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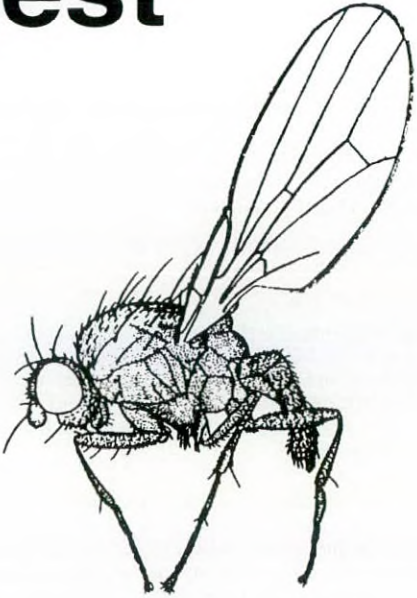
Cover illustration: *Clusia tigrina* (Fallén) (Clusiidae). mating pair on a dead beech (*Fagus sylvatica*) at Priory Park (TQ254494), Reigate, Surrey, August 2006. Photo: Jeremy Early.

Dipterists Digest



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Editorial Panel

Dipterists Digest is the journal of the **Dipterists Forum**. It is intended for amateur, semi-professional and professional field dipterists with interests in British and European flies. All notes and papers submitted to **Dipterists Digest** are refereed.

The scope of **Dipterists Digest** is:

- the behaviour, ecology and natural history of flies;
- new and improved techniques (e.g. collecting, rearing etc.);
- the conservation of flies;
- provisional and interim reports from the Diptera Recording Schemes, including maps;
- records and assessments of rare or scarce species and those new to regions, countries etc.;
- local faunal accounts and field meeting results, especially if accompanied by good ecological or natural history interpretation;
- descriptions of species new to science;
- notes on identification and deletions or amendments to standard key works and checklists.

Articles must not have been accepted for publication elsewhere and should be written in clear and concise English. **Contributions should preferably be supplied either as E-mail attachments or on 3.5" computer disc or CD in Word or compatible formats and accompanied by hard copy.**

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Style and format should follow articles published in the most recent issue. A short Summary (in the form of an Abstract) should be included at the beginning of each article. References to journals should give the title of the journal in full. Scientific names should be italicised. Authors of scientific names should be given in full and nomenclature should follow the most recent checklist, unless reflecting subsequent changes. Figures should be drawn in clear black ink, about 1.5 times their printed size and lettered clearly. **Colour photographs will also be considered.** Descriptions of new species should include a statement of the museum or institution in which type material is being deposited.

Authors will be provided with twenty separates of papers of two or more pages in length.

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The diversity of Diptera associated with a British hedge

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Summary

Diptera (true flies) were recorded at a single hedge, 85 metres in length, on a livestock farm in Devon, south-west England, over a two year period. Of these 830 species were identified. Members of some well-represented families were not, or scarcely, included in this total because they were not identified to species level: it is estimated that altogether over 1,000 species were present. The hedge is considered representative of lane-side hedges in south-west England and some other European regions. Excluding families from which few or no individuals were identified to species level, 17% of British species were found. The most species-rich families were Mycetophilidae, Syrphidae, Muscidae, Dolichopodidae, Limoniidae Hybotidae and Empididae. Observations from the hedge and published literature suggest that the majority of species present benefited from the hedge if not as larval habitat, then for adult food, mating, shelter or movement through the landscape. A minimum of 22% of species recorded at the hedge were considered likely to occur there as larvae: 162 species were recorded from emergence traps: these covered only 0.5% of the ground surface area; 163 species found are known to develop in association with decaying wood, including 97 of the 132 species recorded that are fungus feeders; 126 are associated with dung and 85 known to develop in living plant tissue. Assemblage analysis and other evidence suggest the hedge's high species-richness reflected its well structured form with, in addition to the shrub layer, emergent trees, a central bank, a ditch and herb-rich margins at both sides. Other important factors likely to explain the high biodiversity observed were the heterogeneity of other semi-natural habitats nearby, the small scale and high degree of landscape connectivity, the richness of plant species and the low intensity of local agricultural practices. Twenty-seven species considered nationally threatened or scarce were recorded. It is concluded that hedges, when placed in small-scale heterogeneous agricultural landscapes, can provide important resources for Diptera, facilitating the survival of species-rich and diverse assemblages.

Introduction

Hedges are a common form of field boundary in many parts of the world, including much of Europe (Zanden *et al.* 2013). They are widely recognised as being of considerable biodiversity value, both as habitats in their own right and as ecological corridors facilitating movement of organisms through the landscape (e.g. Lawton *et al.* 2010). In farmland landscapes, they are important refugia for wildlife associated with trees, scrub and unimproved grassland (Pollard *et al.* 1974). This paper explores the extent of the Diptera (true fly) fauna associated with a single hedge in Britain.

Within farmed landscapes, hedges are likely to support more biodiversity than cropped land even though they occupy far less space. Speight (2001), working on a farm in Ireland, showed that the favourable maintenance of infrastructure habitats, especially hedges together with their associated ditches and field margins, has greater potential to sustain Syrphidae and Sciomyzidae faunas than trying to make productive land more "eco-friendly". Likewise, on an organic farm in Somerset, England, Evans *et al.* (2011), researching food webs associated with seed-eating animals (of which 82% were invertebrates), noted that the majority of the biodiversity on a farm can be conserved by appropriately managing uncultivated habitats such as hedges and woodlands. A further study at the same Somerset farm explored the trophic interactions between 560 taxa and found that hedges and waste ground, together comprising just 4.5% of the total area of the farm, were disproportionately important to the integrity of the overall ecological network (Evans *et al.* 2013).

While the diversity of vertebrates associated with hedges has been well studied (e.g. Hinsley and Bellamy 2000), comparatively little is known about the diversity of their invertebrate fauna, at least at the species level (Dover and Sparks 2000, Lewis 1969, Maudsley 2000, Pollard 1968). The research reported here aims to help fill this knowledge gap for one order of insects, the Diptera, as part of a wider study, the main aim of which was to assess the diversity of life associated with a single hedge, to inform the case for conservation of this habitat (Wolton and Vergette 2012).

Previous studies relating specifically to hedge Diptera have largely focussed on the extent to which hedges harbour species of economic importance, as pollinators, crop pests or predators of pests (Frouz and Paolett 2000, Holland *et al.* 2012, Hradetzky and Kromp 1997, Lewis 1970, MacLeod 1999, Wratten *et al.* 2003).

Studies assessing insect diversity are fewer in number. Pollard and Holland (2006) used insecticide fogging to assess the diversity of arthropods within the woody element of sample sections from 13 hedgerows in Hampshire, England; 10% of the 13,390 arthropods collected were Diptera, belonging to 19 families – however, these were not identified to species level. Peng *et al.* (1992) used suction trapping to examine the temporal and spatial distribution of Diptera around an emergent hedgerow tree. They caught over 84,000 individuals, but again these were only for the most part identified to family level. The study most comparable to the one reported here is that of three traditional orchards within the Wyre Forest, Worcestershire, England (Smart and Winnall 2006). All the orchards included species-rich hedges and permanent pasture along with the fruit trees, many of which had saproxylic habitats like rot holes; 659 Diptera species were recorded over a single year.

The word hedge is used throughout this paper, as opposed to hedgerow, to signify that all major structural components closely associated with the feature were sampled. A hedge consists of more than a line of shrubs (the strict hedgerow). It also has soil and herbaceous communities at the base, and often has emergent hedgerow trees, a ditch on at least one side, and strips of marginal vegetation that differ from field cropped areas. The marginal strips are variously referred to as field margins, buffer strips, headlands and verges. All the components – shrub layer, emergent tree, base, ditch and margin – together comprise the hedge, although any given hedge may vary in the number of components it has and their quality as a habitat (Wolton *et al.* 2013).

The study hedge

The hedge is at Locks Park Farm, near Hatherleigh, in central Devon (National Grid Reference SS518022), south-west England, at an altitude of 110m above sea level. The farm comprises 35ha of permanent pasture for cattle and sheep. It lies on poorly draining acidic clay soils of the Culm Measures and has been managed at low intensity for many decades. The farm was registered organic. The surrounding landscape is one of small fields with frequent soft rush *Juncus effusus*, bordered by an intact network of species-rich hedges extending for tens of kilometres in all directions (Fig. 1). The fields are interspersed by small semi-natural broadleaved woodlands and conifer plantations, and are drained by small oligotrophic streams cut through the clay and underlying shale. Mature trees with features such as rot holes and sap flows are frequent, although large open-grown specimens are rare. A small farm pond with fringing tall fen vegetation lies 30m away from the hedge, separated from it only by another, parallel, hedge.

The study hedge was chosen not for any particular attribute but because it is highly accessible to the senior author, starting just 40m from the farmhouse where he lives. It is typical of many lane-side hedges of north Devon occurring on the Culm Measures (cf. Land Use Consultants 2012).

The hedge is 85m long, orientated north-south, and runs along one side of the main access lane to the farm buildings. The average width of the hedge (between the outer boundaries of the margins) is 6.55m and the hedge occupies 560m^2 (0.056ha). Parallel to it on the other side of the lane and 5m away is another, similar, hedge. The age of the study hedge is not known but predates the 1845 parish tithe map. At the southern end it joins a very small stream bordered by mature pedunculate oak *Quercus robur*, ash *Fraxinus excelsior* and alder *Alnus glutinosa* trees. At the northern end, beyond a 2.5m gateway, is a small thicket of mature blackthorn *Prunus spinosa* and holly *Ilex aquifolium*. Neither stream nor thicket was included within the hedge length sampled.

As is typical of a Devon hedge (Devon County Council and The Devon Hedge Group 1997), the hedge has a bank underlying the shrubs and trees. This bank is about 2.5m wide at the base and rises on average 0.75m above the base of the small ditch that runs along the lane side. Vegetation on top of the bank beneath the shrub layer, being heavily shaded, is sparse but lords-and-ladies *Arum maculatum* is occasional and bryophytes cover fallen branches. Ferns, mainly *Dryopteris* species, are frequent on the bank sides together with primrose *Primula vulgaris*.

The shrub layer is species-rich (Defra 2007) with on average 9 woody species per 30m length. The most frequent shrubs are hawthorn *Crataegus monogyna* (94% incidence at two-dimensional cross-sections taken every 5m), blackthorn (65%), hazel *Corylus avellana* (65%) and grey willow *Salix cinerea* (29%). Pedunculate oak (12%) and downy birch *Betula pubescens* (12%) are less frequent. Bramble *Rubus fruticosus* agg. and field-rose *Rosa arvensis* between them form an almost continuous, if in places thin, band down either side of the hedge, occasionally on the field side forming outgrowths up to 2m wide. Using the classification system developed by French and Cummins (2001), the hedge falls within their Mixed-hazel class. In response to repeated cycles of cutting and laying, the shrubs have developed small-scale coppice stools with associated micro-habitats.

In the study years, 2011 and 2012, the shrubs were about 3.5m high and 3.0m wide to the tips of the shoots. The hedge was last laid over the winter of 1999/2000, and either top and/or sides were subsequently trimmed (to a box profile) with a flail cutting head every 3 to 5 years to maintain a bushy structure.

Emerging out of the shrub layer are three young oak trees, 25 years old, each about 7m high. These lack any veteran features.

The ditch, which is 0.75m across at the top, has damp mud and leaf litter in the bottom throughout the year, and carries flowing water during periods of heavy rainfall. It is wet enough to support some yellow iris *Iris pseudacorus*. The ditch has received no management for at least 20 years, being largely self-cleaning.

Between the ditch and the lane lies an herbaceous verge on average 1.3m wide. This is dominated by predominantly tall herbs, especially nettle *Urtica dioica*, hemlock water-dropwort *Oenanthe crocata* and, in places, bracken *Pteridium aquilinum*. Cleavers *Galium aparine* is abundant and hogweed *Heracleum sphondylium*, wild angelica *Angelica sylvestris* and cow parsley *Anthriscus sylvestris* are frequent. The lane-side verge is cut most years in the winter, largely to control bramble growth.

Fig. 1. The location of the hedge (red line in centre) in the surrounding landscape. The area covered is 1.5km x 1.5km. Image taken 2010. Source: Google Earth. © 2103 Google. Image © 2014 Getmapping plc.

On the other side of the hedge there is a scalloped herbaceous margin about 2.0m wide leading onto a semi-improved pasture field used for grazing by cattle and sheep and occasionally cut for silage or to control soft rush. This field margin is grassier than the lane-side one, with abundant Yorkshire fog *Holcus lanatus* and bents *Agrostis* spp, together with much soft rush, meadowsweet *Filipendula ulmaria* and nettle. Frequent herbs include common knapweed *Centaurea nigra*, mint *Mentha* spp, bugle *Ajuga reptans* and hedge woundwort *Stachys sylvatica*. This margin is not cut, only grazed, to encourage both the development of a tussocky structure and plant species diversity.

The hedge is in favourable condition for biodiversity for all attributes (i.e. dimensions, continuity, undisturbed ground and perennial vegetation cover, non-native species and nutrient enrichment) developed by Hedgelink (Defra 2007, Appendix 9).

Sampling methods

Only flies observed or caught within 2m of the tips of the branches of the hedge shrubs or trees were recorded. Recording started on 1 January 2011 and ended on 31 December 2012.

Fig. 2. Malaise trap at field side of study hedge on 11 July 2011. The hedge was last cut in autumn 2008.

Flies and other insects (cf. Table 1) were found using a variety of methods: principally by careful searching by eye, sweeping with a hand net, attraction to a Robinson mercury-vapour light trap and use of a Malaise trap (Figs 2 and 3). The hedge was visited on most days, often several times a day during sunny summer days, for the purpose of making field observations and netting specimens. Most visits lasted about ten minutes, during which the length of the hedge was walked slowly, on one side or both. Particular attention was paid to flowering plants. Sweep netting took place at irregular intervals throughout the year, but especially during the spring before bramble growth made it difficult. The light trap was tucked into the base of the shrubby growth on one side or the other of the hedge, and used about once a week in the first year and once a month in the second year. On each occasion, it was run throughout the night and the catch examined in the morning. The Malaise trap was placed for roughly the same amount of time on each side of the hedge, in the middle third. It was set perpendicular to the hedge across the ditch and/or margin, so that the lower end was inserted into the shrub layer. It was operated on an almost continuous basis between early

July 2011 and 31 December 2012, the collecting bottle being emptied at least once every 3 days. The bottle contained an insecticide-impregnated strip.

In March 2012, six emergence traps were placed in the hedge (Fig. 3). These were simple fine mesh domes on a wire armature, the edges being firmly pegged onto the ground. Each trap covered approximately 0.5 m². Two were placed on the bank top below the middle of the shrub layer, two over the ditch and two on the lane-side margin. The traps were kept in the same locations until removal in October 2012. They were emptied using a pooter every two or three days. No attempt was made to keep samples from each trap separate.

Fig. 3. Emergence and Malaise traps at lane-side of study hedge on 7 April 2012. The two emergence traps in the centre of the hedge, under the shrubs, cannot be seen.

Assemblage analysis

Species were allocated to assemblage types using the ISIS (= Invertebrate Species-habitats Information System) classification developed by Natural England (Webb and Lott 2006). This system allocates invertebrate species to a three-tier hierarchy, fidelity to type increasing with tier. For example, the woodland group (first tier) contains two Broad Assemblage Types (BATs), 'arboreal canopy' and 'wood decay'. The wood decay BAT in turn contains four

Specific Assemblage Types (SATs), encompassing the most fastidious species. A measure of the quality of each BAT can be gained by dividing the total rarity score generated by ISIS by the number of species to give a Species Quality Index (SQI). The database is undergoing development and as yet not all families of Diptera have been allocated assemblages. The 2010 version was used here.

Identification

Most species determinations were by the authors largely as follows: HB (Anthomyiidae, Calliphoridae, Sarcophagidae and some Tachinidae), PJC (Mycetophilidae, Sciaridae and allies and Drosophilidae), CMD (Dolichopodidae, Ephydridae, Opomyzidae and some other Acalyptratae), JK (Ptychopteridae and Tipuloidea), AP (Empididae and Hybotidae) and AES (Ptychopteridae, Tipuloidea, Trichoceridae and rare Syrphidae). David Gibbs identified Pipunculidae, John Ismay Chloropidae, Erica McAlister Culicidae and Richard Lane some Bibionidae. RJW determined the remainder.

Results

A total of 817 Diptera were determined to species level from the hedge, with a further 13 additional species identified to genus, giving a total of 830 species recorded (see Appendix for full list). This total includes 19 species identified largely through galls or leaf mines from families that were otherwise not recorded (i.e. Agromyzidae and Cecidomyiidae). If these 19 species together with Phoridae, Ceratopogonidae, Chironomidae and Simulidae (all families from which few or no species were identified) are excluded from the analysis, then 16.7% of all species on the British List were recorded at the hedge over the two years of the study. Table 1 compares this proportion with that found for other insect orders or suborders.

Table 1. The proportion of all species known from the British Isles recorded at the hedge, for insect orders or sub-orders where the majority of specimens were identified to species level. British totals are from Barnard (2011) except for Diptera (Chandler 2013).

Insecta Order/Suborder	Number of species on British list	Number of species recorded in hedge	% of British list in hedge
Aculeata	610	45	7.4
Diptera (excluding families not or scarcely recorded)	4,867	811	16.7
Heteroptera	554	43	7.8
Lepidoptera	2,570	426	16.6
Symphyta	487	56	11.5
Trichoptera	198	34	17.2

Table 2. Number of Diptera species recorded in the hedge for each major family and selected higher taxonomic groupings, and these numbers expressed as a proportion of all species known from the British Isles (Chandler 2013).

Families with more than 100 species recorded in the British Isles	**Number of species on British list**	**Number of species recorded in hedge**	**% of British list in hedge**
Anthomyiidae	244	17	7.0
Dolichopodidae	299	46	15.4
Empididae	208	34	16.3
Ephydridae	151	25	16.6
Hybotidae	180	34	18.9
Limoniidae	216	42	19.4
Muscidae	287	55	19.2
Mycetophilidae	480	126	26.3
Sciaridae	266	19	7.1
Sphaeroceridae	138	21	15.2
Syrphidae	281	93	33.1
Tachinidae	266	15	5.6
Selected higher taxonomic groupings			
Lower Brachycera*	159	28	17.6
Sciaroidea (excluding Cecidomyiidae)	820	159	19.4
Sciomyzoidea	109	24	22.0
Tipuloidea	327	72	22.0
All species (excluding families from which few or no individuals were identified to species level)	**4,867**	**810**	**16.6**

* = Families covered by Stubbs and Drake (2001)

At major family and selected higher taxonomic levels, the proportions of British Diptera species recorded at the hedge are given in Table 2. Typically between 15% and 20% of species were recorded in the hedge. Syrphidae (33%), Mycetophilidae (26%), Sciomyzoidea (principally Sciomyzidae and Sepsidae) (23%), Limoniidae (19%), Muscidae (20%) and Hybotidae (19%) were particularly well represented, while Anthomyiidae (7%)

and Tachinidae (6%) were poorly represented. Anthomyiidae, however, were only identified in the second year.

Table 3. Number of species per family caught in emergence traps, for those families where more than 3 species or 10 individuals were recorded. See Appendix for details of species caught in emergence traps.

Emergence traps	**Number of species**	**Number of individuals**
Dolichopodidae	20	369
Empididae	11	32
Ephydridae	2	Several 10s
Fanniidae	4	About 10
Heleomyzidae	4	5
Hybotidae	14	73
Limoniidae	23	Many 100s
Lonchopteridae	1	About 50
Muscidae	8	16
Mycetophilidae	11	21
Rhagionidae	3	18
Scathophagidae	3	7
Sciaridae	10	About 25
Sciomyzidae	5	10
Sphaeroceridae	6	12
Stratiomyidae	6	26
Syrphidae	5	8
Tipulidae	4	About 20
Total	**140**	

Of the species recorded 511 are in the ISIS database and assemblage analysis was based on these. Muscids were the major omission. Of the nine Broad Assemblage Types (BATs) recognised, four contained more than 10% of the species: 'grassland & scrub matrix' (21%), 'permanent wet mire' (16%), 'shaded field & ground layer' (14%) and 'flowing water' (12%). The wood decay BAT contained 8% of the species. 29% of species were not allocated to any BAT, being considered generalists. The Species Quality Index (SQI) for 'grassland & scrub matrix' was 1.34, for 'shaded field & ground layer' 1.86, for 'permanent wet mire' 2.14 and for 'flowing water' 2.44. It was considerably higher for 'wood decay' at 4.75, indicating that this assemblage is of greater conservation significance than others.

Six Specific Assemblage Types (SATs) were recognised, although each had 4% or fewer of the species listed for each SAT in the ISIS dictionary. The three SATs with most species were 'reedfen and pools' (4 species), 'bark & sapwood decay' (4 species) and 'heartwood decay' (5 species). These figures again suggest that the hedge supported an important dead wood fauna.

From the emergence traps 162 Diptera species in 38 families were recorded. This figure does not include Phoridae, Psychodidae and Chironomidae, families from which many individuals were caught in the traps but which were not identified to species level. Of the families recorded most were represented by fewer than 3 species or 10 individuals. The exceptions to this are given in Table 3. The Limoniidae and Dolichopodidae were the best represented families with 23 and 20 species respectively, followed by Hybotidae, Empididae, Mycetophilidae and Sciaridae. The families with the most numerous individuals were the Limoniidae (by a considerable margin), Dolichopodidae, Hybotidae, Lonchopteridae, Empididae and Ephydridae. Individuals of species of Limoniidae were not counted but some species were abundant; otherwise the single most numerous species was *Dolichopus popularis* Wiedemann (Dolichopodidae) with 282 individuals caught. Of the species caught in the emergence traps 25 are known to have larvae associated with decaying wood, 19 with dung, 15 with fungi or myxomycetes and 10 with living plant tissue (references cited below). The use of other larval micro-habitats has not been analysed.

Of the total of 830 identified species, 85 (10%) are known to be phytophagous (Uffen and Chandler 2010 plus additional unpublished data) (see Appendix for details of the 85 species). This drops to 70 species if Agromyzidae and Cecidomyiidae are excluded, large phytophagous families from which only 10 leaf-mining and 5 gall-forming species were respectively identified – many grass feeding agromyzids, for example, are likely to have been present. The food plants of five of the 85 species are not known. Of the remaining 80 species, the food plants of 66 (82.5%) are present in the hedge, and those of a further seven species within 50m of the hedge.

Based on the 730 Diptera species listed by Alexander (2002) as known or likely to be associated with decaying wood (including associated fungi) in Great Britain, 137 such species were recorded from the hedge (17% of the hedge total). While Alexander (2002) included some species speculatively and a few non-saproxylic species based on casual records, the additional species that have been reared from saproxylic fungi more recently raises the total with a known association with decaying wood to 163 (20% of the hedge total, see Appendix for details). Some of these are generally saprophagous species that may also develop in decaying herbaceous vegetation, while many of the fungus feeders have been reared from terrestrial as well as saproxylic species.

A total of 132 species (16% of the total) have been reared from fungi or myxomycetes (Chandler 2010 and unpublished data) (see Appendix for details). These comprise 72 species of Mycetophilidae and 60 species from other families. Of these 132, 35 (18 Mycetophilidae and 17 from other families) have been recorded only from fungi with hosts other than living or decaying wood (mycorrhizal and other terrestrial fungi). Three of the 132 species are confined to myxomycetes.

From the list of 379 species associated with dung, as either adults or larvae, given by Skidmore (2010), 126 Diptera species (15% of the hedge total) were recorded (see Appendix for details). Of the 126 species, 73 have been recorded as developing in cattle dung or manure heaps, with a further 13 recorded at this dung type only either as adult visitors or as casual invaders from another habitat. The 71 species were from 15 different families, in particular Muscidae (30 species), Sphaeroceridae (11) and Sepsidae (10). In contrast, just 15 of the species have been recorded developing in sheep dung, with a further 5 as adults or casuals. Other types of dung occurring at or close to the hedge utilised by recorded flies are dog (19 species), rodent (7 species) and birds including chicken (4 species).

The hoverflies (Syrphidae) recorded as adults from the hedge included 93 species (Table 4). For 45 of these species five or fewer individuals were recorded. Seven species were abundant with over 500 individuals observed.

Table 4. Numbers of individuals recorded for each hoverfly (Syrphidae) species.

Number of individuals. (Numbers > 5 estimated)	**Number of species**	**Examples**
1	12	Includes *Platycheirus scutatus* and *P. aurolateralis* with only one male recorded for each; several females from this species group were also recorded
2	19	
3-5	14	
6-10	13	
11-50	19	More numerous species in this category are *Cheilosia albitarsis, Cheilosia pagana, Epistrophe eligans, Melanostoma mellinum, Orthonevra nobilis, Riponnensia splendens, Sericomyia silentis, Syrphus torvus* and *Xylota segnis*
51-500	9	*Cheilosia illustrata, Cheilosia scutellata, Chrysogaster solstitialis, Episyrphus balteatus, Meliscaeva auricollis, Neoascia podagrica, Rhingia campestris, Syrphus ribesii* and *S. vitripennis*
>500	7	*Eristalis arbustorum, E. nemorum, E. pertinax, Helophilus pendulus, Melanostoma scalare, Platycheirus albimanus* and *Syritta pipiens*
Total number of species recorded	**93**	

A further 25 hoverfly species were recorded within about 200m of the hedge between 2009 and 2013, through casual observation and hand netting; 18 of these were recorded just once, and a further two just twice. The remaining five species were recorded more often and either known to develop nearby or this is considered highly likely: *Platycheirus ambiguus* (Fallén), *Microdon myrmicae* Schönrogge *et al.*, *Brachyopa bicolor* (Fallén), *B. scutellaris* Robineau-Desvoidy and *Brachypalpus laphriformis* (Fallén).

If hoverfly species recorded five or fewer times are excluded (to reduce the impact of vagrants or casual visitors), then the larval micro-habitats (after Stubbs and Falk 2002, Speight 2008) of 42 (87%) of the remaining 48 species occur in the hedge (Table 5).

Table 5. Larval micro-habitats of hoverflies (Syrphidae) that could have developed in the hedge. Only species for which more than five individuals were recorded were included in this analysis.

Larval micro-habitat	**Number of species recorded using this micro-habitat**	**Species**
Aphids on woody plants or herbs	17	*Baccha elongata, Eupeodes corollae, Eupeodes latifasciatus, Eupeodes luniger, Epistrophe eligans, Episyrphus balteatus, Leucozona laternaria, Leucozona lucorum, Melanostoma mellinum, Melanostoma scalare, Meliscaeva auricollis, Platycheirus albimanus, Platycheirus granditarsus, Platycheirus peltatus, Syrphus ribesii, Syrphus torvus, Syrphus vitripennis*
Fungi	1	*Cheilosia scutellata*
Decaying timber or wood	3	*Sphegina elegans, Xylota segnis, Xylota sylvarum*
Decaying ditch vegetation and mud	14	*Chrysogaster solstitialis, Eristalinus sepulchralis, Eristalis abusiva, Eristalis arbustorum, Eristalis horticola, Eristalis intricaria, Eristalis nemorum, Eristalis pertinax, Eristalis tenax, Helophilus pendulus, Neoascia meticulosa, Neoascia podagrica, Riponnensia splendens, Syritta pipiens*
Bumblebee (*Bombus* spp) and wasp (*Vespula* spp) nests	1	*Volucella bombylans*
Phytophagous	6	*Cheilosia albipila, Cheilosia albitarsis, Cheilosia antiqua, Cheilosia illustrata, Cheilosia pagana, Merodon equestris*
Total number of species recorded more than five times	**42**	

Only 5 species of hoverfly were caught in emergence traps, all in low numbers: *Melanostoma scalare* (Fabricius) (3 individuals), *Platycheirus albimanus* (Fabricius) (1), *Sphegina clunipes* (Fallén) (2), *Syritta pipiens* (Linnaeus) (1) and *Syrphus ribesii* (Linnaeus) (1). It should be noted that the emergence traps were left in the same place throughout the period March to October so will not have recorded those species (e.g. *Eristalis*) which overwinter as adults, nor late brood individuals from those species which have more than one brood during the year.

Hoverflies of 44 species were observed feeding on the flowers of tall members of the Apiaceae (umbellifers), mainly *Oenanthe crocata*, *Angelica sylvestris* or *Heracleum sphondylium*.

A total of 27 nationally scarce or threatened species was recorded from the hedge, as shown in Table 6. This list includes a number of data deficient species for which insufficient records are available to make an accurate assessment of status but which are likely to be at least scarce. Status assessments follow, as far as available information permits, the standard criteria developed by the International Union for Conservation of Nature and adopted by the Joint Nature Conservation Committee (IUCN 2003). Where the larval micro-habitat of these species is known or suspected, seven are predatory, seven feed in decaying wood or associated fungi, and five are phytophagous. Just one is saprophagous (other than on wood) and one is a parasitoid.

Table 6. Nationally threatened, Nationally Scarce and Data Deficient species recorded. Status assessments according to: Nematocera and Aschiza (Falk and Chandler 2005), Empidoidea (Falk and Crossley 2005), Acalyptratae (Falk, Ismay and Chandler in prep.), Syrphidae (Ball and Morris in prep.), and Falk (1991) for species not in the foregoing. The authors of this paper have updated some of this information to reflect on-going reviews using IUCN criteria. Larval development micro-habitat: ^{a} – parasitoid, ^{c} – coprophagous, ^{d} – saproxylic (not on fungi), ^{df} – fungus on dead wood, ^{f} – terrestrial fungus, ^{p} – phytophagous, ^{r} – predator, ^{s} – saprophagous (not wood), ^{u} – unknown.

Family	Species	No.	Method	Status
Cylindrotomidae	*Diogma glabrata* ^{p}	?	Malaise	Nationally Scarce
Drosophilidae	*Amiota basdeni* $^{df?}$	2	Malaise	Data Deficient
Drosophilidae	*Stegana longifibula* $^{df?}$	1	Malaise	Data Deficient
Empididae	*Kowarzia madicola* $^{r?}$	1	Malaise	Data Deficient
Keroplatidae	*Neoplatyura biumbrata* ^{u}	1	Malaise	Vulnerable
Lauxaniidae	*Sapromyza albiceps* $^{s?}$	3	Swept	Nationally Scarce
Muscidae	*Lispocephala pallipalpis* $^{r?}$	1	Malaise	Nationally Scarce
Muscidae	*Mydaea affinis* ^{r,f}	1	Malaise	Nationally Scarce
Mycetophilidae	*Allodia angulata* ^{u}	1	Malaise	Nationally Scarce
Mycetophilidae	*Exechia dizona* ^{df}	3	Malaise	Nationally Scarce
Mycetophilidae	*Leia bilineata* ^{d}	2	Malaise	Nationally Scarce
Mycetophilidae	*Mycetophila strigatoides* ^{df}	3	Malaise	Nationally Scarce
Mycetophilidae	*Sceptonia tenuis* ^{u}	1	Malaise	Nationally Scarce
Mycetophilidae	*Trichonta nigritula* ^{u}	1	Malaise	Nationally Scarce
Mycetophilidae	*Trichonta pulchra* ^{u}	6	Malaise	Nationally Scarce

Periscelididae	*Periscelis annulata* [d]	1	Malaise	Nationally Scarce
Psilidae	*Chyliza vittata* [p]	1	Malaise	Nationally Scarce
Scathophagidae	*Conisternum decipiens* [u]	4	To UV	Nationally Scarce
Sciomyzidae	*Pherbellia brunnipes* [r]	2	Emergence trap	Nationally Scarce
Sciomyzidae	*Pherbellia griseola* [r]	1	Emergence trap	Nationally Scarce
Syrphidae	*Platycheirus aurolateralis* [r]	1	Malaise	Data Deficient
Syrphidae	*Cheilosia carbonaria* [p]	1	Malaise	Nationally Scarce
Syrphidae	*Cheilosia nebulosa* [p]	2	Netted + Malaise	Nationally Scarce
Syrphidae	*Ferdinandea ruficornis* [d]	1	Malaise	Nationally Scarce
Syrphidae	*Parasyrphus nigritarsis* [r]	1	Netted	Nationally Scarce
Tachinidae	*Eloceria delecta* [a]	3	Malaise	Nationally Scarce
Tephritidae	*Cryptaciura rotundiventris* [p]	2	Swept + Malaise	Vulnerable

Discussion

The hedge sampled is similar in structure and plant species composition to many others running alongside lanes in Devon and elsewhere in south-west England (RJW pers. obs.). For those families covered, a remarkable 17% of the UK's Diptera fauna was recorded. It is probable that if species from families not covered were identified and with further sampling, over 1,000 species could be found. To place this in context, work in Surrey, south-east England, suggests that high quality nature conservation sites support a fifth or more of the British insect fauna (AES, unpublished data). This study shows that hedges can provide resources such that similar levels of insect biodiversity can be found in association with them as with nature reserves and other sites recognised as being of high nature conservation importance.

