emca European Mosquito Control Association
brill.com/jemc

JOURNAL OF THE EUROPEAN MOSQUITO CONTROL ASSOCIATION
42 (2024) 41–50

BRILL WAGENINGEN ACADEMIC

RESEARCH ARTICLE

A snapshot mosquito field survey reveals the occurrence of *Aedes geminus*, *Anopheles daciae*, and *Culex torrentium* in the Republic of Ireland

F. Schaffner[1]*, *J.M. Medlock*[2], *A.G.C. Vaux*[2] and *I.A. Giantsis*[3,4]

[1]Francis Schaffner Consultancy, Lörracherstrasse 50, 4125 Riehen, Switzerland; [2]Medical Entomology group, UK Health Security Agency, Porton Down, Wiltshire SP4 0JG, United Kingdom; [3]European Biological Control Laboratory, USDA-ARS, Marinou Antypa 54, 55102 Thessaloniki, Greece; [4]Department of Agriculture, Faculty of Agriculture, Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece; *fschaffner.consult@gmail.com

Received 8 February 2024 | Accepted 26 March 2024 | Published online 23 April 2024

Abstract

A snapshot mosquito field survey was conducted in the Republic of Ireland in April–May 2017 and 2018 (for the VectorNet project) to provide mosquito distribution data as there is a dearth of recent data available for that region. The occurrence data obtained serve as a baseline for a preliminary public and veterinary health risk assessment and to promote further targeted vector surveillance. Morphological identification was complemented by genetic analyses to determine the species identity of members of the Anopheles Maculipennis Complex and the Culex Pipiens Assemblage. A total of 52 samples, including 50 immature aquatic samples and 2 adult catches, were collected from 72 locations inspected and distributed over 30 of the 34 vice counties across the country. Seventeen mosquito taxa were collected, and here we provide the first records of *Aedes geminus, Anopheles daciae* and *Culex torrentium* for the Republic of Ireland. We also confirm the occurrence of both *Anopheles algeriensis* and *Culiseta alaskaensis* which have only been found once before in Ireland.

Keywords

Culicidae – first report – distribution – *Anopheles algeriensis* – *Culiseta alaskaensis*

1 Introduction

Mosquito (Diptera: Culicidae) distribution data are crucial for informing and assessing public and veterinary risk related to pest or vector species, and they are relevant to understanding mosquito biology and diversity. There is limited recent mosquito distribution data for the Republic of Ireland (hereafter Ireland). The National Biodiversity Data Centre, the Republic of Ireland, maintains a biodiversity data base with an online mapping tool. It has gathered 232 mosquito occurrence records collected between 1854 and 2008 for 18 species recorded from 122 locations in Ireland (NBDC, 2023). This data set consists of 97.8% of historical records from the period 1854–1991 (Ashe *et al.*, 1991; IBS, 2023) and only 5 modern records (from 5 locations for the period 2001–2016) are listed. A rapid literature search on Web of Science™ on 26/III/2023 did not reveal additional records, and to our knowledge no recent mosquito survey of Ireland has been published. However, a recent distribution chart for Euro-mediterranean mosquito species lists 20 species for Ireland (Robert *et al.*, 2019; Table 1).

Published with license by Koninklijke Brill BV | DOI:10.52004/2054930X-20241007

TABLE 1 Summary of Culicidae species reported from Ireland by 2019.

Species/Taxa	NBDC[1]	Robert *et al.* (2019)[1]	This study[2] (2017–2018)
Aedes (*Aedes*) *cinereus*	△	△	–
Ae. (*Aed.*) *cinereus/geminus*	–	–	○[3]
Ae. (*Aed.*) *geminus*	–	○	○
Ae. (*Ochlerotatus*) *cantans*	△	△	○
Ae. (*Och.*) *caspius*	△	△	–
Ae. (*Och.*) *detritus s.l.*	△□	△	○●
Ae. (*Och.*) *dorsalis*	△	△	–
Ae. (*Och.*) *punctor*	△	△	○
Ae. (*Rusticoidus*) *rusticus*	△	△	●
Anopheles (*Anopheles*) *algeriensis*	△	△	●
An. (*Ano.*) *claviger s.s.*	△	△	○●
An. (*Ano.*) *maculipennis s.l.*	△	△	○[3]
An. (*Ano.*) *daciae*	–	–	○
An. (*Ano.*) *plumbeus*	△	△	○
Coquillettidia (*Coquillettidia*) *richiardii*	△	△	–
Culex (*Culex*) *pipiens*	△	△	○●
Cx. (*Cux.*) *torrentium*	–	○	○
Culiseta (*Culicella*) *litorea*	△	△	●
Cs. (*Cuc.*) *morsitans*	△	△	○●
Cs. (*Culiseta*) *alaskaensis*	△	△	○
Cs. (*Cus.*) *annulata*	△□	△	○●
Cs. (*Cus.*) *subochrea*	△	△	–
Total no. of taxa:	18	20	17

[1]NBDC = National Biodiversity Data Centre; Triangle = historical data (<2000); Square = modern data (≥2000).
[2]Our field data: Circle = data 2017; Disk = data 2018.
[3]Not counted as species in our findings.

