Biogeography, population dynamics and status of *Micropeza lateralis* Meigen, 1826 (Diptera, Micropezidae) in Europe

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Summary

Nationally scarce *Micropeza lateralis* Meigen, 1826 (Diptera, Micropezidae) new to Devon and observed at a strong colony in Nottinghamshire and photographed. Population dynamics and ecological niches explored. Key to European species of *Micropeza* provided.

Keywords

Micropezidae; *Micropeza*; *Micropeza lateralis,* Broom Stilter; *Micropeza corrigiolata,* Common Stilter*; Micropeza brevipennis*, Lucerne Stilter; European distribution; dispersal strategies; population dynamics, metapopulations; ecological niche model, LANMAP, IUCN status. Visual European identification key: *Micropeza nigra, Micropeza angustipennis, Micropeza grallatrix, Micropeza cingulata.* nomina dubia: *Micropeza hispanica, Micropeza atripes.* species inquirenda: *Micropeza kawalli*

Fig. 1. Lateral body of Broom Stilter (*Micropeza lateralis*) male (watercolour, D.Sumner)

Introduction

Long associated with Broom (*Cytisus scoparius*), the sweep netting effort around these bushes during the Dipterists Forum field trip to Nottinghamshire resulted in a number of captures of *Micropeza lateralis*. By determining exactly where members reported catching *Micropeza lateralis* at Rainworth Heath (SK591593) aided by Google Earth, and returning to these sites, I backtracked along their most likely route (Malcolm Smart and Peter Chandler) to locate the most likely small patches of good grass cover beside Broom.

My objective was to observe and photograph so my equipment comprised a tripod stool, close-focus binoculars and camera equipment. Fifteen minutes close scrutiny at one small patch (Fig. 2.A) was insufficient to see them, then Keith Alexander arrived, was asked to sweep the tall grasses around the Broom I had been examining and caught two.

On subsequent return visits specimens were again found in the same location and also in other parts of the extensive Broom scrub.

Habitat

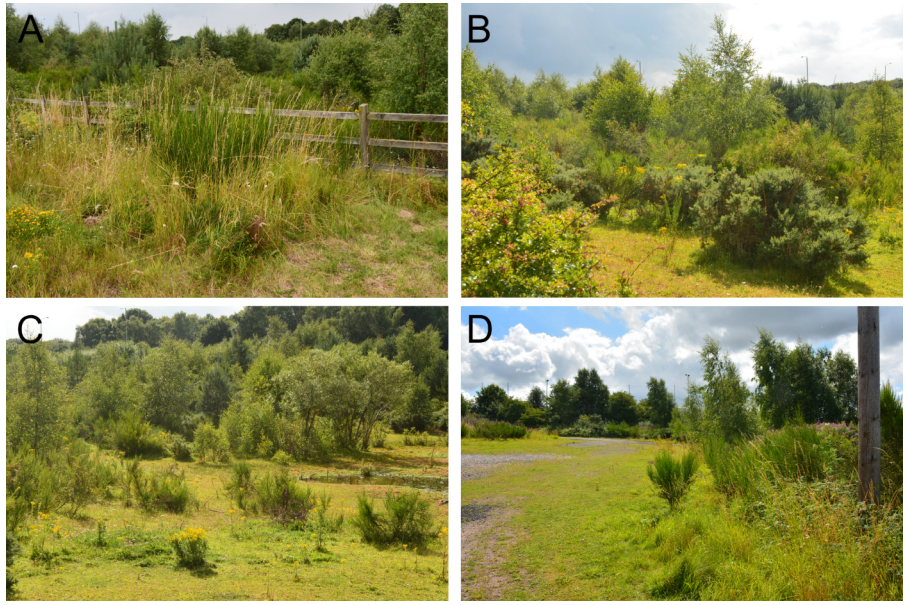


Fig. 2. [A] Typical location for *M.lateralis*, Rainworth, 2015-08-01, 53°7'26"N 1°6'58"W, OSGB: SK 59254 58863. [B] Horse-grazed Broom scrub adjacent to bypass, Rainworth, 2015-08-01 [C] Broom scrub, Rainworth, 2015-08-01 showing pools. [D] Broom scrub on amenity site, Rainworth 2015-08-01, 53°7'17"N 1°7'1"W, OSGB SK 59192 58603, subsequently developed.

Habitus

Fig. 3. *Micropeza lateralis* Female. Bicton Common OSGB SY037855 (R. Wolton 2015)

Fig. 4. *Micropeza lateralis* Female Rainworth OSG: SK 59254 58863 (D.Sumner 2015)

Fig. 5. *Micropeza lateralis* Male Rainworth OSG: SK 59254 58863 (D.Sumner 2015)

Identification

Ten species of *Micropeza* are recorded in Europe. One of these, *M. nigra*, is confined to Turkey (Kemal & Kocak 2015) and the eastern mediterranean, one to Romania, Lithuania, Hungary & Caucasus (*M. angustipennis*), two (*M. atripes, M. cingulata*) to East European Russia, one to Spain (*M. hispanica*) and one, *M. kawalli,* which is only recorded in Lithuania (Pakalniškis, 2006). Of the remaining four, two are currently known from the UK (*M. corrigiolata & M. lateralis*) and of the two others, *M. brevipennis* may be overlooked here or may find its way to the UK, occuring in warm lowland meadows associated with Lucerne (*Medicago sativa*, = alfalfa), whilst *M. grallatrix* is strictly southern Mediterranean.

Visual Key to European species of *Micropeza*

Based upon images, descriptions and known biogeography.

1—Body mostly black. Pleura without stripes.