Towards an explanation of the high species richness, the following key questions are discussed below: (1) is the hedge structure particularly favourable; (2) to what degree is plant and insect diversity linked; (3) what are the effects, if any, of local agricultural practices; (4) how important is the range of other habitats in the local landscape; (5) is landscape connectivity likely to be an important factor; (6) is there any 'green lane' effect from the hedge having another one running parallel to it on the other side of a lane; (7) what are the larval development resources provided by the hedge; (8) to what extent is the hedge beneficial or harmful to fly survival.

Influence of hedge structure. The presence of the full suite of major structural components (shrub layer, emergent trees (albeit only young ones), base/bank, ditch and margins) is likely to account for a large proportion of the species richness found. This contention is supported by the ISIS analysis which found that three of the four major broad assemblage types identified were grassland and scrub matrix, shaded field and ground layer and flowing water, all to be expected from the hedge composition. The fourth major assemblage, permanent wet mire, is more characteristic of the surrounding landscape.

On a farm in Ireland, Speight (2008) demonstrated that hedges that consisted of a shrub layer together with a field margin and ditch supported more Syrphidae species than any one of these components on its own. The presence of a field margin doubled the number of species, and a ditch increased the potential fauna by a further 30%. For both vertebrates and invertebrates, Wolton *et al.* (2013) analysed which hedge structural components are used by the 157 UK priority and farmland quality indicator species (Defra 2012) which are at least partially dependent on UK hedges. They found that the majority (65%) of these species are dependent on more than one hedge component, with over a third (35%) being dependent on three or more components. Multiple hedge component dependency was even more striking for widespread species: 81% of them are dependent on more than one component. The most important combinations found were: Shrub + Tree (19 species), Shrub + Base + Margin (9) and Shrub + Tree + Margin (8).

Although the study hedge had several young emergent oaks rising to 7m, it lacked any tall or mature trees, and this is likely to have limited its invertebrate species richness. In late July 1986 and 1987, Peng *et al.* (1992) used suction traps to sample the Diptera of an 11.5m tall flowering lime tree (*Tilia* sp.) emerging from a hedge. Based on the large numbers caught, they suggested that hedgerow trees are important influences on the distribution and local concentration of the dipterous fauna of lowland Britain. Indeed, emergent trees act as swarm markers for many Diptera families (e.g. Empididae, Hybotidae, Stratiomyidae, Phoridae and Anthomyiidae) (ARP pers. obs.). Peng *et al.* (1992) found that all families, with the exception of Scatopsidae (which may have used the traps themselves as swarm markers), were caught more frequently immediately next to the tree foliage than in traps 4.5m away. Most families were concentrated at the mid-level (5m high) of the tree, exceptions being the Anisopodidae which were more frequent in the high traps (8.8m) and the Mycetophilidae which were more frequent in the low level traps (1.2m). Working on farms in Oxfordshire (south-east England), Merckx *et al.* (2009) found that the presence of hedgerow trees resulted in a substantially higher abundance (+60%) and species richness (+38%) of larger moths in the immediate landscape compared to similar landscapes without hedgerow trees, although this only applied to landscapes subject to an agri-environment scheme (e.g. Environmental Stewardship (Natural England 2013)). In a follow-up study they showed that in typically exposed agricultural landscapes this effect was largely due to the shelter provided by hedgerow trees, rather than to the trees providing larval food (Merckx *et al.* 2010). Nevertheless, species that fed as larvae on trees and shrubs benefited more through the presence of hedgerow trees than those that did not. In a further paper they confirmed that hedgerow trees led to a local increase in macro-moth species richness, but not to an increase in abundance, across all farmland (regardless of whether or not it was in an agri-environment scheme) (Merckx *et al.* 2012). They concluded that it is likely that hedgerow trees are ecologically keystone structures in intensive agricultural landscapes, with a disproportionate effect on ecosystem functioning, given the small area occupied by any individual tree. This suggests that if mature trees had been present in the hedge sampled in this paper, species-richness may have been even greater.

Influence of botanical diversity. Eight ferns, 63 herbs, 11 grasses and 11 woody shrubs or trees were recorded in the hedge – 93 vascular plants in all. In the Devon context this is not exceptional – 293 vascular plant species were found in the hedges of a "very ordinary small (24ha) farm" in the county (Michelmore and Proctor 1994) on similar surface geology to that of the hedge reported here. Nevertheless, as a mixed-hazel hedge, it may be expected to be among the most floristically species rich in Britain (French and Cummins 2001). To what extent did this plant species richness affect that of Diptera present? It is to be expected that invertebrate diversity will increase with plant species diversity because many phytophagous invertebrates are host specific (e.g. Maudsley 2000). However, Webb *et al.* (2010), assessing the needs of animal species across a wide range of habitats, noted that structural diversity is often critical and more important than botanical diversity. In this study more Diptera species recorded are known to develop as larvae on decaying wood, fungi or even dung than on living plants.

Influence of local land management practices. It is to be expected that the low intensity with which surrounding farmland is managed (compared to the intensive arable farming typical of much of eastern England) will have increased species richness (Schweiger *et al.* 2005). Burel *et al.* (2004), comparing a range of farms in Brittany (France), found that the species-richness of both Chironomidae and Empididae communities decreased as field sizes became larger and with intensity of land use.

A further landscape factor that may have boosted species number of the hedge is the farm's organic status. Other than occasional use of wormers and insecticides applied directly to cattle and sheep to limit fly strike and nuisance, no pesticides or inorganic fertilizers had been used on the land for at least 20 years. Wickramasinghe *et al.* (2004) compared nocturnal aerial insects on 24 matched pairs of organic and conventional farms, focussing on 18 families commonly eaten by bats in the British Isles. They found that insect abundance and species richness were significantly higher on organic farms than on conventional farms. However, whether this was due to no agrochemicals being used on organic farms or because these farms were intrinsically richer in semi-natural habitats is not clear. Rundlöf and Smith (2006), investigating butterfly diversity, found that organic farming only increased species-richness in intensively farmed homogeneous landscapes. Boutin *et al.* (2011) explored the value of hedgerows for moth diversity on organic and conventional farms in North America. They found there was no significant difference in moth diversity between these farm types, except for one family (Notodontidae), which was more species-rich on organic farms. In contrast, species richness was greatly influenced by the range of habitat types present, and they concluded that the maintenance of non-crop habitats such as hedges within agro-ecosystems appears paramount to preserving biodiversity. Thus, while research suggests that the wide range of different habitats present in the vicinity of the hedge, the small field size and the low intensity of agricultural use will have acted to boost species numbers, evidence for organic status having any such influence is less clear.

Influence of local landscape. The landscape within a 1km radius of the hedge contains a range of different habitats and resources: improved, semi-improved and unimproved pastures, mature trees with veteran features, small broadleaved and conifer woodlands, farm ponds and minor streams. It is to be expected that this heterogeneity will have increased species diversity in the local landscape (Hendrickx *et al.* 2007) and consequently at the hedge. For example, some Diptera which develop in other habitats will have visited the hedge either for food, shelter or mates, or been "trapped" by it while moving, actively or passively, through the landscape. The similarity between families of the proportion (15% – 20%) of British species found (Table 2) gives further weight to this view. For example, the high number of craneflies (Tipuloidea) and of fungus gnats (Mycetophilidae) is likely to reflect the good representation of wet woodland habitats in the vicinity. Research on Empididae behaviour demonstrates the benefits of small-scale habitat heterogeneity particularly well, different habitats providing different resources. Whereas the larvae may inhabit one habitat, the adults will mate in another and feed in a third. Certain species (e.g. some *Hilara* spp) occur as larvae in open grassland, form mating swarms around bushes and hunt at the edges of ponds (Delettre *et al.* 1992, 1998). All three habitats need to be present in close proximity for such species to thrive.

Influence of landscape connectivity. For vertebrates, a substantial body of evidence exists to demonstrate that intact hedge networks can be beneficial for regular commuting between breeding and feeding areas (e.g. hazel dormouse *Muscardinus avellanarius* (Linnaeus) (Bright 1998) and bats (Cowan and Crompton 2004)). Few invertebrates are known to commute in the same way. Nevertheless, Cranmer *et al.* (2012) have demonstrated that bumblebees (*Bombus* spp) prefer to use linear landscape features such as hedges to travel between food sources and their nests, and Heard *et al.* (2012) reported the same for solitary wasps. Other invertebrates have been shown to move preferentially along hedges in the search for food, mates or breeding sites rather than across open fields, for example butterflies (Dover and Sparks 2000), moths (Coulthard 2012) and carabid beetles (Charrier *et al.* 1997). Indeed, hedges are likely to be important for the movement and dispersal of a range of grassland, scrub and woodland species in agricultural landscapes (Burel and Baudry 2012, Davies and Pullin 2007). The fact that the hedge surveyed in this study lay within a well connected landscape, with an intact network of hedges running for many kilometres in each direction, linking not just to one another but also to a range of other semi-natural habitats, is likely to have contributed to its high species count.

It should be noted though, that while high levels of connectivity may make it easier for organisms to obtain the resources they need to survive and reproduce, increase genetic flow and facilitate survival of metapopulations, it may also assist with the spread of predators, pests and diseases: it is not necessarily a good thing (Kettunen *et al.* 2007). Furthermore, research has yet to determine, for flying invertebrates such as Diptera, the degree to which gaps in hedge networks, whether small or large, affect population viability or effective dispersal – do hedges have to be physically joined to one another to act as effective movement corridors?

Green lane effect. Green lanes (defined as farmland tracks with unsealed surfaces bordered on each side by hedgerows) are known to be exceptionally valuable to wildlife (Croxton *et al.* 2005, Dover *et al.* 2000, Gardiner 2010, Walker *et al.* 2005). Compared to single hedges, this is probably because of their higher structural diversity, wider verges, modified microclimate and lower agricultural inputs. While the hedge in the current study was not strictly part of a green lane because the farm lane it bordered was tarmaced (Sparks and Anderson 2004), nevertheless it will have been more sheltered and warmer than some other hedges in the landscape because there was a hedge running parallel to it on the other side of the lane. Also, the lack of grazing on the lane-side verge resulted in different herbaceous communities than on the field side, increasing plant and structural diversity. Thus the green lane effect is likely to have enhanced the hedge's species-richness.

Larval resources. The 162 species (20% of the total recorded) that emerged from the ground or leaf litter beneath the **emergence traps** may be expected to have larval stages in the hedge. This high number was unexpected given that these traps covered only a tiny proportion (0.5%) of the ground surface and are unlikely to have sampled species that overwinter as adults. A further 19 species were recorded in the larval stage as either leaf mines or galls, and one *Bibio marci* (Linnaeus), emerged from a sample of leaf litter collected from the hedge. So, at the very least 22% of the Diptera fauna developed within the hedge: the true proportion is likely to be considerably higher. For instance, 42 (87%) of hoverfly species recorded more than five times could have potentially developed in the hedge since the necessary larval micro-habitat was probably present (Table 5), whereas only 5 species were actually found within emergence traps (Table 3).

Of species with larvae known to feed on **living plant tissue**, 85 were recorded (10% of the total species count), although this may be considerably less than the true figure since few agromyzids or cecidomyiids were identified. Only ten phytophagous species were caught in the emergence traps, despite the presence within the hedge of the food plants of 66 of the phytophagous species recorded. This further suggests that the larvae of many more species than those recorded in the emergence traps may have developed in the hedge.

Hedges, including the one described in this paper, can contain considerable amounts of **decaying wood**. This may be associated with mature trees, pollards, coppice stools and root systems, in the form of fallen branches or twigs, or even as flail chippings. Clements and Alexander (2009) sampled invertebrate faunas in hedges of different ages in Somerset, England, looking for **saproxylic** invertebrates and in particular for ancient woodland and old growth indicator species. The hedges did not contain any large ancient trees, were in intensively managed farmland and were not "especially unusual within the wider context of south-western England". They were found to support an "unexpectedly good range" of ancient woodland and old growth saproxylic invertebrates. Clements and Alexander concluded that old (mainly pre-17th Century) hedges are potentially an important habitat resource for these invertebrates, as well as for saproxylic invertebrates in general. They noted that networks of old hedgerows can collectively support a similar range of such species to substantial areas of ancient semi-natural woodland or wood-pasture, including good numbers of nationally or regionally scarce and local species.

Results from this study support Clements and Alexander's view, with 163 species (20% of the total) known to feed on decaying wood or associated fungi (Alexander 2002 and unpublished data). Indeed, the ISIS analysis suggests that the heartwood decay, and bark and sapwood decay, assemblages identified were of higher quality than other Diptera assemblages assessed by this method. Unlike many saproxylic Coleoptera, most saproxylic flies do not require mature or ancient trees for development: younger and smaller trees and branches are just as acceptable (Perry and Rotheray 2010). Given the greater prevalence of veteran tree features in the surrounding landscape than in the hedge, it is probable that the hedge was more important as an adult food and dispersal corridor than as a larval development site specifically for the key species identified by ISIS (i.e. *Brachypalpoides lentus* (Meigen), *Criorhina berberina* (Fabricius), *C. floccosa* (Meigen), *Ferdinandea ruficornis* (Fabricius), *Myathropa florea* (Linnaeus), *Sphegina elegans* Schummel, *Tipula flavolineata* Meigen, *Xylota sylvarum* (Linnaeus) and *Xylophagus ater* Meigen).

Many more of the species recorded from the hedge than the 132 (16% of the total) known to feed as larvae on **fungi or myxomycetes** are likely to be using this micro-habitat. Likewise, the true number of saproxylic species is likely to be much higher than 163. For example, saproxylic species probably predominate among the 50 or so species for which the larval micro-habitats are not yet known, but which are likely to be fungus feeders (PJC pers. obs.). Evidence of fungal fruiting bodies and hyphae was abundant within the hedge, and at least 56 fungus species have so far been identified (Wolton and Vergette 2012, with further records); 280 species of fungi have been recorded in a single hedge bank in Germany (Müller 2013).

The high proportion, 32%, of the flies listed by Skidmore as associated with **dung** is to be expected given that the hedge is located within a livestock farming area, especially since cattle are the predominant stock and over half (58%) of the 126 species recorded are known to develop in cattle dung or manure heaps. Smart and Winnall (2006) recorded 78 fly species associated with cattle dung (including adult visitors and casuals) at the three orchards in the Wyre Forest they sampled. The comparatively low number of species known to develop in sheep dung – just 14 were recorded at the hedge – may to some extent reflect differences in research effort (Skidmore 2010).

It is clear that decaying wood, fungi and dung are all likely to be of considerable importance as larval development sites for hedge-associated Diptera, as well as living plant tissue.

Is the hedge beneficial, neutral or harmful to fly survival? While the diversity of Diptera associated with the hedge is remarkably high, a key question is how many of these species actually benefit from the hedge? Is the hedge having a positive effect through the provision of larval micro-habitat, or for adults through providing food, resting or mate-seeking places, shelter from adverse weather or predators, or dispersal corridors? Alternatively, is it having a negative effect through acting as a barrier to dispersal or increasing predation risks? Or is the effect merely neutral, the hedge acting as a semi-permeable net, temporarily retaining flies as they move through the landscape?

The capacity of the hedge to provide larval resources has already been discussed. Many species may develop elsewhere but find food as adults in the hedge: for example, some of the saproxylic species found are unlikely to have developed in the hedge but were recorded using the hedge for food or dispersal. Saproxylics like *Ferdinandea cuprea* and *Brachypalpoides lentus* were observed feeding on tall umbellifers, while *F. ruficornis*, *Periscelis annulata* (Fallén) and *Xylophagus ater* individuals caught in the Malaise trap may well have been using the hedge for shelter while searching for suitable breeding sites elsewhere. Similarly, six of the 44 species of hoverfly recorded feeding at the hedge on the flowers of tall umbellifers (Apiaceae) are unlikely to have developed in the hedge because the appropriate larval micro-habitat was not present. Other hoverflies unlikely to have immature stages in the hedge were seen resting on leaves, often basking, taking advantage of the shelter afforded by the hedge. Yet other flies that may not have developed in the hedge were observed swarming or displaying mate-seeking behaviour alongside it, e.g. the empid *Rhamphomyia barbata* (Macquart), the tabanid *Hybomitra distinguenda* (Verrall) and the muscid *Hydrotaea irritans* (Fallén).

For some flies, the hedge may have decreased survival chances, but available evidence either way on this point is weak. Hedges act as windbreaks and concentrate small flying insects from passing airborne populations, particularly during windy weather (Lewis 1969): swarms of empidids have been observed to feed among such wind concentrated prey (ARP pers. obs), but the net effects on survival are unknown. Likewise, the movement of predatory carabid beetles between fields can be significantly slowed by the presence of hedges (Mauremootoo *et al.* 1995, García *et al.* 2000) and lines of poplar trees (*Populus* sp.) have been shown to restrict the movement between fields of three species of hoverfly (Wratten *et al.* 2003), but again the effects on survival are unknown. A particularly relevant study is that of Delettre and Morvan (2000), who investigated the influence of hedges on the spatial distribution of adult aquatic Chironomidae (non-biting midges) in Brittany, France. They found that in densely hedged landscapes these midges dispersed less far from their riverine development sites than in more open landscapes. This was partly, they believed, because the hedges acted as filters, serving both to keep the insects close to favourable larval habitat but also limiting lateral dispersal. They noted that hedges might benefit aquatic chironomids through providing shelter and particularly as markers for mating swarms: hedges that were better structured and less permeable supported greater numbers of individuals. They concluded that local landscape features, such as hedges or riparian vegetation, are essential for the completion of chironomid biological cycles, even though these features occupy only small areas (Delettre 2005).

On balance, evidence from the hedge and from published sources suggests that the great majority of fly species recorded at the hedge were benefiting from its presence. However, a few may have been effectively trapped by the hedge, decreasing their survival chances through delaying or preventing effective movement to essential resources not present in the hedge, or through increasing their chances of being preyed upon. For others, the hedge may have been neutral in its effects. More research is required on this topic.

Representation of Diptera families. The strong representation of Mycetophilidae (fungus gnats) (27% of the British list) is likely to reflect the high volumes of dead wood, mainly small branches and twigs, in the hedge base as well as in surrounding wooded habitats, that of Syrphidae (hoverflies) (34% of the British list) the abundance of nectar sources in the hedge margins, especially tall umbellifers (Apiaceae), and that of Tipuloidea (craneflies) (22% of the British list) good larval micro-habitat in the wet soils and leaf litter of the ditch, margins and other nearby habitats including ponds. The poor representation of Anthomyiidae from the hedge may perhaps be explained by the year in which they were sampled (2012) being a poor one for members of this family. Peng *et al.* (1992) found that there was a 33 fold difference in numbers of anthomyiids captured at the hedgerow tree they studied between the two consecutive years over which sampling took place. Similarly, large inter-year variation in numbers may explain the low number of tachinid species caught.

Influence of trapping techniques. The relatively high proportion of the British fauna of Diptera, Trichoptera and Lepidoptera recorded in comparison to other insect orders (Table 1) is likely to reflect both the efficiency of Malaise and light traps at catching them (Fry and Waring 2001), as well differences in species resource specificity and habitat preferences. The light trap may have artificially boosted the hedge species count by attracting flying insects from landscape features beyond the hedge itself (Fry and Waring 2001). The methods by which each species was found were not recorded. However, the great majority were caught in the Malaise trap. Among the Diptera the light trap was more effective than other techniques only at catching winter gnats (Trichoceridae), craneflies and some fungus gnats.

Scarce and threatened species. The discovery of 27 species of threatened or nationally scarce Diptera at the hedge demonstrates the capacity of hedges to be important for species of conservation significance as well as for those that are widespread and common.

Conclusions

The great diversity of flies associated with a single hedge, including nationally threatened or scarce species, provides further evidence for the considerable importance of this habitat for the conservation of invertebrates in agricultural landscapes. While the hedge was in favourable condition and in a British context of high quality, it nevertheless was neither exceptional in the context of south-west England nor indeed of some other European regions, e.g. north-west France (Müller 2013). Many other hedges will be of similar importance. Although few, if any, Diptera are true hedge specialists, as opposed to being associated with woodland, trees, scrub, grassland or freshwater, nevertheless it is highly probable that hedges are essential for the continued survival of many in agricultural landscapes.

As argued by Dirkmaat (2012) in the context of European cultural landscapes, much greater recognition should be given to the capacity of hedges to deliver biodiversity objectives, as well as a wide range of ecosystem services (Land Use Consultants and GHK Consulting Ltd 2009), through the improved development of policy and resourcing of agri-environment schemes, at both European Union and individual country levels.

Similar studies on hedges in different landscapes are to be encouraged, to provide further information on the value of hedges for invertebrate biodiversity and conservation.

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Appendix: Inventory of Diptera recorded at the hedge

Nomenclature follows Chandler (2013; most recently updated 21 December 2013). Families are in checklist order. Species are in alphabetical order within families.

● = caught in emergence trap

Larval development micro-habitat for analyses given in results and for species given in Tables 4 and 5. (No attempt has been made to ascribe larval development micro-habitat for other species.) ^{a} = parasitoid, ^{c} = coprophagous, ^{d} = saproxylic (excluding fungi), ^{df} = fungus or myxomycete on dead wood, ^{f} = terrestrial fungus, ^{p} = phytophagous, ^{r} = predator, ^{s} = saprophagous (exc wood), ^{u} = unknown.

Tipulidae

Nephrotoma flavipalpis (Meigen, 1830)
$^{d?}$*Tipula confusa* van der Wulp, 1883
Tipula fascipennis Meigen, 1818
^{d} *Tipula flavolineata* Meigen, 1804
Tipula fulvipennis De Geer, 1776
Tipula lateralis Meigen, 1804
Tipula luna Westhoff, 1879
●*Tipula lunata* Linnaeus, 1758
Tipula maxima Poda, 1761
Tipula obsoleta Meigen, 1818
●*Tipula oleracea* Linnaeus, 1758
Tipula pagana Meigen, 1818
^{c} *Tipula paludosa* Meigen, 1830
Tipula pruinosa Wiedemann, 1817
Tipula rufina Meigen, 1818
Tipula signata Staeger, 1840
Tipula subcunctans Alexander, 1921
Tipula unca Wiedemann, 1817
●*Tipula varipennis* Meigen, 1818
●*Tipula vittata* Meigen, 1804

Cylindrotomidae

●^{p} *Cylindrotoma distinctissima* (Meigen, 1818)
^{p} *Diogma glabrata* (Meigen, 1818)

Pediciidae

●*Dicranota claripennis* (Verrall, 1888)
Pedicia littoralis (Meigen, 1804)
Pedicia rivosa (Linnaeus, 1758)
●*Tricyphona immaculata* (Meigen, 1804)
^{df} *Ula sylvatica* (Meigen, 1818)

Limoniidae

●^{d} *Austrolimnophila ochracea* (Meigen, 1804)
^{c} *Cheilotrichia cinerascens* (Meigen, 1804)
Dicranomyia autumnalis (Staeger, 1840)
●*Dicranomyia chorea* (Meigen, 1818)
●*Dicranomyia modesta* (Meigen, 1818)
Dicranomyia morio (Fabricius, 1787)
●*Dicranophragma adjunctum* (Walker, 1848)
●*Dicranophragma nemorale* (Meigen, 1818)
^{d} *Epiphragma ocellare* (Linnaeus, 1761)
Erioconopa trivialis (Meigen, 1818)
Erioptera fuscipennis Meigen, 1818
●*Erioptera griseipennis* Meigen, 1838
●*Erioptera lutea* Meigen, 1804
Euphylidorea lineola (Meigen, 1804)

•*Ilisia maculata* (Meigen, 1804)
•*Ilisia occoecata* Edwards, 1936
Limnophila schranki Oosterbroek, 1992
•*Limonia macrostigma* (Schummel, 1829)
•*Limonia nubeculosa* Meigen, 1804
[c,d?] *Limonia phragmitidis* (Schrank, 1781)
[df] *Metalimnobia bifasciata* (Schrank, 1781)
[f] *Metalimnobia quadrinotata* (Meigen, 1818)
•*Molophilus appendiculatus* (Staeger, 1840)
•*Molophilus bifidus* Goetghebuer, 1920
•*Molophilus cinereifrons* de Meijere, 1920
•*Molophilus griseus* (Meigen, 1804)
Molophilus medius de Meijere, 1918
•*Molophilus obscurus* (Meigen, 1818)
•*Molophilus ochraceus* (Meigen, 1818)
•*Molophilus serpentiger* Edwards, 1938
Neolimnomyia filata (Walker, 1856)
•*Ormosia hederae* (Curtis, 1835)
•*Ormosia lineata* (Meigen, 1804)
•*Ormosia nodulosa* (Macquart, 1826)
•*Paradelphomyia senilis* (Haliday, 1833)
Phylidorea ferruginea (Meigen, 1818)
Phylidorea fulvonervosa (Schummel, 1829)
Pilaria discicollis (Meigen, 1818)
Pseudolimnophila lucorum (Meigen, 1818)
Rhipidia maculata Meigen, 1818
Symplecta stictica (Meigen, 1818)
•*Tasiocera murina* (Meigen, 1818)
Trimicra pilipes (Fabricius, 1787)

Bibionidae
Bibio lanigerus Meigen, 1818
Bibio leucopterus (Meigen, 1804)
Bibio longipes Loew, 1864
Bibio marci (Linnaeus, 1758)
Bibio pomonae (Fabricius, 1775)
•*Bibio varipes* Meigen, 1830
[c,d?] *Dilophus febrilis* (Linnaeus, 1758)

Bolitophilidae
[df] *Bolitophila hybrida* (Meigen, 1804)

Diadocidiidae
•[df] *Diadocidia ferruginosa* (Meigen, 1830)

Ditomyiidae
•[df] *Symmerus annulatus* (Meigen, 1830)

Keroplatidae
Antlemon servulum (Walker, 1837)
Isoneuromyia semirufa (Meigen, 1818)
[df] *Keroplatus testaceus* Dalman, 1818
[df] *Macrocera fasciata* Meigen, 1804
[d] *Macrocera stigma* Curtis, 1837
[d] *Macrocera vittata* Meigen, 1830
[d] *Macrorrhyncha flava* Winnertz, 1846
Monocentrota lundstroemi Edwards, 1925
Neoplatyura biumbrata (Edwards, 1913)
Neoplatyura modesta (Winnertz, 1863)
Neoplatyura nigricauda (Strobl, 1893)

Mycetophilidae
[df] *Acnemia nitidicollis* (Meigen, 1818)
•[df] *Allocotocera pulchella* (Curtis, 1837)
•*Allodia* sp. (indet. female)
Allodia angulata (Lundström, 1913)
[df] *Allodia lugens* (Wiedemann, 1817)
[df] *Allodia lundstroemi* Edwards, 1921
[df] *Allodia neglecta* Edwards, 1925
[df] *Allodia ornaticollis* (Meigen, 1818)
[f] *Allodia truncata* Edwards, 1921
[f] *Allodia zaitzevi* Kurina, 1998
[f] *Allodiopsis domestica* (Meigen, 1830)
•[df] *Anatella flavomaculata* Edwards, 1925
[df] *Anatella lenis* Dziedzicki, 1923
Anatella longisetosa Dziedzicki, 1923
Anatella minuta (Staeger, 1840)
Anatella setigera Edwards, 1921
Anatella turi Dziedzicki, 1923
[df] *Apolephthisa subincana* (Curtis, 1837)
Boletina bidenticulata Sasakawa & Kimura, 1974
[p] *Boletina dubia* (Meigen, 1804)
Boletina edwardsi Chandler, 1992
[df] *Boletina gripha* Dziedzicki, 1885
Boletina griphoides Edwards, 1925
Boletina pallidula Edwards, 1925
Boletina rejecta Edwards, 1941
Boletina sciarina Staeger, 1840
Brevicornu fissicauda (Lundström, 1911)
[f] *Brevicornu griseicolle* (Staeger, 1840)
Brevicornu griseolum (Zetterstedt, 1852)
Brevicornu ruficorne (Meigen, 1838)
[f] *Brevicornu sericoma* (Meigen, 1830)
Brevicornu verralli (Edwards, 1925)
[df] *Coelosia tenella* (Zetterstedt, 1852)

Cordyla sp. near *murina* Winnertz, 1863
^{f}*Cordyla brevicornis* (Staeger, 1840)
●^{f}*Cordyla crassicornis* Meigen, 1818
^{f}*Cordyla flaviceps* (Staeger, 1840)
^{f}*Cordyla fusca* Meigen, 1804
^{df}*Dynatosoma fuscicorne* (Meigen, 1818)
^{df}*Ectrepesthoneura hirta* (Winnertz, 1846)
●^{df}*Epicypta aterrima* (Zetterstedt, 1852)
Exechia borealis Lundström, 1912
^{df}*Exechia dizona* Edwards, 1924
^{f}*Exechia dorsalis* (Staeger, 1840)
Exechia exigua Lundström, 1909
●^{df}*Exechia fusca* (Meigen, 1804)
●^{df}*Exechia parva* Lundström, 1909
Exechia pseudofestiva Lackschewitz, 1937
Exechiopsis crucigera (Lundström, 1909)
^{f}*Exechiopsis fimbriata* (Lundström, 1909)
^{d}*Leia bilineata* (Winnertz, 1863)
^{df}*Leia bimaculata* (Meigen, 1804)
Leia fascipennis Meigen, 1818
^{df}*Leia winthemii* Lehmann, 1822
^{df}*Leptomorphus walkeri* Curtis, 1831
Megalopelma nigroclavatum (Strobl, 1910)
Megophthalmidia crassicornis (Curtis, 1837)
^{df}*Monoclona rufilatera* (Walker, 1837)
^{df}*Mycetophila abiecta* (Laštovka, 1963)
^{df}*Mycetophila adumbrata* Mik, 1884
^{f}*Mycetophila alea* Laffoon, 1965
^{df}*Mycetophila britannica* Laštovka & Kidd, 1975
^{df}*Mycetophila cingulum* Meigen, 1830
Mycetophila curviseta Lundström, 1911
Mycetophila edwardsi Lundström, 1913
Mycetophila eppingensis Chandler, 2001
^{df}*Mycetophila fraterna* Winnertz, 1863
^{df}*Mycetophila fungorum* (De Geer, 1776)
^{f}*Mycetophila hetschkoi* Landrock, 1918
^{df}*Mycetophila ichneumonea* Say, 1823
^{df}*Mycetophila luctuosa* Meigen, 1830
^{df}*Mycetophila ocellus* Walker, 1848
^{df}*Mycetophila ornata* Stephens, 1846
●^{df}*Mycetophila perpallida* Chandler, 1993
Mycetophila pumila Winnertz, 1863
^{df}*Mycetophila ruficollis* Meigen, 1818
^{f}*Mycetophila signatoides* Dziedzicki, 1884
Mycetophila sordida van der Wulp, 1874
^{f}*Mycetophila strigata* Staeger, 1840
^{df}*Mycetophila strigatoides* (Landrock, 1927)
^{df}*Mycetophila trinotata* Staeger, 1840
Mycetophila unicolor Stannius, 1831
Mycetophila unipunctata Meigen, 1818
●^{df}*Mycomya annulata* (Meigen, 1818)
^{df}*Mycomya cinerascens* (Macquart, 1826)
Mycomya circumdata (Staeger, 1840)
Mycomya fimbriata (Meigen, 1818)
^{df}*Mycomya marginata* (Meigen, 1818)
^{df}*Mycomya neohyalinata* Väisänen, 1984
Mycomya prominens (Lundström, 1913)
^{f}*Mycomya tenuis* (Walker, 1856)
^{df}*Mycomya winnertzi* (Dziedzicki, 1885)
Palaeodocosia vittata (Coquillett, 1901)
^{df}*Phronia conformis* (Walker, 1856)
Phronia egregia Dziedzicki, 1889
Phronia exigua (Zetterstedt, 1852)
Phronia forcipata Winnertz, 1863
^{df}*Phronia humeralis* Winnertz, 1863
^{d}*Phronia nitidiventris* (van der Wulp, 1859)
^{df}*Phronia tenuis* Winnertz, 1863
Phronia triangularis Winnertz, 1863
^{df}*Phthinia mira* (Ostroverkhova, 1977)
^{df}*Platurocypta punctum* (Stannius, 1831)
^{df}*Platurocypta testata* (Edwards, 1924)
●*Pseudexechia aurivernica* Chandler, 1978
^{df}*Rondaniella dimidiata* (Meigen, 1804)
^{f}*Rymosia fasciata* (Meigen, 1804)
Sceptonia costata (van der Wulp, 1859)
^{f}*Sceptonia flavipuncta* Edwards, 1925
Sceptonia fumipes Edwards, 1925
Sceptonia membranacea Edwards, 1925
Sceptonia nigra (Meigen, 1804)
Sceptonia tenuis Edwards, 1925
^{df}*Sciophila* ? *hirta* Meigen, 1818 or *S. lutea* Macquart, 1826 (indet. females)
●*Synapha fasciata* Meigen, 1818
Synapha vitripennis (Meigen, 1818)
^{d}*Syntemna hungarica* (Lundström, 1912)
^{df}*Tetragoneura sylvatica* (Curtis, 1837)
^{df}*Trichonta foeda* Loew, 1869
^{df}*Trichonta melanura* (Staeger, 1840)
Trichonta nigritula Edwards, 1925
Trichonta pulchra Gagné, 1981
^{df}*Trichonta terminalis* (Walker, 1856)
Zygomyia humeralis (Wiedemann, 1817)
Zygomyia semifusca (Meigen, 1818)
Zygomyia valida Winnertz, 1863
^{df}*Zygomyia vara* (Staeger, 1840)