Global change, in particular in land-use and climate, favours changes in distribution ranges for both native and invasive mosquito species (Elbers *et al.*, 2015). This also applies to vector-borne diseases (VBDs) (Franklinos *et al.*, 2019; Rocklöv and Dubrow, 2020) of which surveillance is better performed using an integrated approach (Braks *et al.*, 2011). The One Health network 'VectorNet' was developed to apply this approach, commissioned by the European Food Safety Authority (EFSA) and the European Centre for Disease Prevention and Control (ECDC). VectorNet aims to facilitate risk assessments of VBD threats through the collection, mapping and sharing of distribution data for ticks, mosquitoes, sand flies, and *Culicoides* biting midges that are vectors of pathogens of importance to animal and/or human health in Europe (Braks *et al.*, 2022). Capacity building and vector distribution data collections are among its foremost activities. Reporting presence or absence of any species is crucial to understand vector biology, biodiversity and distribution changes. Therefore, and because little modern mosquito distribution data exist for Ireland, we performed some capacity building on vector surveillance techniques together during the field surveys. Here we report the results of a snapshot mosquito field survey across the country performed in 2017 and 2018, as a baseline for a preliminary risk assessment and to enable further targeted vector surveillance.

2 Material and methods

A first survey was performed in 2017, from 15th to 18th of May (4 days), together with a tick survey and occasional trapping of *Culicoides* biting midges, along the western coast of Ireland. A second survey was performed in 2018, from 27th of April to the 10th of May (13 days), mainly over the central and eastern parts of the country. Habitats sampled were visually identified

during road trips as suitable for mosquitoes (e.g. artificial containers, small ponds) or previously identified on satellite images (e.g. wetlands; Google Earth™ imagery). Mosquitoes were sampled according to standard procedures (Medlock *et al.*, 2018). Mosquito immatures (eggs, larvae or pupae) were collected in aquatic habitats with an aquatic net and a white plastic tray, and specimens were removed from water with a pipette and placed in 70% ethanol in a plastic vial. Pupae and in some cases a few larvae (4th instar) were kept in water from breeding site until the adults emerged. Occasional adult collections were performed by human landing catches with a mouth aspirator and by resting catches with a sweep net (Bioform, Nürnberg, Germany) around human bait or vegetation. Larvae and adults were morphologically identified using available identification keys (Becker *et al.*, 2010; Schaffner *et al.*, 2001).

Morphological identification was complemented by genetic assays to determine the species identity of members of the Anopheles Maculipennis Complex and the Culex Pipiens Assemblage. DNA isolation and amplification of the ribosomal internal transcribed spacer 2 (ITS2) was performed on a few *Anopheles* specimens, as described elsewhere (Collins and Paskewitz, 1996). The sequences obtained were compared with sequences in the GenBank database though the BLAST® online tool. To discriminate between *Anopheles daciae* and *An. messeae*, aligned sequences were visually checked for the presence of the five species-specific diagnostic polymorphic sites (Brusentsov *et al.*, 2023; Nicolescu *et al.*, 2004). The differentiation of the sibling species *Culex pipiens* and *Cx. torrentium* samples was performed by the multiplex PCR developed by Smith and Fonseca (2004). Briefly, the KAPA Express Extract Kit (KAPA-Biosystems, Wilmington, MA, USA) was used for DNA extraction from each specimen following the manufacturer's instructions. The multiplex PCR targeting the acetylcholinesterase-2 (ace-2) locus was carried out in 10 µl reactions, each one containing 5 µl Platinum Green PCR 2× mix (Invitrogen, Waltham, MA, USA), 0.3 pmol of each primer ACEquin, ACEtorr, ACEpip and B1246s (Smith and Fonseca, 2004), approximately 50 ng extracted DNA and ultra-pure water up to the volume of 10 µl. PCR conditions were as described in Smith and Fonseca (2004).

3 Results

Our snapshot mosquito field survey across Ireland resulted in 52 samples, including 50 immature samples and 2 adult catches (Table 2). A total of 72 locations distributed over 30 out of the 34 vice counties were investigated (Figure 1). Among them, 50 locations (69.5%) provided at least one mosquito specimen.

Overall, 1,959 mosquito specimens were collected, including 1,050 eggs, 630 larvae and 254 pupae in immature samples, and 23 females and 2 males in adult catches. An additional 151 females and 130 males were obtained from immature rearing to facilitate or confirm species identification. A total of 17 taxa were found. On five occasions the species could only be identified at the species group level (one larval sample of *Ae. cinereus/geminus* and four larval samples of *Cx. pipiens/torrentium*) (Supplementary Table S1).

Among the 18 species previously known to occur in Ireland (IBS, 2023), 14 species (78%) were observed. Two additional species, namely *Ae. geminus* and *Cx. torrentium* were also found. Our data are the first substantiated records for these species which were both included in Robert *et al.* (2019) based on our shared observations. Among the 24 specimens investigated by the multiplex PCR assay, only 17 resulted in a confident identification, explicitly 6 individuals of *Cx. pipiens* and 11 of *Cx. torrentium*. These specimens were obtained from two different locations for both species, without any sympatry observed. Larvae belonging to the Maculipennis Complex were found at one location, and ITS2 sequencing was conducted on 3 larvae and one adult male (obtained from a reared larva). Our sequences (GenBank

TABLE 2 Sampling effort of our snapshot field study in the Republic of Ireland, 2017–2018.

Sampling period	No. of locations	Total no. of samples	No. of immature samples	No. of adult catches	No. of vice counties
2017	39	18	17	1	12
2018	33	34	33	1	23
Total	72	52	50	2	30[a]

[a]Five vice counties were investigated during both years.