——————————————————————————**2**

——Body mostly brown and/or yellow. Pleura with yellow longitudinal stripes

——————————————————————————**7**

2—Legs more than half black

——————————————————————————**3**

——Legs predominantly yellow or yellowish brown

——————————————————————————**6**

3—Legs entirely black

——————————————————————melanic forms, *nomina dubia* & non-European species

Micropeza hispanica Bigot, 1886 is probably a melanic form of something (perhaps *M. corrigiolata*), one Spanish record. ***Micropeza atripes*** Bezzi, 1895. The author considered it to be a melanic form of *M. corrigiolata*, one Italian record. ***Micropeza kettaniae*** Ebejer, 2019 is recorded from Morocco, approximately 70km south of Spain.

——Legs mostly black. Black species.

——————————————————————————**4**

4—Mid and hind femora mainly yellow with two black rings.

——————————————————————**Micropeza nigra [Black Stilter]**

Turkey and southwards

——Only the hind femora are yellow with black rings.

——————————————————————————**5**

5—All segments of the antenna dark yellow.

Propleuron with a row of long setae on the ventral margin. Coxae & legs all black except hind femora. Thorax black with some yellowing on the humeri and the sides of the scutellum. Yellow colouration on the head starts in the anterior part of the frons alongside the eyes, then down past the antennae and around the mouth opening in a thin band.

——————————————————**Micropeza cingulata [Black-legged Stilter]**

A mainly black species, only known from East European Russia

——Only the bases of the antennae yellow, the third is black/brown

Genae rusty yellow, frons & vertex black/brown. Thorax & abdomen glossy black. Legs yellow, mid & hind femora light brown.

——————————————————————Micropeza kawalli [Scarce Stilter]

Recorded just once in Latvia (Courland) by Gimmerthal in 1847, listed for Lithuania in Pakalniškis, 2006. *species inquirenda*

6—Haltere yellow; fore coxa clear yellow and simple; wing long, extending beyond the end of tergite 6.

——————————————————**Micropeza corrigiolata [Common Stilter]**

compared with *M. lateralis*: Smaller, mainly black species. Vertex and occiput black. Thorax practically entirely black. usually 2-4 pairs of longer setae on the metasternum; ♂ cercus usually yellowish, hypopygium mainly black; ♀ pleurae with a distinctive pattern, dark patches extending down the sternites, ovipositor sheath completely black ventrally. 5-6.5mm

——Haltere brown; fore coxa long and bulging, yellow with a proximal blackening and a distal cream patch; wing short, not quite reaching the end of tergite 6

Face black with white dusting by the eyes (which continues on to the genae). Metasternum with at most 1 pair of longer setae; ♂ cercus brown; ♀ pleural membrane with a distinctive colour pattern consisting of a continuous brown (burnt umber) stripe above a cream-coloured belly; ovipositor sheath yellowish brown ventrally

——————————————————**Micropeza brevipennis [Lucerne Stilter]**

7—Yellow/sienna + pale brown. Arista brown. Pleura with a long thin white diagonal stripe. ♂ S5 with a ventral tuft of long black bristles

Propleuron without ventral setae; scutellum at most medially with a brownish spot, otherwise yellow; abdominal tergites largely yellow/pale brown

——————————————————**Micropeza angustipennis [Pale Stilter]**

Countries surrounding the Black Sea (Steppic lowlands and hills)

——Mid-brown with some yellow. Arista white; propleuron with well developed ventral setae; scutellum almost completely brown; tergites dark brown with raw sienna hind margins

——————————————————————————**8**

8—Upper half of occiput black with a central yellow patch extending horizontally from the eye (Figs. 1, 4 & 5). Antennal flagellum black.

Mesonotum brown (burnt sienna), 2 anterior thin black stripes & 2 posterior thin yellow stripes. Pleura with an upper golden yellow stripe, below this a burnt umber stripe and finally more golden yellow on the lower pleura and all coxae.

——————————————————**Micropeza lateralis [Broom Stilter]**

compared with *M. corrigiolata*: Larger, brown and sienna species. Vertex and occiput streaked and spotted with sienna. Side margins of thoracic disc, and lower part of pleurae sienna. ♂ hypopygium mainly sienna. 6 - 8.5mm

——Upper ⅔ of occiput black with variably sized streaks of colour extending up into the black from the pale genae. Antennal flagellum orange to dark.

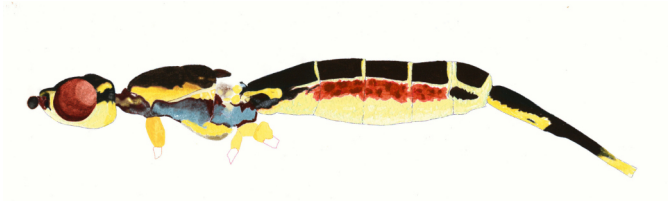
Mesonotum black with no stripes. On the pleura the black fades through maroon to an upper golden yellow stripe, again fading through maroon to golden yellow on the lower pleura. Coxae cream-coloured.

——————————————————**Micropeza grallatrix [Mediterranean Stilter]**

Southern parts of Mediterranean countries such as Portugal, Spain and Italy

The above key is devised primarily to aid identification from photographs. The hind femorae are illustrated at each couplet (where known), for further illustrations consult micropezids.myspecies.info Scarce material is scattered widely across various European museums and collections.