Sciaridae

Bradysia bicolor (Meigen, 1818)
[d] *Bradysia fungicola* (Winnertz, 1867)
●[p] *Bradysia giraudii* (Egger, 1862)
●[f] *Bradysia nitidicollis* (Meigen, 1818)
●*Bradysia forficulata* (Bezzi, 1914)
●[df] *Bradysia pectoralis* (Staeger, 1840)
●*Bradysia placida* (Winnertz, 1867)
●*Corynoptera forcipata* (Winnertz, 1867)
[d] *Ctenosciara hyalipennis* (Meigen, 1804)
●[d] *Leptosciarella rejecta* (Winnertz, 1867)
●[d] *Leptosciarella trochanterata* (Zetterstedt, 1851)
[d] *Leptosciarella viatica* (Winnertz, 1867)
●*Phytosciara flavipes* (Meigen, 1804)
[p] *Phytosciara halterata* (Lengersdorf, 1926)
●*Schwenckfeldina carbonaria* (Meigen, 1830)
[d] *Sciara hemerobioides* (Scopoli, 1763)
[d] *Trichosia confusa* Menzel & Mohrig, 1997
[d] *Trichosia splendens* Winnertz, 1867
[d] *Zygoneura sciarina* Meigen, 1830

Cecidomyiidae

[p] *Dasineura pustulans* (Rübsaamen, 1889)
[p] *Dasineura ulmaria* (Bremi, 1847)
[p] *Dasineura urticae* (Perris, 1840)
[p] *Rabdophaga salicis* (Schrank, 1803)
[p] *Rhopalomyia ptarmicae* (Vallot, 1849)

Psychodidae

Boreoclytocerus ocellaris (Meigen, 1804)
Pericoma cognata Eaton, 1893
[c] *Pericoma trivialis* Eaton, 1893
[c,df] *Psychoda cinerea* Banks, 1894
[c,df] *Psychoda phalaenoides* (Linnaeus, 1758)
Threticus lucifugus (Haliday in Walker, 1856)
[c] *Tinearia alternata* (Say, 1824)

Trichoceridae

[c,df] *Trichocera ?hiemalis* (De Geer, 1776)
[c,df] *Trichocera ?saltator* (Harris, 1776)
[df] *Trichocera annulata* Meigen, 1818
Trichocera major Edwards, 1921
●[c,df] *Trichocera regelationis* (Linnaeus, 1758)

Anisopodidae

●[df] *Sylvicola cinctus* (Fabricius, 1787)
[c] *Sylvicola punctatus* (Fabricius, 1787)

Scatopsidae

[f] *Apiloscatopse flavicollis* (Meigen, 1818)
[df] *Apiloscatopse scutellata* (Loew, 1846)
Efcookella albitarsis (Zetterstedt, 1850)
[c,d] *Scatopse notata* (Linnaeus, 1758)
Thripomorpha coxendix (Verrall, 1912)

Ptychopteridae

●*Ptychoptera albimana* (Fabricius, 1787)
Ptychoptera contaminata (Linnaeus, 1758)
Ptychoptera lacustris Meigen, 1830
Ptychoptera scutellaris Meigen, 1818

Dixidae

●*Dixella martinii* (Peus, 1934)

Culicidae

Anopheles claviger (Meigen, 1804)
Culex pipiens Linnaeus, 1758

Thaumaleidae

Thaumalea ?testacea Ruthe, 1831

Ceratopogonidae

Atrichopogon muelleri (Kieffer in Müller, 1905)
Serromyia sp. (indet. female)
Stilobezzia gracilis (Haliday, 1833)

Xylophagidae

[d] *Xylophagus ater* Meigen, 1804

Rhagionidae

●*Chrysopilus cristatus* (Fabricius, 1775)
Rhagio lineola Fabricius, 1794
●*Rhagio scolopaceus* (Linnaeus, 1758)
●*Rhagio tringarius* (Linnaeus, 1758)

Tabanidae

Haematopota pluvialis (Linnaeus, 1758)
Hybomitra distinguenda (Verrall, 1909)
Tabanus bromius Linnaeus, 1758
Tabanus maculicornis Zetterstedt, 1842
Tabanus sudeticus Zeller, 1842

Stratiomyidae

•*Beris chalybata* (Forster, 1771)
Beris clavipes (Linnaeus, 1767)
•*Beris fuscipes* Meigen, 1820
•*Beris geniculata* Haliday in Curtis, 1830
Beris morrisii Dale, 1841
Beris vallata (Forster, 1771)
Chloromyia formosa (Scopoli, 1763)
•[d?] *Chorisops nagatomii* Rozkošný, 1979
•*Chorisops tibialis* (Meigen, 1820)
[c] *Microchrysa cyaneiventris* (Zetterstedt, 1842)
[c] *Microchrysa flavicornis* (Meigen, 1822)
[c] *Microchrysa polita* (Linnaeus, 1758)
Oxycera rara (Scopoli, 1763)
•[d] *Pachygaster leachii* Stephens in Curtis, 1824
[c]*Sargus bipunctatus* (Scopoli, 1763)
[c]*Sargus flavipes* Meigen, 1822
[c]*Sargus iridatus* (Scopoli, 1763)

Bombyliidae

Bombylius major Linnaeus, 1758

Asilidae

•*Dioctria linearis* (Fabricius, 1787)

Hybotidae

Bicellaria vana Collin, 1926
Crossopalpus minimus (Meigen, 1838)
Drapetis ephippiata (Fallén, 1815)
•[d]*Drapetis simulans* Collin, 1961
[d] *Euthyneura halidayi* Collin, 1926
[d] *Euthyneura myrtilli* Macquart, 1836
Hybos culiciformis (Fabricius, 1775)
•*Hybos femoratus* (Muller, 1776)
[d] *Leptopeza flavipes* (Meigen, 1820)
[c] *Ocydromia glabricula* (Fallén, 1816)
[d] *Oedalea flavipes* Zetterstedt, 1842
[d] *Oedalea holmgreni* Zetterstedt, 1852
[d] *Oedalea stigmatella* Zetterstedt, 1842
•*Platypalpus annulipes* (Meigen, 1822)
•*Platypalpus aristatus* (Collin, 1926)
Platypalpus calceatus (Meigen, 1822)
•*Platypalpus ciliaris* (Fallén, 1816)
Platypalpus clarandus (Collin, 1926)
•*Platypalpus cursitans* (Fabricius, 1775)
•*Platypalpus leucocephalus* (von Roser, 1840)
Platypalpus longicornis (Meigen, 1822)
Platypalpus minutus agg. (Meigen, 1804)
•*Platypalpus optivus* (Collin, 1926)
Platypalpus pallidiventris (Meigen, 1822)
[d] *Platypalpus pallipes* (Fallén, 1815)
Platypalpus pectoralis (Fallén, 1815)
Platypalpus stabilis (Collin, 1961)
Stilpon graminum (Fallén, 1815)
•*Symballophthalmus fuscitarsis* (Zetterstedt, 1859)
•*Tachydromia aemula* (Loew, 1864)
•[d] *Tachypeza nubila* (Meigen, 1804)
•*Trichina bilobata* Collin, 1926
Trichina clavipes Meigen, 1830
•*Trichina elongata* Haliday, 1833
•*Trichina pallipes* (Zetterstedt, 1838)

Empididae

•*Chelifera precabunda* Collin, 1961
Chelifera precatoria (Fallén, 1816)
Clinocera fontinalis (Haliday, 1833)
Dolichocephala irrorata (Fallén, 1815)
•*Dolichocephala oblongoguttata* (Dale, 1878)
Empis aemula Loew, 1873
Empis aestiva Loew, 1867
Empis albinervis Meigen, 1822
Empis bicuspidata Collin, 1927
•*Empis grisea* Fallén, 1816
Empis livida Linnaeus, 1758
•*Empis lutea* Meigen, 1804
Empis nigripes Fabricius, 1794
•*Empis pennipes* Linnaeus, 1758
•*Empis praevia* Collin, 1927
Empis punctata Meigen, 1804
•*Empis stercorea* Linnaeus, 1761
•*Empis tessellata* Fabricius, 1794
[c] *Empis trigramma* Wiedemann in Meigen, 1822
Empis volucris Wiedemann in Meigen, 1822
•*Hilara anglodanica* Lundbeck, 1913
Hilara chorica (Fallén, 1816)
Hilara interstincta (Fallén, 1816)
Hilara litorea (Fallén, 1816)
•*Hilara thoracica* Macquart, 1827
Kowarzia bipunctata (Haliday, 1833)

[r?]*Kowarzia madicola* (Vaillant, 1964)
Rhamphomyia albohirta Collin, 1926
Rhamphomyia barbata (Macquart, 1823)
Rhamphomyia crassirostris (Fallén, 1816)
Rhamphomyia longipes (Meigen, 1804)
Rhamphomyia subcinerascens Collin, 1926
Rhamphomyia sulcatella Collin, 1926
Rhamphomyia tibialis Meigen, 1822

Dolichopodidae

Achalcus bimaculatus Pollet, 1997
Achalcus cinereus (Haliday in Walker, 1851)
Achalcus flavicollis (Meigen, 1824)
●*Anepsiomyia flaviventris* (Meigen, 1824)
Argyra argentina (Meigen, 1824)
●*Argyra argyria* (Meigen, 1824)
Argyra diaphana (Fabricius, 1775)
Argyra ilonae Gosseries, 1988
Argyra leucocephala (Meigen, 1824)
●*Argyra perplexa* Becker, 1918
●*Campsicnemus armatus* (Zetterstedt, 1849)
●*Campsicnemus curvipes* (Fallén, 1823)
Campsicnemus loripes (Haliday, 1832)
Campsicnemus scambus (Fallén, 1823)
Chrysotus cilipes Meigen, 1824
Chrysotus cupreus (Macquart, 1827)
●*Chrysotus gramineus* (Fallén, 1823)
Diaphorus oculatus (Fallén, 1823)
Dolichopus brevipennis Meigen, 1824
Dolichopus festivus Haliday, 1832
●*Dolichopus pennatus* Meigen, 1824
Dolichopus planitarsis Fallén, 1823
Dolichopus plumipes (Scopoli, 1763)
●*Dolichopus popularis* Wiedemann, 1817
●*Dolichopus simplex* Meigen, 1824
Dolichopus trivialis Haliday, 1832
[c]*Dolichopus ungulatus* (Linnaeus, 1758)
●*Dolichopus urbanus* Meigen, 1824
●*Dolichopus wahlbergi* Zetterstedt, 1843
●*Gymnopternus aerosus* (Fallén, 1823)
Gymnopternus cupreus (Fallén, 1823)
[d]*Medetera ?borealis* Thuneberg, 1955
●[d]*Medetera abstrusa* Thuneberg, 1955
Microphor holosericeus (Meigen, 1804)
Poecilobothrus nobilitatus (Linnaeus, 1767)
●*Rhaphium appendiculatum* Zetterstedt, 1849
●*Rhaphium caliginosum* Meigen, 1824
Rhaphium crassipes (Meigen, 1824)
●[d]*Sciapus platypterus* (Fabricius, 1805)
●*Sybistroma obscurellum* (Fallén, 1823)
●*Sympycnus desoutteri* Parent, 1925
Syntormon aulicus (Meigen, 1824)
●*Syntormon bicolorellus* (Zetterstedt, 1843)
Syntormon denticulatus (Zetterstedt, 1843)
Syntormon pumilus (Meigen, 1824)
●*Teuchophorus nigricosta* (von Roser, 1840)

Opetiidae

●[d]*Opetia nigra* Meigen, 1830

Platypezidae

[df]*Polyporivora ornata* (Meigen, 1838)
[df]*Polyporivora picta* (Meigen, 1830)
[df]*Protoclythia modesta* (Zetterstedt, 1844)

Lonchopteridae

Lonchoptera bifurcata (Fallén, 1810)
●*Lonchoptera lutea* Panzer, 1809

Syrphidae

Anasimyia contracta Claussen & Torp, 1980
[r]*Baccha elongata* (Fabricius, 1775)
[d]*Brachypalpoides lentus* (Meigen, 1822)
[p]*Cheilosia albipila* Meigen, 1838
[p]*Cheilosia albitarsis* sens. str. (Meigen, 1822)
[p]*Cheilosia antiqua* (Meigen, 1822)
[p]*Cheilosia bergenstammi* Becker, 1894
[p]*Cheilosia carbonaria* Egger, 1860
[p]*Cheilosia fraterna* (Meigen, 1830)
[p]*Cheilosia illustrata* (Harris, 1780)
[p]*Cheilosia impressa* Loew, 1840
[p]*Cheilosia lasiopa* Kowarz, 1885
[p]*Cheilosia nebulosa* Verrall, 1871
[p]*Cheilosia pagana* (Meigen, 1822)
[p]*Cheilosia proxima* (Zetterstedt, 1843)
[f]*Cheilosia scutellata* (Fallén, 1817)
[p]*Cheilosia variabilis* (Panzer, 1798)
[p]*Cheilosia vulpina* (Meigen, 1822)
Chrysogaster cemiteriorum (Linnaeus, 1758)
[s]*Chrysogaster solstitialis* (Fallén, 1817)
Chrysotoxum bicinctum (Linnaeus, 1758)
[d]*Criorhina berberina* (Fabricius, 1805)
[d]*Criorhina floccosa* (Meigen, 1822)
Dasysyrphus albostriatus (Fallén, 1817)
Dasysyrphus venustus (Meigen, 1822)

[r] *Epistrophe eligans* (Harris, 1780)
Epistrophe grossulariae (Meigen, 1822)
[r] *Episyrphus balteatus* (De Geer, 1776)
[s] *Eristalinus sepulchralis* (Linnaeus, 1758)
[s] *Eristalis abusiva* Collin, 1931
[s] *Eristalis arbustorum* (Linnaeus, 1758)
[s] *Eristalis horticola* (De Geer, 1776)
[s] *Eristalis intricaria* (Linnaeus, 1758)
[s] *Eristalis nemorum* (Linnaeus, 1758)
[s] *Eristalis pertinax* (Scopoli, 1763)
[c] *Eristalis tenax* (Linnaeus, 1758)
[r] *Eupeodes corollae* (Fabricius, 1794)
[r] *Eupeodes latifasciatus* (Macquart, 1829)
[r] *Eupeodes luniger* (Meigen, 1822)
[d] *Ferdinandea cuprea* (Scopoli, 1763)
[d] *Ferdinandea ruficornis* (Fabricius, 1775)
Helophilus hybridus Loew, 1846
[s] *Helophilus pendulus* (Linnaeus, 1758)
Helophilus trivittatus (Fabricius, 1805)
Lejogaster metallina (Fabricius, 1781)
Leucozona glaucia (Linnaeus, 1758)
[r] *Leucozona laternaria* (Müller, 1776)
[r] *Leucozona lucorum* (Linnaeus, 1758)
Melangyna arctica (Zetterstedt, 1838)
Melangyna cincta (Fallén, 1817)
Melangyna lasiophthalma (Zetterstedt, 1843)
Melangyna umbellatarum (Fabricius, 1794)
Melanogaster hirtella (Loew, 1843)
[r] *Melanostoma mellinum* (Linnaeus, 1758)
●[r] *Melanostoma scalare* (Fabricius, 1794)
[r] *Meliscaeva auricollis* (Meigen, 1822)
Meliscaeva cinctella (Zetterstedt, 1843)
[p] *Merodon equestris* (Fabricius, 1794)
[d] *Myathropa florea* (Linnaeus, 1758)
[s] *Neoascia meticulosa* (Scopoli, 1763)
[s] *Neoascia podagrica* (Fabricius, 1775)
Orthonevra nobilis (Fallén, 1817)
[r] *Parasyrphus nigritarsis* (Zetterstedt, 1843)
Parhelophilus frutetorum (Fabricius, 1775)
Parhelophilus versicolor (Fabricius, 1794)
Pipiza austriaca Meigen, 1822
Pipiza bimaculata Meigen, 1822
●[r] *Platycheirus albimanus* (Fabricius, 1781)
Platycheirus angustatus (Zetterstedt, 1843)
[r] *Platycheirus aurolateralis* Stubbs, 2002
Platycheirus clypeatus (Meigen, 1822)
[r] *Platycheirus granditarsus* (Forster, 1771)
[r] *Platycheirus peltatus* (Meigen, 1822)
Platycheirus rosarum (Fabricius, 1787)
Platycheirus scutatus (Meigen, 1822) sens. str.
[c] *Rhingia campestris* Meigen, 1822
[s] *Riponnensia splendens* (Meigen, 1822)
Scaeva pyrastri (Linnaeus, 1758)
Scaeva selenitica (Meigen, 1822)
Sericomyia silentis (Harris, 1776)
Sericomyia superbiens (Müller, 1776)
Sphaerophoria interrupta (Fabricius, 1805)
●[d] *Sphegina clunipes* (Fallén, 1816)
[d] *Sphegina elegans* Schummel, 1843
●[s, c] *Syritta pipiens* (Linnaeus, 1758)
●[r] *Syrphus ribesii* (Linnaeus, 1758)
[r] *Syrphus torvus* Osten-Sacken, 1875
[r] *Syrphus vitripennis* Meigen, 1822
Volucella bombylans (Linnaeus, 1758)
Volucella pellucens (Linnaeus, 1758)
Xanthandrus comtus (Harris, 1780)
[d] *Xylota segnis* (Linnaeus, 1758)
[d] *Xylota sylvarum* (Linnaeus, 1758)

Pipunculidae
Cephalops varipes (Meigen, 1824)
●*Cephalosphaera furcata* (Egger, 1860)
Chalarus fimbriatus Coe, 1966
Chalarus spurius (Fallén, 1816)
Dorylomorpha ? extricata (Collin, 1937)
Dorylomorpha infirmata (Collin, 1937)
Dorylomorpha imparata (Collin, 1937)
Eudorylas obliquus Coe, 1966
Jassidophaga beatricis (Coe, 1966)
Pipunculus campestris Latreille, 1802

Micropezidae
Neria cibaria (Linnaeus, 1761)

Psilidae
[p] *Chamaepsila pallida* (Fallén, 1820)
●[p] *Chamaepsila rosae* (Fabricius, 1794)
[p] *Chyliza vittata* Meigen, 1826
[p] *Loxocera albiseta* (Schrank, 1803)
[p] *Loxocera aristata* (Panzer, 1801)
●[p] *Psila fimetaria* (Linnaeus, 1761)

Conopidae
Conops flavipes Linnaeus, 1758
Conops quadrifasciatus De Geer, 1776

Physocephala rufipes (Fabricius, 1781)

Lonchaeidae

^{c,p} *Lonchaea chorea* (Fabricius, 1781)
^{d} *Lonchaea contigua* Collin, 1953
^{d} *Lonchaea postica* Collin, 1953
^{p} *Lonchaea tarsata* Fallén, 1820
^{p} *Protearomyia nigra* (Meigen, 1826)
^{p} *Silba fumosa* (Egger, 1862)

Pallopteridae

^{d} *Palloptera muliebris* (Harris, 1780)
^{p} *Palloptera saltuum* (Linnaeus, 1758)
^{p} *Palloptera scutellata* (Macquart, 1835)
^{p} *Palloptera trimacula* (Meigen, 1826)
^{p} *Palloptera umbellatarum* (Fabricius, 1775)
^{d} *Palloptera ustulata* Fallén, 1820

Piophilidae

Allopiophila luteata (Haliday, 1833)
^{c} *Allopiophila vulgaris* (Fallén, 1820)

Tephritidae

^{p} *Acidia cognata* (Wiedemann, 1817)
^{p} *Chaetostomella cylindrica* (Robineau-Desvoidy, 1830)
^{p} *Cryptaciura rotundiventris* (Fallén, 1814)
^{p} *Euleia heraclei* (Linnaeus, 1758)
^{p} *Philophylla caesio* (Harris, 1780)
^{p} *Tephritis vespertina* (Loew, 1844)
^{p} *Xyphosia miliaria* (Schrank, 1781)

Lauxaniidae

Calliopum simillimum (Collin, 1933)
Meiosimyza decipiens (Loew, 1847)
Meiosimyza rorida (Fallén, 1820)
Minettia inusta (Meigen, 1826)
Minettia longipennis (Fabricius, 1794)
Minettia tabidiventris (Rondani, 1877)
Pseudolyciella stylata Papp, 1978
$^{s?}$ *Sapromyza albiceps* Fallén, 1820
Sapromyza halidayi Shatalkin, 2000
Sapromyza sexpunctata Meigen, 1826
•^{c} *Tricholauxania praeusta* (Fallén, 1820)

Chamaemyiidae

Chamaemyia sylvatica Collin, 1966

Dryomyzidae

^{c} *Dryomyza anilis* (Fallén, 1820)
^{c} *Dryope flaveola* (Fabricius, 1794)

Sciomyzidae

Elgiva cucularia (Linnaeus, 1767)
•*Euthycera fumigata* (Scopoli, 1763)
Limnia paludicola Elberg, 1965
•^{r} *Pherbellia brunnipes* (Meigen, 1838)
•^{r} *Pherbellia griseola* (Fallén, 1820)
Pherbellia ventralis (Fallén, 1820)
Pteromicra angustipennis (Staeger, 1845)
Renocera pallida (Fallén, 1820)
Tetanocera arrogans Meigen, 1830
Tetanocera elata (Fabricius, 1781)
Tetanocera ferruginea Fallén, 1820
•*Tetanocera hyalipennis* von Roser, 1840
•*Tetanocera silvatica* Meigen, 1830

Sepsidae

^{c} *Nemopoda nitidula* (Fallén, 1820)
^{c} *Saltella sphondylii* (Schrank, 1803)
^{c}*Sepsis cynipsea* (Linnaeus, 1758)
^{c} *Sepsis flavimana* Meigen, 1826
•^{c} *Sepsis fulgens* Meigen, 1826
^{c} *Sepsis orthocnemis* Frey, 1908
^{c} *Sepsis punctum* (Fabricius, 1794)
^{c} *Sepsis violacea* Meigen, 1826
^{c} *Themira annulipes* (Meigen, 1826)
^{c} *Themira minor* (Haliday, 1833)

Clusiidae

^{d} *Clusia flava* (Meigen, 1830)
^{d} *Clusiodes albimanus* (Meigen, 1830)
^{d} *Clusiodes gentilis* (Collin, 1912)
^{d} *Clusiodes verticalis* (Collin, 1912)

Agromyzidae

^{p}*Agromyza anthracina* Meigen, 1830
^{p}*Agromyza idaeiana* (Hardy, 1853)
^{p}*Amauromyza labiatarum* (Hendel, 1920)
^{p} *Cerodontha iraeos* (Robineau-Desvoidy, 1851)
^{p} *Phytomyza angelicae* Kaltenbach, 1872
^{p} *Phytomyza angelicastri* Hering, 1932
^{p} *Phytomyza aprilina* (Goureau, 1851)
^{p} *Phytomyza cirsii* Hendel, 1923

^{p} *Phytomyza primulae* (Robineau-Desvoidy, 1851)
^{p} *Phytomyza spondylii* Robineau-Desvoidy, 1851

Opomyzidae
•^{p} *Geomyza balachowskyi* Mesnil, 1934
^{p} *Geomyza tripunctata* Fallén, 1823
^{p} *Opomyza florum* (Fabricius, 1794)
•^{p} *Opomyza germinationis* (Linnaeus, 1758)
•^{p} *Opomyza petrei* Mesnil, 1934

Anthomyzidae
^{p} *Anagnota bicolor* (Meigen, 1838)
•^{p} *Paranthomyza nitida* (Meigen, 1838)

Periscelididae
^{d} *Periscelis annulata* (Fallén, 1813)

Asteiidae
^{d} *Asteia amoena* Meigen, 1830
^{df} *Leiomyza scatophagina* (Fallén, 1823)

Milichiidae
Desmometopa sordida (Fallén, 1820)

Chloropidae
^{p} *Cetema elongatum* (Meigen, 1830)
^{p} *Cetema neglectum* Tonnoir, 1921
^{p} *Chlorops hypostigma* Meigen, 1830
^{p} *Elachiptera cornuta* (Fallén, 1820)
^{p} *Elachiptera megaspis* (Loew, 1858)
^{f} *Tricimba lineella* (Fallén, 1820)

Heleomyzidae
^{c} *Heleomyza captiosa* (Gorodkov, 1962)
•*Heteromyza commixta* Collin, 1901
^{f} *Suillia affinis* (Meigen, 1830)
•^{f} *Suillia atricornis* (Meigen, 1830)
•^{df} *Suillia bicolor* (Zetterstedt, 1838)
Suillia dawnae Withers, 1987
^{f} *Suillia flavifrons* (Zetterstedt, 1838)
^{df} *Suillia fuscicornis* (Zetterstedt, 1847)
•^{f} *Suillia notata* (Meigen, 1830)
^{f} *Suillia pallida* (Fallén, 1820)
^{f} *Suillia ustulata* (Meigen, 1830)
^{df} *Suillia variegata* (Loew, 1862)
^{c} *Tephrochlamys rufiventris* (Meigen, 1830)
Tephrochlamys tarsalis (Zetterstedt, 1847)

Trixoscelididae
Trixoscelis ?frontalis (Fallén, 1823)

Chyromyidae
^{c,d} *Chyromya flava* (Linnaeus, 1758)

Sphaeroceridae
•^{c} *Borborillus vitripennis* (Meigen, 1830)
^{c,df} *Chaetopodella scutellaris* (Haliday, 1836)
^{c} *Coproica ferruginata* (Stenhammar, 1855)
•^{c} *Copromyza equina* Fallén, 1820
^{c} *Copromyza nigrina* (Gimmerthal, 1847)
•^{c} *Copromyza stercoraria* (Meigen, 1830)
^{c,df} *Crumomyia fimetaria* (Meigen, 1830)
•^{c} *Crumomyia notabilis* (Collin, 1902)
^{c} *Eulimosina ochripes* (Meigen, 1830)
^{c} *Ischiolepta pusilla* (Fallén, 1820)
^{c} *Leptocera fontinalis* (Fallén, 1826)
^{c} *Leptocera nigra* Olivier, 1813
•^{c} *Lotophila atra* (Meigen, 1830)
^{f} *Phthitia plumosula* (Rondani, 1880)
^{c} *Pseudocollinella humida* (Haliday, 1836)
Pullimosina antennata (Duda, 1918)
•^{c} *Spelobia clunipes* (Meigen, 1830)
^{c} *Spelobia ?luteilabris* (Rondani, 1880)
^{df} *Spelobia parapusio* (Dahl, 1909)
^{c,f} *Sphaerocera curvipes* Latreille, 1805
^{c,df} *Sphaerocera monilis* Haliday, 1836

Drosophilidae
$^{df?}$ *Amiota basdeni* d'Assis-Fonseca, 1965
^{d} *Chymomyza fuscimana* (Zetterstedt, 1838)
^{f} *Drosophila hydei* Sturtevant, 1921
^{df} *Drosophila phalerata* Meigen, 1830
$^{d?}$ *Drosophila subsilvestris* Hardy & Kaneshiro, 1968
^{df} *Hirtodrosophila cameraria* Haliday, 1833
^{df} *Hirtodrosophila confusa* (Staeger, 1844)
^{df} *Leucophenga maculata* (Dufour, 1839)
Lordiphosa andalusiaca (Strobl, 1906)
•*Lordiphosa fenestrarum* (Fallén, 1823)
^{p} *Scaptomyza flava* (Fallén, 1823)
^{p} *Scaptomyza graminum* (Fallén, 1823)
^{p} *Scaptomyza pallida* (Zetterstedt, 1847)
$^{df?}$ *Stegana longifibula* Takada, 1968
^{df} *Stegana nigrithorax* Strobl, 1898

Diastatidae
Diastata adusta Meigen, 1830
Diastata fuscula (Fallén, 1823)
Diastata nebulosa (Fallén, 1823)

Ephydridae
Axysta cesta (Haliday, 1833)
Ditrichophora calceata (Meigen, 1830)
Ditrichophora fuscella (Stenhammar, 1844)
•[p] *Hydrellia griseola* (Fallén, 1813)
[p] *Hydrellia maura* Meigen, 1838
Hydrellia nigricans (Stenhammar, 1844)
Ilythea spilota (Haliday in Curtis, 1832)
Limnellia quadrata (Fallén, 1813)
[p] *Notiphila cinerea* Fallén, 1813
Notiphila maculata Stenhammar, 1844
[p] *Notiphila riparia* Meigen, 1830
•*Parydra coarctata* (Fallén, 1813)
Parydra littoralis (Meigen, 1830)
Parydra pusilla (Meigen, 1830)
Philygria picta (Fallén, 1813)
Philygria vittipennis (Zetterstedt, 1838)
[p] *Psilopa leucostoma* (Meigen, 1830)
Psilopa nigritella Stenhammar, 1844
Psilopa nitidula (Fallén, 1813)
[c] *Scatella stagnalis* (Fallén, 1813)
Scatella tenuicosta Collin, 1930
Scatophila ?despecta (Haliday, 1839)
Scatophila unicornis Czerny, 1900
Trimerina madizans (Fallén, 1813)

Scathophagidae
Conisternum decipiens (Haliday in Curtis, 1832)
Cordilura albipes Fallén, 1819
Leptopa filiformis Zetterstedt, 1838
[p] *Nanna fasciata* (Meigen, 1826)
[p] *Norellisoma lituratum* (Wiedemann in Meigen, 1826)
Norellisoma opacum (Loew, 1864)
•[p] *Norellisoma spinimanum* (Fallén, 1819)
•[c] *Scathophaga furcata* (Say, 1823)
[c] *Scathophaga inquinata* Meigen, 1826
•[c] *Scathophaga stercoraria* (Linnaeus, 1758)
Scathophaga suilla (Fabricius, 1794)

Anthomyiidae
Anthomyia sp. (indet. females)
[c] *Botanophila fugax* (Meigen, 1826)
Botanophila striolata (Fallén, 1824)
[p] *Chirosia* sp. (indet. females)
[p] *Egle rhinotmeta* (Pandellé, 1900)
Hydrophoria lancifer (Harris, 1780)
Hydrophoria ruralis (Meigen, 1826)
[c,d?] *Hylemya nigrimana* (Meigen, 1826)
[c] *Hylemya vagans* (Panzer, 1798)
Paradelia intersecta (Meigen, 1826)
[p] *Pegomya bicolor* (Wiedemann, 1817)
[p] *Pegomya flavifrons* (Walker, 1849)
[p] *Pegomya haemorrhoum* (Zetterstedt, 1838)
[p] *Pegomya solennis* (Meigen, 1826)
[c] *Pegoplata infirma* (Meigen, 1826)