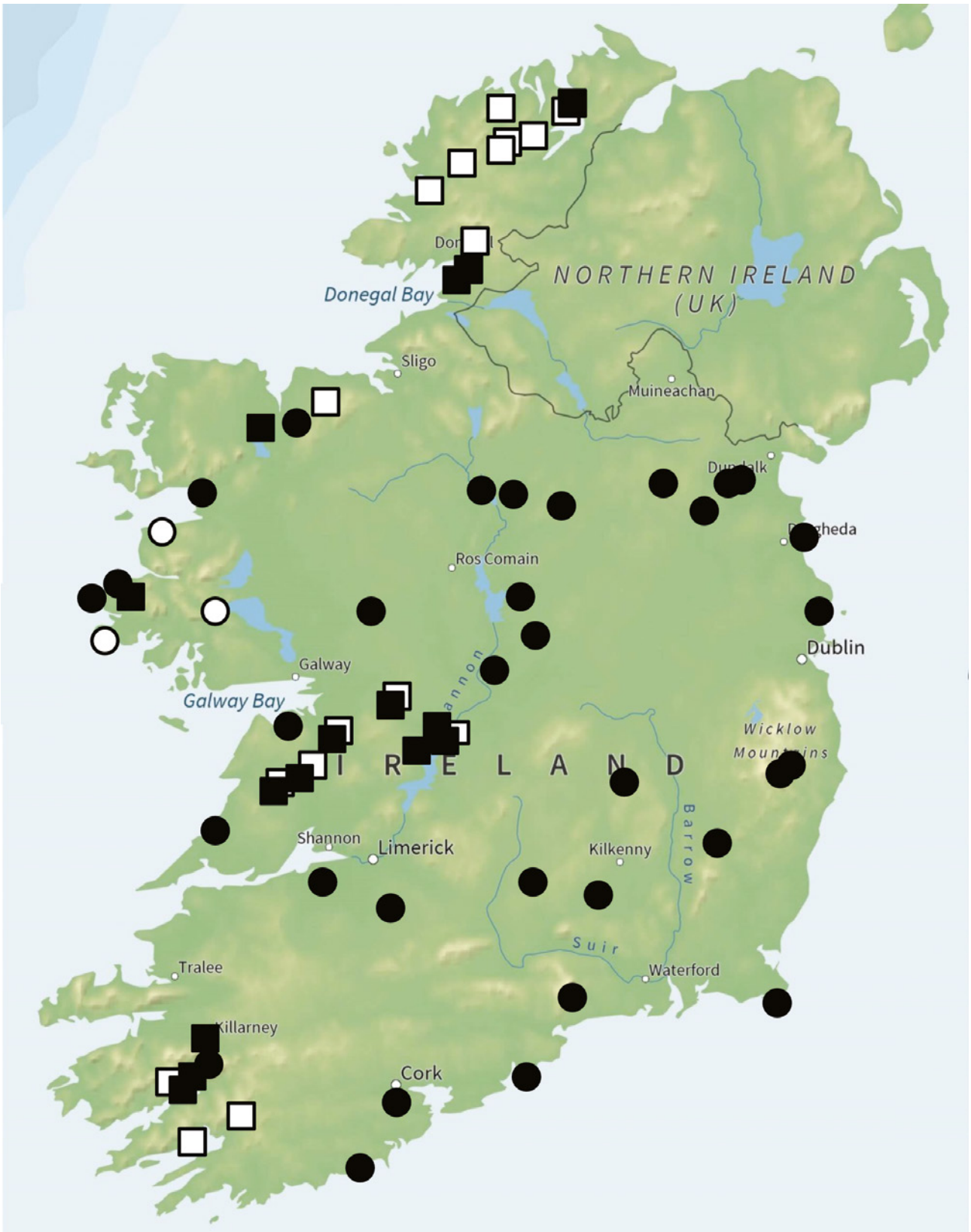

FIGURE 1 Location of mosquito sampling locations in the Republic of Ireland, 2017 (squares) and 2018 (circles). Full symbols: locations positive for mosquito occurrence; Empty symbols: locations negative. Map background: mapswire.com (CC BY 4.0).

FIGURE 2 Alignment of our Irish ITS2 sequences (labels ending with 'IE') with sequences from Romania (RO; Nicolescu *et al.*, 2004), Belgium (BE; Smitz *et al.*, 2021), Luxembourg (LU; Schaffner *et al.*, 2023), Russia (RU; Brusentsov *et al.*, 2023), and United Kingdom (UK; Danabalan *et al.*, 2014). Species-specific nucleotide positions are highlighted in blue for *Anopheles messeae*, in yellow for *An. daciae*.

accession numbers PP263055-PP2630558) showed between 99.74 and 100% similarities with several sequences of both *An. messeae* and *An. daciae*. However, the visual check of the sequences aligned together with sequences from various countries allowed us to assign our four sequences to *An. daciae*, since three, four or all five species-specific diagnostic sites indicated that species (Figure 2).

Among the 50 larval habitats which yielded mosquito specimens, a large majority were stagnant temporary water bodies (n=36; 72%) including ditches, ponds, dips in peat or forests, flooded forests and reed beds. The second most numerous were human-made (artificial) containers (n=8; 16%), such as diverse plastic containers, tyres, a discarded fridge and a wooden boat. The other sites were (semi-) permanent water bodies with vegetation (n=4; 8%), formed by borders of large ditches, ponds, and lakes, and slowly running water (n=2; 4%), in a ditch and a stream (Figure 3).