Lateral aspects of European *Micropeza* species (females)



Broom Stilter

Micropeza lateralis

Lucerne Stilter

Micropeza brevipennis

Common Stilter

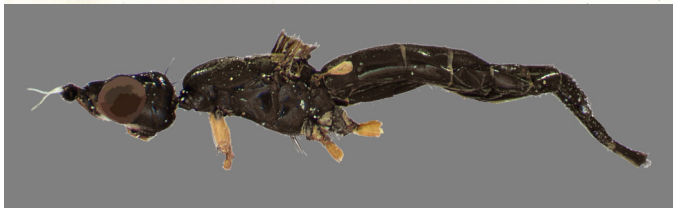
Micropeza corrigiolata

Mediterranean Stilter

Micropeza grallatrix

Pale Stilter

Micropeza angustipennis



Black Stilter

Micropeza nigra

Biogeography

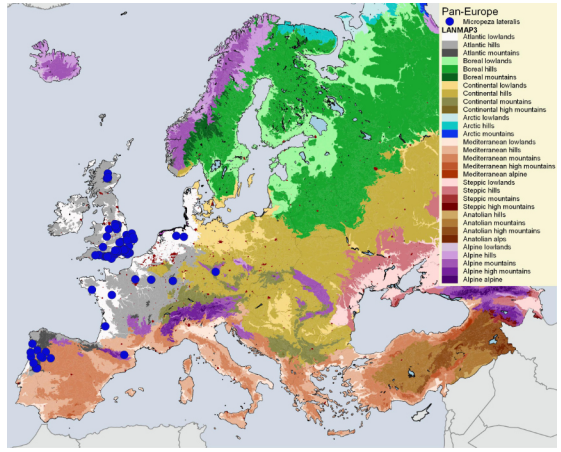


Fig. 6. European distribution
As points on LANMAP (Mücher, 2010), compiled 2020

Fig. 7. Europe: Country presence
(Sumner, 2018d + updates 2020)

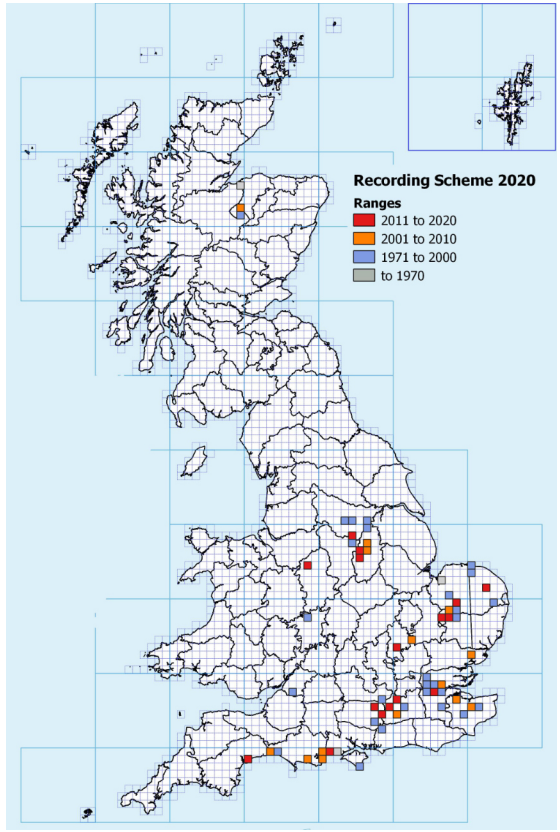


Fig. 8.GB distribution
By decade intervals, compiled 2020. Based upon 146 occurrences. Historic (grey) records may represent losses, both Culbin (Scotland) and New Forest are frequently visited by dipterists. Sites indicated by blue tiles may need investigation, though chance captures of single dispersing individuals can account for any of the outlying occurrences. The notable change since the 2016 map (Sumner, 2018d) is the cluster of records in Surrey and North Hampshire (Thames Basin Heath region), mainly from contributors to iRecord.

Phenology

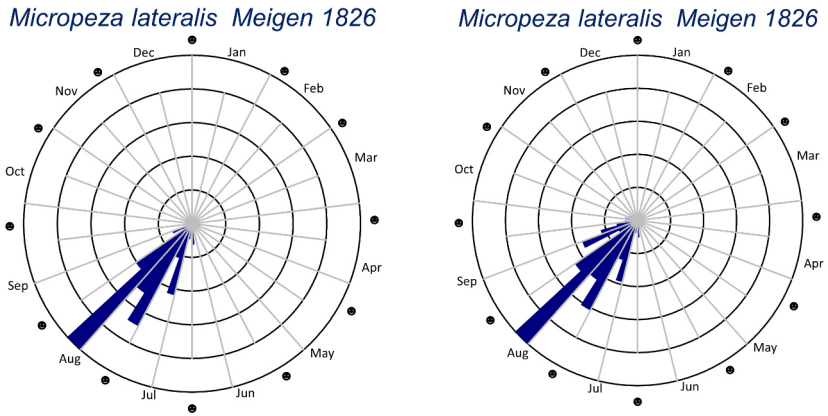


Fig. 9. **Fantail phenology - A. UK** (left) **& B. Europe** (right)
Radial sectors representing 4 week periods, months indicated by black dots (Sumner, 2018c). Bivoltine in the southern parts of Europe (South Germany, Portugal). Compiled 2020 from 209 records.

Biology

The strategy of feeding on root nodules of legumes in sandy soils

Nitrogen is a primary nutrient required for plant growth. Soil texture such as the percentage of sand determines the extent to which nitrogen is leached out of soils, as does factors such as soil drainage, soil texture and slope steepness. Plants in sandy soils, in which water moves quickly through large pores, are vulnerable to nitrogen loss.