Fanniidae
[c,df] *Fannia canicularis* (Linnaeus, 1761)
[c] *Fannia fuscula* (Fallén, 1825)
[c,f] *Fannia lepida* (Wiedemann, 1817)
Fannia lustrator (Harris, 1780)
Fannia mollissima (Haliday, 1840)
[c,df] *Fannia monilis* (Haliday, 1838)
[d] *Fannia polychaeta* (Stein, 1895)
[d] *Fannia posticata* (Meigen, 1826)
•[c] *Fannia serena* (Fallén, 1825)
•*Fannia similis* (Stein, 1895)
•*Fannia sociella* (Zetterstedt, 1845)
•*Fannia subsimilis* Ringdahl, 1934
[df] *Piezura pardalina* Rondani, 1966

Muscidae
[c] *Azelia cilipes* (Haliday, 1838)
[c] *Azelia nebulosa* Robineau-Desvoidy, 1830
[c] *Azelia triquetra* (Wiedemann, 1817)
•[c] *Azelia zetterstedtii* Rondani, 1866
Coenosia agromyzina (Fallén, 1825)
[c] *Drymeia hamata* (Fallén, 1823)
[c] *Eudasyphora cyanella* (Meigen, 1826)
[c] *Eudasyphora cyanicolor* (Zetterstedt, 1845)
[c] *Graphomya maculata* (Scopoli, 1763)
[c] *Haematobosca stimulans* (Meigen, 1824)
•[c] *Hebecnema nigra* (Robineau-Desvoidy, 1830)
[c] *Hebecnema nigricolor* (Fallén, 1825)
•[c] *Hebecnema vespertina* (Fallén, 1823)
•[c] *Helina depuncta* (Fallén, 1825)
Helina evecta (Harris, 1780)
[c] *Helina impuncta* (Fallén, 1825)

•*Helina maculipennis* (Zetterstedt, 1845)
[c] *Helina obscurata* (Meigen, 1826)
•[c] *Hydrotaea albipuncta* (Zetterstedt, 1845)
Hydrotaea cyrtoneurina (Zetterstedt, 1845)
[c] *Hydrotaea dentipes* (Fabricius, 1805)
[c] *Hydrotaea diabolus* (Harris, 1780)
[c] *Hydrotaea irritans* (Fallén, 1823)
[c] *Hydrotaea militaris* (Meigen, 1826)
Limnophora maculosa (Meigen, 1826)
Limnophora triangula (Fallén, 1825)
[r?] *Lispocephala pallipalpis* (Zetterstedt, 1845)
[c] *Mesembrina meridiana* (Linnaeus, 1758)
[c] *Morellia aenescens* Robineau-Desvoidy, 1830
[c] *Morellia hortorum* (Fallén, 1817)
[c] *Morellia simplex* (Loew, 1857)
[c] *Musca autumnalis* De Geer, 1776
[c,df] *Muscina levida* (Harris, 1780)
[c,df] *Muscina prolapsa* (Harris, 1780)
[r,f] *Mydaea affinis* Meade, 1891
[c,f] *Mydaea corni* (Scopoli, 1763)
Mydaea nebulosa (Stein, 1893)
Mydaea orthonevra (Macquart, 1835)
[f] *Mydaea setifemur* Ringdahl, 1924
[c,df] *Mydaea urbana* (Meigen, 1826)
[c] *Myospila meditabunda* (Fabricius, 1781)
[c] *Neomyia viridescens* (Robineau-Desvoidy, 1830)
[c] *Phaonia errans* (Meigen, 1826)
[c] *Phaonia incana* (Wiedemann, 1817)
[c,df] *Phaonia pallida* (Fabricius, 1787)
•[d] *Phaonia palpata* (Stein, 1897)
[df] *Phaonia rufiventris* (Scopoli, 1763)
[c,df] *Phaonia subventa* (Harris, 1780)
[c] *Phaonia tuguriorum* (Scopoli, 1763)
Phaonia valida (Harris, 1780)
[c] *Polietes lardarius* (Fabricius, 1781)
Spanochaeta dorsalis (von Roser, 1840)
[c] *Stomoxys calcitrans* (Linnaeus, 1758)
•[c] *Thricops diaphanus* (Wiedemann, 1817)
[c] *Thricops semicinereus* (Wiedemann, 1817)

Calliphoridae
Bellardia viarum (Robineau-Desvoidy, 1830)
[c] *Calliphora vicina* Robineau-Desvoidy, 1830
[c] *Calliphora vomitoria* (Linnaeus, 1758)
[c] *Lucilia ampullacea* Villeneuve, 1922
[c] *Lucilia caesar* (Linnaeus, 1758)
Melanomya nana (Meigen, 1826)
[c] *Melinda gentilis* Robineau-Desvoidy, 1830
•*Melinda viridicyanea* (Robineau-Desvoidy, 1830)
[c] *Pollenia amentaria* (Scopoli, 1763)
Pollenia angustigena Wainwright, 1940
[c] *Pollenia griseotomentosa* (Jacentkovský, 1944)
[c] *Pollenia rudis* (Fabricius, 1794)

Sarcophagidae
Brachicoma devia (Fallén, 1820)
•*Nyctia halterata* (Panzer, 1798)
Sarcophaga variegata (Scopoli, 1763) agg.
[c] *Sarcophaga aratrix* Pandellé, 1896
[c] *Sarcophaga sinuata* Meigen, 1826
Sarcophaga vagans Meigen, 1826

Tachinidae
Dufouria chalybeata (Meigen, 1824)
[a] *Eloceria delecta* (Meigen, 1824)
Eurithia anthophila (Robineau-Desvoidy, 1830)
Lypha dubia (Fallén, 1810)
Macquartia pubiceps (Zetterstedt, 1845)
Pales pavida (Meigen, 1824)
Phasia hemiptera (Fabricius, 1794)
Phryxe nemea (Meigen, 1824)
Phryxe vulgaris (Fallén, 1810)
Ramonda spathulata (Fallén, 1820)
Siphona geniculata (De Geer, 1776)
Tachina fera (Linnaeus, 1761)
Thelaira nigrina (Fallén, 1817)
Thelaira solivaga (Harris, 1780)
Voria ruralis (Fallén, 1810)

Dipterists Digest 2014 **21,** 37-40

Eristalinus sepulchralis (Linnaeus) (Diptera, Syrphidae): re-discovery of an old development site

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Summary

In July 2013, we encountered a high density of adult *Eristalinus sepulchralis* (Linnaeus) (Syrphidae) flying about accumulations of wet, decaying seaweed on the Hebridean Island of Sanday. Males defended territories on or above the seaweed while females deposited batches of eggs in crevices at the crust. A wide range of other Diptera was present and we observed oviposition by the hoverflies *Neoascia tenur* (Harris), *Eristalinus aeneus* (Scopoli), *Eristalis intricarius* (Linnaeus) and *Eristalis tenax* (Linnaeus). Decaying seaweed could be a major development site for saprophagous Diptera in the Scottish Isles and, perhaps, elsewhere.

Introduction

Eristalinus sepulchralis (Linnaeus) is a distinctive eristaline hoverfly with a loop in vein R^{4+5}, a dark body and entirely hairy, spotted eyes (Stubbs and Falk 2002). It is known throughout the British Isles, but is most frequent in southern England (Ball *et al.* 2011). In Britain, the larval development site is rich, organic mud and accumulations of decaying vegetation in water bodies of various kinds, from ponds to estuarine marshes and also farmyard drains (Hartley 1961).

In Scotland the status and distribution of *E. sepulchralis* differs from that of England and Wales. In Scotland, it is infrequent and confined mainly to coastlines (Ball *et al.* 2011). This pattern of distribution, involving a change from being widespread in southern England to being less frequent in northern England and having even fewer Scottish populations which are confined mostly to coastal regions, is similar to other wetland Diptera. For example, it is evident in the hoverfly *Tropidia scita* (Harris) (Syrphidae) (Ball *et al.* 2011) and the psilid *Imantimyia albiseta* (Schrank) (Psilidae) (Rotheray *et al.* 2013).

In relation to coastal regions, Lundbeck (1916, p. 417) stated that in Denmark, adult *E. sepulchralis* can occur 'near the shore' and quoted rearing records from 'below seaweed'. Yerbury (1919) stated that in early spring in Devon, *E. sepulchralis* occurs frequently on flowers of sea thrift, *Armeria maritima* (Plumbaginaceae), but then wanders inland. In Scotland, an even earlier association of *E. sepulchralis* with seaweed (Fucaceae) was recorded from the Ard Peninsula, near Port Ellen on the island of Islay. In August 1907, *E. sepulchralis* adults were observed by a Mr Alexander Ross 'flying abundantly about a quantity of decaying seaweed collected for kelp-making' (Anon 1911). In this paper we provide further evidence of *E. sepulchralis* and other eristalines having an association with seaweed.

Methods

The data reported here were obtained from the Inner Hebridean Island of Sanday. Sanday is a small, kidney-shaped island of about 134ha connected by a man-made bridge to the larger island of Canna, both islands lying just north-west of Rum. Along the south coast of Sanday is the inlet of Suileabhaig (NG281043). On the high shore of Suileabhaig, on 23.vii.2013, we encountered on either side of a burn or stream running into the sea, extensive amounts of decaying seaweed divided into patches of various sizes and depths by rocks, water pools and grassland. Patches consisted of a dry 'crust' under which were dense, compacted layers of seaweed in varying stages of wet decay and up to 40cm deep. Over a period of about 90 minutes, we made direct observations of numerous adult flies on and near decaying seaweed using, especially, Pentax Papilio 8.5x21, 'butterfly binoculars', that are capable of focusing over distances as short as 40cm. The conditions were warm, still and sunny.

On 25.vii.2013 a small amount of decaying seaweed containing Diptera larvae and puparia was collected into plastic bags. This material was transferred to three glass bottles with net covers. Bottles were kept in cool, dark conditions.

Results

When we encountered the decaying seaweed on 23 July, the tide was out and we were immediately aware of the odour of decay and of the sight and sound of a high density of hoverflies flying over and near it. Many individuals were also resting on nearby rocks and other substrates. Of the hundreds and possibly thousands of individuals present, the most conspicuous were, in order of abundance assessed by eye, *E. sepulchralis*, *Eristalis intricarius* (Linnaeus), *Eristalinus aeneus* (Scopoli) and *Eristalis tenax* (Linnaeus). *Neoascia tenur* (Harris) (Syrphidae) was also abundant, about the margins of seaweed patches. Among other Diptera present were many of the seaweed fly *Coelopa* (*Fucomyia*) *frigida* (Fabricius) (Coelopidae), yellow dung fly *Scathophaga stercoraria* (Linnaeus) (Scathophagidae), and many others not identified, including Dolichopodidae and a diverse array of Cyclorrhapha. Furthermore, on examining the crust, we found it full of many types of Diptera puparia; thousands were present and the majority were empty.

Females of all large eristalines recorded were observed landing on the crust and extending their ovipositors into cracks and crevices. Eggs were found in these crevices. Irrespective of species, ovipositing females were constantly attended by male *E. sepulchralis* flying directly into them. Female *E. intricarius* and *E. sepulchralis* did not seem deterred by these physical encounters and made slight shifts in position or, they walked or flitted to a nearby place on the crust. In contrast, female *E. aeneus* and *E. tenax* oviposited under curtains of grass that hung down the sides of grassland bordering seaweed patches. *Neoascia tenur* also oviposited in crevices of the crust and males flew after each other and females, but male *E. sepulchralis* did not interact with them. On disturbing the seaweed to look for larvae, we found many long-tailed, eristaline puparia within or close to the crust. In wet material underneath, down to 40+cm, were large numbers of long-tailed larvae of various sizes, i.e. about 12-15 larvae per handful of decaying seaweed. Usually the largest individuals were deepest in position. It was also noticeable that eristaline females arrived to oviposit at places in the crust we had disturbed.

On 25.vii.2013 we returned to the site to collect larvae and puparia. On this occasion, it was high tide and conditions were dull and overcast. The sea had reached the seaweed patches, which were floating but not breaking up. Numbers of adult flies were high but not as high as on 23 July. By the end of September 2013, several specimens of *C. frigida* and two males and a female *E. sepulchralis* emerged from the bottles. Shortly after this, the material in the bottles dried out and nothing more emerged.

Discussion

Since 2010, we have examined decaying seaweed at various places on the coasts of Sanday and Canna and especially at the inlet of Suileabhaig, but only in July 2013 were large numbers of hoverflies observed. At Suileabhaig, decaying seaweed appears to have been continuously present over many years, an impression reinforced by the nature of the patches and by the number of empty puparia within the crust. Patches are probably maintained by fresh inputs of seaweed during high tides. From what we saw on 25 July, patches float and are not dispersed or broken up by the tide. They are probably protected by the surrounding rocks and grassland and by the densely compacted nature of the decaying seaweed itself. These circumstances may also explain the depth of seaweed patches, over 40cm in many places, which of itself, is indicative of a prolonged period of accumulation. The tide also suggested that patches are inundated more by seawater than freshwater from the burn. Most patches of decaying seaweed were, in any case, well off to the side of the main course of this burn.

The durability of decaying seaweed at Suileabhaig, and the warm conditions of July 2013, probably explain the amount of active decay indicated by a pervading odour about the inlet. These odours were probably an attractant for the vast numbers of flies we encountered. Although decaying seaweed is the main development site for *C. frigida* (Egglishaw 1960) and *E. aeneus* (Hartley 1961) and apart from the seaweed rearing records of *E. sepulchralis* in Lundbeck (1916), the remaining hoverflies found on seaweed, are apparently only known from other types of development site (Hartley 1961). It is unfortunate that by the time GER noticed the decaying seaweed in the bottles had dried out, the only hoverfly to emerge was *E. sepulchralis*. It remains possible therefore, that decaying seaweed is not suitable for the other syrphids we saw ovipositing. Although if not suitable and given the numbers we saw, the negative effect on abundance must be considerable.

The only other Scottish rearing record for *E. sepulchralis*, that we have been able to locate, is a single female with its puparium reared by E.C. Pelham-Clinton in 1962 from 'saline mud' at Port Appin in Argyllshire. This specimen is in the collections of the National Museums of Scotland. Hence, in Scotland *E. sepulchralis* is not restricted to breeding in decaying seaweed, but the record supports a coastal distribution for this species in Scotland. Rotheray *et al.* (2013) suggested that the psilid *I. albiseta*, which has a similar pattern of distribution to *E. sepulchralis*, is warm-adapted and, in Scotland, is confined to coastlines and river valleys due to their relatively mild climates. The same may be the case for *T. scita* and *E. sepulchralis*. Their coastal distributions are not explained by the distribution of associated habitats and plants. None of these is confined to coastlines in Scotland: *Juncus* for *I. albiseta* and *Phragmites* beds for *T. scita* (bsbimaps.org.uk), and organic mud and accumulations of decaying vegetation in water bodies of various kinds for *E. sepulchralis* (Hartley 1961). The most obvious explanation for the mismatch between the distribution of these species in Scotland and their critical resources is climate.

On both Canna and Sanday, mud and decaying vegetation are present at inland water bodies of various kinds, including marshes, bogs and pools. In addition, cattle and sheep are kept on the islands. Yet the only place we found adult *E. sepulchralis* other than near decaying seaweed, was in nearby flower-rich grassland where single individuals were netted. In addition, a few adults of *E. tenax* occurred in this grassland and, in late July 2013, *E. intricarius* males were fairly numerous in sheltered spots, hovering and flying above the grass and females were frequent at buttercup flowers *Ranunculus* spp (Ranunculaceae). These observations indicate how remarkable was the high density of hoverflies over decaying seaweed. It is probably a significant development site for *E. sepulchralis*, *E. intricarius* and *E. tenax* on Canna and Sanday and possibly, on other Scottish Islands and coastlines. Decaying seaweed may be similarly important for a wide range of Diptera that are better known from other media, such as dung in the case of the yellow dung fly *S. stercoraria*. In the northern Isles, perhaps due to lack of alternatives, more species use decaying seaweed for development than is usual elsewhere. The importance of decaying seaweed as a development site for island Diptera requires further elucidation and should be investigated.

The behaviour of male *E. sepulchralis* at beds of decaying seaweed seems remarkable for the attention they paid to females of other species. If males of these other species were present, we did not notice them. From their numbers, male *E. sepulchralis* were experiencing a high frequency of contact with other flies. This may have elicited and maintained a high level of responsiveness, such that males approached whatever insect they perceived. The observations of female *E. intricarius* and *E. tenax*, moving into the shade of overhanging grasses to oviposit, may have been a reaction to disturbance from male *E. sepulchralis*, but other explanations are possible, such as innate preferences to oviposit in shaded or sheltered places or, they went there to cool down.

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Further observations on the ecology of *Ellipteroides alboscutellatus* (von Roser) (Diptera, Limoniidae) in England and Wales

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Summary

This paper provides descriptions of nine new sites for this species in England and Wales, and updates the details of habitat, ecology and field observations within the framework of a previous paper (Heaver 2006). Details are given of conductivity and pH of the flushes. The micro-habitat remains flushed *Palustriella* moss beds on perched springline tufa flushes, the majority of which are now to be found in woodland.

Introduction

Since the first paper describing the ecology of this species was published (Heaver 2006), further observations have continued during the period 2005-2012. The same fieldwork approach was adopted as before, although adding data on flush pH and conductivity for some sites, whilst integrating all the new locations into the existing soil type and underlying geology reference tables. The pen picture descriptions for the new sites follow that of the previous ones, and should be read in conjunction to gain a full appreciation of the habitat of this species in Britain.

Ellipteroides alboscutellatus (von Roser, 1840) is a Western Palaearctic species, Oosterbroek (2013) noting its occurrence in Albania, Austria, Belgium, Bulgaria, the Czech Republic, Estonia, France, Germany, Great Britain, Hungary, Italy, Lithuania, Macedonia, Netherlands, Romania, Serbia, Slovakia, Slovenia, Spain, Switzerland, Ukraine (Carpathians), Morocco and Lebanon. As such, it is useful to consider the habitat in other countries and try to place the British fauna within a wider context, and part of this study addresses that issue.

Materials and methods

The same methodology as described by Heaver (2006) was adopted for the investigation of the new sites, although water flow was not measured, only visually estimated within simple flow speed categories. Further detail on the nature of the tufa seepages was considered important and resulted in the use of an Extech Instruments ExStik EC500 pH/Conductivity/TDS/Salinity & Temperature meter. The water temperature of springs was recorded in degrees centigrade, whilst conductivity was measured in µS. Both pH and conductivity were calibrated by the provided buffer solutions with the ExStik sample kit, but later by recourse to a Myron L Company KCI-700 µS TDS/Conductivity solution. Both the sample probe and sample containers were double washed with Aqwsafe bottled distilled water at 0 ppm dissolved solids. Temperature and conductivity were generally taken together, although in a few instances this did not happen.

The revised British distribution map (Fig. 1) was constructed using Quantum GIS (2013) version 1.7.5 Wroclaw build, with the Countries (GB) 2011 Boundaries (Generalised, Clipped) shapefile (ONS, 2011) as the outline. Grid reference data were batch processed using the online Gridreferencefinder.com tool, pasting the transformed data into Apache Open Office 4 Calc spreadsheet, which itself was saved as a CSV file. This was imported into Quantum GIS using the Add Delimited Text Layer plugin. Both the CSV file and the outline shapefile were coordinate referenced to the WGS84 projection. Production of Fig. 2, mapping sites to bedrock geology, followed the same procedure, but using the BGS (2013) DiGMapGB-625 data 1: 625 000 ESRI® [Bedrock geology] shapefile.

Basic statistical analyses were carried out using the open source SOFA package v.1.3.4, running a Kruskal-Wallis H test since the conductivity and pH data, being founded on tufa systems, is enough skewed in its distribution away from normality.

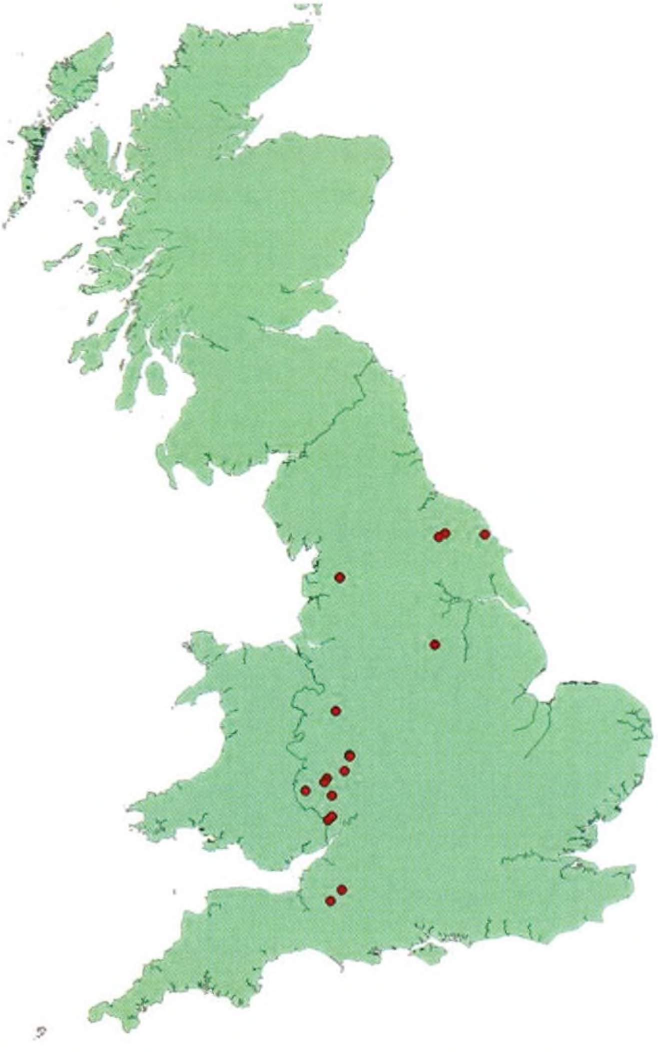

Fig. 1. Current British distribution of *Ellipteroides alboscutellatus*.

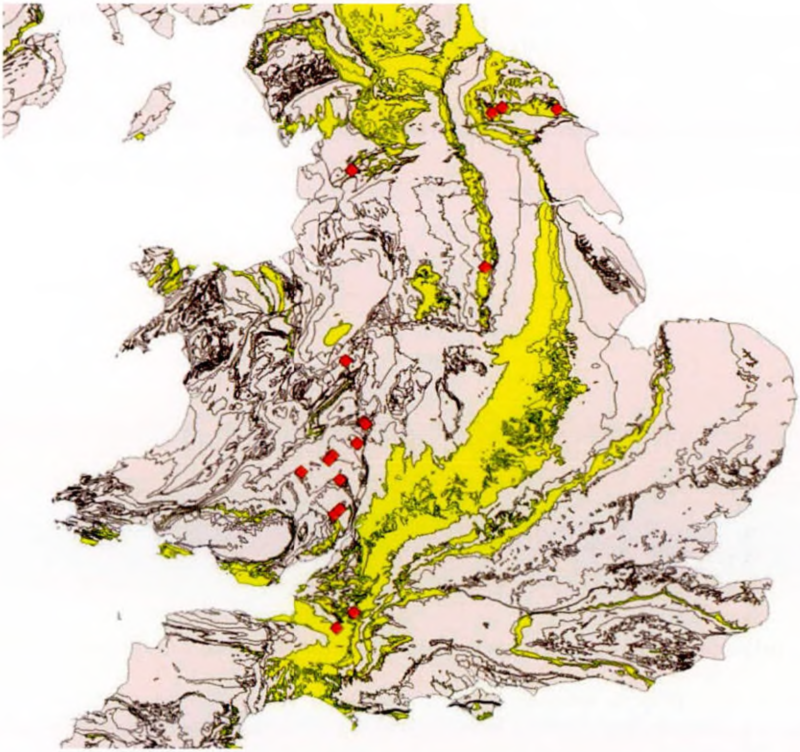

Fig. 2. Plot of *Ellipteroides alboscutellatus* sites against limestone bedrock formations.

Results

Table 1 tabulates the conductivity, pH and temperature measurements for three British sites. The fact that they are point data should be borne in mind, as fluctuations in pH and conductivity can be expected within such systems.

To place the British site data in a broader context, it was considered that there was need to review comparable data from elsewhere, something that seems, unfortunately, fairly scarce in the entomological literature, though less so in geomorphological works. Four other datasets have been accessed. These are the base data from adults caught in Malaise and targeted sweep net samples (Rádková 2011), from fen streamlets of the outer part of the West Carpathians on the Moravian-Slovak border, from other Slovakian data from a Western Carpathians study (Novikmec *et al.* 2007) which undertook larval sampling of the Hluboký potok stream spring system but set within the context of decades of other sampling regimes and techniques, and Arp *et al.* (2010) data from the Westerhofer Bach, located to the west of the Harz Mountains, c. 27 km NNE of Gottingen, Germany. In addition, Özkul *et al.* (2010) gave data on the Güney waterfall perched springline tufa deposit and associated spring waters in Turkey. It is worth noting that *Ellipteroides* is *only* recorded from the Carpathian studies, and not from either the German or Turkish site, and their inclusion within this analysis is founded entirely on demonstrating the geo-chemical parameter range within the tufadepositing systems of types that are used. Both look, from photographs, to have similarity with British *Ellipteroides* sites, though larger in scale.

Not enough data points were able to be collected to allow a between-site comparison of British site pairs. The conductivity ranged from 495 to 629 μS.cm-^{1} (n=8). However, combining all British data points does allow inter-country comparisons to be carried out.

Site name	Conductivity μS.cm^{-1}	pH	Temp ^{0}C
Ashberry Pastures	496	8.02	17
Ashberry Pastures	597	7.5	12.9
Blaiskey Bank	546	7.55 ^{a}	12
Blaiskey Bank	518	7.88	14.2
Blaiskey Bank	520	8	18.4
Blaiskey Bank	495	7.99	20.5
Pentaloe brook, mid flush	629	-	-
Pentaloe brook, upper flush	583	-	-

Table 1. pH and conductivity data from selected British *Ellipteroides* tufa flushes.

Looking at the group B sites of Rádková (2011), a group in which *Ellipteroides alboscutellatus* was an indicator taxon, a Kruskal-Wallis test shows a significant difference between conductivity levels in the Slovak autumn samples and the British sites (H=10.5, 1d.f, p=0.001), with median values = 394 μS.cm^{1} (Carpathians) and 533 μS.cm^{-1} (British sites). A similar result was found when comparing the Slovak spring sample with the British sites (Kruskal-Wallis, H=7.714, 1 d.f, p=0.005), with median values = 422 μS.cm^{-1} (Carpathians) and 533 μS.cm^{-1} (British sites).

Further analysis can be made between country pairs, and looking at the German Westerhofer Bach data and that derived from the Turkish Güney waterfall perched springline shows a significant difference in conductivity: Kruskal-Wallis H=8.25, 1 d.f, p=0.004, with median values = 994 μS.cm^{-1} (Westerhofer Bach), and 439 μS.cm^{-1} (Güney waterfall). However, this is not surprising given that the Westerhofer Bach data range, at between 903-1037 μS.cm^{-1}, is double that of some of the other site groups.

A comparative analysis of the collected pH values between the British data set and the spring measurements presented by Rádková (2011) has also been performed. Using Kruskal-Wallis (H=0.867, 1 d.f, p=0.352), this showed no significant difference between the two groups.

Table 2 extends the geological and soil type characteristics of the new British sites, and follows that in Heaver (2006), whilst Fig. 2 plots all British sites against a limestone descriptor of the GIS table. Site descriptions of the type provided by Heaver (2006) are also given in Appendix 1 for the eight new sites and briefly for a ninth.

Discussion

Eight of the new British sites fall into a similar pattern as that described by Heaver (2006), and present no great variation of type away from the perched springline seepage originally described. The ninth, the Prisk Wood site, is very atypical and is a possible exception that requires more study. The old record made by Henderson in 1926 for the only Scottish site (the Cadder Wilderness Plantation, East Dunbartonshire) as given on the NBN Gateway is deemed to be in error (Geoff Hancock *pers comm*), and was probably a case of misidentification, with the correction not being recorded in Henderson's collection in The Hunterian (Zoology Museum).

The new sites described here are plotted (Fig. 1), along with the rest of the British sites, to present an updated British distribution map. Some of the new sites bear a resemblance to those described previously (Heaver 2006): Blaiskey Bank Spring SSSI and the Pentaloe brook flush, or Whitewell Coppice and Hurdlestone Wood. The geographical proximity of some of the sites to each other is reflected in the similarity of soil types (Table 2) on which they occur, with both the Bromyard and Crwbin series being found in the Herefordshire sites. The bedrock geology provides a good match for a number of the sites (Fig. 2) when selected for limestone, an attribute layer in the mapped data table that includes limestones, mudstones, calcareous mudstones, and some siltstones. It, however, poorly matches the central Herefordshire borders group, which are better represented by the selection of Upper Devonian mudstones, sandstone and siltstones. Together both geological groups indicate areas where additional springline flushes might occur.

In an attempt to assess how typical the British sites are within the European range context, more exploration of the published data has been undertaken. However, in most reports of occurrence hardly any habitat details are given, though what little has been found is presented here. Various research groups (e.g. Bitušík *et al.* 2004) have carried out much research work in parts of the Carpathian Mountains, and the following discussion relies heavily on such work.

Rádková (2011) noted that claystone, calcareous sandstones and limestones predominate in the south-western part of the Outer Western Carpathians, the White Carpathians and their immediate surroundings. The groundwater is rich in carbonates and has a high content of carbon dioxide (CO_2), which enables the formation of springs with tufa precipitation. Their study sites showed a strong gradient from mineral-rich springs with precipitation of tufa (calcareous tufa forming fens) to extremely poor Sphagnum fens.

The "trickle flowing fen" has carbonated water that is extremely rich in minerals, the average conductivity values of around 422 $\mu S.cm\text{-}^1$ and the average pH value of around 7.9. The spring water has a high content of calcium ions and CO_2, high pH, and with the typical ground water to precipitation of tufa ($CaCO_3$) pathway (Rádková 2011). The habitat described is quite recognisable as a typical British *E. alboscutellatus* site.

Bulánková (2007) had similar findings on the Stupavský potok brook in the Carpathian mountains, and demonstrated that the species occurred in five out of her seven substrate classes, though it showed a preference for sand substrates. This was closely followed by her "macro" and "microlithic" sediment classes. There is no definition of the sediment classes used, but given that these would be tufa-forming systems, one can see some analogy to the equally-undefined "tufaceous silts and gravels" used as descriptors in this work.

The main direction of variation in the community biplot holding *E. alboscutellatus* also reflected changes in the nature of the substrate, with the trickle groups A and B within which *E. alboscutellatus* occurs (although weakly in A), having a coarse, inorganic substrate in the form of sand, gravel and stones. They were also notable for having a lower organic content than found in other samples (Rádková 2011).

Rádková (2011) performed a Principal Component Analysis on the macro-invertebrate assemblages of fen streamlets in the outer part of the Western Carpathians. This gave a distinctive group on the biplot composed of *E. alboscutellatus* larvae, the larvae of the stratiomyid *Oxycera pygmaea* (Fallén), and the widespread seepage caddis *Beraea maurus* (Curtis). Whilst *O. pygmaea* has not been encountered on the British sites, *O. pardalina* Meigen is a common associate species in this habitat (Heaver 2006). It is possible that undertaking co-incident mapping of these other species, in conjunction with the bedrock geology map may well point to new flush areas, many of which remain largely ignored and uncommented on within the woodlands in which they typically occur. This is, in part, because they have a low floral diversity and so do not merit attention from non-entomologists, much in the same way as exposed riverine sediments have been overlooked in the past.

Rádková (2011) further recorded that *E. alboscutellatus* was one of several taxa in her study, where the number of individuals within the communities reached abundances greater than 1% of the total number of individuals (742 adults taken, representing 5% of fauna). She utilised the EUNIS habitat classification, and placed the species in the C2.21 epirithral stream section (European Environment Agency 2014), where the streamlets fan out below the main springhead. This is a typical British situation, and would well describe Whitwell Coppice, for example. Novikmec *et al.* (2007), working on Carpathian stream systems, similarly noted *E. alboscutellatus* as being the dominant species (20-100% of the sampled fauna) in the Hluboký potok Hlu2 sampling site, and sub-dominant (10-20%) in both Hlu3 and Stu1samples, with the two Hlu sites being closer than Stu1 under a complete linkage cluster analysis. This numerical dominance is consistent with the field observations in British sites where, at the time of emergence, it seems by far the commonest insect on the wing.