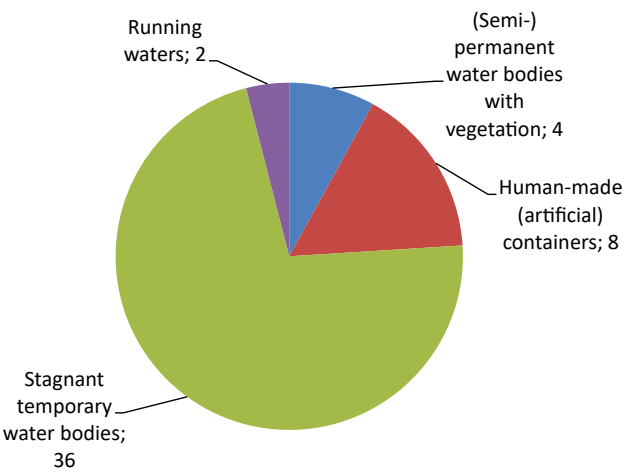

FIGURE 3 Types of aquatic larval habitats which yielded mosquito specimens in our snapshot study in the Republic of Ireland 2017–2018. Total number = 50.

4 Discussion

A snapshot field study performed across the Republic of Ireland for 4 days in May 2017 and 13 days in April/May 2018 resulted in the detection of 17 mosquito taxa. Among these, 14 were already known to occur in Ireland, and three, namely *Ae. geminus*, *An. daciae* and *Cx. torrentium* are reported here for the first time. We also confirm the occurrence of both *An. algeriensis* and *Cs. alaskaensis* which were found earlier in Ireland on single occasions only. All observed species can be considered native to Ireland and no invasive species (e.g. *Ae.* (*Stegomyia*) *albopictus* (Skuse, 1894), *Ae.* (*Hulecoeteomyia*) *japonicus* (Theobald, 1901)) were detected despite targeted investigations.

The following paragraphs provide details of the species caught, and a commentary of their preferred habitats and previous records.

Aedes (*Aedes*) *cinereus* Meigen, 1818 and *Ae.* (*Aed.*) *geminus* Peus, 1970 are two sibling species which can

only be identified from each other morphologically by examining the male genitalia. Both species develop in natural temporary freshwater bodies between late spring and early autumn. We found specimens at two locations in North Kerry on 18 May 2017 (Figure 4A). In one case we morphologically identified *Ae. geminus* based on 2 male genitalia. Immatures of *Ae. cinereus/geminus* and *Ae. geminus* were collected from stagnant shaded pools, together with *Ae. punctor* in one case. There are four historical data under the name *Ae. cinereus* (1854–1985) (NBDC, 2023), with no indication of examination of male genitalia.

Aedes (*Ochlerotatus*) *cantans* (Meigen, 1818) develops in natural temporary freshwater bodies in spring. We found it in Monaghan, Meath and Kilkenny, on 5 and 10 May 2018, in two forest ditches and a pond under willows. The identification of male genitalia (n=2, from one location) confirms the accuracy of the sorting from its sibling species *Ae.* (*Och.*) *annulipes* (Meigen, 1830). There are four historical data of *Ae. cantans* (1856–1985), while *Ae. annulipes* is not listed (NBDC, 2023).

Aedes (*Och.*) *caspius* (Pallas, 1771) and *Aedes* (*Och.*) *dorsalis* (Meigen, 1830) show morphological similarities and can be confused with each other. They develop in temporary brackish waters, thus mainly along the coasts, in spring and summer. We did not find them in our study. There is one historical record for *Ae. caspius* (1981), two for *Ae. dorsalis* (1927 and 1929) (NBDC, 2023).

Aedes (*Och.*) *detritus sensu stricto* (*s.s.*) Haliday, 1833 and *Ae.* (*Och.*) *coluzzii* Rioux, Guilvard & Pasteur, 1998 are two sibling species which can be distinguished only by molecular tools (protein electrophoresis or ITS2 sequencing). They develop in temporary brackish waters in spring and summer. We collected specimens at four locations in East Donegal (15 May 2017), West Cork (28 April 2018), West Galway (2 May 2018; Figure 4B) and Dublin (5 May 2018) in strandline pools, estuary puddles and a ditch, all flooded by brackish water. Since we could