Where primary production is thus limited by nitrogen, nitrogen fixing organisms and symbioses have an enormous competetive advantage. Their activity fixes nitrogen and alleviates the nitrogen limitation in the system as a whole (Vitousek, P.M., and Howarth, R.W. 2007). In sandy soils therefore, nitrogen-fixing legumes are important components of the plant community. In legumes atmospheric nitrogen is fixed into forms made usable to the plant via bacteria living in symbiotic relationships in the roots which form specific structures - root nodules. The application of fertiliser reduces root-nodule formation.

Consequently these nutrient-rich root nodules should prove to be a specific target for certain animals. There's a little research on this feeding pattern, arising from crop pest investigations, Bibro & Foote (1986) describe members of the Platystomatid genus *Rivellia* consuming legume root nodules and in New Zealand (where Micropezids are absent) the Coleopteran, *Sitona lepidus* (a weevil), is a pest on lucerne (*Medicago sativa*) however the whole plant is favoured at different stages of the weevil's life history (Barratt, Barker & Addison, 1996)

Micropezid larvae

Larval habitats of the Micropezids are little known and most have never been reared or collected, one exception is *Micropeza corrigiolata* whose larvae develop in the root nodules of several plants which they hollow out and and finally leave to pupate in the soil (Müller, 1957.) Ferrar (1987) states that eggs are laid just beneath the soil surface; larvae attack only fresh, healthy nodules, never decaying ones, and tunnel into them and hollow them out, until only an empty shell remains. Fully-fed third instar larvae burrow to about 30cm depth in the soil to overwinter; pupariation occurs in the soil in the spring. Perry (pers. comm.) states "I once found *M.corrigiolata* emerging from the soil in my garden, where Broad Beans had been planted the previous year.". Marshall (2012) proposes that other *Micropeza spp*. may have similar habits. Whilst Smith (1989) noted that *M.corrigiolata* larvae may bore into the root nodules of leguminous crops such as field pea (*Pisum arvense*), red clover (*Trifolium pratense*) and alfalfa (*Medicago sativa*) he remarked that the immature stages of *M.lateralis* were unknown. Allen (1982) suggested an association with Broom.

Biotic & abiotic associations

Based upon a number of observations and hypotheses posed in this and previous publications, the following are examined:

A. Hypotheses with respect to host plant: 1. That *M.lateralis* larvae feed on legume root nodules. 2. That *M.lateralis* larvae feed on the root nodules of Common Broom (*Cytisus scoparius*). 3. That *M.lateralis* larvae feed on the root nodules of other leguminous plants.

Detailed observation of adult behaviour could reveal much, however none has been observed following the four visits so far to Rainworth except for the fact that, as has been previously observed, that it can be found in vegetation surrounding Broom. Chance encounters by photographers may prove to be the best source of such observations.

An investigation that could be carried out is the digging up of the root nodules of Common Broom (and other legumes such as *Lotus*), examining them for larvae and then breeding them out. Projects of this nature would be difficult to implement.

B. Hypotheses with respect to Biotope: *M.lateralis* does not necessarily occur on Lowland heathland, rather on the grassy ruderal scrub and wet habitats which may actually occur outside the heathland boundaries. If the lowland heathland is dry one would not expect to find *M.lateralis* present but lowland heathland proximity may be an indicator of more suitable habitats. We suggest that *M.lateralis* seeks a degree of habitat heterogeneity and that the relationship with Lowland heathland is tenuous.

This is not an hypothesis that is easily testable. Given the descriptions here it may be possible to locate further suitable *M.lateralis* habitats in the UK and Europe.

C. Hypothesis with respect to Soils & Water: Analysis of the soil types at the known UK locations supports the hypothesis that freely draining, nutrient poor soils close to water are optimum. (Stuke, 2006 - "*ruderal on sandy ground*")

Soil type maps seem to offer a much more effective tool than habitat maps to locate other possible *M.lateralis* sites.

The above hypotheses are further investigated below:

Using occurrence data to examine Associations and Biotopes

The occurrence dataset of *M.lateralis* for the UK (see table 1) indicates that the species has been recorded in 86 locations (2016 figures). In most of these cases (except the 2015 Rainworth records) the records were obtained by sweep-netting in random locations. In some cases the detail of the location which was recorded is extremely poor, one or two only accurate to the 10km square and many only to the 1km square. Even precise locations given for sweep-netted occurrences may be poor, since entomologists typically sweep along a track, then record the location's position at best (via GPS) only when they pause to examine their catch, by estimating from a map or by incorrectly accepting the given centroid to a site.

1. Association with Common Broom (*Cytisus scoparius*)

Given the general vagueness of much of the *M.lateralis* location data and the fact that Common Broom is extremely widely distributed (BSBI's Online Atlas of the British Flora and Fauna at https://tinyurl.com/y39pjac2), no such analysis could be made.

2. Association with Biotopes

Comparison of *M.lateralis* locations to published habitat maps (Magic at http://www.magic.gov.uk) was made using Magic's online tools. The system chosen was the UK's Priority Habitat Inventory which details the 56 habitats of principal importance for the conservation of biodiversity (Defra, 2014), maps of which are provided on the Magic site.

Lowland heathland was the prime habitat examined, with any wetland habitats checked as a secondary factor.

The same cause of imprecision regarding location again constrains attempts to form definite associations.

Priority habitat	Locations within 2km
Lowland heathland	31
Lowland fens	9
Reedbeds	4
none	42

Fig. 10. Priority Habitats detected within 2km of the recorded locations of *M. lateralis* (2016)

Indicating no association with the biotopes examined. Nothing to suggest that any of them are associated with *M. lateralis* and certainly nothing to include *M. lateralis* as a typical species of any of the Priority Habitats.