The Hluboký potok Hlu2 sampling site spring is described as having "a lot of cascades, a high slope and a lot of moss-covered rocks" (Novikmec *et al.* 2007), and might be considered something like the Hackfall wood site. The habitat surrounding Hluboký potok Hlu2 is further described as "young beech stands with mixture of maple (5%), with 80% of shading. *Asperula odorata, Dentaria bulbifera, Dryopteris filix-mas, Petasites albus, Rubus idaeus* and *Senecio nemorensis* are presented in undergrowth", a description, albeit with different species, that could be applied to many British *E. alboscutellatus* sites in terms of having a drier vegetation stand around the seepage areas and having a degree of tree shading but not complete cover.

The differences noted here between conductivity levels between country sites say more about the variability in geo-chemistry between calcareous aquifers than they do about micro-habitat choice by *E. alboscutellatus*, though it is useful to understand the physio-chemical ranges found in habitats that could support it. Through all these investigations it is now possible to state that *Ellipteroides alboscutellatus* can be found within conductivity range between 161-629 $\mu S.cm^{-1}$.

As noted earlier, it is unknown if *Ellipteroides alboscutellatus* occurs in the Westerhofer Bach site or at the Güney waterfall, and so whether it can tolerate the more elevated conductivity levels found there remains unclear. Whether the faunal dominance of *E. alboscutellatus* at both the Hlu2 sampling site (which has a mean conductivity of 181.4 $\mu S.cm\text{-}^{1}$, Novikmec *et al.* 2007) and at Blaiskey Bank SSSI (anecdotally now the strongest British population, with the highest conductivity sample at 546 $\mu S.cm\text{-}^{1}$), actually indicates a more optimal conductivity range is as yet unclear.

Table 2. Location and Characteristics of *Ellipteroides alboscutellatus* sites in Britain.

Site Name	**County**	**Grid Ref**	**Soil type**	**Soil description**	**Geology Influencing Soil Characteristics**
Park Wood B	Herefordshire	SO588177	Crwbin 313c	Shallow, well drained loamy soils over limestone	Trenchard Group, Carboniferous limestones
Hackfall Wood	North Yorkshire	SE236771	Soilscape 6^1	Freely draining slightly acid loamy soils	Namurian Upper Carboniferous, Millstone Grit series
Whitewell Coppice	Shropshire	SJ621186	Stanway 711a	Slowly permeable seasonally waterlogged often stoneless fine silty or fine silty over clayey soils on rock	Palaeozoic siltstone, shale and mudstone
The Dropping Wells	Herefordshire	SO551144	Crwbin 313c	Shallow, well drained loamy soils over limestone	Trenchard Group, Carboniferous limestones
Hill Hole Dingle	Herefordshire	SO538542	Bromyard 571b	Well drained reddish fine silty soils over shale and siltstone	Devonian reddish silty shale, siltstone, sandstone
Moccas Park	Herefordshire	SO334428	Bromyard 571b	Well drained reddish fine silty soils over shale and siltstone	Devonian reddish silty shale, siltstone, sandstone.
Blaiskey Bank Spring	North Yorkshire	SE625886	Soilscape 17^1	Slowly permeable seasonally wet acid loamy and clayey soils	Corallian Upper Jurassic
Hawks Wood Thorpe Salvin	South Yorkshire	SK525817	Aberford 511a	Shallow, locally brashy, well-drained calcareous fine loamy soils	Faulted Magnesian limestone
Prisk Wood	Gwent	SO532090	Soilscape 6^1	Shallow, well drained loamy soils over limestone	Much quartz conglomerate

The pH values measured in both the Carpathians and the British sites showed no significant differences, and are comparable and typical of the pH values (pH 7.7-8.2) given by, for example, Heery (2007) in a study of tufa vegetation communities in Ireland. Bulánková (2007) recorded the highest pH value (pH 8.44) on the Stupavský potok brook in June, whilst Rádková's (2011) Group B sites had an average pH of 7.58 ± 0.89. As such, and combining all data it is now possible to state that the pH tolerance of *E. alboscutellatus* lies at least in the range 7.5-8.44.

Flight period.
The new sites have provided more flight data periods, and in Britain this ranges from 8 July to 15 August (n=11), but combining it with the previous flight data shows a flight period still ranging from 10 June (exceptionally early it seems) to 28 August. This fits in with the scant European flight data, with records ranging from 25 June 2008 (Starý 2009, Bohemian site), 5 July 2000 (Pârvu 2004, Romanian site), 2 July and 8 August 2005 (Podėnas and Podėnienė 2008, Italian site).

APPENDIX 1: Catalogue of site descriptions.

Blaiskey Bank Spring SSSI (SE625886)

This is a large, open flush system on a hillside, backed by acidic *Betula* woodland with *Vaccinium*, though the lower section below the fence is heavily grazed out. A secondary flush system, not entered, lies just along the same hill-slope within the garden of a farmhouse, and looks of similar quality as the main SSSI flush, though its lower sections are truncated by the farmhouse access track.

The main tufa seepage arises sharply from a linear spring-line at the woodland edge, and has 5 or 6 runnels fanning out to form a deltaic structure, with strong to medium water flow. The flushes run, albeit in deep channels at the lower reaches, to the bottom of the site where the whole hydrological system appears to sump into a ditch. It is likely that the farm track that runs along there truncated the original seepage somewhat. Most of the flush has 0% canopy cover, with only 50% at the woodland edge at the springhead. The flushed areas are open, with sedges and *Deschampsia*, with *Eriophorum vaginatum*, harebell *Campanula rotundifolia*, and butterwort *Pinguicula vulgaris* being occasional to locally frequent. Marsh helleborine *Epipactis palustris* was occasional. The springhead line has 70% *Palustriella communis* cover, with 20% open and tufaceous gravels and silts, with 10% *Carex* and *Juncus* cover.

Most runnels were active, though those on the furthest eastern reaches were dry at the time of the visit. Large *Palustriella* sheets were on the main bank by the wood, with no surface water flow, though they probably sit on a tufa bench with flow from beneath. *Ellipteroides* was abundant on this site, with 14 being easily captured in one net sweep, and this being repeatable across the site. The large numbers that were *in copula* suggests a strong and recent emergence on this site. At least one cranefly had fallen to the sticky trapping leaves of the common butterwort. Site visited on 10.vii.2009.

Park Wood SSSI B, Herefordshire (SO588177)

Recent forestry operations within this woodland had removed a large area of thick and scrubby coppice growth further along from the Park Wood site previously recorded, revealing a secondary and previously hidden flush. Park Wood B is a broad seepage c. 150m in length, with a variable slope. At its widest, the flushed area is some 11m wide, running down to smaller runnels only 2m wide. The seepage zones are split by drier baulks with woodland vegetation, such as abundant dog's mercury *Mercuralis perennis* and enchanter's nightshade *Circaea lutetiana*, and bramble *Rubus* species. The flushes have relatively small amounts of *Palustriella*, and more open tufaceous gravel deposits, with a good amount of petrifying dead wood across the system. Canopy cover was 70%, with ash *Fraxinus excelsior* dominant, with oak *Quercus* and low hazel *Corylus avellana* scrub. Water levels were low, with only slight water flow perceptible and, unlike the original Park Wood site, this had far fewer tufa dams. Hart's tongue fern *Asplenium scolopendrium* was frequent, with *Dryopteris* ferns occasional, and hemp agrimony *Eupatorium cannabinum* frequent. Water mint *Mentha aquatica,* was abundant in places, with brooklime *Veronica beccabunga*, yellow pimpernel *Lysimachia nemorum*, meadowsweet *Filipendula ulmaria* and marsh valerian *Valeriana dioica* being rare.

This system has no clear and defined springhead, just a broad and gently sloping muddy pool with rocks and bryophytes. The flush length is c. 30m. The lower parts of the flush system are fed water through tufaceous gravels, with only dry tufa gravels above this; there was little visible water flow in these sections. The bottom part of the flush sumps (1.2m wide) below the riverside track, and does not obviously express itself on the River Wye riverbank. There are heavy tufa gravel deposits around this sump area, with a low pool and waterfall arrangement, having good water flow. The gravels are mostly bare on this lower reach, probably because of previous shading. Around 10 *Ellipteroides* were seen on the system, and there is undoubtedly exchange of adults between the two parts of the Park Wood tufa system. Site visited on 26.vii.2008.

Moccas Park NNR, West 6 (SO334428)

This site was found by Andy Godfrey in 2001, as part of a larger entomological survey of the Lower Park invertebrates, commissioned by English Nature. The discovery of *E. alboscutellatus* here was rather eclipsed by the finding of the hoverfly *Myolepta potens* (Harris) (Syrphidae).

The seepage is a linear system only about 1.5m wide and about 26m long, which runs down parallel to the Park boundary fence, and on the edge of one of the more wooded sections of the Upper Park. There is less than 10% canopy cover from the oak-ash woodland here, with the under-storey heavily bracken dominated.

The flush itself has soft rush *Juncus effusus* as the dominant species, with abundant water mint and the blue-green *Carex* species as frequent. *Palustriella* cover is good and it was scored as abundant. *Briza* was present but rare, on the drier banks. Water flow was moderate over silty tufaceous gravels. The resident deer herd obviously make some passage through the flush area, helping keep it open though not greatly impacting upon it. Only 1 *Ellipteroides* was found but then the visit was at the extreme end of the flight period. Site visited on 15.viii.2008.

Whitwell Coppice SSSI (SJ621186)

This site is an 18m wide braided stream system, flowing through very open and heavily deer-grazed deciduous woodland. It flows through a small alder-dominated valley not far from the upper edge of the wood, with sycamore frequent on the drier ground. The main flush occurs under 85% canopy cover, with some denser areas locally, though generally the alder trees are tall and thin and so allow light to the flush floor. Ash-hazel woodland surrounds the small valley. This is one of Britain's most important geological localities, internationally recognised as the standard reference section for the base of the Homerian Stage, the upper half of the Wenlock Series of the Silurian System (Natural England 2013).

Palustriella is present only in the canopy gaps over tufaceous gravels and lateral seeps, and in the more slack waters in the otherwise very strong water flow. There are some drier baulks present, though recent "flood-defence" excavations, probably connected with the nearby property, have damaged some of these. A footpath and board walk conveniently cross the system. The flush system extends for around 100m, and has dominant *Carex pendula* stands, with occasional *Ribes*. Below this main zone is a lateral wash zone where the topography allows the stream to braid on ground that otherwise enforces it to stay in channel, and here occasional hemp agrimony is found.

The stream has built a complex braided channel with much channel cross-over, with areas of flushed tufaceous gravel both with and without *Palustriella*, though the moss patches are nowhere extensive. A series of small tufa rills are present as the valley descends through the wood, and these have much woody debris. Dog's mercury is dominant in the drier woodland, with occasional enchanter's nightshade and ivy *Hedera helix*. Below the boardwalk, the main channel flow is augmented by 2 smaller streams joining it, though the impression was gained that these are not as base-rich, as tufa deposition below is reduced, presumably a consequence of the dilution and changes in the system pH. *Ellipteroides* was present in both flushed areas, although more numerous in the upper main one. Pete Boardman visited this site a few days later on 12 July, and also noted large numbers to be present (Boardman 2013). Site visited on 8.vii.2012.

The Dropping Wells, The Biblins (SO551144)

This site is well known as a geological feature and as the backdrop to the Biblins campsite by the River Wye. It is a large limestone cliff, with an extensive tufa seepage on its face, this pooling to an impacted seepage system at its base. Heavy visitor pressure and fencing have resulted in a combination of excessive erosion and lack of grazing in this basal area. The expected *Palustriella* sequence one might expect from such an arrangement is thus greatly truncated.

The vertical face of the cliff has some *Palustriella* bathed in the dropping water seeps, giving a complex of wet faces and drier buttresses. The bottom 100m or so is at a slope of c. 35°, but is badly trampled. The south-facing cliff face is fronted by light ash-hazel woodland, though the basal tufa gravels are 90% bare and trampled. Pendulous sedge *Carex pendula* occurs in the runnels at the cliff base, with *Equisetum* and hemp agrimony being rare. Behind the fenced section, the cliff face water effectively sumps. *Palustriella* occurs along a small part of the cliff bottom, in a narrow band and at about 3m up from the base. The vertical flush community is a mix of *Deschampsia*, hemp agrimony, *Mentha*, *Tussilago*, and algal and bryophyte mats. Only one *Ellipteroides* was swept from this area.

A discussion with the campsite staff revealed an easy way to the cliff top, and this was duly explored. Here, extending back c. 30m from the cliff edge is a fine tufa seepage stream system, though dry weather at the time of recording had reduced its extent a little. The main tufa stream is c. 1m wide with bare tufaceous gravels, with occasional *Palustriella,* and frequent *Juncus*, this grading into a perched and flushed *Phragmites* reedbed closer to the cliff edge and some 40m along. *Carex* is rare here, and hemp agrimony is occasional in the stands. The flushed areas had a 40% canopy cover of low birch, alder *Alnus*, oak and rare alder buckthorn *Frangula alnus*. Small runnels join the stream from the slope behind, through pond sedge beds. The overall impression is a complex of habitats, queuing up to the cliff edge. Safety consideration precluded exploring too far into the system, and *Palustriella* may be more abundant in less visible parts of the seepage complex.

The drier woodland areas at the back of the flush and between the several flush areas along the cliff edge have much bramble, with hemp agrimony and pendulous sedge in the wetter interface. The hydrology has been, in part, impacted by water collection from one of the springheads, a large water tank having been driven into the system, though there remains enough water to keep it dynamic, and *Ellipteroides* has not been greatly affected. A return visit in 2012 showed that the system still looked in good condition. Site originally visited on 11.vii.2005.

Prisk Wood SSSI (SO532090)
This, the only Welsh site, is woodland with a small stream that has a pebbly bed, and a surrounding ground flora of hart's tongue fern, *Dryopteris*, and mossy boulders, but no *Palustriella*. The 95% canopy cover is from small-leaved lime, sycamore, field maple, and canopy-layered ivy. Peter Kirby originally identified this site in 2004 (Gwent Wildlife Trust 2004). A single *Ellipteroides* was swept from here in 2005, though the specimen has been subsequently lost, and it is unclear if the main population centre lies nearby and has yet to be discovered. Further confirmation that this indeed supports a population of *E. alboscutellatus* is needed as the watercourse is a very atypical habitat. It actually looks to be a more typical habitat of the closely related *E. limbatus* (Blythe 2010). Site visited on 11.vii.2005.

Hill Hole Dingle SSSI (SO538542)
This NCR site is a wooded stream valley with a range of tufa seepages along its length, issuing from the banks into the main channel.

The largest seepage has the springhead on the dingle edge, just below the break of slope, where it then forms a wide braid down to the stream channel. The springhead has strong flow, and the flushed areas have much dead wood. It lies under a 70% canopy of dominant ash, with some hazel, over patchy *Palustriella* beds with large extents of intervening bare tufaceous gravels. Herb robert *Geranium robertianum* is occasional as is figwort *Scrophularia*, with poor bramble bushes being frequent, with some stands of opposite-leaved golden saxifrage *Saxifraga oppositifolia*, frequent meadowsweet and dominant wood millet *Milium effusum* in some parts. There is a strong water flow throughout. The more open areas have *Palustriella* hummocks with flushed tufaceous gravels, all having extensive terracing with complex braided flow patterns. Adjacent to this area is a less active *Palustriella*-dominated area leading onto the stream below. There is much damp tufa deposition here, but it is only building at the main seepage, so it is likely that the flow has been shifted by decades of deposition. Other sections are under 90% canopy cover, again of ash-hazel woodland, with the same flow as the adjacent area but covering only 15% of the ground, and covered in much fallen timber. The main flush is some 18m wide, with the adjacent flushes being perhaps another 9m.

Further downstream, and on both banks are a range of other, although smaller, tufa seepages. A steep 50° slope down to the stream is a solid *Palustriella* bed, flanked by tufaceous gravels, the seepage into the stream seemingly through the bare tufa, although it will all be flushed. This seepage stands at some 5m long by 4m wide, and is best described as *Palustriella* hummocks, shaded by light hazel and rare wych elm *Ulmus glabra*. Opposite-leaved golden saxifrage is frequent here, with occasional herb robert and nettle *Urtica dioica*, rare enchanter's nightshade and hard fern *Blechnum spicant*. Lateral but basal water flow is good here, and is more obvious in the side gravels. The whole riverbank is extremely friable and slumping, exacerbated by extensive deer passage. There is no clear springhead here.

Another nearby flush some 7m upstream of this occurs on a shallower (35°) slope, with the bottom of the seepage entering into the stream, although covered at the time by a large log jam. Two large trees lie across this seepage. There are stronger water flows here, but less *Palustriella* cover, with many patches of flushed tufaceous gravel. The flora is similar to the nearby flush, though this was sunnier, albeit under an 80% canopy of ash. The top of the riverbank here has a massive sedimentary rock slab face, with seepages arising in a broad zone of wetness, under 80% canopy shade from the woodland trees, and again much opposite-leaved golden saxifrage. The ground to the side of this was boggy, with strong water flows in this area, and many deer tracks.

Just about all of the seepage areas held *Ellipteroides*, and there is probably some interchange of adults between the sub-sites. A large storm event a few years later had the stream torrent carve much of the lower bank away, truncating the seepages at their base, though leaving the upper areas and the springheads untouched. Both *Stratiomys potamida* Meigen and *Oxycera terminata* Meigen (Stratiomyidae) were swept from the lower seepage areas by the stream when it was first discovered. Site visited on 13.vii.2006.

Hackfall Wood (SE236771)

As noted before (Heaver 2006) this site had not been visited by the author at the time, but now has been and is described here. This is possibly one of the better sites for *Ellipteroides*, having not only a fine waterfall but also an extensive streamside series of seepages down its length. The sides of the waterfall have extensive and steep *Palustriella* beds, assisted by some recent tree clearance around the falls that must have greatly improved the amount of light getting through. At the time there was only about 15% canopy cover over the two main water channels down the falls. Much dead wood lay in the cascade, with tufaceous silts in the pebbly channel, and a lateral side flow channel coming out from the still shady side margin woodland of hazel coppice. There were many *Palustriella* cushions here, surrounded by a typical ground flora of *Dryopteris* ferns, hard fern, dog's mercury, opposite-leaved golden saxifrage, with rare pendulous sedge. Though the side stream area had good flow, it nowhere matched the falls, though there were more gravels than silts in the former. Canopy cover away from the falls rose to 95% dense hazel coppice over the side flush, with a similar ground flora.

Near to this complex is an area with much tufaceous gravel in a 1m wide channel, with the first of the lateral stream seeps arising from another 0.5m wide channel out of hazel coppice, with a wide fan of wet quaking woodland soil. The lower parts of this seep were augmented by the stream itself, and had an *Equisetum telmateia* stand under 75% hazel canopy, with tufaceous gravel and silts in channel.

This whole complex itself then joins the main stream, which flows down the valley into the main river. Though not fully explored, it seems to have an 80% ash-hazel canopy over-topping it, with areas of the same ground flora type. Two *Ellipteroides* were taken at the base of the falls.

Some 200m downstream of this section are a set of tufaceous gravel seeps into the main stream channel, arising from out of the adjacent hazel coppice. There is much terracing here, with petrifying dead wood, and *Palustriella* cushions flushed with base rich water.

The full extent of the seepage system down the valley was not assessed, as the weather started to turn to heavy rain, but it looked to be extensive. Site visited on 13.vii.2007.

Hawks Wood, Thorpe Salvin, South Yorkshire (SK525817)
As with the Hackfall Wood site (Heaver 2006), this is a known site for the species but has not yet been visited. The record derives from Bill Ely's observation dated 28 July 1999, as recorded on the NBN (National Biodiversity Network). The mapped soil type is described as a shallow, locally brashy, well-drained calcareous fine loamy soil, of the Aberford 511a series. It appears from aerial photography to be a lateral seepage system into the Chesterfield Canal, in an area formerly worked for lime-kilns.

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Dipterists Digest 2014 **21**, 55-58

A second record of *Tipula* (*Pterelachisus*) *trifascingulata* Theowald (Diptera, Tipulidae) in France

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Summary

The second French record for the rare cranefly *Tipula trifascingulata* Theowald, 1980 is reported here.

Introduction

Tipula trifascingulata Theowald, 1980 is rarely recorded in Europe, with most of the known pre-2010 localities situated in central Europe (Germany, Switzerland and Austria). Nine of a total of 34 records worldwide were reported from the Netherlands in 2012, so there is the possibility that the species is extending its range. Loew first recorded it in 1864, as *T. trifasciata*, from a female; Savchenko recorded the first male in 1964 (Oosterbroek *et al.* 2013). Theowald (1980) proposed the replacement name as *trifasciata* was preoccupied.

The first French record

The first record of this species in France (as *T. trifasciata* Loew, 1864) was made by C. Pierre at a site near St Pierre de Chartreuse [45° 20'29.19"N 5° 48' 57.59"E, Département Isère, Commune St Pierre de Chartreuse] in July 1920. An account was presented to the Société Linnéenne de Lyon on 11 October 1920 by Pierre and he recorded it there as follows: '*T. trifasciata* Lw., Juillet, Saint-Pierre-de-Chartreuse, sur la mousse humide des rochers, le long du Guiers' (on damp moss on rocks along the River Guiers) (Pierre 1921). This is in the calcareous part of the Alps, about 20km south of Chambèry, and east of Les Échelles. The River Guiers flows through a wooded ravine beneath limestone cliffs.

The location of the second French record

The second French specimen recorded here, a male, was captured by a Malaise trap set up by Dominique Langlois, the Conservation Officer in the Ravin de Valbois National Nature Reserve [47° 05' 2.84"N 6° 05' 39.51"E, Département Doubs, Commune Cléron] (Réserves Naturelles de France 2014). This is about 203km NNE of the first site. The fortnightly Malaise trap sample was taken on 2 June 2009, and so the catch represents the period 19 May – 2 June 2009.

The Ravin de Valbois National Nature Reserve is situated quite near to the River Loue, east of Cléron, between Cléron and Chassagne-Saint-Denis, near Ornans, about 25km south of Besançon (the D101 is the nearest road). The wooded gorge starts at the Château Saint Denis, is 3km long, and lies between 300 and 550m altitude. It forms part of the Loue/Lison Natura 2000 site. There is a waterfall at the eastern end and the stream flows westward into the R. Loue. The cliffs are calcareous while the floor of the ravine, where the stream flows, is clay. The landscape is very similar to that found around St Pierre de Chartreuse, site of the first French record. The reserve is 335ha in extent, with two forested areas - La Forêt de Valbois - left uncut since 1910. Old trees are frequent and there is much dead wood. The ecological details of the site are as follows:

Fig. 1. Malaise trap in place, in the Ravin de Valbois (photo: Dominique Langlois).

Macro-habitat: Dominant trees beech (*Fagus sylvatica*) with large-leaved lime (*Tilia platyphyllos*) Corine 41.13. Pedunculate oak (*Quercus robur*) is found by the river at the bottom of the ravine.

Supplementary Habitats: Malaise trap 4 was one of 8 placed in the ravine and was located among beeches, with pedunculate oaks near the stream below, nearer the eastern end in a clearing with *Molinia* and *Carex davalliana* (Fig. 1). The steep slope of the ravine causes the trees to fall before reaching their full age. Some of these fall across the stream. Rocks fall from the limestone cliffs into the gorge, becoming covered in mosses.

Tufaceous, Springs: Corine 54.12.

Altitude: 400 m.

Aspect: On the slope of the ravine, orientated to the north-east (see photograph).

Geology: Jurassic limestone cliffs, with Oxford and Argovian Marls in the ravine.

Description of the species

The species has a striking appearance, resembling *Tipula* (*Pterelachisus*) *mutila* Wahlgren in its black and white patterned wings, lack of vein R_2 and in its smaller size (Fig. 2). The male genitalia are distinct in having a pair of thin processes posteriorly, on the sternite (Fig. 3). Oosterbroek (2014), Oosterbroek *et al*. (2013) and Theowald (1980) provide more details.

The specimen has been deposited in the World Collection at the Natural History Museum, London.

Fig. 2. ***Tipula trifascingulata*** **female (photo: Henk Soepenberg).**

Conclusions

The larvae are as yet unknown, but it is possible that they, in common with some others of the subgenus *Pterelachisus*, feed on the mosses that cover boulders and fallen tree trunks in these damp calcareous ravines. From the evidence presented here, the adults emerge from late May to July in France, and the recent Dutch records followed this same pattern (Oosterbroek *et al.* 2013).

Evidence suggests that it has recently spread northward through Europe. There would, however, seem to be a low probability that the species will become established in England from Belgium or the Netherlands.

Fig. 3. Posterior part of abdomen: left, lateral view; right, ventral view (photos: author).

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Rearing of *Eumerus nudus*, *E. olivaceus* and *E. pulchellus* (Diptera, Syrphidae) from asphodel, with notes on separation of *E. nudus* and *E. olivaceus*

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Summary

For the first time, larval host plants are reported for the syrphids *Eumerus nudus* Loew, 1848 and *Eumerus olivaceus* Loew, 1848. Observations are provided on the rearing of *E. nudus* from tubers of *Asphodelus ramosus* and *E. olivaceus* from tubers of *A. albus* and *A. ramosus*. Rearing of *Eumerus pulchellus* Loew, 1848 is also reported from tubers of *A. ramosus*. Notes are provided on recognition of the adults of these three *Eumerus* species. The potential significance of synchronous occupancy of tubers, bulbs, etc., by the phytophagous/ saprophagous larvae of more than one syrphid species is discussed.

Introduction

Eumerus is arguably the most poorly known of all the large European syrphid genera. Upwards of 60 species have been reported from the continent, but the only key purporting to deal with them all is that of Stackelberg (1961), which was produced before 17 of the species now known from Europe had been described. Further, Stackelberg's key omits some of the European species then known and involves some very dubious interpretations of others. Given the difficulties inherent in identification of the adults, it is perhaps unsurprising that almost nothing is known about the life histories of the great majority of European *Eumerus* species. The known larvae (Speight 2012) inhabit the tissues of water and nutrient storage organs of herbaceous plants – rhizomes, bulbs, tubers, corms etc. – usually beneath the soil surface, but sometimes in the litter layer (for instance fallen platyclades and fruit of *Opuntia:* Pérez-Bañón and Marcos-García 1998) and are partly phytophagous, partly saprophagous. A few have been the subject of investigation, because their larvae can be pests of horticulture, e.g. in onion or narcissus crops (see for instance, Creager and Spruijt 1935).

Malaise trapping of syrphids, carried out (January 2011 – December 2012) in the Jardin Mediterranéen, at Banyuls-sur-Mer (Pyrenées-Orientales), almost at sea-level on the Mediterranean coast of France, yielded eleven species of *Eumerus*, and *Platynochaetus setosus* (Fabricius, 1794), most of them in some numbers. This prompted the idea of searching for larvae of these species there, since the life histories of most of them were unknown. A preliminary search, carried out one afternoon in late September, resulted in discovery of large final instar larvae, apparently belonging to the genus *Eumerus*, in tubers of *Asphodelus ramosus*. Two other localities above Banyuls, in the vicinity of the Tour de Madeloc, were then searched the next day, attention being confined to plants of *A. ramosus*. At both localities more *Eumerus* larvae were found in the tubers of this plant. A second collection of larvae was made in January 2013, from tubers of *Asphodelus albus* collected at 1700m, from Angoustrine in the Pyrenees.

Here we provide the first information on the life histories of two of the three *Eumerus* species reared from these asphodel tubers and also seek to increase the reliability with which the adults of all three of them can be identified.

Methods

A) Collection of larvae

When in bloom, *Asphodelus ramosus* displays a metre-high spike of white flowers on a sturdy, rod-like stem, encircled by tough, grey-green, lanceolate leaves, similar to those of *Iris* plants. It is a strictly Mediterranean species, in the vicinity of Banyuls occurring only within 5km of the coast. It flowers in May, the plant thereafter progressively dying back, to present by the end of summer a dead and blackened flowering stem with the curled and withered remnants of its leaves around the base. Underground, it has by then formed a huge mass (up to the size of a football) of tubers on its roots, numbering anywhere from 20 to the best part of 100. Each tuber is more or less cylindrical, 8-10cm long and nearly 2cm in diameter, tapering to a point at both ends (Fig. 1). The root mass is at 15-20cm depth in the ground. In late summer / early autumn dead asphodel plants are extremely easy to locate and recognise from their general appearance, and the individual species can be identified from the size and character of the seed pods. A pick-axe or a mattock makes a suitable tool for excavating the root masses beneath the dead stems.

Fig. 1. Root mass of *Asphodelus ramosus* (late September).

With an asphodel root mass dug up and put on a white, plastic sheet it was possible to systematically check each tuber for presence of larvae. Uninvaded tubers are very solid and without holes in them. Invaded tubers can often be identified by the presence of a visible hole, 1-2mm diameter, into the interior of the tuber. But squeezing the tubers proved a more reliable guide, since entry holes were not necessarily evident. An invaded tuber was invariably soft, due to the cavity within. Only 1 or 2 tubers per root mass were found to contain larvae, but up to 7 larvae could be found together in an occupied tuber (Fig. 2). The larvae in a tuber were not necessarily of the same size, suggesting the possibility of multiple origins (and identities) of its occupants. Entirely empty tubers were also found within the root masses, with just the dry, papery skin of the tuber remaining. The flesh of healthy tubers of *Asphodelus ramosus* is a bright yellow-green, but the flesh of tubers containing larvae was in various stages of liquefaction, usually reduced to a black, viscous liquid, in which the larvae wallowed. The tubers from Angoustrine were found frozen when excavated from the ground in January, as were the larvae within them. Once thawed out, and provided with *A. albus* tubers, these larvae continued to feed and wallow in the decaying tuber contents, like the Banyuls larvae.

Fig. 2. Consumed asphodel tuber with larvae (arrows indicate larvae).

B) Rearing of larvae

Collected larvae were transferred, in the tubers they inhabited, to a transparent plastic container, approximately 15x10x10cm, with small holes drilled through its lid, to provide aeration. The bottom of the container was first lined with white paper kitchen towelling. The container was itself placed within a cardboard shoe box and the lid of the shoe box put back on, so that the larvae could be kept in the dark. The shoe box was then kept in a centrally-heated room. The room temperature in the immediate vicinity of the shoe box was checked by a thermometer kept on top of it, which demonstrated that temperature varied from 16-22°C. Periodically, a tuber of *A. ramosus* was added to those in the larval container, from a bundle of tubers kept in a plastic bag in a refrigerator. Every few days the contents of the larval container were searched through for puparia. Some of the larvae were definitely feeding, the added tubers being progressively hollowed out, their flesh after a few weeks reduced to the same thick black "syrup". Other larvae remained almost immobile in the liquefied tuber tissue, which was retained within the tuber by its tough, impermeable skin. This outer skin was untouched by the larvae, apart from the initial entry hole made through it. By February all larval feeding seemed to have ceased, but the larvae remained immersed in the liquefied tuber tissue (Fig. 3) until shortly before pupation. All larvae left the tubers prior to puparium formation.

Fig. 3. Larva of *Eumerus olivaceus or E. nudus* covered in decomposed asphodel tuber "syrup".

Once found, a puparium was removed and placed in a small plastic tub lined with a pad of kitchen towelling. A slip of paper carrying a unique number was also added to the tub, so that the progress of each puparium could be followed individually. The tub was itself then placed in another plastic container like the larval container (Fig. 4), again with small holes drilled in its lid, to provide aeration. The floor of the puparial container was lined with paper kitchen towelling and half a carrot (sliced lengthwise, so that it would lie flat and not roll around in the container) was then added to provide a low level of humidity. Finally, some dry, dead, branching stems of a small herbaceous plant (marjoram) were added to the puparial container, so that any hatching fly would have something to hang from, whilst its wings were expanding and drying. The puparial container was then placed alongside the larval container, in the same shoe box, so that it was in the dark and subject to the same temperature regime as the larvae.