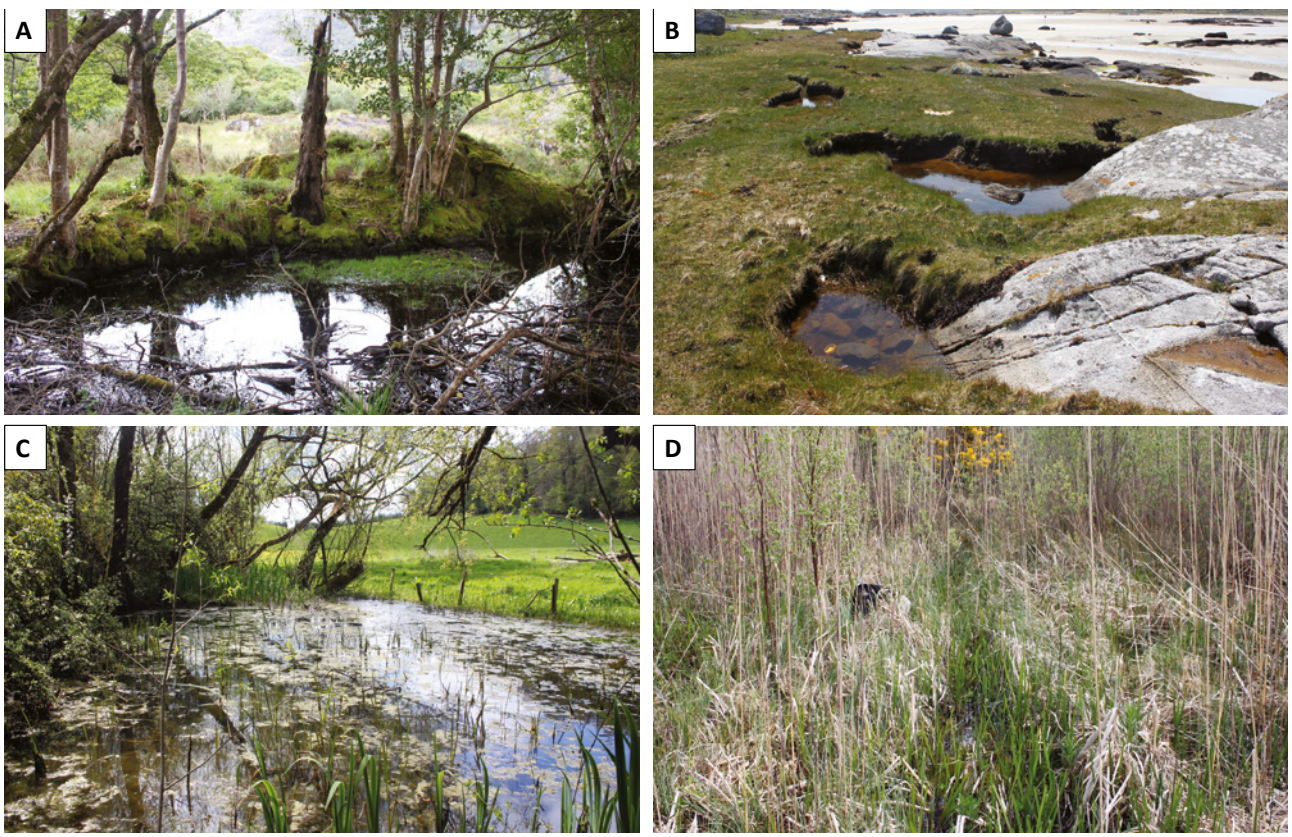

FIGURE 4 Examples of aquatic larval habitats found to yield mosquito species in Ireland, 2017–2018, from the categories 'Stagnant temporary water body' (A, B, D) and '(Semi-) permanent water body' (C). (A) Collection site of *Aedes cinereus/geminus* and *Aedes punctor*: a shaded pool at Gortderraree, Kerry, 18 May 2017; (B) Collection site of *Aedes detritus s.l.*: small see shore puddles at Claddaghduff, West Galway, 2 May 2018; (C) Collection site of *Aedes rusticus*, *Culiseta annulata* and *Culiseta morsitans*: a large pond in pasture at Coolderry, Monaghan, 5 May 2018; (D) Collection site of *Anopheles algeriensis*, *Anopheles claviger s.s.* and *Culiseta morsitans*: a reed bed at Bawn, Offaly, 7 May 2018.

not perform any molecular analysis, we attribute these specimens to *Ae. detritus sensu lato* (*s.l.*). There are 17 historical records and 3 modern data (1854–2016), to be also attributed to *Ae. detritus s.l.* (NBDC, 2023).

Aedes (*Och.*) *punctor* (Kirby, 1837) develops in temporary freshwater bodies, typically peat bogs, between spring and autumn. We collected specimens on one occasion in North Kerry on 18 May 2017, from a freshwater shaded pool (Figure 4A). There are only two historical records from 1970 and 1985 (NBDC, 2023).

Aedes (*Rusticoidus*) *rusticus* (Rossi, 1790) develops in freshwater ponds in winter and spring. We collected it on five occasions in Monaghan (2 locations, 5 May 2018; Figure 4C), Longford (6 May 2018), North Kerry (9 May 2018) and Kilkenny (10 May 2018) in ditches, ponds and a flooded willow forest. There are 13 historical records (1894–1991) (NBDC, 2023).

Anopheles (*Anopheles*) *algeriensis* Theobald, 1903 develops in temporary or semi-permanent freshwater bodies. We found specimens at two neighbouring locations in Offaly, on 6 and 7 May 2018 (Figure 4D). At the first site we were bitten by females at sunset, and at the second site, a few dozen metres away, we could collect larvae in a reed bed, together with *An. claviger s.s.* and *Cs. morsitans*. There is a single historical record (1989) from Clare (NBDC, 2023).