3. Bioclim modelling

This species distribution modelling technique offers some limited capacity to examine potential distribution with respect to climatic abiotic factors. This particular climatic dataset is freely available for use in GIS.

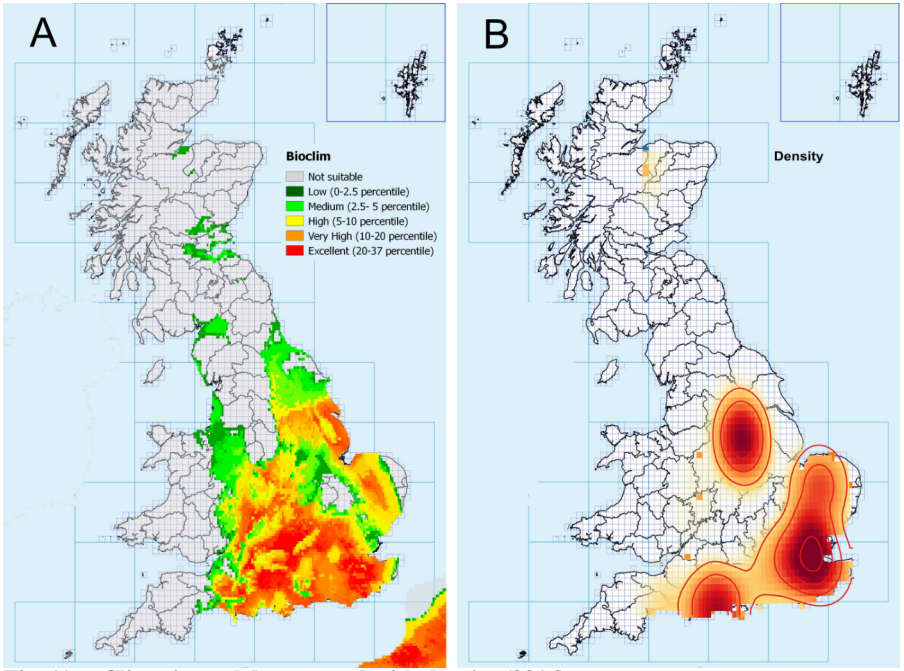


Fig. 11. Climatic model compared with density (2016)
A Bioclim = ecological niche modelling or habitat suitability modelling. **B** Simple density map of occurrences.

The simple distribution plot onto LANMAP (fig. 6) indicates that *M. lateralis* is confined to Atlantic Lowlands and Hills (accounting, for example, for its absence from predominantly Boreal regions). The Bioclim model applied to just the British Isles (fig. 11A) further refines that climatic model.

These analyses are useful up to a point if one assumes the limiting factors are just climatic (temperatures, precipitation.) However, as the density map suggests, other factors may be involved, accordingly more detailed soil categories and hydrogeology were examined:

4. Associations with soil & water

Habitat suitability modelling using additional abiotic factors of soil and water is more complex and made unfeasible because of the unavailability of suitable databases, most are behind paywalls.

Empirically, one can begin with the simple plotting of occurrences onto background maps of these factors:

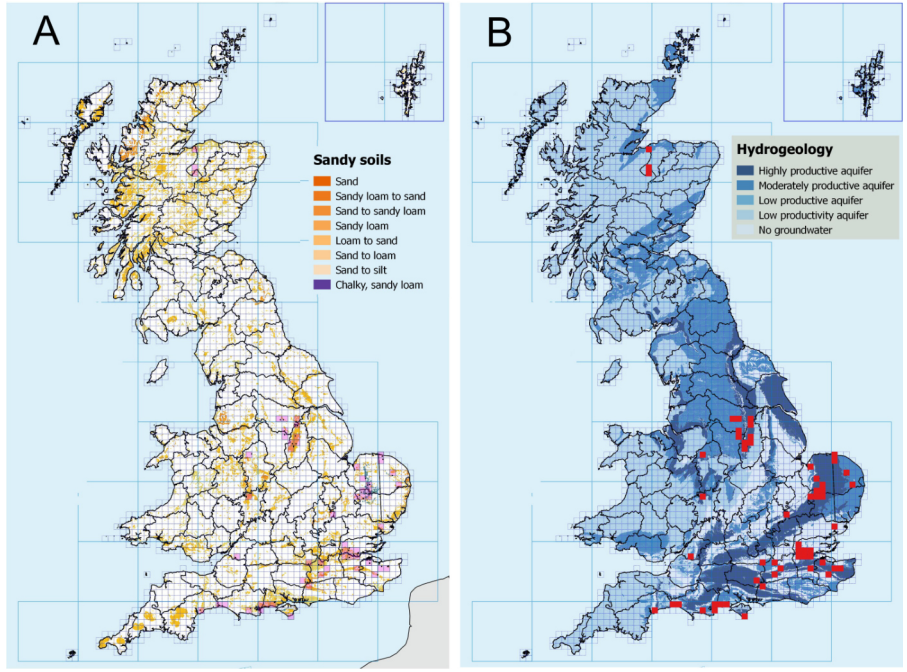


Fig. 12. Occurrences with respect to soil and hydrogeology
A Soils, occurrences as purple 1km squares. **B Hydrogeology**, occurrences as red squares. Abiotic data from British Geological Survey.

There is a clear association with each of the above abiotic factors. In the case of sandy soils in west Scotland, climatic conditions may also be a limiting factor. The association with highly productive aquifers seems strong.

To further investigate this suggested association with wetter soils, Soilscape's more detailed maps of soils were then compared to *M. lateralis* distribution using their online tools (http://www.landis.org.uk/soilscapes/) which utilises the LandIS soil categories (Thompson, 2007).

