2015) The ecological foundations of transmission potential and vector-borne disease in urban landscapes. *Functional Ecology*, 29(7), 889–901. Available from: https://doi.org/10.1111/1365-2435.12487

Lloyd-Evans, L. (1967) Bird parasites. *Rye Meads Ringing Group Report*, 4, 14–21.

López-Calderón, C., Magallanes, S., Marzal, A. & Balbontín, J. (2021) The migration system of barn swallows Hirundo rustica breeding in southwestern Spain and wintering across West Africa. *Ardeola*, 68(2), 335–354. Available from: https://doi.org/10.13157/arla.68.2.2021.ra2

Maa, T.C. (1964) On the genus Ornithomya Latreille from Africa (Diptera: Hippoboscidae). *Journal of Medical Entomology*, I(2), 197–205.

Maa, T.C. (1965) On the name Ornithomya vs. Ornithomyia. *Journal of Medical Entomology*, 1(4), 394.

Maa, T.C. (1966) On the genus Pseudolynchia Bequaert (Dipteria: Hippoboscidae). *Pacific Insects Monograph*, 10, 125–138. Available from: https://pdfs.semanticscholar.org/5e9e/bc24e1e08128b1eadb908ba8148f03c70a73.pdf

Maa, T.C. (1969) A revised checklist and concise host index of Hippoboscidae (Diptera). *Pacific Insects Monograph*, 20, 261–299. Available from: http://hbs.bishopmuseum.org/fiji/pdf/maa1969b.pdf

Maa, T.C. & Petersen, B.V. (1987) Hippoboscidae. In: *Manual of Nearctic Diptera. Agriculture Canada Monograph No. 28*, Vol. 2, pp. 1271–1281. Biosytematics Research Centre (formerly Intitute) Ottawa, Ontario.

MacArthur, R.H. & Wilson, E.O. (1967) *The theory of Island biogeography*. Princeton: Princeton University Press.

Minter, M., Dasmahapatra, K.K., Thomas, C.D., Morecroft, M.D., Tonhasca, A., Schmitt, T. et al. (2020) Past, current, and potential future distributions of unique genetic diversity in a cold-adapted mountain butterfly. *Ecology and Evolution*, 10(20), 11155–11168. Available from: https://doi.org/10.1002/ece3.6755

Nartshuk, E.P., Matyukhin, A.V., Zabashta, A.V. & Zabashta, M.V. (2019) First record of louse fly Pseudolynchia garzettae Rondani, 1879 (Diptera: Hippoboscidae) in East Europe. *Russian Entomological Journal*, 28(1), 91–92. Available from: https://doi.org/10.15298/rusentj.28.1.16

Nuttall, P.A. (2021) Climate change impacts on ticks and tick-borne infections. *Biologia*, 77, 1503–1512. Available from: https://doi.org/10.1007/s11756-021-00927-2

Oboňa, J., Fogašová, K., Fulín, M., Greš, S., Manko, P., Repaský, J. et al. (2022) Updated taxonomic keys for European Hippoboscidae (Diptera), and expansion in Central Europe of the bird louse fly Ornithomya comosa (Austen, 1930) with the first record from Slovakia. *ZooKeys*, 1115, 81–101. Available from: https://doi.org/10.3897/zookeys.1115.80146

Palmer, C.J. (1987) Pseudolychnia garzettae Rondani (Dipt., Hippoboscidae), an unrecognized addition to the British list. *Entomologist's Monthly Magazine*, 123, 234.

Petersen, F.T., Meier, R., Kutty, S.N. & Wiegmann, B.M. (2007) The phylogeny and evolution of host choice in the Hippoboscoidea (Diptera) as reconstructed using four molecular markers. *Molecular Phylogenetics and Evolution*, 45(1), 111–122. Available from: https://doi.org/10.1016/j.ympev.2007.04.023

Pigeon Racing UK & Ireland. (2023) Pigeon facts. https://www.pigeonracinguk.co.uk/about/pigeon-facts

R Development Core Team. (2022) *R: a language and environment for statistical computing*. (4.2.2). Vienna, Austria: R Foundation for Statistical Computing. Available from: https://www.r-project.org/

Redfern, C.P.F. & Clark, J.A. (2001) Ringers' manual. In: *British trust for ornithology*, 4th edition. Thetford: British Trust for Ornithology.