Anopheles (*Ano.*) *claviger s.s.* (Meigen, 1804) is a member of the Claviger Complex which also comprises its sibling species *An.* (*Ano.*) *petragnani* Del Vecchio, 1939. They can be distinguished by tiny characters at their larval stage. Immatures can be found in temporary or semi-permanent freshwater bodies. We found the species at 10 locations in Limerick (flooded forest, 17 May 2017), Wexford (semi-permanent pond border, 27 April 2018), Clare (ditch, 30 April 2018), North-East Galway and Wicklow (ditches, 4 May 2018), Cavan (dip in wet meadow, 5 May 2018), Leitrim (flooded forest, 6 May 2018), Offaly (dip in peat area and reed bed, 6 and

FIGURE 5 Examples of aquatic larval habitats found to yield mosquito species in Ireland, 2017–2018, from the category 'Human-made container' (A,B) and 'Stagnant temporary water body' (C,D). (A) Collection site of *Culex pipiens* and *Culex torrentium*: a basin at Rathmullan, West Donegal, 15 May 2017; (B) Collection site of *Culex torrentium* and *Culiseta alaskaensis*: tyres at Laghey, East Donegal, 17 May 2017; (C) Collection site of *Culiseta annulata* and *Culiseta litorea*: a ditch in pasture at Tully, West Galway, 2 May 2018; (D) Collection site of *Anopheles claviger s.s.*, *Anopheles daciae*, *Culex pipiens*, *Culiseta annulata* and *Culiseta morsitans*: a pond at Portumna, South-East Galway, 17 May 2017.

7 May 2018, respectively; Figures 4D, 5D), and Kilkenny (ditch, 10 May 2018). All our samples belong to *An. claviger s.s.*. There are 31 historical records (1901–1989) (NBDC, 2023).

Anopheles (*Ano.*) *maculipennis s.l.* Meigen, 1818 and *Anopheles* (*Ano.*) *daciae* Linton, Nicolescu & Harbach, 2004: the first taxon includes undetermined species members of the Maculipennis Complex and the second is one of these members. Members of the complex can accurately be distinguished only by genetic analysis. They develop mainly in (semi-) permanent water bodies, from mid-summer to autumn. We collected specimens at one location in Galway, on 17 May 2017 from a pond (Figure 5D). There are nine historical records as *An. maculipennis s.l.* (1918–1982) (NBDC, 2023), as no accurate molecular identification has been performed (Ashe *et al.*, 1991). Some authors suggested *An.* (*Ano.*) *messeae* Falleroni, 1926 occurs in Ireland (Sinka *et al.*, 2012; White, 1989) while others reported *An. maculipennis s.s.* Meigen, 1818 (Snow, 1998) or both of them together with *An.* (*Ano.*) *atroparvus* van Thiel, 1927 (Wilkerson *et al.*, 2021) to occur, but we did not find any substantiated record of these species in the literature. The four ITS2 sequences obtained from our specimens are all attributed to *An. daciae* despite some variability in the diagnostic nucleotide set (Figure 2).

Anopheles (*Ano.*) *plumbeus* Stephens, 1828 is a tree-hole breeding species, occasionally found in human-made containers such as tyres, when the water is held for a long time. We caught one biting female in a forested area in Clare, 17 May 2017. There are also 10 historical records (1899–1990) (NBDC, 2023).

Coquillettidia (*Coquillettidia*) *richiardii* (Ficalbi, 1889) is a permanent waterbreeding species, of which the larvae and pupae breathe through the tissues of plant roots to which they are attached. Immatures develop in water bodies with erect vegetation, such as *Phragmites*, *Typha*, or *Carex* species. We did not detect this species in our field study, but there are two historical records (1926 and 1989) (NBDC, 2023).

Culex (*Culex*) *pipiens* Linnaeus, 1758 and *Culex* (*Cux.*) *torrentium* Martini, 1925 are two sibling species that can be accurately distinguished only from examination of male genitalia. *Culex pipiens* itself is a species complex. In Europe, the complex comprises two forms (or biotypes) showing biological and behavioural differences and named *pipiens* and *molestus*. Among other traits, the first one is mainly ornithophilic, the second mainly mammalophilic. They develop in any artificial or natural water bodies, even with high organic matter (e.g. grey waters). In our field study we collected eight samples of specimens belonging to the species group (Table 3). While four samples could not be accurately identified to the species level, and thus are classified as *Cx. pipiens/torrentium*, three others were attributed to *Cx. pipiens* (Figures 5A,D) and three to *Cx. torrentium* (Figures 5A,B). Identification was performed by morphological examination of male genitalia for both *Cx. pipiens* (n=3) and *Cx. torrentium* (n=1) as well as on larvae submitted to the molecular assay (n=6 and 11, respectively, for two samples each). Both species were found sympatric in two samples. There are 78 historical records for *Cx. pipiens* (1832–1990), but there is no indication if male genitalia were examined, thus they should be referred to *Cx. pipiens/torrentium* (NBDC, 2023).

Culiseta (*Culicella*) *litorea* (Shute, 1928) develops in temporary coastal more or less brackish, water bodies.

TABLE 3 Samples of the *Culex pipiens* species group collected in the Republic of Ireland, 2017–2018.

Vice county	Location ID	Larval habitat	Specimens	Species	PCR specimens
West Donegal	Donegal01	Bassin	8 L[1]	*Cx. pipiens*	2
West Donegal	Donegal01	Bassin	5 L[1], 1 M	*Cx. torrentium*	
East Donegal	Donegal12	Tyres	11 L	*Cx. torrentium*	6
West Galway	Galway01	Pond	1 L	*Cx. pipiens/torrentium*	
South-East Galway	Galway05	Pond	8 L, 9 P, 3 M, 6 F	*Cx. pipiens*	
Clare	Clare02	Ditch, slightly running	1 L	*Cx. pipiens/torrentium*	
North Kerry	Kerry02	Black plastic container	70 L[1]	*Cx. pipiens*	4
North Kerry	Kerry02	Black plastic container	50 L[1]	*Cx. torrentium*	5
Meath	Meath01	Wooden boat	300 E	*Cx. pipiens/torrentium*	
Mid Cork	Cork04	Plastic containers	300 E, 11 L	*Cx. pipiens/torrentium*	

[1]These numbers are estimates, extrapolated from identification results.