5. Associations with soil types

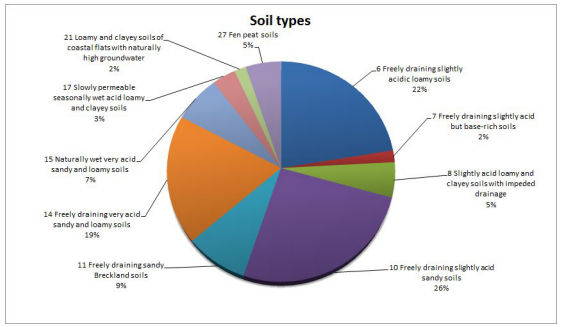


Fig. 13. Soil types determined at *M. lateralis* locations (2016)
Proportions of Soilscape's LandIS categories at each occurrence.

The majority of the sites are on freely draining soil, most of those being sandy, type 6 described as draining to local groundwater. High groundwater is a feature of types 15 & 21. The type 8 soils (impeded drainage) were chines on the south coast, steep valleys with streams running to the sea, these comprised more freely draining soils overlain on the type 8 clays.
Details of these associations are discussed more closely below in respect of metapopulations.

Dispersal behaviour

When we capture a fly at a particular location its presence there at that particular time and under those particular atmospheric conditions were determined by the insect's dispersal strategy. They move around, when they can, in search for resources, be this food, water, mates, hosts or ovipositioning sites. This dispersal can take place at different spatial and temporal scales (Lombaert, Boll & Lapchin, 2006) and is the result of complex behavioural traits which have evolved to exploit resources in complex heterogenous habitats.
These behavioural traits are the result of the insect processing a number of sensory cues in its search for resources (Bowler & Benton, 2005). In discussing phytophagous crop pests Heard (2000) details visual, olfactory, gustatory and tactile stimuli in addition to humidity and light intensity in respect of just one of these strategies: host plant selection. These responses change as the insect ages so a species may initially stay close to its emergence site but later on disperse and utilise a set of distance cues to detect potential hosts at varying degrees of distance from its emergence site. Air and ground temperature, pressure, day length, detection of polarised light reflections from water surfaces may also play a part in this complex suite of behaviours.

Feeding behaviour

This is unknown but from the mouthparts we can surmise generalised feeding. The aphid, *Acyrthosiphon pisum*, and two psyllid species (*Arytainilla spartiophila* and *Arytaina genistaei*) are known to occur on Common Broom in large numbers in particular years, apparently stressing the plants (Fowler et al 1996). This would produce a rain of honeydew onto plants below the branches of the shrub - the tall grasses where most catches of *M.lateralis* are made.

The Biology of *M.lateralis*

Based upon observations in Nottinghamshire we hypothesise the following:

The main or sole host plant of *Micropeza lateralis* is Common Broom (*Cytisus scoparius*), a component of the Scrub feature of Lowland Heathland (Buglife 2006). Common Broom is usually found in sunny sites on dry* sandy soils and can form scrub which ranges from extensive mature thickets, through developing thickets to sparse isolated clumps of bushes. All may be more or less intensively grazed. The habitat seemingly favoured by *M.lateralis* is the more extensive Broom scrub in which the shrubs are of different ages, in the process of regenerating and colonising and which are less intensively grazed - that is they are surrounded by tall dense grasses which prover cover and some protection from desiccation. For optimal breeding conditions the presence of water nearby is important since Micropezids are readily desiccated. Some open areas seem also to be necessary although this may be a ruderal (Stuke, 2006) feature favouring the Broom colonisation/ regeneration rather than the insect. All members of the genus *Micropeza* require high ground temperatures (Stubbs, pers comm & Roháček, 2012.)

*a better description for *M.lateralis* sites would be "well-drained" - see Fig.2

There have been reports of *M.lateralis* catches in areas well away from Common Broom (Stubbs pers comm), indeed the Bicton Common (Fig.5) specimen was caught in an area of exposed damp mud and scattered soft rush (*Juncus*) clumps (Wolton pers comm) but we are loth to suggest an alternative food plant as a reason for this, rather to propose that this is due to dispersal, humidity-seeking behaviour and some rather effective sweep netting. Perry (pers. comm.) records sweeping many from the underside of oak leaves in an otherwise dry region and *M. corrigiolota* has been noted on several occasions seeking the deep shade of hedgerow shrubs during hot conditions. Common Broom is ubiquitous, *M.lateralis* is a large Micropezid, a group known to seek out conditions of high humidity (c.f. Freidberg, 1984 who records sweeping *Micropeza* from springs with *Juncus* and *Mentha*) - which may well be the places *Micropeza* finds mates.
Bird's Foot Trefoil (*Lotus corniculatus*), a food plant of *M.corrigiolata*, is often present in the Broom scrub, the only identified host plant, "*this does not mean that it does not use other Fabaceae*" (Alexander pers comm) there is one record of the two species of *Micropeza* having been found together (Perry pers comm.)
In a recent paper by Hoebeke & Wheeler, 2016, the presence of *M.lateralis* is recorded in the United States. The paper tells us that Common Broom (*Cytisus scoparius*), was introduced into the Pacific Northwest as an ornamental from western Europe as early as the mid-1800s and was later planted extensively to stabilize and beautify roadside slopes and coastal sand dunes until it became an invasive pest species. The authors tell of a proportion of fauna related to European broom which has been introduced into North America with the host plant and speculate that other species may have arrived in broom litter accompanying solid ship ballast. It is probable that there was a higher proportion of broom litter than Bird's Foot Trefoil litter in this "broom litter", further suggesting an association with Common Broom.