C) Identification of adults

Reference collections (MNHN, Paris; NNMN, Leiden; IRSNB, Brussels), together with Stackelberg's (1961) key and named reference material received from other syrphidologists (C. Claussen, M.J. Ebejer, K. Kassebeer) were used in confirming the identity of the reared species. Features that may be used to recognise these species are presented in the Results section of this text. Intra-specific variability was adduced from the material available to us from the Malaise trapping in the Jardin Mediterranéen (*E. nudus*, n = 20; *E. pulchellus*, n = 350), the reared specimens listed here and supplementary material of *E. olivaceus* in the reference collections of MS (n = 35).

Fig. 4. Plastic container used for hatching *Eumerus* puparia (see text).

Figs 5-6. Puparia: 5, *Eumerus olivaceus*; 6, *Eumerus nudus*.

Results

A) Pupariation and eclosion

The first puparium was found on 25 December and hatched on 5 January, producing a fine male of *Eumerus olivaceus*. The fly was left in the puparial container for 12 hours, to fully mature, and then removed, killed and identified. The same procedure was followed with the specimens that hatched subsequently. Altogether, three *Eumerus* species were reared from the asphodel tubers, *E. olivaceus, E. nudus* and *E. pulchellus*. The puparia of *E. olivaceus* and *E. nudus* (Figs 5 and 6) are 10-11.5mm long (including the posterior respiratory process) and 4.5-4.75mm wide, of the same shape and with no obvious, distinguishing features. Those of *E. pulchellus* are noticeably smaller (8mm long, including the posterior respiratory process; 3mm wide), with a longer posterior respiratory process and with a less rugose surface (Fig. 7). The puparia of *E. nudus* and *E. olivaceus* were formed either loose, hidden within the layers of paper tissue on the floor of the container, or strongly attached to that tissue, in concealed positions. Puparia of *E. pulchellus* were formed loose, anywhere on the container floor, within tissue or entirely exposed.

Fig. 7. Puparia of *Eumerus olivaceus* (left) and *E. pulchellus* (right).

Table 1 shows dates of pupariation and eclosion for each of the reared specimens. In total 25 adults were reared. One larva died and one of the adults was unable to expand its wings on emergence. All puparia formed hatched. There was no visible evidence of parasitism or fungal infections. The dates of hatching of the *E. nudus* and *E. pulchellus* puparia (Table 1) are within the known flight period of these species in the wild, in the Mediterranean zone of Europe (Speight 2012). The dates of emergence of the *E. olivaceus* puparia from larvae collected around Banyuls-sur-Mer are not within the known flight period of that species. By contrast, the dates of hatching of the puparia from Angoustrine, shown in Table 2, more or less are, though a little early.

Puparial formation	**Adult eclosion**	**Species**	**Sex**
16.iii.2013	27.iv.2013	n	m
16.iii.2013	25.iv.2013	n	f
30.iii.2013	28.iv.2013	n	m
15.iv.2013	23.v.2013	n	f
18.iv.2013	23.v.2013	n	f
18.iv.2013	24.v.2013	n	f
23.iv.2013	26.v.2013	n	m
23.iv.2013	30.v.2013	n	m
27.iv.2013	6.vi.2013	n	f
1.v.2013	7.vi.2013	n	f
2.v.2013	9.vi.2013	n	f
7.v.2013	11.vi.2013	n	f
26.v.2013	1.vii.2013	n	m
1.vi.2013	5.vii.2013	n	m
3.vi.2013	6.vii.2013	n	f
25.xii.2012	5.i.2013	o	m
10.i.2013	12.ii.2013	o	f
13.i.2013	16.ii.2013	o	f
16.ii.2013	22.iii.2013	o	f
13.iv.2013	25.iv.2013	p	f
20.iv.2013	8.v.2013	p	f
25.iv.2013	15 v.2013	p	m

Table 1. Dates of puparium formation and eclosion of adults, for the larvae of *Eumerus nudus* and *E. olivaceus* collected in the vicinity of Banyuls-sur-Mer. Abbreviations used: f = female; m = male; o = *Eumerus olivaceus*; n = *Eumerus nudus*; p = *Eumerus pulchellus*.

Puparial formation	**Adult eclosion**	**Species**	**Sex**
9.iv.2013	22.iv.2013	o	m
9.iv.2013	25.iv.2013	o	f
23.iv.2013	7.v.2013	o	f

Table 2. Dates of puparium formation and eclosion of adults, for the larvae of *Eumerus olivaceus* collected from Angoustrine. Abbreviations used are as in Table 1.

The Malaise trap data, available from the Jardin Mediterranéen at Banyuls, show that adults of *E. nudus* were on the wing there from 1 May to 30 September. Adults of *E. pulchellus* were present in the traps almost throughout the year. *Eumerus olivaceus* was not collected in the Jardin Mediterranéen.

B) Recognition of the reared species

The adults of the *Eumerus* species reared from the Banyuls asphodel tubers are not well served in existing identification literature: *E. nudus* and *E. olivaceus* are extremely similar to each other and cannot reliably be separated using Stackelberg's (1961) key. The third, *E. pulchellus*, is reasonably easy to recognise in the male, but the female is extremely difficult to identify. Vujić and Šimić (1999) provided figures of the male terminalia of *E. olivaceus* and *E. pulchellus,* as recognised here, but no other information on identification of the males of either species, and no information on identification of the females. In Stackelberg's (1961) key, the male of *E. pulchellus* is included, but the female is omitted, without explanation. To clarify the identity of the species reared, and hopefully to render them easier to recognise in future, a diagnosis of each is presented here, together with comments on their separation from other European species. Terminology used for morphological features follows Speight and Sarthou (2012). Reference specimens of *E. nudus* reared during this study, plus their puparia, have been deposited in the following collections: CIBIO, University of Alicante, Spain; Dept of Biology and Ecology, University of Novi Sad, Serbia; the National Museums of Scotland, Edinburgh, UK.

1. *Eumerus nudus* and *Eumerus olivaceus*

In Stackelberg's (1961) key the eyes of *E. nudus* are said to be bare, which they are not, and males of *E. nudus* and *E. olivaceus* are supposedly distinguished by a whitish band along the posterior margin of tergite 4, present in *E. nudus* but absent in *E. olivaceus*. However, this pale band can be just as well developed in males of *E. olivaceus* as it is in males of *E. nudus*. It may also be absent in males of *E. nudus*.

Both *E. nudus* and *E. olivaceus* are among the *Eumerus* species without any trace of orange or red on the antennae or abdomen, except for a dirty yellow mark or band at the posterior margin of the fourth tergite, often present in the males. Tergites 2-4 do, however, each have a pair of well-developed, transverse bars of silver-grey pruinosity. These two species are both also among the small number of European *Eumerus* species in which the anteroventral line of black spikes on the hind femur is carried on a low ridge (very shallow in females of *E. nudus*), as in *Merodon* species, rather than arising directly from the surface of the femur as in most *Eumerus* species. They are both large, with a body length of 11-12mm. Additional useful features are that the facial hair covering is silver-grey, the mesoscutal hairs are upstanding, rather than recumbent and the legs are unornamented apart from the anterior and posterior rows of spines beneath the hind femur. This latter characteristic is more helpful in identifying the males, since males of many *Eumerus* species have additional projections of one sort or another on the hind trochanter, hind femur or hind tibia. The hind femur is greatly thickened in both of these species – more so than in many other *Eumerus* species – being no more than 3x as long as deep in the males (closer to 4x as long as deep in females). In the males of both species, the eye suture is about as long as the median length of the frons and the surface of sternite 4 is not flat, but carries a pair of massive outgrowths. Put together, this combination of morphological attributes segregates *E. nudus* and *E. olivaceus* from other European *Eumerus* species and the greater difficulty lies in separating them from one another. Recognition of the males is easier than recognition of the females, because the massive protuberances on sternite 4 are of diagnostic shape. These protruberances are normally visible without any preparation of the specimen being necessary, in contrast to the male terminalia, which at least have to be pulled out before they can be seen – a procedure first requiring relaxation of the specimen, in dry, pinned material. Examination of sternite 4 is thus a more practical proposition than examination of the terminalia, and provides a similar degree of reliability to the resultant determination. *Eumerus nudus* and *E. olivaceus* may be separated as follows:

Eumerus nudus: eyes almost bare, the hairs sparse, difficult to see and less than half as long as a posterior ocellus; scutellar hairs extremely short, no longer than 0.1 the median length of the scutellum; male with sternite 4 longer than wide and a pair of uniquely-shaped projections and an antero-median brush (Fig. 8) of extremely, long, strong, bristles (which may be either black or white).

Eumerus olivaceus: eye hairs moderately dense, distinct and as long as a posterior ocellus; scutellar hairs longer, one sixth to one quarter as long as the median length of the scutellum; male with sternite 4 wider than long and a pair of uniquely-shaped projections but without an anteromedian brush of bristles, as shown in Fig. 8.

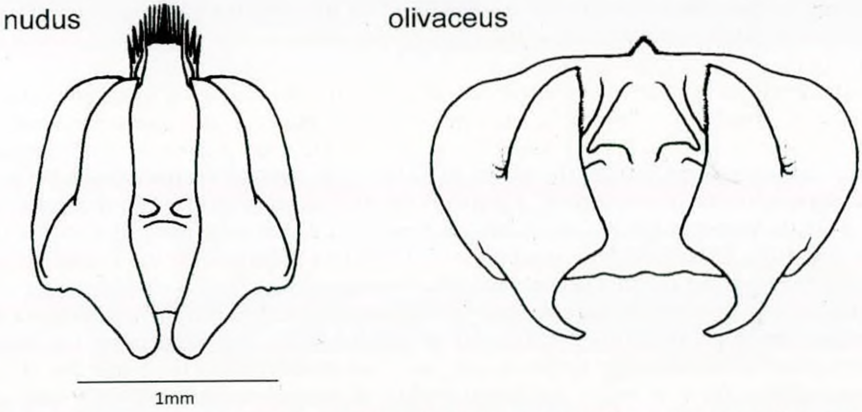

Fig. 8. *Eumerus* species, male sternite 4 of *E. nudus* and *E. olivaceus,* diagrammatic, with general hair covering omitted. Both figures show the anterior margin of the sternite at the top.

2. *Eumerus pulchellus*

Eumerus pulchellus is one of the large group of rather small European *Eumerus* species without any red or orange markings on the abdomen and with a pair of oblique, silver-grey dust bars on each of the tergites 2–4. In terms of some of the features much used by Stackelberg (1961), *E. pulchellus* is an inconvenient insect, since (in both male and female) its third antennal segment varies in colour from a monochrome dark brown to largely orange, the longitudinal dust stripes on the mesoscutum can be well developed or rudimentary and its legs vary from all-black to extensively yellow. The male, luckily, has other features which, taken together, make it readily identifiable: the hind leg lacks protuberances, projections or excavations on any of its segments; on the lateral margins of both tergite 3 and tergite 4 there is a fringe of extremely long, whitish hairs – longer than the depth of the third antennal segment – that curve beneath the abdomen; although there is some variation in its overall proportions, sternite 4 (often largely obscured by the long, marginal hairs of adjacent tergites) is also characteristic, being flat, with a convex basal margin, a deeply concave, but otherwise simple, apical margin and a surface entirely unornamented by protuberances or hair patches, as shown in Fig. 9.

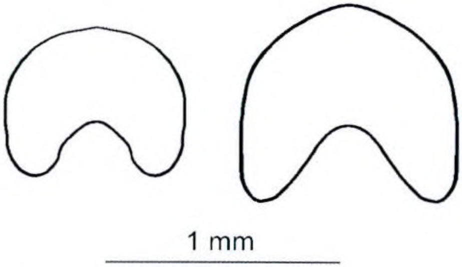

Fig. 9. Sternite 4 of *Eumerus pulchellus* male, diagrammatic, from two different specimens, to show the intra-specific variability of its proportions. Anterior margin of the sternite shown towards the top of the page.

The female is markedly more difficult to identify. Speight *et al.* (2013) provided a key, in which the female of *E. pulchellus* is separated from most of the commoner western European *Eumerus* species, but that key does not include the widespread southern European species *E. amoenus* Loew, 1848. The female of *E. pulchellus* may be distinguished from that of *E. amoenus* by the presence in *E. pulchellus* of obvious hairs on the lateral margin of tergite 3, in the posterior third of its length. In females of *E. amoenus* the lateral margin of tergite 3 is bare. The following combination of features distinguishes the female of *E. pulchellus* from females of other known European *Eumerus* species:

Face thinly pale grey dusted; frons, at level of anterior ocellus, half the width of an eye at the same level; ocellar triangle equilateral or slightly wider than long; upper eye hairs distinctly longer than a posterior ocellus; second antennal segment distinctly shorter than third antennal segment; humeral callus and lateral margin of the mesoscutum undusted, shining; mesoscutum with two, longitudinal stripes of pale grey dusting, these stripes varying from distinct to hardly visible; hairs on scutellar disc no longer than one quarter the median length of the scutellum; costal vein of wing brown for most of its length (may be yellowish at base); hind femur, in dorsal view, >4x as long as its maximum width; ventral surface of the hind femur without a bulge, basally; apical part of ventral surface of hind femur with a posterolateral row of 12–16 stout black spines; white hairs on the posterolateral margin of the ventral surface of the hind femur, including some as long as one third of the maximum depth of the femur; hind tibia without a transverse cleft on the ventral surface; basal third of the length of the posterolateral margin of the ventral surface of the hind tibia with a sharp ridge carrying very short, black, procumbent spinules; second tarsomere of hind tarsus almost 2x as long as wide; tergites entirely without red, orange or yellowish markings; tergite 5 without a longitudinal ridge, enclosing a shallow depression, close to its lateral margins; tergites without any translucent pale markings; tergites 2–4 each with a pair of transverse, silver-grey dust bars; hairs on tergite 5 white; body length 7-8mm.

Discussion

The *Eumerus* larvae collected from tubers of *Asphodelus ramosus* in September 2012 were all subject to the same conditions subsequent to collection. If there was any form of competition between the larvae, within the asphodel tubers, this was not evident. When found in the wild multiple larvae were present in nearly every occupied tuber, and this multiple occupancy continued in captivity. Those that were successfully reared to eclosion demonstrated the presence of three species, *Eumerus nudus*, *E. olivaceus* and *E. pulchellus*, though the uniform appearance of the larvae gave no clue that there was more than one species present, prior to pupariation. At pupariation, it became clear that some larvae were maturing at a smaller size than others, and forming a puparium of different appearance (Fig. 7). On eclosion, these puparia proved to be of *E. pulchellus*. However, the puparia of *E. nudus* and *E. olivaceus* were indistinguishable from one another. Some were paler than others, the nearly black puparia being almost entirely covered in the liquefied tuber contents that adhered to their surface and then dried on (Fig. 6), but this variability was observed in puparia of both species. Puparia of both species could be clean or covered in the black tuber residuum. Neither anterior nor posterior respiratory processes of the puparia showed any obvious species-specific characteristics, including the posterior spiracular plate. Only when they hatched was it apparent that the larger puparia included both *E. nudus* and *E. olivaceus*. If the developmental stages of these two species are to be separated, it would seem that the differences between them will have to be sought in the number and arrangement of the numerous setae occurring over much of the body surface. Comparison between the sclerotised larval mouth-hooks of *E. nudus* and *E. olivaceus*, retained within the puparia, also failed to reveal any obvious difference between these two species. But more detailed examination, based on informed survey of a wider range of *Eumerus* puparia, would probably be required to detect subtle differences, should they exist.

The *Eumerus* species collected as larvae in September 2013, from *Asphodelus ramosus* tubers, showed different patterns of pupariation and emergence. *Eumerus pulchellus* and *E. nudus* remained as larvae throughout the winter months, to pupariate in April, resulting in eclosion at the beginning of what would be their normal flight period in the vicinity of Banyuls, to judge from Malaise trap data collected in 2011 and 2012. Whatever factors trigger pupariation and eclosion in those two species were not, it would seem, interfered with by the artificial conditions under which the larvae were kept in captivity. By contrast, among the September-collected larvae of *E. olivaceus*, pupariation commenced in December, and eclosion started in January, whereas under natural conditions the flight season for this species begins in May. So it has to be concluded that the captive rearing regime described here resulted in an artificially rapid maturation of the *E. olivaceus* larvae collected from the wild in the autumn. However, the *E. olivaceus* larvae collected in January produced adults at the beginning of the normal *E. olivaceus* flight period. Whether this indicates that conditions in which larvae were kept in the period September/December dictated the premature emergence of resultant adults, or this was precipitated by failure to subject the larvae to a period of cold, is unclear. Since the mature larvae seem easy to keep, the conditions that trigger pupariation could probably be established under laboratory conditions, by subjecting captive larvae to different temperature regimes during the winter months.

There was no noticeable increase in size of the larvae between collection and pupariation, even though they entered undamaged asphodel tubers when presented with them and then remained in those tubers until long after their content was entirely liquefied, moving on only when the liquid content had been consumed or drained away. From the fact that their puparial phase is evidently of short duration (6-7 weeks in *E. nudus*, 2-4 weeks in *E. olivaceus*, 2-3 weeks in *E. pulchellus*), and the other observations made of their development in the shoe box, one can deduce that, under normal circumstances, the larvae of all three of these *Eumerus* species pass the winter within asphodel tubers, moving from one tuber to another as their contents become exhausted, and pupariate in the surrounding soil, in April to early May. Alternatively, if they find themselves in a non-leaky tuber, whose contents have been well liquefied, they may well remain there, more of less comatose through the winter, "bathing" in the mucky brew they have generated. The conclusion that these species overwinter as larvae is supported by the collection of larvae of *E. olivaceus* in January, frozen within asphodel tubers, indicating also that, in this species at least, the larvae are physiologically capable of surviving winter conditions in the soil, since the larvae, once thawed out, subsequently pupariated and hatched into adults of normal appearance. More extensive investigation of the larvae in the wild, involving such activities as digging up asphodel root masses, at regular intervals through the winter and early spring, to determine whether the larvae remain there till spring, would be helpful, to confirm more details of the life history of these insects.

Finding the larvae of *Eumerus nudus* and *E. olivaceus* came about as a result of Malaise trapping, demonstrating the presence of 11 identifiable *Eumerus* species, plus *Platynochaetus setosus*, in the Jardin Méditerranéen, at Banyuls-sur-Mer (Pyrenées-Orientales, France). No prior study of *Eumerus nudus* or *E. olivaceus* led to discovery of their larvae. The local asphodel was investigated simply because it was known to have tubers, is frequent in the Jardin, is easily recognised in the autumn (when the search for larvae was carried out) and is closely related to *Asphodelus aestivus*, already known (Ricarte *et al.* 2008) to host the larvae of *Eumerus pulchellus*. Its tubers were easily dug up and damaged tubers could be distinguished from healthy ones in the field. They were found to contain larvae of three *Eumerus* species. But rhizomes of an *Orobanche* and the rhizomes/tubers of a *Smyrnium* species examined during the same search yielded no larvae and as yet there is no indication of what the larval host plants of the three remaining *Eumerus* species found at the Jardin Méditerranéen with unknown larvae (*Eumerus argyropus* Loew, *E. elaverensis* Séguy, *E. subornatus* Claussen) or *Platynochaetus*, might be. Other possible plant hosts were not examined, due to time constraints, and further larval searches embracing a wider range of plants, particularly at other times of the year, might be expected to yield further *Eumerus* larvae. But is it possible to carry out more targeted searching, using clues provided by the adult flies as to what their larval host plants might be?

There is a tendency for the adults of syrphid species with phytophagous larvae to visit (but by no means exclusively) the flowers of the plant species acting as their larval hosts. They also tend to fly in the immediate vicinity of their larval host plant. These tendencies are well developed among *Cheilosia* species and in *Portevinia maculata* (Fallén) (see Speight 2012). The larval host plants of few *Merodon* species are yet known, but the same tendencies seem to be manifested in species of this genus, also (see, for instance, Ricarte *et al.* 2008). *Opuntia*-associated *Eumerus* species can be found in the immediate vicinity of their host plant, to judge from observations on *E. obliquus* (Fabricius) adults in the Jardin Méditerranéen, but adults of other *Eumerus* species do not seem so closely associated. In particular, they seem to show no preference for the flowers of their larval host plants, when flower-visiting. Indeed, they seem to ignore entirely the flowers of their larval host plants. Observations by one of us (MS), of a large population of *Eumerus olivaceus* where

Asphodelus albus was in flower, in large, dense stands, showed no use of the *A. albus* flowers by *E. olivaceus* and no use of the plant's foliage as a resting site, though the flies settled on the foliage of other plants in the vicinity. Similarly, observation (again by MS) of a *Eumerus ruficornis* Meigen population, showed neither use of the flowers of *Scorzonera humilis*, its presumed larval host (Johansson 2011), nor use of that plant's foliage for resting purposes. At present, then, one can conclude that adult *Eumerus* cannot be relied upon to provide many clues, from their behaviour or flower-visiting activities, to their larval host plants. Further, what is known already of the host plants of European *Eumerus* larvae (Speight 2012) indicates that a wide range of plant families are involved, so that it cannot be assumed that unknown plant hosts should be searched for only among the members of genera or families already known to support one or more *Eumerus* species. But there are two additional elements that can be brought into play, when considering how to find *Eumerus* larvae. Firstly, the time of year the adults are in flight can be expected to indicate when the larval host plant is accessible for oviposition purposes and thus, hopefully, also to human observation. Since most potential host plants are present only as sub-surface storage organs for much of the year, among those that are visible at some locality, when adults of a *Eumerus* species are on the wing, should logically be the plant providing for its larvae. Secondly, the flight season of a species can indicate when larvae might most successfully be searched for in the bulb, tap root or tuber of their host plant, namely a few weeks after the flight season commences. This ploy could not be expected to help in all cases – *vide* the two *Eumerus* species whose rearing is described in the present text. But many of the known syrphid larvae that feed in plant tissues feed up rapidly once they hatch from the egg, and then vacate the host plant, to either diapause in the soil or enter a prolonged puparial phase, so that reliance on being able to find the larvae in their host plant at almost any time of the year is not realistic. That approach would seem more likely to result in digging up entirely the correct host plant but finding absolutely nothing, because six months out of seven the larvae aren't there!

Is it coincidental that *Eumerus* larvae have repeatedly been found, and not singly, together with larvae of other syrphids, or of other *Eumerus* species, within bulbs etc. (Brunel and Cadou 1994; Ricarte *et al.* 2008; the present study)? The only thorough study (Creager and Spruijt 1935) of the food requirements of *Eumerus* larvae, carried out on larvae of *Eumerus funeralis* Meigen (as *E. tuberculatus* Rondani), demonstrated clearly that the larvae could not complete their development on the tissues of the plant, but to do so required the accompanying decay organisms, essentially yeasts. It is an intriguing notion that the cohabitation of the larvae of *Eumerus* species with the larvae of other syrphid genera, and with one another, may be less coincidental than characteristic, if *Eumerus* larvae make use of decay facilitated by strictly phytophagous syrphid larvae, or by each other. Experiences with rearing *E. nudus* and *E. olivaceus* indicate that last instar larvae of these species can carry with them the decay organisms they require, when moving from an exhausted asphodel tuber to an undamaged one. But what happens when an egg of *E. nudus* hatches? Does the newly-hatched larva carry with it the micro-organisms needed to decay asphodel tubers in such a way as to produce the decomposition products it requires? Or does it start its development as strictly phytophagous? Then again, perhaps it requires the actions of some other organism to gain access to the tissues of an asphodel tuber and or to initiate appropriate decay processes. The intricacies of the life histories of these small insects clearly require more investigation. As of now, the concept of communities (rather than assemblages) of *Eumerus* and other plant-feeding syrphids, with larvae living in the same bulbs/tubers, cannot be ruled out, with one or more of the *Eumerus* species largely dependent for their survival on the activities of the larvae of other members of the community. Such interdependence might more easily explain the rarity of some *Eumerus* species, than would simple dependence on a rare plant host.

Acknowledgements

We are grateful to Benjamin Falgas (Biodiversarium, Banyuls-sur-Mer) for sharing with us his extensive knowledge of the indigenous plant species present in the Jardin Mediterranéen, which was of considerable help in deciding which plants to dig up, and where, in our hunt for *Eumerus* larvae.

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Vujić, A. and Šimić, S. 1999. Genus *Eumerus* Meigen 1822 (Diptera: Syrphidae) in area of former Jugoslavia. *Glasnik Prirodnjačkog Muzeja u Beogradu*, B **49-50** (1995-1998), 173-190.

Corrections and changes to the Diptera Checklist (31) – Editor

It is intended to publish here any corrections to the text of the latest Diptera checklist (publication date was 13 November 1998; the final 'cut-off' date for included information was 17 June 1998) and to draw attention to any subsequent changes. All readers are asked to inform me of errors or changes and I thank all those who have already brought these to my attention.

Changes are listed under families; names new to the British Isles list are in bold type. The notes below refer to addition of 7 species, deletion of 1 species and loss of 1 name due to synonymy, resulting in a new total of **7088** species (of which 38 are recorded only from Ireland). As in the 1998 checklist, + indicates occurrence in Ireland (as well as Britain) and ++ in Ireland but unrecorded from Britain.

An updated version of the checklist, incorporating all corrections and changes that have been reported in *Dipterists Digest*, is now available for download from the Dipterists Forum website. It is intended to update this regularly.

Mycetophilidae. The following species were added by P.J. CHANDLER (2014. Fungus Gnats Recording Scheme Newsletter **7**, 6 pp. **In** *Bulletin of the Dipterists Forum* No. 77, Spring 2014):
Epicypta ***fumigata*** (Dziedzicki, 1923 – *Allophallus*)
Exechiopsis (S. *Exechiopsis*) ***forcipata*** (Lackschewitz, 1937 – *Exechia*)
Mycomya (S. *Mycomya*) ***danielae*** Matile, 1972

Sciaridae. Frank Menzel advised on the following nomenclatural changes:
1. The following synonymy was proposed by K. HELLER and D. WEBER (2013. Trauermücken (Diptera: Sciaridae) aus Höhlen des Großherzogtums Luxemburg. pp 320-336. **In** Weber, D. (Ed.) Die Höhlenfauna Luxemburgs. *Ferrantia* **69**, 408 pp. Luxembourg: Musée national d'histoire naturelle du Luxembourg [+ CD-Rom]:
Bradysia ***forficulata*** (Bezzi, 1914 – *Neosciara*) = *B. nocturna* Tuomikoski, 1960

2. The following changes result from W. MOHRIG, K. HELLER, H. HIPPA, P. VILKAMAA and F. MENZEL (2013. Revision of the Black Fungus Gnats (Diptera: Sciaridae) of North America. *Studia dipterologica* **19**(2012), 141-286):
Bradysia ***bellingeri*** Shaw, 1953 = *B. trispinifera* Mohrig & Krivosheina, 1979
Bradysia ***impatiens*** (Johannsen, 1912 – *Sciara*) = *B. difformis* Frey, 1948
Corynoptera ***fatigans*** (Johannsen, 1912 – *Sciara*) = *Corynoptera perpusilla* Winnertz, 1867 [preocc., not *C. perpusilla* (Walker, 1848)]
Cratyna ***longispina*** (Pettey, 1918 – *Neosciara*) = *Cr. tuberculata* (Tuomikoski, 1960)
Lycoriella ***agraria*** (Felt, 1898 – *Sciara*) = *L. cellaris* (Lengersdorf, 1934)
Lycoriella ***sativae*** (Johannsen, 1912 – *Sciara*) = *L. castanescens* (Lengersdorf, 1940)
Scatopsciara ***brevicornis*** (Zetterstedt, 1851 – *Sciara*) = *S. nacta* Johannsen sensu Menzel & Mohrig, 2000, misident. [*S. nacta* (Johannsen, 1912) was found to be a synonym of *S. atomaria* (Zetterstedt, 1851)]
Sciara ***hebes*** (Loew, 1869 – *Trichosia*) = *S. mendax* Tuomikoski, 1960
Trichosia ***habilis*** (Johannsen, 1912 – *Sciara*) = *T. edwardsi* (Lengersdorf, 1930)
Xylosciara ***spinata*** (Pettey, 1918 – *Neosciara*) = *X. betulae* Tuomikoski, 1960

Phoridae. The following species is added in the present issue:
Phalacrotophora ***delageae*** Disney, 1979

Anthomyzidae. The following new genus and species was added by J. ROHÁČEK (2013. *Reliquantha variipes* gen. & sp. nov., a peculiar new taxon of Anthomyzidae (Diptera) from Great Britain with uncertain relationships. *Acta entomologica Musei Nationalis Pragae* **53,** 793-814) (also see Chandler, P. 2014. *Reliquantha variipes* – a new genus and species of fungus-associated anthomyzid from Britain. *Bulletin of the Dipterists Forum* No. 77, Spring 2014, pp. 14-15):
RELIQUANTHA Roháček, 2013
Reliquantha ***variipes*** Roháček, 2013

Chloropidae. John and Barbara Ismay advised on the following corrections and additions:
1. The following changes result from E.P. NARTSHUK and H. ANDERSSON (2013. The frit flies (Chloropidae, Diptera) of Fennoscandia and Denmark. *Fauna entomologica scandinavica* **43**, 1-282):
Aphanotrigonum ***brachypterum*** (Zetterstedt, 1848 – *Oscinis*) [species status, formerly a variety of *nigripes* (Zetterstedt, 1848)]
Aphanotrigonum ***cinctellum*** (Zetterstedt, 1848 – *Oscinis*) = *fasciella* (Zetterstedt, 1855), new synonym
COLLINIELLA Nartshuk & Andersson, 2013 [ex *Aphanotrigonum*]
Colliniella meijerei (Duda, 1932 – *Conioscinella*).
DIPLOTOXOIDES Andersson, 1977 [ex *Diplotoxa*]
Diplotoxoides dalmatinus (Strobl, 1900 – *Diplotoxa*).
Incertella nigrifrons (Duda, 1933 – *Conioscinella*) (transferred from *Conioscinella*)

2. The following synonymies, followed by Nartshuk and Andersson (2013), are due to E.P NARTSHUK and H. ANDERSSON (2002. New synonyms and overlooked species – group names in Palaearctic Chloropidae (Diptera, Cyclorrhapha). *Zoosystematica Rossica* **11**(2), 187–191):
Chlorops rufinus (Zetterstedt, 1848) = *citrinellus* (Zetterstedt, 1848) = *bipunctus* (Duda, 1933) = *fennicus* (Duda, 1933)
Pseudopachychaeta ***oscinina*** (Fallen, 1823 – *Phytomyza*) = *heleocharis* (Nartshuk, 1964)

3. Delete *Chlorops novakii* Strobl, 1902 (a misidentification of *Chlorops pumilionis* (Bjerkander, 1778) by J.W. Ismay).

4. The following genus and species, not yet formally added, was reported from Thurrock (leg. C.W. Plant) by P.R. HARVEY (2007. The AGM Address. Brownfield invertebrates in Essex - nationally important and under threat. *Essex Naturalist* (*New Series*) **24,** 8-14):
HOMALURA Meigen 1826 (subfamily Chloropinae)
Homalura ***tarsata*** Meigen 1826

Larvae of *Psychoda* species (Diptera, Psychodidae) feeding on slug eggs

– In the autumn of 2007 I found a number of slugs in my kitchen waste composting bins which I had not seen before. I collected some of these slugs, which were kindly identified as *Lehmannia valentiana* (Ferussac) by Adrian Norris. This slug is an introduced species found in glasshouses and more recently in open habitats (Kerney, M. 1999. *Atlas of the Land and Freshwater Molluscs of Britain and Ireland*. Harley Books, Colchester). I cultured the slugs in plant propagating boxes. The boxes were kept in an unheated garage along with other propagating boxes, each containing a different species of slug. The slugs were all fed on a diet of carrot, potato, turnip and oat flakes.

On 17 February 2008, 25 freshly laid eggs were removed from the *L. valentiana* culture and placed in one mass onto moist filter paper in a single petri dish. The frosts of late February 2008 killed all of the slugs that I had been culturing in the propagating boxes. The 25 *L. valentiana* eggs appeared to be frost damaged. I kept the eggs and on warmer days during the spring of 2008, I placed the petri dish containing the frost damaged *L. valentiana* eggs inside one of the kitchen waste composting bins. I displaced the lid on the petri dish slightly before replacing the lid on the composting bin.