We collected immatures, mainly pupae, at five locations in Wexford (27 April 2018), Clare (30 April and 1 May 2018), West Galway (2 May 2018; Figure 5C) and Waterford (8 May 2018), in a pond border, two ditches in pasture, a marshland and a reed bed. There are four historical records (1982–1987) (NBDC, 2023).

Culiseta (*Cuc.*) *morsitans* (Theobald, 1901) develops in temporary inland freshwater bodies. We collected immatures at 21 locations distributed over 16 vice counties, in both 2017 and 2018. Larval habitats were dips and ditches in meadows and forests, ponds, a reed bed and a peat dip (Figures 4C,D, 5D). There are also nine historical records (1929–1989) (NBDC, 2023).

Culiseta (*Culiseta*) *alaskaensis* (Ludlow, 1906) inhabits temporary and semi-permanent water bodies. We found the species at a single location in East Donegal (15 May 2017), with immatures breeding in a tyre (Figure 5B). A single historical record exists in Kildare (13 September 1939) (IBS, 2023).

Culiseta (*Cus.*) *annulata* (Schrank, 1776) is a Culicine that develops in temporary and semi-permanent water bodies. We collected the species at 27 locations distributed over 16 vice counties in both 2017 and 2018. Immatures were found in various artificial containers, ditches, ponds, flooded forests, a reed bed and a lake border (Figure 4C, 5C,D). There are 42 historical records (1832–1990) and two modern records (2001 and 2008) (NBDC, 2023).

Culiseta (*Cus.*) *subochrea* (Edwards, 1921) also develops in temporary and semi-permanent water bodies. We did not record the species in our field study but there is one historical data from Dublin (1932) (NBDC, 2023).

5 Conclusions

Our study shows that a snapshot survey (17 days in total, in April/May) can detect species that are rare or even previously unrecorded in an area. Further investigations need to be performed in Ireland, targeting native species throughout the country, in particular, in poorly investigated habitats such as phytotelms. Additionally, surveillance targeting *Aedes* invasive species should be prioritised, as the continued increase of ground traffic originating from the European continent and arriving directly into Ireland via ferries represents a likely route of invasion by these species. Such surveillance would also be useful at used tyre importation platforms and lucky bamboo (*Dracaena* spp.) greenhouses, points of entry (e.g. ferry ports and international airports), and in major cities.

Supplementary material

Supplementary material can be found online at https://doi.org/10.6084/m9.figshare.25498435

Table S1. Mosquito species occurrences (number of locations) per vice-county in our field survey, Republic of Ireland, 2017–2018.

Acknowledgements

We are grateful to the Irish 'VectorNet tick team' led by Anetta Zintl (University College Dublin, Ireland), for organising the field trip in 2017. We also acknowledge our colleagues Jeannine Hauri for performing the PCR (University of Zürich, Switzerland), as well as Guy Hendrickx and Veerle Versteirt (AVIA-GIS, Belgium) for coordinating VectorNet, and William Wint for reviewing our manuscript. The funding for this study was provided by VectorNet and the specific contract #7 (SC.EFSA.ALPHA.2016.01) of the European Food Safety Authority (EFSA), implementing the framework contract OC/EFSA/AHAW/2013/02-FWC1 supported by the EFSA and the European Centre for Disease prevention and Control (ECDC).

Conflict of interest

Francis Schaffner is editor-in-chief and Jolyon Medlock is associate editor of the Journal of the European Mosquito Control Association; they had no influence in the review process and decision making on this manuscript. The other co-authors declare no conflict of interest.

Data availability

The detailed data that supports the findings of this study are available at figshare: https://doi.org/10.6084/m9.figshare.25126571.

References

Ashe, P., O'Connor, J.P. and Casey, R.J., 1991. Irish mosquitoes (Diptera: Culicidae): a checklist of the species and their known distribution. Proceedings of the Royal Irish Academy Section B 91B: 21–36.

Becker, N., Petrić, D., Zgomba, M., Boase, C., Madon, M., Dahl, C. and Kaiser, A., 2010. Mosquitoes and their control.

Springer, Heidelberg, Germany. https://doi.org/10.1007/978-3-540-92874-4

Braks, M., Schaffner, F., Medlock, J.M., Berriatua, E., Balenghien, T., Mihalca, A.D., Hendrickx, G., Marsboom, C., Van Bortel, W., Smallegange, R.C., Sprong, H., Gossner, C.M., Czwienczek, E., Dhollander, S., Briët, O. and Wint, W., 2022. VectorNet: putting vectors on the map. Frontiers in Public Health 10: 809763. https://doi.org/10.3389/fpubh.2022.809763

Braks, M., van der Giessen, J., Kretzschmar, M., van Pelt, W., Scholte, E.-J., Reusken, C., Zeller, H., van Bortel, W. and Sprong, H., 2011. Towards an integrated approach in surveillance of vector-borne diseases in Europe. Parasites and Vectors 4: 192. https://doi.org/10.1186/1756-3305-4-192