Status

In Falk, Ismay, & Chandler, 2016 (A Provisional Assessment of the Status of Acalyptratae flies in the UK), *M.lateralis* is designated as **Nationally Scarce (provisional)**, described as "Species which are estimated to occur within the range of 16 to 100 10km squares" (this category was previously termed "Nationally Notable")

The provisional status was accorded as these were assessments based on data which would be insufficient for a formal IUCN status review. Indeed the data upon which the assessments were made was not current and did not include any data published electronically (i.e. the assessments did not include publicly accessible data made available on NBN Atlas), being based solely upon some published papers.

The formal IUCN Species Status Review reports are founded on a data table demonstrating hectad or tetrad count changes between defined time periods. Data published on the NBN Atlas may be used to determine these changes by the simple expedient of displaying the distribution map, selecting the Grid map and adjusting the date ranges. The following analysis however, incorporates data not yet submitted to NBN Atlas. The Provisional Assessments are revised at 10 year intervals and the 2016 version (Falk et al) is based upon data which did not extend beyond 2010, thus decades will suffice as date ranges.

	Pre 2001	2001 to 2010	2011 to 2020
Total UK Occurrences	83	37	26
Hectads (10km sq)	38	15	17
Monads (1km sq)	45	20	17

Fig. 14. UK occurrences of *Micropeza lateralis* by decades (October 2020)
Sources: All UK sources as specified in **Data Sources & References**

Accordingly the status designation is here revised to **Nationally Scarce** (methodology: Sumner, 2017)

Threats

In Falk et al. (2016) these are described as "*Habitat loss to agriculture, afforestation, fires etc. Mismanagement of sites through overgrazing, or cessation of grazing with subsequent scrub invasion and a loss of certain vegetation elements. Removal of Broom.*" To this can be added "***Mismanagement of sites due to amenity mowing and grazing, loss of sites due to development. Changes in water table due to drought or water course management. Nutrient enrichment.***" Though a ruderal species requiring Broom regrowth, insensitive development and Victorian tidiness regimes (Sumner, 2019) are detrimental. As a late species (fig.9.) current conservation mowing practises are contraindicated (Denton, 2013.)

Fig. 15. Habitat management by mowing in Sherwood Forest Country Park. 2015-07-15, SK 62229 68022

Populations

Increasing fragmentation of formerly contiguous ecosystems poses a severe threat to species forming metapopulations when extinction rates of local populations exceed colonisation rates (Tockner & Riede, 2009). The following study of "habitat patches" (*sensu* Bowler & Benton, 2005) overlain with *M. lateralis* occupancy serves to identify metapopulations which have arisen in part due to the degree of isolation resulting from such fragmentation. The conjectures below might serve to locate breeding sites for *M.lateralis*; we seem to have narrowed it down a lot for the Nottinghamshire metapopulation.

The UK distribution map suggests four metapopulations: mid Nottinghamshire, Brecklands & Norfolk and the Hampshire Basin, all of which seem well defined clusters. The South Essex to North Downs region (in the Home Counties) is less easily defined.

Scattered records elsewhere may indicate further metapopulations, the Worcestershire record is located on a large area of freely draining slightly acid sand soils which runs in a band to the north east of Kidderminster and warrants further searching in this region.

The Staffordshire record is on spoil but heaths at Hanchurch (SJ831399) and Blackbrook (SJ775397) across to Trentham Lake (SJ864401) may prove more productive.

The 2008 Abernethy Forest records are a welcome rediscovery by P. Kirby; Collin (1945) states he caught it in July 1933 and August 1935 at Culbin Sands, both areas are well recorded by other dipterists, both are on sand or sandy loam.

For other sites the distance from the metapopulations described suggests they may be smaller local "satellite" populations or chance captures of dispersing individuals.

Metapopulation 1: Nottinghamshire

In Nottinghamshire there are extensive amounts of Broom scrub throughout Sherwood Forest and Clumber park. Excessive tidying in some of these areas include mowing up to the trees and some intensive grazing. Small breeding satellite colonies are sure to exist in the more neglected areas of Clumber and Sherwood but the habitats observed so far have been suboptimal in the main.

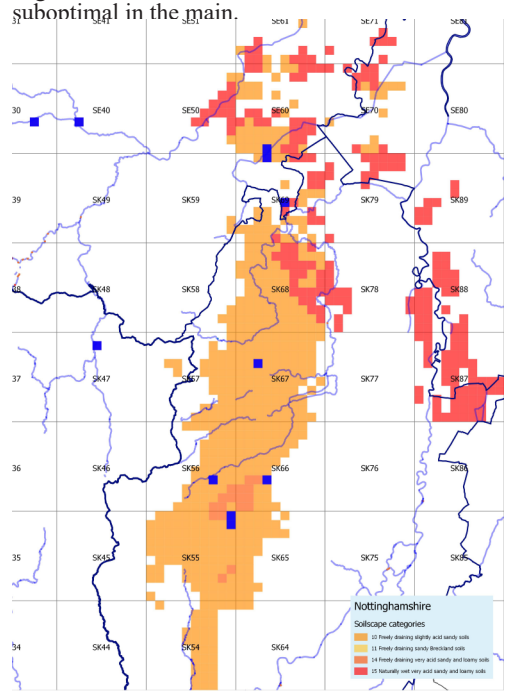


Fig. 16. Distribution of *M. lateralis* (blue squares) in Nottinghamshire and South-west Yorkshire.
Orientation: 10km squares labelled in their centres, Vice County boundaries (clockwise from top left): South-west York, North Lincoln, Notts, Derby.