On 11 May 2008, I noticed that fly larvae were active in the slug egg mass. The slug eggs themselves were still quite solid and were not liquefied to any noticeable degree. The petri dish containing the slug eggs was then transferred back to the garage. On 19 May, I found a pupa on top of one of the slug eggs and found two more pupae underneath the slug egg mass. These were removed and placed into separate petri dishes. The first adult fly emerged on 20 May 2008. The flies were identified as psychodids and were preserved in alcohol for later identification to species. Some of the flies were later kindly identified by Peter Chandler as two males and a female of *Psychoda surcoufi* (Tonnoir) and one female of *Psychoda albipennis* (Zetterstedt). These flies are thought to be generalist scavengers. *Psychoda surcoufi* has been reared from cow dung collected in the field and on dung, decaying leaves, decaying hay and *Phormidium* in the laboratory. *Psychoda albipennis* has been found developing in horse dung, cow dung, rotting carrots, rotting cabbages and decaying grass cuttings (Satchell, G.H. 1947. The larvae of the British species of *Psychoda* (Diptera: Psychodidae). *Parasitology* **38**, 51-69; Satchell, G.H. 1947. The ecology of the British species of *Psychoda* (Diptera: Psychodidae). *Annals of Applied Biology* **34**, 611-621.

Psychodids are abundant in my kitchen waste composting bins every year; presumably the larvae feed on the decaying vegetation. I assumed that the psychodid larvae reared from the frost damaged slug eggs had attacked the eggs as the slug embryo had been killed and the egg had decayed to some extent. I therefore set up an experiment to see if the larvae attacked freshly damaged slug eggs.

On 31 May 2008, I collected slug eggs from a culture of *Deroceras reticulatum* (Muller). This slug is a pest of agricultural crops and is also common in gardens. The slug eggs were placed in batches of five onto moist filter paper in the centre of each petri dish. Twenty-four petri dishes were set up altogether. In twelve of the petri dishes, a single slug egg in each petri dish was damaged by puncturing it with a metal probe. Twelve petri dishes, each with five undamaged slug eggs, were set up as controls. The 24 petri dishes were placed randomly onto two trays next to the kitchen waste composting bins. The lids were slightly displaced from the petri dishes and two large black crates placed over the two trays. The crates were raised slightly to allow access to invertebrates. The eggs were exposed for three days over the course of a week during the time when moth flies were active around the bins.

Dead psychodid flies were found in the petri dishes containing the damaged slug eggs and also in the control petri dishes. A dead psychodid fly was found with its ovipositor embedded in one of the damaged slug eggs. After the last exposure, the petri dish lids were replaced and the petri dishes placed in a shed. On 12 June, a single psychodid larva was active in the slug egg mass in which the dead psychodid fly had been found with its ovipositor embedded in a damaged slug egg. Two psychodid larvae were active in the same petri dish on the slug egg mass on 29 June; however, none of these larvae developed into pupae or flies. Some of the slug eggs deliberately damaged in this experiment subsequently hatched, indicating that the damage had not killed the slug embryo. It is possible that the failure of the psychodid larvae to develop in this experiment was because the embryo in the damaged slug egg was still alive, or the damaged slug egg was still fresh and needed to go through a period of decay before it was suitable food for the larvae to complete their development.

My thanks to Peter Chandler for kindly identifying the two psychodid species and to Adrian Norris for kindly identifying the slug *L. valentiana* – **KEVIN AYRE**, 22 Langholm Road, East Boldon NE36 0ED

Ctenophora ornata Meigen (Diptera, Tipulidae) at Jealott's Hill, Berkshire – On the night of 11 July 2013 a male of the cranefly *Ctenophora ornata* Meigen was captured by a Rothamsted light trap (site No. 662) located on agricultural field borders at Jealott's Hill, Berkshire. This species was given Red Data Book 1 status (Falk, S. 1991. A review of the scarce and threatened flies of Great Britain (part 1). *Research & survey in nature conservation* **No. 39**, pp 1-194, JNCC, Peterborough), so its presence on this site is worthy of note.

This cranefly is associated with rot holes in large trees growing in woodland and wood pasture, and beech (*Fagus sylvatica*) is frequently mentioned in association with it. Larvae have been found feeding in wet rotten wood mould with the texture of porridge.

The main centres of population for *C. ornata* in Britain are the New Forest and Windsor Forest and Great Park. In 2013 a number of records of this species, centred on the latter area (Kramer, J. 2013. News of *Ctenophora ornata*. *Cranefly News* **26,** 2. **In** *Bulletin of the Dipterists Forum* No 76), with an outlying record from Ruislip. Middlesex, suggested that a significant local dispersal had occurred. Recent records from Sherwood Forest, Nottinghamshire, were also reported.

Jealott's Hill is an outlier of Windsor Great Park and has many relict species, such as the heart moth *Dicycla oo* (Linnaeus) and the festoon *Apoda limacodes* Hufnägel (Lepidoptera), from when it was an integral part of the Park. The specimen concerned was shown at the annual exhibition of the British Entomological & Natural History Society, Kempton Park, on 16 November 2013 and is now in their Diptera collection at Dinton Pastures near Reading – **IAN SIMS,** 2 The Delph, Lower Earley, Reading, Berks RG6 3AN

A second Scottish record for _Brachypalpus laphriformis_ (Fallén) (Diptera, Syrphidae) – A single male *Brachypalpus laphriformis* (Fallén) was observed sunning on an oak stump along an avenue of veteran oaks (NM7172) leading from Kinlochmoidart House westwards along the base of the wooded south-facing hillside at the east end of Loch Moidart SSSI, 1.vii.2013. The specimen permitted close observation before flying off. This hoverfly was first noted in Scotland in 2010, from Perthshire (Wilkinson, G. 2010. *Dipterists Digest* (*Second Series*) **17,** 165-167). The SSSI is partly designated for its extensive coastal oak woodland and is noted for its interesting saproxylic beetle fauna. Veteran oaks are concentrated at the eastern, inland end – veteran is a term describing a tree with habitat features such as wounds or decay (*Ancient Tree Guide no.4: What are ancient, veteran and other trees of special interest.* Woodland Trust). The record arose during the course of Site Condition Monitoring commissioned by Scottish Natural Heritage – **KEITH N.A. ALEXANDER**, 59 Sweetbrier Lane, Heavitree, Exeter EX1 3AQ

Dipterists Digest 2014 **21**, 77-80

Phalacrotophora delageae Disney (Diptera, Phoridae) new to Britain

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Summary

Phalacrotophora delageae Disney, 1979 is recorded from Britain for the first time, together with notes on the swarming behaviour of females.

Introduction

After leading an insect course for the Epping Forest Field Studies Centre on 29 June 2013, MCH spent some time recording insects at Rushey Plain, just north of the Centre (within unit 110 of the Epping Forest SSSI, at grid reference TQ413983, vice-county South Essex). An unfamiliar female fly was taken, by sweeping around the trunk of an ancient beech *Fagus sylvatica*. It was clearly in family Phoridae and matching in appearance the distinctive genus *Phalacrotophora* (Fig. 1), and in the key by Disney and Beuk (1997) it ran to *Phalacrotophora delageae* Disney. Females of *Phalacrotophora delageae* can be differentiated from similar species in the genus by the presence of long hairs on abdominal segment 8, which does not bear any hooked structure (Fig. 2), and the unswollen, yellow hind metatarsus (Fig. 3); males can only be distinguished from *P. berolinensis* with great difficulty.

Fig. 1. ***Phalacrotophora delageae*** **from Epping Forest, 2013.**

Fig. 2. ***Phalacrotophora delageae*** **ovipositor from left.**

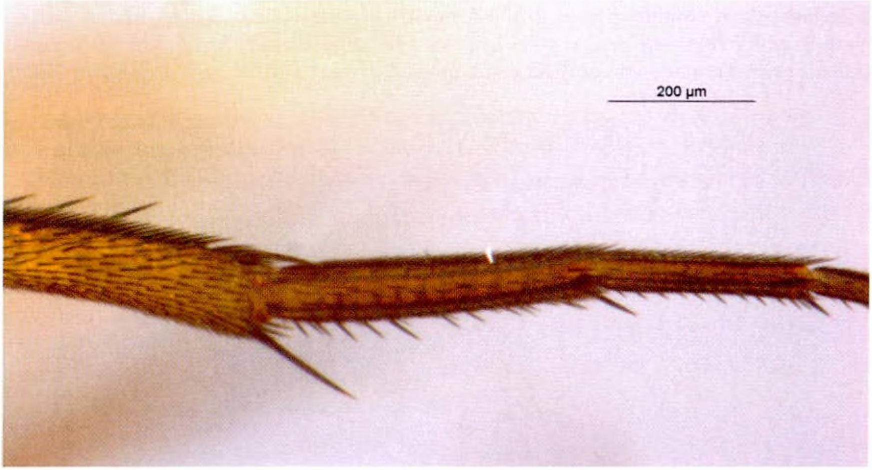

Fig. 3. ***Phalacrotophora delageae*** **anterior view of left hind metatarsus.**

Figs 1-3 © Martin Harvey and Hope Department of Entomology, Oxford University Museum of Natural History.

Previous records of this species are from France, The Netherlands, Czech Republic, and Hungary (http://www.faunaeur.org), Slovakia (http://www.discoverlife.org), Germany (Triltsch 1999) and Poland (Durska *et al.* 2003), but the species has not been recorded from Britain before.

MCH sent the Epping Forest specimen to Henry Disney, who confirmed the identification, and has retained the specimen for the world collection of Phoridae held at the

Cambridge University Museum of Zoology; Henry was aware that AGI had previously found this species in Britain, but had not formally published it. AGI's record was from near Norwich (TG193070, vice-county East Norfolk), in June and July 2006, when individuals were seen swarming about the bases of sycamore *Acer pseudoplatanus* and ash *Fraxinus excelsior* trees in mixed woodland.

Behavioural notes

This swarm consisted of 20–30 females flying between 0.2 and 1 metre above the ground, and within 0.2 metres of the trunk. When undisturbed, up to ten females would settle on the tree trunk, in a head-down posture, each one staying like this for up to a minute before settling elsewhere or joining the swarm again. In the head-down posture, the flies extend the abdomen and point it towards the tree, exposing a membranous patch at the base of the fifth tergite.

Fig. 4. Display posture of a *Phalacrotophora delageae* female, Norwich, 2006.

The unchitinised part of the tergite appears to glow brightly. It contrasts with the black tergites 2 to 4 in front and the orange of the remainder of the fifth segment. However, examination of live specimens in the dark, and under an ultra-violet lamp, produced no evidence of luminescence or fluorescence.

While sitting in the head-down pose, the females vibrate their wings, presumably creating a distinctive sound. Visually this appears to be exactly the same as the wing-waving of *Drosophila* species when 'singing'. After a while, the females stop their display and sit on projections on the tree trunk where they interact in a casual way. Then they join the swarm again before landing in the display posture for another session.

No males were seen at the swarming sites, and no concentrations of coccinellid larvae or pupae were apparent close by. So the purpose of these female *Phalacrotophora* swarms is a bit of a mystery, but it seems likely that the visually striking display posture, combined with the 'song' and possibly pheromones, must be to attract a mate. Photographs showing behaviour of the females in this swarm can be seen on the Diptera.info website at http://www.diptera.info/articles.php?article_id=9.

A further remarkable photo at http://davesgarden.com/guides/bf/showimage/14194/ illustrates that eversible organs of female *Phalacrotophora* are involved in mating.

Larvae of the genus *Phalacrotophora* are parasitoids of ladybird pupae. In other parts of the world *Phalacrotophora delageae* has been reared from the pupae of various ladybird species, including the 7-spot *Coccinella septempunctata* (Linnaeus), 2-spot *Adalia bipunctata* (Linnaeus) and 10-spot *Adalia decempunctata* (Linnaeus).

Acknowledgements

MCH thanks Henry Disney for confirming the identity of the Epping Forest specimen and putting the authors in touch, and James E. Hogan, Hope Department of Entomology, Oxford University Museum of Natural History, for assistance with photo-stack imaging of the Epping Forest specimen.

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Dipterists Digest 2014 **21,** 81-82

Dipterists Day Exhibits 2013
– compiled by Editor from exhibitors' notes

Details are given here only of exhibits that did not also appear at the 2013 Exhibition of the British Entomological and Natural History Society.

BLOXHAM, M.G. – A study of craneflies in a dingle woodland, Sot's Hole Local Nature Reserve in Sandwell Valley (SP011923), designed to promote invertebrate conservation. The theme of the display was a project designed to convey to Sandwell Valley site managers and also the local community (in the shape of a 'Friends of Sot's Hole' group) that there was more to their reserve than the habitual list of familiar and highly visible organisms such as oak trees and foxes. Heavily wooded and lying in the deep gulley of a well-known fault line, the site has been quite highly praised by a majority of visitors. Unfortunately, recent trends have been towards increasingly dubious incursions into the woodlands for amenity purposes, and it was difficult to find ways of channelling this so that general biodiversity was safeguarded.

To place some emphasis on the importance of invertebrates a series of events was planned. A water biologist was brought in so that methodology used in sampling invertebrates could be seen. Three invertebrate survey days ('Life in the Undergrowth') enabled the public to enjoy the spectacle of sweep nets being used. *Tipula maxima* Poda, *Tipula vittata* Meigen and *Tipula fulvipennis* De Geer (Tipulidae), and *Pedicia rivosa* (Linnaeus) (Pediciidae), were captured and duly impressed visitors. A walk was organised to see important ecological features along the stream.

The characteristics of the stream were discussed, beginning with the concept of low flow pollution, when contamination by drainage of uncertain origin from surrounding housing estates, hospitals and a school was a factor for extended periods – the water biologist had noted the poverty of the fauna at the lowest levels of the bed. Photographs were displayed of several other aspects of the stream, including marginal uncontaminated seepages. These hosted a distinctive assemblage of craneflies, including *Dicranomyia lucida* (de Meijere) (Limoniidae) – an indicator of good quality dingle woodland. The display showed how the watercourse situation with regard to invertebrate development was ultimately mitigated by several local factors connected with its general environment, structure and flow characteristics during the year. The white-footed ghost *Dolichopeza albipes* Ström (Tipulidae) and plenty of other insects can still be found along its course.

Site managers and the 'Friends' group could see that the situation was ideal for many different insects that would meet the dietary requirements of many bird species recorded on site. It was felt that the project had made some impact with the public and managers, with some particularly inaccessible spots in the woods possibly being designated as Primary Biodiversity Areas where disturbance is minimised. If this does come to pass, the craneflies may become unexpected champions of local wildlife conservation!

A list was displayed of 58 cranefly species that had been recorded in Sot's Hole during the history of recording there.

A subsidiary display included a short account of the Birmingham and Black Country cranefly fauna, with a small set of representative species from different habitats on display. Information on craneflies in this district is provided by S.J. Falk and S. Lane (1999. *A Survey* *of the Insects of Sutton Park, Birmingham*. 92 pp. National Lowland Heathland Programme. Published by the Staffordshire & West Midlands Heathland Partnership).

The following species were exhibited. **Tipulidae:** *Dictenidia bimaculata* (Linnaeus) and *Tanyptera atrata* (Linnaeus) (specimens to represent these species recorded at old timber in Sutton Park circa 1904), *Dolichopeza albipes* Sot's Hole); *Tipula truncorum* Meigen (damp soil in light woodlands – Sandwell Valley). **Cylindrotomidae:** *Cylindrotoma distinctissima* (Meigen) (larvae on herbage – Park Hall Farm near Fort Dunlop); *Triogma trisulcata* (Schummel) and *Phalacrocera replicata* (Linnaeus) (boggy pools and marshy areas with mosses – Sutton Park and Walsall area). **Pediciidae:** *Dicranota bimaculata* (Schummel) (semi-aquatic larvae in stream beds and margins in Sot's Hole and Sutton Park). **Limoniidae:** *Atypophthalmus inustus* (Meigen) (larvae in wet woodland fungi – Sot's Hole); *Dicranomyia lucida* (larvae in rich mud seepages – Sot's Hole); *Metalimnobia bifasciata* (Schrank) and *M. quadrinotata* (Meigen) (larvae in fungi in open woodland –Sutton Park and Sandwell Valley).

PERRY, I. – A selection of uncommon Diptera found during 2013.

Scatopsidae: *Aspistes berolinensis* Meigen, Norfolk, Lynford Water (TL826948), 18.vi, swept from sparsely vegetated, sandy margin of gravel pit; *Holoplagia transversalis* (Loew), Suffolk, Dunwich Heath (TM477675), 1.vii, found in association with the ant *Lasius fuliginosus* (Latreille).

Rhagionidae: *Chrysopilus erythrophthalmus* Loew, Perthshire, River Garry, Linn of Tummel (NN911606), 15.vii.

Stratiomyidae: *Odontomyia ornata* (Meigen), Surrey, Wisley Common (TQ070588), 1.vi, a bizarre record of a species largely confined to coastal grazing levels.

Syrphidae: *Syrphus nitidifrons* Becker, Norfolk, Lynford (TL818933), 2.v, a female on flowers of box *Buxus sempervirens*, apparently the third British specimen following its discovery in Dorset in 2010 and subsequent record from the New Forest in 2011. There have been several other recent unpublished records; it was thought to be associated with conifers, but it has been found on two occasions in a sycamore wood (Roger Morris *pers. comm.*). This appears to be a recent colonist, which may now be quite widespread across Southern England.

Tephritidae: *Cryptaciura rotundiventris* (Fallén), Perthshire, River Tay, Aberfeldy (NN867497), 13.vii, a female on flowers of ground elder *Aegopodium podagraria*.

Milichiidae: *Milichia ludens* (Wahlberg), *Phyllomyza beckeri* Kramer, *P. donisthorpei* Schmitz, *P. equitans* (Hendel) and *P. rubricornis* Schmitz, Suffolk, Dunwich Heath (TM477675), 25.vi, all swept from around a nest of the ant *Lasius fuliginosus* – an association with this ant has not been noted before with *P. beckeri* and *P. rubricornis*, but is well known for the other species.

Ephydridae: *Hecamedoides glaucellus* (Stenhammar), Lynford Water (as above), 3.vi, swept from sandy margin of gravel pit enriched with bird guano and found in association with the sepsids *Themira biloba* Andersson and *T. putris* (Linnaeus).

Fanniidae: *Fannia gotlandica* Ringdahl, Oxfordshire, Warburg NR (SU715879), a male 4.ix and a female 31.viii, both swept from a damp track during a period of drought.

Tachinidae: *Cyrtophleba ruricola* (Meigen), Lynford Water (as above), 26.vi, apparently the first record for the region and may indicate a recent northern expansion of its range; *Anthomyiopsis nigrisquamata* (Zetterstedt), Perthshire, Carie, Rannoch Forest (NN614565), 17.vii, females on suckering aspen *Populus tremula*; *Macquartia viridana* Robineau-Desvoidy, Devils Ditch (TL577650), Cambridgeshire, 1.v, on chalk grassland, apparently the first record for the county.

Dipterists Digest 2014 **21,** 83-88

A comparison of white and yellow pan traps for the collection of Diptera

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Summary

The use of white and yellow pan traps was compared for the collection of Diptera. It was found that whilst for most families there was no difference in the numbers of specimens collected, for Empididae and Syrphidae the differences were significant. The use of pan traps for the collection of Diptera is discussed, and is compared with netting/sweeping.

Introduction

Pan traps are a well established method for collecting insects. They have been widely used for surveying bee populations, as there is interest in the economic importance of pollinator activity (Toler *et al.* 2005, Roulston *et al.* 2007, Gollan *et al.* 2011, Grundel *et al.* 2011), and some of these surveys have also included Diptera (Campbell and Hanula 2007, Vrdoljak and Samways 2012, Bashir *et al.* 2013, Saunders and Luck 2013). Pan traps have also been used in surveys of Empidoidea (Pollet and Grootaert 1994) and Dolichopodidae (Vincent 2013). These studies have used pan traps of a variety of colours, usually white and yellow, but also including red, blue, green and black, in a variety of habitats. The present study has used just white and yellow pan traps in a single location to discover whether it was a useful addition to the main netting/sweeping method of survey.

Methods

This study was carried out in Marley Wood (SP479079, V.C. 22), part of Wytham Woods, which are owned and managed by the University of Oxford for carrying out research. The pan traps used were white or yellow inverted 'frisbees', one of each colour, with a diameter of 23cm. These were laid on the ground adjacent to one another (within 30cm) and filled to a depth of about 1cm with water, to which a few drops of detergent had been added. It should be noted that these traps were adequate for the time that they were left, but if they were to be left for several days then a larger, deeper design of trap would be required.

The location was a small well lit woodland glade which received sunlight (if present) for the duration of each sampling period. The description of this site is semi-natural ancient woodland National Vegetation Classification W8e; *Fraxinus excelsior – Acer campestre - Mercurialis perennis* woodland. The pan traps were left for a period of about 2-3 hours, in either late morning or early afternoon, whilst the local area was surveyed for Diptera by netting/sweeping. Samples were collected between 15 April 2013 and 5 October 2013, on eighteen occasions at intervals of seven to fourteen days in generally fine weather (total trapping time 1.5-2.0 days). Diptera specimens were generally identified only to family level for the study, but some specimens were identified to species level. Other orders that were present in the samples (Hymenoptera, Coleoptera, etc.) were not recorded. Statistical analysis was performed using a Chi Square Test to show that there was no difference in the proportion of individuals of each family, or species, in white and yellow pan traps.

Results

Table 1 shows a summary of the total number of specimens in each family obtained in this study; 733 specimens in 22 families were collected in the pan traps. On the same dates and at the same location 867 specimens in 38 families were collected by netting/sweeping.

Table 1. The number of specimens collected by family for each pan colour.

Family	White	Yellow	p Value
Agromyzidae	1	1	1.000
Anthomyiidae	52	46	0.545
Bibionidae	0	1	-
Calliphoridae	17	19	0.739
Chloropidae	2	1	0.564
Dolichopodidae	161	157	0.823
Dryomyzidae	1	0	-
Empididae	28	1	<0.0001
Fanniidae	17	27	0.132
Muscidae	42	59	0.091
Opomyzidae	1	0	-
Phoridae	1	1	1.000
Pipunculidae	1	1	1.000
Rhinophoridae	1	0	-
Sarcophagidae	13	19	0.289
Scathophagidae	0	1	-
Sciaridae	0	1	-
Sciomyzidae	0	1	-
Sepsidae	3	0	-
Stratiomyidae	2	1	0.564
Syrphidae	7	28	0.0006
Tachinidae	13	5	0.059
TOTAL	**363**	**370**	

Some of the species collected in pan traps, that were not collected in this study by netting/sweeping, are: *Sargus iridatus* (Scopoli) (Stratiomyidae), *Chalcosyrphus nemorum* (Fabricius), *Melangyna lasiophthalma* (Zetterstedt) and *Syrphus vitripennis* (Syrphidae), *Opomyza germinationis* (Linnaeus) (Opomyzidae), *Norellisoma spinimanum* (Fallén) (Scathophagidae), *Muscina levida* (Harris) and *Phaonia subventa* (Harris) (Muscidae), *Lucilia ampullacea* Villeneuve (Calliphoridae), *Lophosia fasciata* Meigen and *Nowickia ferox* (Panzer) (Tachinidae).

The Syrphidae was the only family in which all specimens were identified to species. There were 35 specimens of 12 species, four collected in the white pan traps and 10 in the yellow pan traps; only two species were collected from pan traps of both colours, *Platycheirus albimanus* and *Xylota segnis*. There was an unequal distribution of species between the two trap colours: *Xylota segnis* was distributed three in the white trap and eight in the yellow trap, in the tribe Eristalini the distribution was one in the white trap and 15 in the yellow trap. By netting/sweeping on the same occasions there were 271 specimens of 51 species of Syrphidae.

Table 2. The species and number of Syrphidae collected in each colour of pan trap.

Species	Pan Trap Colour	
	White	Yellow
Chalcosyrphus nemorum (Fabricius)	0	1
Episyrphus balteatus (De Geer)	0	1
Eristalis nemorum (Linnaeus)	0	1
Eristalis pertinax (Scopoli)	0	3
Helophilus pendulus (Linnaeus)	0	10
Melangyna lasiophthalma (Zetterstedt)	0	1
Myathropa florea (Linnaeus)	1	0
Neoascia tenur (Harris)	0	1
Parhelophilus frutetorum (Fabricius)	0	1
Platycheirus albimanus (Fabricius)	2	1
Syrphus vitripennis Meigen	1	0
Xylota segnis (Linnaeus)	3	8
Total species	4	10
Total specimens	7	28

In Tachinidae the difference in numbers collected was due to the collection of nine *Siphona geniculata* (De Geer) in the white trap and none in the yellow trap. Likewise in the Muscidae, not all identified to species, in the yellow trap there were three *Eudasyphora cyanella* (Meigen) and eight *E. cyanicolor* (Zetterstedt), both absent in the white trap.

Discussion

Differences in the numbers of specimens collected by each colour trap could be due to a general preference for colour by all species in a family, or that only some species in a family have a preference. Overall the total number of specimens collected by each trap colour was similar (363 in 18 families v. 370 in 18 families), but within this total there are family differences. In most families the number of specimens was too low to analyse reliably by the Chi Square Test even if they had all been identified to species, and differences between catches in yellow and white pan traps were found to be significant or highly significant for only two families.

Families not present in the pan trap collection in this study, but collected by netting/sweeping were: Anisopodidae, Bombyliidae, Cylindrotomidae, Ephydridae, Hybotidae, Keroplatidae, Lauxaniidae, Limoniidae, Lonchopteridae, Pediciidae, Psilidae, Ptychopteridae, Rhagionidae, Tabanidae, Tephritidae, Tipulidae and Ulidiidae. Some, but not all, of these families were well represented both in terms of numbers of individuals and of species. However, some of these families might have been collected in pan traps earlier or later in the day, or if the sample size had been greater. Certainly Ephydridae, Limoniidae, Rhagionidae, Tipulidae and Ulidiidae may be readily collected in pan traps (Peter Vincent *pers. comm.*).

It is apparent that pan trapping is not a good method for collecting Syrphidae. However, three of the 12 species recorded from pan traps were not collected by netting/sweeping: *Chalcosyrphus nemorum, Melangyna lasiophthalma* and *Syrphus vitripennis,* the first two of which I do not commonly find, so pan trapping is capable of collecting less common species of Syrphidae not always found by concurrent netting/sweeping.

In this study Empididae appear to have a preference for the white pan trap. However, Pollet and Grootaert (1994) in their more extensive study did not find this, but rather that different species had different preferences. Overall they collected 19 species in the white traps and 18 species in the yellow traps, but the number of specimens was 180 in the white traps and 386 in the yellow traps. They collected both Dolichopodidae and other Empidoidea (Empididae + Hybotidae) and found that abundant species have a large influence on the results. What is remarkable was that two species were apparently so abundant as measured by this method: *Dolichopus ungulatus* (Linnaeus) comprised 53.3% of the total catch of Dolichopodidae and 63.1% of this catch by yellow pan traps, and *Platypalpus annulipes* (Meigen) comprised 45.2% of the total catch of Empididae + Hybotidae and 64% of this catch by yellow pan traps.

In those studies that recorded Diptera as well as Hymenoptera and other orders (Campbell and Hanula 2007, Vrdoljak and Samways 2012, Bashir *et al.* 2013, Saunders and Luck 2013), the general findings were that different coloured pan traps showed different abundance and/or collected different species, that pan traps did not collect all species present, and that no single coloured pan trap was best for all species. Campbell and Hanula (2007), in their study of flower visiting insects in three forested ecosystems, found that pan traps were more effective than Malaise traps, but from their three sites they only collected 10, 16 and 13 species of Diptera. Vrdoljak and Samways (2012) showed that whilst the white and yellow pan traps collected the majority of species sampled (>80%, not all Diptera) that other colours of pan traps were necessary to collect additional species. Furthermore, they suggested that whilst pan traps may provide good estimates of species richness, that relative population estimates are difficult as catches only represent those proportions of the population susceptible to pan trapping. In the study of flower visitors by Bashir *et al.* (2013), of the 31 species of Diptera collected the maximum number of species (29) and individuals were recorded by netting, 27 species were collected in pan traps and 21 by Malaise trapping. Of the 31 species collected 25 were most abundant by netting and six by pan trapping; in their study Malaise traps were never the most effective.

Studies of pan trapping in which only Hymenoptera were recorded give additional findings that may also be relevant to Diptera. Gollan *et al.* (2011) in their study collected only 66 of the over 400 species found in the area. Roulston *et al.* (2007) found that whist there was overlap in the species collected, netting obtained nearly twice as many species as pan traps, and they collected 17 species only by netting, whereas three species were collected only by pan traps. Toler *et al.* (2005) suggested that the prevalent colour of flowers in bloom had no effect on the species collected, and that pan trapping is biased towards certain groups with many common species being under-represented in the catch.

Netting/sweeping is a method that actively collects Diptera rather than the passive pan trap method. This inevitably leads to various biases; the experienced operator will see more specimens to net, and when sweeping may have a more thorough technique. It may be that the faster flying or agile species are under-represented by netting/sweeping, whereas this is not a factor in pan trapping. A further bias in quantitative studies is that species easily identified in the field, especially those that are common or abundant, may not all be recorded and taken for identification. There are also microhabitats that are not amenable to netting/sweeping; from plants which are thorny including brambles, the interior of bushes, and the base of tussocks. Pan traps as a passive method avoid operator experience and technique, and may be left for several days to collect both early morning and late evening: although the purpose of this study was to evaluate the value of setting pan traps only for the period of the active netting/sweeping in the vicinity.

There are other active and passive methods of collecting Diptera, including the use of pooters, portable suction devices, fogging, emergence traps, and Malaise traps, but these are outside the aims of this study. These methods as well as those used in this study are described in Grootaert *et al.* (2010).

Conclusions

White and yellow pan traps are an effective method for collecting Diptera. Even the deployment of two differently coloured pan traps left in a single suitable location resulted in a relatively large catch, which included some species not collected at this site by netting/sweeping. They are a passive method not dependent upon the field skills of the collector, except in relation to being sited effectively as differences in results occur dependent on position and height. Whilst netting/sweeping is overall the best method for collecting Diptera, both in terms of numbers collected and diversity of species collected, nevertheless pan traps are a very useful supplement. Different coloured pan traps may collect different species, and even when there is overlap in the species collected there may be a difference in the apparent abundance. For this reason it is essential to use different coloured pan traps in any survey. In addition to the white and yellow pan traps used in this study many other colours have been used including brown, orange, green, red, black, and blue (Disney *et al.* 1982). Each pan trap colour is effective to a greater or lesser extent for different families of Diptera, and for different species within those families. Not all species of a family are collected by pan traps, including apparently relatively abundant species collected by netting/sweeping; thus any study of presence/abundance may be flawed if solely reliant on pan traps or conversely solely reliant on netting/sweeping.