Brusentsov, I.I., Gordeev, M.I., Yurchenko, A.A., Karagodin, D.A., Moskaev, A.V., Hodge, J.M., Burlak, V.A., Artemov, G.N., Sibataev, A.K., Becker, N., Sharakhov, I.V., Baricheva, E.M. and Sharakhova, M.V., 2023. Patterns of genetic differentiation imply distinct phylogeographic history of the mosquito species *Anopheles messeae* and *Anopheles daciae* in Eurasia. Molecular Ecology 32: 5609–5625. https://doi.org/10.1111/mec.17127

Collins, F.H. and Paskewitz, S.M., 1996. A review of the use of ribosomal DNA (rDNA) to differentiate among cryptic *Anopheles* species. Insect Molecular Biology 5: 1–9. https://doi.org/10.1111/j.1365-2583.1996.tb00034.x

Danabalan, R., Monaghan, M.T., Ponsonby, D.J. and Linton, Y.M., 2014. Occurrence and host preferences of *Anopheles maculipennis* group mosquitoes in England and Wales. Medical and Veterinary Entomology 28: 169–178. https://doi.org/10.1111/mve.12023

Elbers, A.R.W., Koenraadt, C.J.M. and Meiswinkel, R., 2015. Mosquitoes and *Culicoides* biting midges: vector range and the influence of climate change. Revue Scientifique et Technique – Office International des Epizooties 34: 123–137. https://doi.org/10.20506/rst.34.1.2349

Franklinos, L.H.V., Jones, K.E., Redding, D.W. and Abubakar, I., 2019. The effect of global change on mosquito-borne disease. The Lancet Infectious Diseases 19: e302–e312. https://doi.org/10.1016/s1473-3099(19)30161-6

Irish Biogeographical Society (IBS), 2023. Mosquitoes (Culicidae) of Ireland. National Biodiversity Data Centre, Ireland. Available at: https://maps.biodiversityireland.ie/Dataset/68

Medlock, J., Balenghien, T., Alten, B., Versteirt, V. and Schaffner, F., 2018. Field sampling methods for mosquitoes, sandflies, biting midges and ticks. EFSA Supporting Publications 15: 1435E. https://doi.org/10.2903/sp.efsa.2018.EN-1435

National Biodiversity Data Centre (NBDC), 2023. Culicidae, Ireland. Available at: https://maps.biodiversityireland.ie

Nicolescu, G., Linton, Y.M., Vladimirescu, A., Howard, T.M. and Harbach, R.E., 2004. Mosquitoes of the *Anopheles maculipennis* group (Diptera: Culicidae) in Romania, with the discovery and formal recognition of a new species based on molecular and morphological evidence. Bulletin of Entomological Research 94: 525–535. https://doi.org/10.1079/ber2004330

Robert, V., Günay, F., Le Goff, G., Boussès, P., Sulesco, T., Khalin, A., Medlock, J.M., Kampen, H., Petrić, D. and Schaffner, F., 2019. Distribution chart for Euro-Mediterranean mosquitoes (western Palaearctic region). Journal of the European Mosquito Control Association 37: 1–28.

Rocklöv, J. and Dubrow, R., 2020. Climate change: an enduring challenge for vector-borne disease prevention and control. Nature Immunology 21: 479–483. https://doi.org/10.1038/s41590-020-0648-y

Schaffner, F., Angel, G., Geoffroy, B., Hervy, J.-P., Rhaiem, A. and Brunhes, J., 2001. The Mosquitoes of Europe. An identification and training programme. IRD Editions & EID Méditerranée, Montpellier, France (CD-ROM).

Schaffner, F., Weigand, A. and Ries, C., 2023. Atlas and catalogue of the mosquitoes (Diptera, Culicidae) of Luxembourg. Ferrantia 87: 1–117.

Sinka, M.E., Bangs, M.J., Manguin, S., Rubio-Palis, Y., Chareonviriyaphap, T., Coetzee, M., Mbogo, C.M., Hemingway, J., Patil, A.P., Temperley, W.H., Gething, P.W., Kabaria, C.W., Burkot, T.R., Harbach, R.E. and Hay, S.I., 2012. A global map of dominant malaria vectors. Parasites and Vectors 5: 69. https://doi.org/10.1186/1756-3305-5-69

Smith, J.L. and Fonseca, D.M., 2004. Rapid assays for identification of members of the *Culex* (*Culex*) *pipiens* complex, their hybrids, and other sibling species (Diptera: Culicidae). American Journal of Tropical Medicine and Hygiene 70: 339–345. https://doi.org/10.4269/ajtmh.2004.70.339

Smitz, N., De Wolf, K., Gheysen, A., Deblauwe, I., Vanslembrouck, A., Meganck, K., De Witte, J., Schneider, A., Verlé, I., Dekoninck, W., Gombeer, S., Vanderheyden, A., De Meyer, M., Backeljau, T., Müller, R. and Van Bortel, W., 2021. DNA identification of species of the *Anopheles maculipennis* complex and first record of *An. daciae* in Belgium. Medical and Veterinary Entomology 35: 442–450. https://doi.org/10.1111/mve.12519

Snow, K., 1998. Distribution of *Anopheles* mosquitoes in the British Isles. Journal of the European Mosquito Control Association (European Mosquito Bulletin) 1: 9–13.

White, G.B., 1989. Malaria, Geographical distribution of arthropod-borne diseases and their principal vectors. World Health Organization, Geneva, Switzerland, pp. 7–22.

Wilkerson, R.C., Linton, Y.-M. and Strickman, D., 2021. Mosquitoes of the World. Vol. 1 & 2. Johns Hopkins University Press, Baltimore, MD, USA. https://doi.org/10.1353/book.79680