Reeves, W.K. & Lloyd, J.E. (2019) Louse flies, Keds, and bat flies (Hippoboscoidea). In: *Medical and veterinary entomology*, Third Edition London: Academic Press, pp. 421–438. Available from: https://doi.org/10.1016/B978-0-12-814043-7.00020-0

Robinson, R.A., Leech, D.I. & Clark, J. (2022) *The online demography report: bird ringing and nest recording in Britain & Ireland in 2021*. Thetford: BTO. Available from: http://www.bto.org/ringing-report

Santolíková, A., Brzoňová, J., Čepička, I. & Svobodová, M. (2022) Avian louse flies and their trypanosomes: new vectors, new lineages and host–parasite associations. *Microorganisms*, 10(3), 584. Available from: https://doi.org/10.3390/microorganisms10030584

Smith, W.J., Sendell-Price, A.T., Fayet, A.L., Schweizer, T.M., Jezierski, M.T., van de Kerkhof, C. et al. (2022) Limited domestic introgression in a final refuge of the wild pigeon. *IScience*, 25(7), 104620. Available from: https://doi.org/10.1016/j.isci.2022.104620

Snow, D.W. (1953) Visible migration in the British Isles: a review. *Ibis*, 95(2), 242–270. Available from: https://doi.org/10.1111/j.1474-919X.1953.tb00688.x

Soroye, P., Newbold, T. & Kerr, J. (2020) Climate change contributes to widespread declines among bumble bees across continents. *Science*, 367(6478), 685–688. Available from: https://doi.org/10.1126/science.aax8591

Sychra, O., Halajian, A., Engelbrecht, D., Symes, C.T., Oschadleus, H.D., De Swardt, D.H. et al. (2020) Louse-flies (Diptera: Hippoboscidae) of birds from South Africa: prevalence and diversity. *African Entomology*, 28(2), 249–261. Available from: https://doi.org/10.4001/003.028.0249

Taylor, L. (2013) London pigeons a ten year study. http://www.londonpigeons.co.uk

Waite, J.L., Henry, A.R. & Clayton, D.H. (2012) How effective is preening against mobile ectoparasites? An experimental test with pigeons and hippoboscid flies. *International Journal for Parasitology*, 42(5), 463–467. Available from: https://doi.org/10.1016/j.ijpara.2012.03.005

Walker, M.D. & Rotherham, I.D. (2010a) The breeding success of common swifts Apus apus is not correlated with the abundance of their louse Fly Crataerina pallida parasites. *Bird Study*, 57(4), 504–508. Available from: https://doi.org/10.1080/00063657.2010.493581

Walker, M.D. & Rotherham, I.D. (2010b) The common swift louse Fly, Crataerina pallida: an ideal species for studying host-parasite interactions. *Journal of Insect Science*, 10(193), 1–15. Available from: https://doi.org/10.1673/031.010.19301

Wickham, H. & Seidel, D. (2022) *Scales: scale functions for visualization* (1.2.1). https://cran.r-project.org/package=scales

SUPPORTING INFORMATION

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

Data S1. *Supplementary information: additional references and acknowledgements not included in the main text*. References for original species descriptions. Sources of information checked for species records but not referenced in the main text as no relevant records were found. List of all the people who collected specimens for the project. Data for the three species discussed are provided in the tables in the main text. Full details will be uploaded to the Hippoboscidae and Nycteribiidae Recording Scheme records in iRecord in due course. The BTO ringing totals for the United Kingdom and Ireland are freely available in the online ringing report section of the BTO website: http://www.bto.org/ringing-report. The specimens of *O. biloba* and *P. garzettae* have been retained by the author.

How to cite this article: Wawman, D.C. (2023) *Ornithomya biloba*, *Pseudolynchia garzettae* and *Pseudolynchia canariensis* (Diptera: Hippoboscidae): three new United Kingdom colonists and potential disease vectors. *Medical and Veterinary Entomology*, 1–12. Available from: https://doi.org/10.1111/mve.12703