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Current patterns and historical origins of endemicity in British Empididae (Diptera)

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Summary

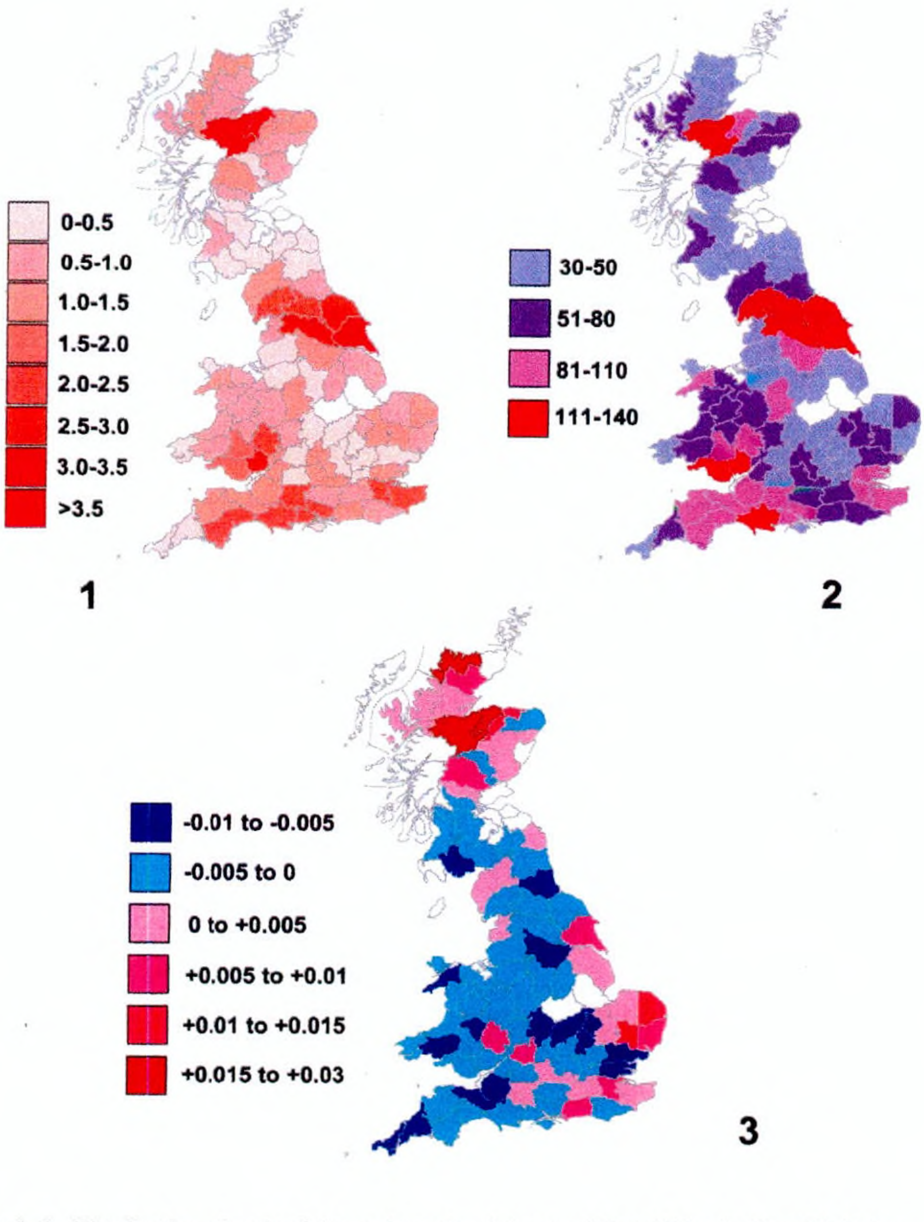
Weighted endemicity and species richness were used to reveal hotspots of endemicity and diversity amongst British Empididae. Weighted endemicity was positively correlated with species richness. Maps of deviation of weighted endemicity from values predicted by a regression model of its relationship with species richness enabled areas of above or below expected endemicity to be identified. Endemicity was highest in areas of Scotland, northern England, the basal south-west peninsula and parts of Wales with parts of eastern and southern England functioning as refugia for lowland species. Results of parsimony analysis of endemism (PAE) were consistent with northern and western areas of endemism being derived from Empididae community lineages, arising from pioneer colonists entering Great Britain at the end of the Devensian Ice-Age. Southern, lowland areas of high endemism were poorly resolved by PAE. It is hypothesised that the assembly of the British Empididae fauna may have been largely complete by the opening of the English Channel about 6,200 BP.

Introduction

A species is endemic if it is confined to a particular place. The spatial scale defining any particular endemism might be huge (e.g. for a taxon endemic to the Palaearctic Realm) or very small (e.g. for a taxon endemic to a small island). Endemism describes the degree of uniqueness of a species to a particular area and should not be confused with rarity, which describes range extent, habitat breadth or site abundance etc., of a species. Some locations support many endemic taxa and an understanding of such 'areas of endemism' and endemicity 'hotspots' at a variety of spatial scales is important, not only in historical biogeography (Henderson 1991, Linder 2001) but also in identifying geographical areas of conservation importance (Kerr and Burkey 2002, Moir *et al.* 2002), especially as so-called 'narrow-range endemics' (those with very restricted ranges) may be more susceptible to extinction (Harvey 2002).

No species of Empididae occurring in Great Britain are entirely restricted to the country but many could be classed as narrow-range endemics in a local (British) context, with highly localised distributions and often being rare. British populations are of conservation interest if only because they represent populations isolated physically (and most likely genetically) from their European counterparts. The historical factors responsible for fragmenting formerly unitary populations of Empididae have not been investigated, but are of great interest as they must have been critical in shaping the composition and distribution of the modern fauna. Additionally, whatever the barriers were that came to limit dispersal of ancestral populations, by fragmenting populations and constraining them to different environments, likely with different selection pressures, the conditions for vicariant allopatric (i.e. geographically isolated) divergence, and perhaps eventual speciation were created.

Estimation of weighted endemism (in which the importance of widely distributed species is down-weighted and range-restricted species up-weighted in the analysis) is an approach that has proved to be a useful tool in identifying centres of high endemism (e.g. Moir *et al.* 2002).



Figs 1–3. Distribution of endemicity and species richness of Empididae in Great Britain: 1, weighted endemicity; 2, species richness; 3, deviation of weighted endemicity from values predicted by a regression model of its relationship with species richness.

This study maps the distribution of weighted endemism in Great Britain, using distribution data of Empididae collated from the Empididae and Dolichopodidae Recording Scheme. Potential hypotheses of the *historical* relationships between the empidid fauna of different geographical areas were developed, using parsimony analysis of endemism (PAE).

PAE is a method used in biogeography to construct a tree showing historical relationships between communities of endemic species present in different geographical areas. The tree produced is analogous to an evolutionary tree but reveals the *historical* branching patterns relating whole communities of endemic species occupying *modern* areas of land. PAE is based on cladistic analysis, which is a way in which evolutionary relationships between species can be represented as a species-cladogram from which their phylogeny can be inferred.

In PAE, however, it is not species that are analysed, but rather entire communities of species inhabiting defined *geographical areas* (referred to as *Operational Geographic Units* or *OGU)* and the result is an area-cladogram from which the historical relationships between the communities inhabiting the different areas can be resolved. The first step in calculating a phylogeny is to construct a matrix containing taxa down one column and their 'character state' in the other (character states define if a character is ancestral or derived) whereas in PAE a matrix is constructed in which geographical areas (OGUs) are used instead of taxa and species states instead of characters (species states define if a particular species is present or absent in a particular area). By convention, ancestral characters score '0' and derived characters '1' in cladistic analyses whereas in PAE species are scored as '0' if absent or as '1' if present. Thereafter, cladistic analysis and PAE are identical and in either case, the same computer programmes can be used to calculate the most parsimonious (i.e. the simplest) tree. Unless the matrix is very small (in which case the analysis is quite simple and an 'implicit enumeration can be used), the calculations are complex involving the generation of many thousands of different ways of configuring the trees, various mathematical 'tricks' have to be employed (e.g. tree bisection reconnection or sectorial searches mentioned in the Methods section) to simplify the process.

The outcome of both cladistic and PAE calculations can be influenced by many things but one of the most important is *homoplasy*. In cladistics, homoplasy describes the situation when a particular character condition occurs in lineages that are remote from each other and may obscure true relationships. In PAE, homoplasy can be introduced by widespread species occurring partially in several areas of endemism and could result in those areas being obscured. In either case, a solution is to 'down-weight' against homoplasy (decrease its numerical importance in the calculation) and various rational approaches to this can be employed, including the implied weighting (Goloboff 1993) method used here. Two statistical measures, the consistency index (CI) and retention index (RI), broadly speaking, report the degree of homoplasy. Statistical support for individual lineages in a tree can be estimated by various statistical resampling procedures (e.g. bootstrapping, jackknife, etc.) but symmetrical resampling is used here as it is less influenced by homoplasy than other methods. A high value of symmetrical resampling support indicates that a particular branch in a tree more likely than one with only a low value.

PAE was originally developed in geology for interpreting the distribution of taxa across two or more stratigraphic horizons (Rosen 1988a, Rosen and Smith 1988) but may also be applicable where distribution patterns are analysed from a single horizon (Rosen 1988b). Although PAE has been widely used with taxa occurring in a single horizon (e.g. Garćia-Barros *et al.* 2002, Linder 2001, Navarro *et al.* 2007) its validity has not been universally accepted (e.g. Brooks and van Veller 2003, Nihei 2006), but Rosen (1988b) has pointed out that most of the apparent problems with using it in this way can be resolved if patterns amongst groups of organisms can be reconciled with geological evidence or palaeoecological data.

Methods

Distributional data for 205 species of Empididae (*sensu* Sinclair and Cumming 2006) comprising 20,256 unique species-10km grid square occurrences were extracted from the British Empididae and Dolichopodidae Recording Scheme database. The data extracted recorded only presence or absence and ignored multiple occurrence at different locations or dates *within* a single 10km square. Genera included (with number of species represented given in brackets) were: *Chelifera* Macquart (13), *Chelipoda* Macquart (2), *Clinocera* Meigen (5), *Dolichocephala* Macquart (5), *Dryodromya* Rondani (1), *Empis* Linnaeus (40), *Hemerodromia* Meigen (6), *Hilara* Meigen (70), *Hormopeza* Zetterstedt (1), *Kowarzia* Mik (3), *Phyllodromia* Zetterstedt (1), *Ragas* Walker (1), *Rhamphomyia* Meigen (52) and *Wiedemannia* Zetterstedt (5). Species richness was calculated as the number of species present in each Vice County (V.C.). V.C.s for which records of fewer than 30 species were available were excluded from the analysis. Reciprocal weighted endemism was calculated using a modification of the method of Moir *et al.* (2009) as follows. The number of 10km grid squares within which each species occurred was counted. Each species was then assigned a value based on this number, with species known from only one 10km grid being given the highest value of 1, species occurring in two 10km grids were given a value of 0.5, three 10km grids valued at 0.333 and so forth. Weighted endemism for each V.C. was then calculated as the sum of values for each species whose range overlapped the V.C. Mean weighted endemism was determined as the weighted endemism for each V.C., divided by the species richness for that V.C.

The Operational Geographic Unit employed in PAE was either (i) single V.C.s, or (ii) two or more V.C.s grouped together regionally on the basis of related geography or by inspection of results obtained in (i). Single V.C. analyses excluded V.C.s with fewer than 30 species present, but analyses of regionally grouped V.C.s included all V.C.s in which species had been recorded. All analyses used the program TNT v1.1 (Goloboff *et al.* 2008), with sufficient memory being allocated to hold 10,000 trees and general RAM set to 2000 Mb. Traditional parsimony-based searches employed implicit enumeration (which guaranteed that all equally parsimonious trees are found), where only a small number (<10) of OGUs were involved, but otherwise employed 100 random-addition replicates using tree bisection reconnection (TBR) branch swapping, retaining 10 trees per replication. In New Technology searches under TNT, parameters were set to include all techniques (sectorial search, ratchet, drift and tree fusing) and the program was set to find the minimum length of tree 10 times. Support was calculated by symmetrical resampling using 1000 replicates. Consistency index (CI) and retention index (RI) were determined by running the *stats.run* script. Traditional parsimony-based searches were performed with 'characters' uniformly weighted (prior-weighted), or down-weighted against homoplasy, using implied weighting regimes in which the concavity constant *k* was varied between 2 and 10 (Goloboff 1993). An outgroup with an all-0 score (all species absent) was arbitrarily set up, but can be rationalised as the entire history of empidid communities in Great Britain, is reasoned to date from after the last glacial maximum when the country was largely ice-covered and all species were probably absent. Linear regression was calculated in PAST (Hammer *et al.* 2001).

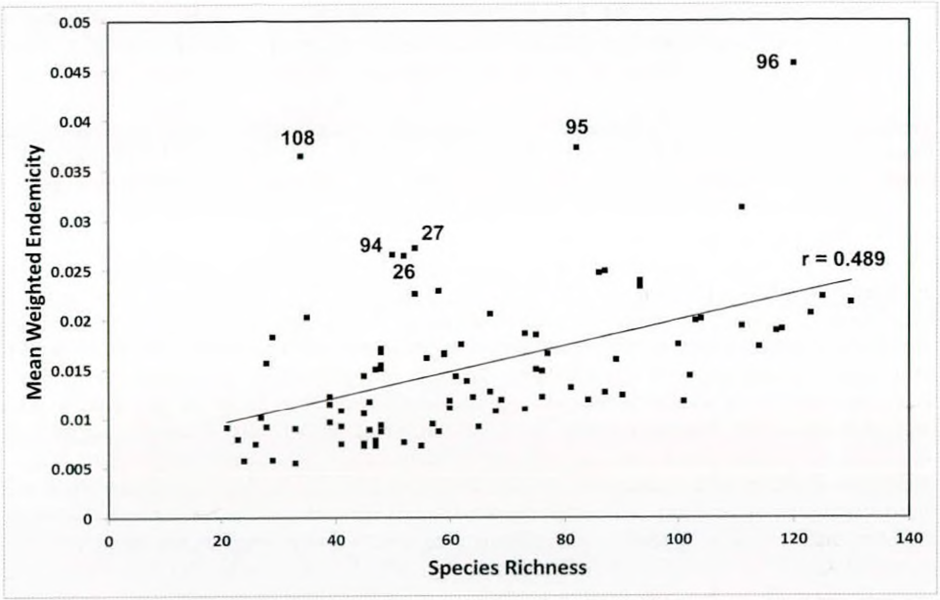


Fig. 4. Relationship between weighted endemicity and species richness at Vice-County (V.C.) level. Numbers refer to V.C.s 26, 27, 94–96 and 98. Regression line and value of *r* indicated.

Results

Distribution of endemicity

Fig. 1 shows how weighted endemicity of Empididae varied across Great Britain. High endemicity was apparent in parts of south-east Wales, East Anglia, south-east and northern England, the basal part of the south-west peninsula and especially areas of the Scottish Highlands. The measures of weighted endemicity are likely to have been underestimates because they were calculated from the sum of values assigned to species using 10km grids as OGU yet applied at a larger spatial scale with V.C.s as OGU. For example, a taxon might be restricted entirely to three 10km squares (score = 0.33 at this 10km scale) but also confined to a single V.C. (score = 1 at V.C. scale). Interestingly, areas of high species richness (Fig. 2) were similarly distributed, suggesting that high species richness correlates with high endemicity. Alternatively, as areas of species richness were largely (but not exclusively) in locations with better recorder coverage, it might be that increased coverage merely serves to detect a larger number of endemic species. A plot of weighted endemicity against species richness (Fig. 4) does indeed show a weak positive correlation (r = 0.489) but cannot help us distinguish between a recorder coverage effect and a 'genuine' relationship between the variables. It is, however, instructive to remark that certain V.C.s retrieved as endemicity hotspots in Fig. 1 correspond with 'outliers' at exceptionally higher values of weighted endemicity than predicted by the regression line in Fig. 4 (e.g. V.C.s 26, 27, 94–96, 108). Furthermore, these outliers were distributed across the full range of variation in species richness and likely genuinely represent V.C.s with exceptionally high endemicity.

When deviations in weighted endemicity above and below the regression line in Fig. 4 were plotted on a map, locations with above and below expected levels of endemicity were revealed (Fig. 3). In this treatment, the Scottish Highland localities and eastern England were again retrieved as endemicity hotspots but the importance of much of south-east Wales, basal south-western and northern England was diminished. Additionally a new zone of above average endemicity was revealed in south-east England (V.C.s 12, 15–17, 22). Interestingly, many of the well-worked areas of high species richness in Fig. 2 were revealed to have below expected levels of endemicity in Fig. 4, suggesting that apparently high endemicity was not a consequence of increased recorder-coverage of the areas concerned.

Parsimony analysis of endemism (PAE)

Traditional parsimony searches with TBR using all V.C.s with more than 30 species of Empididae present retrieved 10 equally parsimonious trees (CI = 0.093, RI = 0.481) but branch support was very low, typically less than 10% of replicates by symmetrical resampling (data not shown). Similar weak support was demonstrated in New Technology searches. The very low value of CI might indicate the involvement of high levels of homoplasy and an attempt to down-weight against this was made using values of k in the range 2–10. Fig. 5 shows the single most parsimonious tree recovered in New Technology searches with $k = 5$ (moderate down-weighting). Although branch support by symmetrical resampling was again low, inspection of Fig. 5 reveals that certain area clades comprised loosely geographically related V.C.s. For example, clade A consisted mostly of V.C.s in the Scottish Highlands, clade B of southern English localities, clade C of predominantly upland V.C.s in Wales, northern and SW England, and clade D of V.C.s in East Anglia.

It is likely that many V.C.s included in the single-V.C. analysis above were under-recorded. Indeed inspection of distribution maps from the Empidid and Dolichopodid Recording Scheme suggests that most mainland V.C.s in Great Britain are likely to have at least 60–80 species of Empididae present and a threshold value for inclusion in the analyses should arguably be at a similar level, rather than the 30 or more species present, as was actually used. PAE requires that data be sufficiently dense at the scale of OGU employed (Laffan and Crisp 2003) but unfortunately that condition would not be met if the many V.C.s with fewer than 60–80 species were excluded. A solution to this problem is to combine multiple V.C.s together into larger regional OGUs, thereby increasing data density. This decreases spatial resolution but effectively increases the ratio of signal to noise. In this study, regional OGUs were selected by rationally grouping V.C.s in reference to areas of high endemicity (Figs 1, 3), the results of PAE using single-V.C.s (Fig. 5) and geographical concordance. Nine regional OGUs were selected and designated: (1) North-west Highlands, (2) Highlands, (3) Scottish Lowlands, (4) Pennine, (5) Eastern England, (6) Wales, (7) South-west England, (8) English Midlands and (9) South Coast. The boundaries of regional OGUs are indicated in Fig. 6.

PAE of regional OGUs using implicit enumeration in TNT retrieved four equally parsimonious trees (CI = 0.604, RI = 0.548), with moderate symmetrical resampling support for most nodes (Fig. 7). Basic tree topology was maintained when the analysis was down-weighted against homoplasy (Fig. 8) and in both weighted and un-weighted analyses, northern localities (Scottish Lowlands, Highlands and NW Highlands) occupied relatively 'basal' positions beyond which SW England and perhaps Wales subtended a sister-group relationship with all the English regional OGUs. In both treatments, resolution of the terminal groupings of English regional OGUs was poor with weak resampling support.

Fig. 5. Single most parsimonious tree recovered in PAE using single V.C.s as OGU employing New Technology searches in TNT with k=5 (moderate down-weighting). V.C. numbers are indicated at the termini. Area clades A–D indicated (see text for details).

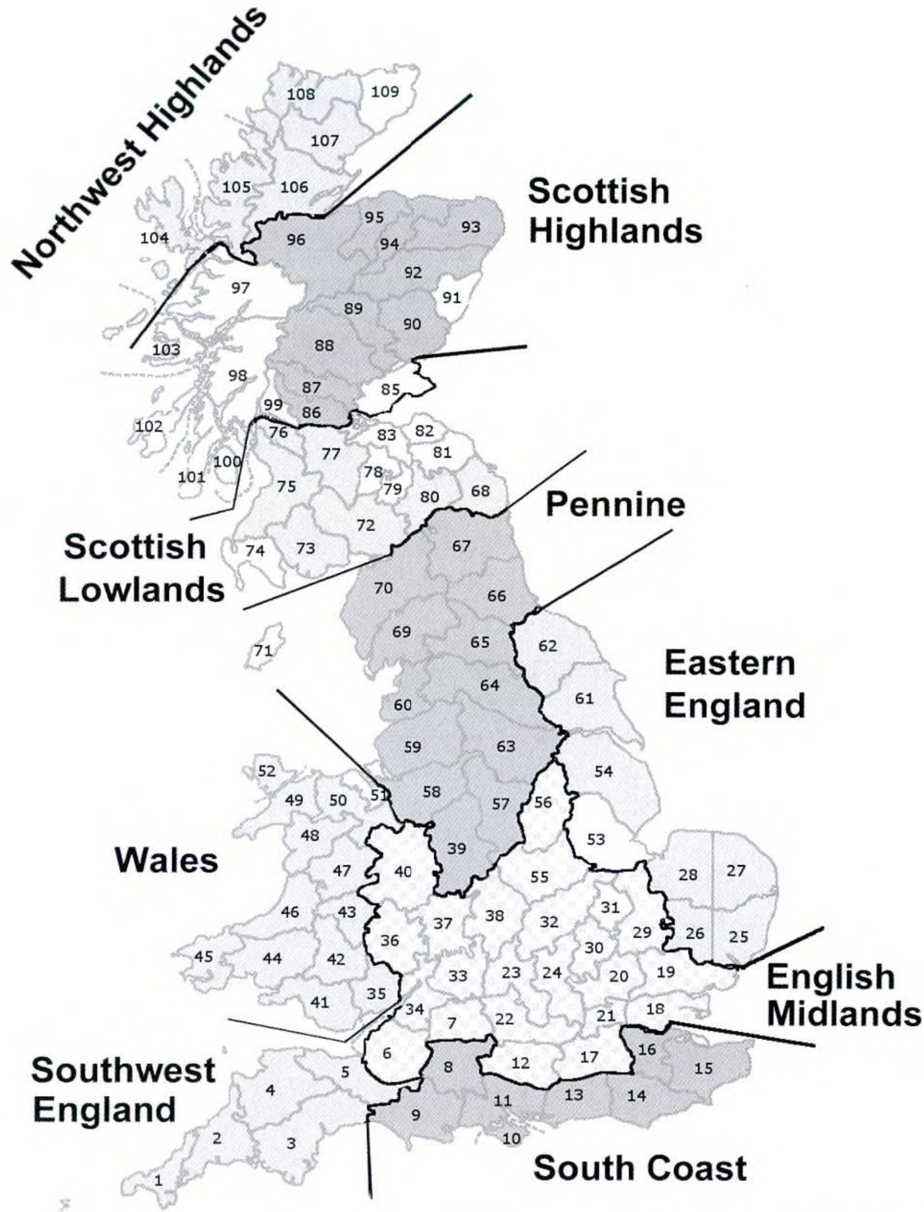


Fig. 6. Map of mainland Great Britain showing geographical limits of regional OGUs used in regional PAE. Shaded areas denote V.C.s with 30+ species recorded. V.C. numbers are indicated.

7

8

Figs 7–8. PAE of regional OGUs using implicit enumeration with symmetrical resampling support indicated for each node (see Fig. 6 for geographic boundaries of the regions): 7, strict consensus of 4 equally parsimonious trees retrieved using prior weights (un-weighted); 8, single most parsimonious tree retrieved using implied weighting (down-weighted with k=3).

Discussion

This work has provided evidence for hotspots of empidid endemicity in parts of south-east Wales, East Anglia, south-east and northern England, the basal part of the south-west peninsula and especially areas of the Scottish Highlands (Fig. 1). However, although weighted endemicity correlated with species richness, and while this relationship might be expected (local conditions favouring the survival of high species diversity could have been equally conducive to the survival of endemics), it was not possible to exclude the possibility that high species richness (and hence high endemicity) might have arisen from better recorder coverage in hotspot areas. An alternative representation of the distribution of endemicity in Great Britain is the map of deviation of weighted endemicity from that predicted by a regression model of its relationship with species richness (Fig. 3). It should be noted that the results for distribution of weighted endemicity and for deviation from expected endemicity plotted in Figs 1 and 3 respectively are not mutually exclusive, arising as they do from different considerations.

Based on deviation from expected levels of endemicity, parts of northern Scotland retain their importance for endemic taxa but much of lowland Scotland, Wales and England are seen to have levels of endemicity below that expected from their species richness. Likely causes of impoverishment of lowland endemics are: (i) below expected levels of endemism occur where barriers to dispersal are low and suitable habitat for taxa to disperse into is widespread; such conditions might pertain for many generalist lowland species, and (2) anthropogenic loss of habitat in areas with below expected endemicity may have preferentially promoted local extinction of local narrow-range endemics. Empidid communities in the uplands of Scotland may have a higher proportion of endemics because they have a larger number of upland specialists that are unable to disperse through adjacent lowlands and during post-glacial climatic warming they have become focussed in increasingly smaller cool, upland areas.

A narrow band extending across southern England (V.C.s 8, 13, 15–17, 22) into the Welsh borders (V.C.s 34, 36) had above expected levels of endemicity (Fig. 3). This band includes areas of the North Downs, Surrey and Hampshire heathlands, ancient Royal Forests and Herefordshire rivers (River Monnow etc.). It is hard to rationalise any biogeographic explanation for this based on biotic, climatic or geographic factors but it is speculated that the areas concerned may have escaped anthropogenic loss of habitat more than was the case elsewhere over much of lowland Britain and have in effect, functioned as refugia for endemic taxa. The eastern coastline of England (V.C.s 25–29, 54, 61) also had above expected levels of weighted endemicity (Fig. 3). Although these parts of England have suffered massive anthropogenic habitat losses, areas of fenland and the Breckland still persist and it is predominantly taxa characteristic of these habitats that contribute to the elevated endemicity of the area. These same taxa are generally widespread on the fenland and dry sandy heaths similar to the Breck, still present on the European mainland in countries bordering the North Sea (*Empis prodromus* Loew and *Rhamphomyia breviventris* Frey are probably good examples of such species). It is tentatively hypothesised that the eastern English endemic communities represent 'Doggerland' relicts, isolated since inundation of the land-bridge with Europe about 6,500–6,200 BP.

Although data were not sufficiently dense to resolve historical relationships between empidid communities at V.C. level using PAE (Fig. 5), consistent and meaningful results were obtained when V.C.s were grouped into regional OGUs (Figs 7, 8). Northern areas of Britain occupied 'basal' positions (that is they subtend the others) in the area cladograms presented in Figs 7 and 8 with south-west England and perhaps Wales (in Fig. 8 at least) occurring in successive sister-group relationship with them. These northern communities are, of course, ancestors of contemporary communities only in that they represent the earliest detectable historical splitting of the lineage of the British empidid fauna. Modern northern communities are just as 'advanced' or 'evolved' as the others, but both have descended through lineages traceable to a common historical origin. There are many examples of likely relict northern and western Empididae including, for example, the range-restricted *Rhamphomyia hirtula* Zetterstedt, *R. aethiops* Zetterstedt, *R. ignobilis* Zetterstedt, *Hilara. hybrida* Collin and *Dolichocephala thomasi* Wagner, and more widespread *Empis borealis* Linnaeus, *E. verralli* Collin and *E. scotica* Curtis.

As discussed in the Introduction, PAE is more likely to reveal historical relationships if the branching patterns revealed can be reconciled with a time-line of historical geological or palaeoecological evidence. Is it possible to establish such a time-line? During the last (Devensian) ice-age, ice coverage was probably at a maximum from 25,000–13,000 BP and although southernmost parts of Britain remained exposed, it would have been a relatively barren land with a very cold climate unsuitable for extensive colonisation by insects. Even during the Younger Dryas (12,800–11,500 BP) the climate remained cold and vegetation cover was probably extremely limited. Certain empidid genera in the subfamily Empidinae, especially in the genus *Rhamphomyia* Meigen, are well adapted to and abundant in modern high latitude and high altitude habitats and are very likely to have been pioneer colonists of southern Britain by the time of the Younger Dryas. Even so, species richness must have been very low at that time. During the Holocene (11,700 BP to present day) the climate gradually warmed and Great Britain began to acquire a richer biota as it was colonised by dispersal of taxa from mainland Europe. A continuous land-bridge with Europe persisted until about 6,200 BP and facilitated expansion of both terrestrial and aquatic forms into an increasingly mild and more vegetated Great Britain. With continuing climatic amelioration, the pioneering cold-adapted empidid communities would have been displaced northwards and westwards and eventually have become isolated in localised endemicity hotspot refugia. The signal of these early pioneering communities is represented in the northern and western 'basal' branches of the area cladograms resolved with PAE. It should not be imagined that modern communities in northern and western refugia are in any way identical with the early pioneers; certainly, they contain some of the original pioneer species (those responsible for high endemicity reported here) but they will have been augmented by progressive immigration and northwards spread of other species that occurred in the period since initial colonisation.

The area cladograms resolved by PAE (Figs 7, 8) indicate that communities now characteristic of much of southern, lowland Britain emerged later than the early cold-adapted pioneer communities discussed above. Given the irrefutably small time period involved and lack of evidence of possible geophysical causes, a vicariant origin of them must be excluded. Most likely, successive waves of dispersal from the near Continent occurred (and no doubt still occur) throughout the Holocene as the climate continued to warm and more diverse niche-space opportunities arose in a warmer, more habitat-diverse Great Britain. Each new dispersal would have modified the empidid communities already present as they responded to competition and opportunities that developed.

Unfortunately, the distal area clades retrieved with PAE were not well resolved with only weak branch support, so it is difficult to disentangle the historical sequence in which southern, lowland communities developed. In particular, the apparently recent origin of the Eastern English area clade appears to contradict the hypothesis that eastern communities are relicts of Doggerland. Alternatively, it might be speculated that weakly resolved terminal branches indicate that the empidid fauna of lowland Britain was largely assembled by the time the land-bridge was submerged. That would imply that the composition of the British empidid fauna had been mostly determined by overland dispersal *via* the land-bridge and that subsequent dispersal by other means would have been minimal. British Empididae became isolated after the opening of the English Channel.

This study has revealed much about the patterns and historical origins of endemicity in British Empididae, but many questions remain unanswered or uncertain and will only be solved when more data is acquired for analysis. In particular, combined distribution data of multiple families of well-recorded British Diptera would allow for more detailed and authoritative analysis.

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Old traditional apple orchards as a development habitat for *Ctenophora pectinicornis* (Linnaeus) (Diptera, Tipulidae) in Worcestershire – Whilst searching for traces of noble chafer *Gnorimus nobilis* (Linnaeus, 1758) (Coleoptera, Scarabaeidae, Cetoniinae) on 23 April 2011 in an old traditionally managed apple orchard near Rochford, Tenbury Wells, Worcestershire, (SO648675), I noticed masses of granular frass unfamiliar to me in a hollow apple trunk full of wood mould. The granules were around 2mm in diameter and buried amongst them were several pupae. I decided to take one home in a jar with frass and wood mould and a few days later a male *Ctenophora pectinicornis* (Linnaeus, 1758) emerged.

Whilst on another search for noble chafers on 22 April 2014 at an old traditionally managed apple orchard near the Three Counties Show Ground at Malvern, Worcestershire, (SO782431), I made a similar find and a female *Ctenophora pectinicornis* emerged two days later.

On 6 May 2014 Rebecca Lashley searched an orchard at Martley Road, Worcester, (SO819565) for traces of noble chafer and, whilst looking into the decaying end of a branch stub about 10cm in diameter, she noticed pupae similar to those seen on 22 April 2014 amongst a small amount of wood mould. She collected two pupae and wood mould for checking. This material was passed to me on 7 April, and shortly afterwards a female *Ctenophora pectinicornis* emerged. To cool the specimen for photography it was left in the collecting jar with frass and the remaining pupa and placed in a domestic refrigerator. After 24 hours at around 5°C a second female emerged whilst in the refrigerator.

Both of the first two orchards were typical old traditionally managed sites with big standard apple trees, all showing various stages of internal decay with open holes leading into trunks or branches that were either hollow or partly filled with wood mould. The third orchard was different, being a neglected commercial orchard thought to be about 60 years old where spraying for pest control ceased about five years previously. The trees had all been managed as low goblet shapes, with branches coming off the same point on the trunk between 0.5m and 1m above ground level. A few trunks were completely hollow, but most were relatively intact and many were partly encased in ivy *Hedera helix*.

K.N.A. Alexander (2013. *Ctenophora pectinicornis* and *Dictenidia bimaculata* reared from larvae found in old apple trees in traditional orchards in Herefordshire. *Cranefly News* No 26, p 3. **In** *Bulletin of the Dipterists Forum* No. 76 Autumn 2013) reported rearing

Ctenophora pectinicornis from apple tree wood mould found at two Herefordshire orchards in March 2012. K.N.A. Alexander, L. Bower and G.H Green (in press. A remarkable saproxylic insect fauna from a traditional orchard in Worcestershire – but are the species resident or transitory? *British Journal of Entomology and Natural History*) found the species in hollow apple trees in an old orchard near Pershore, Worcestershire, during 2013. The database of the Worcestershire Biological Records Centre contains a small number of records of flying *Ctenophora pectinicornis* from several parts of Worcestershire but no other rearing records.

Freshly emerged female of *Ctenophora pectinicornis* with pupal case.

These rearing records of the Nationally Scarce *Ctenophora pectinicornis* add further to the recognition of old traditional apple orchards as important sites for saproxylic invertebrates. The rounded frass may be an indicator of larval activity of *Ctenophora pectinicornis* but this is not proven.

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