A thriving colony of *M.lateralis* was found in Rainworth, south of the dry Rainworth Heath which nestles between disused sewage works and wet woodlands, Broom Scrub has developed on lower lying ground (partially horse-grazed) and roadside verges (Figs.2-4) up to the A617. The Broom scrub extends over the south side of this road onto scrubby ruderal areas with open ground designated as a "play area" (Fig.5) and otherwise used as general amenity land. In 2016 a pétanque terrain and hut was built in the centre of this site, the organisers were informed of the importance of the surrounding Broom shrubs but these were destroyed by 2020. Many nearby ruderal sites remain however.

Metapopulation 2: Brecklands and Norfolk

Historical sites include Broome Heath LNR near Ditchingham (TM347915) and Cockley Cley (TF792042) (Allen, 1982) on the borders of the Brecklands.

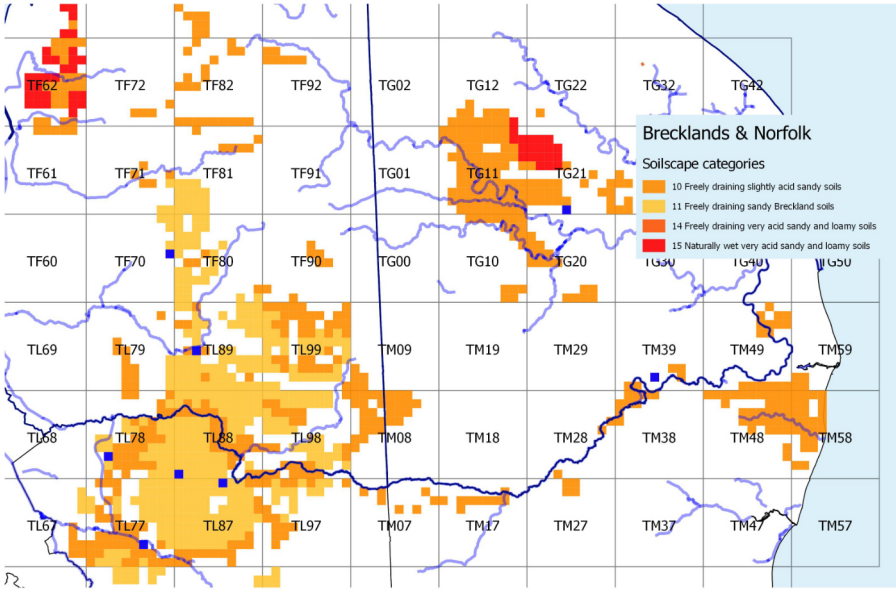


Fig. 17. Distribution of *M. lateralis* (blue squares) in the Brecklands and Norfolk
Orientation: 10km squares labelled in their centres. Vice County boundaries (clockwise from top left): West Norfolk, East Norfolk, East Suffolk, West Suffolk.

More recent records (2001) from Ivan Perry at Maidcross Hill, Lakenheath (TL7282) were on oak foliage in a very dry area and at Lynford Water (TL8294) he also noted the additional presence of *M.corrigiolata* and Bird's Foot Trefoil in 2013.

Further north in Norfolk the main Common Broom sites examined include the Cromer Ridge, a stack of glacial moraines between Holt and Trimingham, an anecdotal record here may be explained by the presence of a few clumps of Broom adjacent to the Holt Country Park car park but this was recently extended and much of the Common Broom cut back.

Metapopulation 3: Hampshire Basin

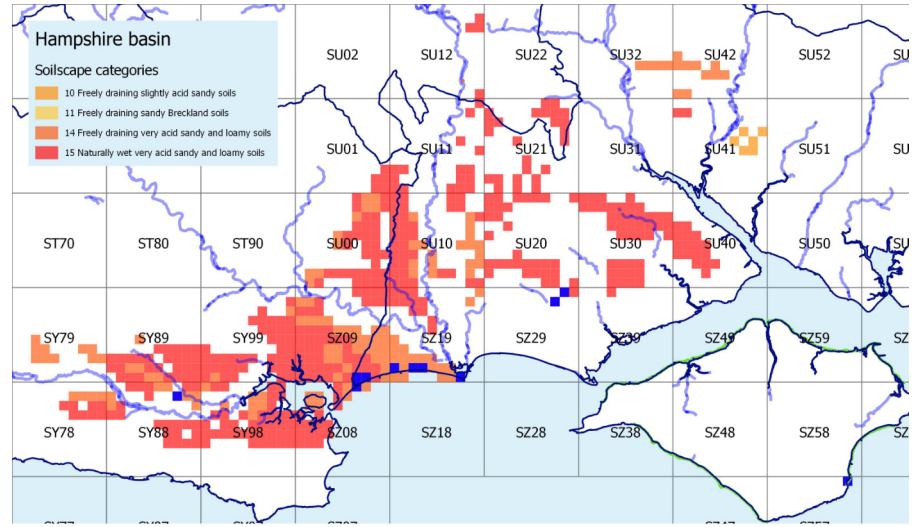


Fig. 18. Distribution of *M. lateralis* (blue squares) in the Hampshire Basin
Orientation: 10km squares labelled in their centres. Vice County boundaries (clockwise from top left): Dorset, South Wilts, South Hants, Isle of Wight.

The Hampshire Basin region is defined in terms of stratigraphy, structure and lithology in Yuangdetkla, 2013, the above map depicts its western portion.

Areas around Bournemouth and Poole Harbour suggest, from the soil types, that these and the nearby New Forest (a large area of lowland heathland) would have suitable habitats. Whilst there are a handful of records at the former sites (mainly coastal edge work by Martin Drake in 2006), several authors indicate that the invertebrate fauna in the New Forest is in decline (Stubbs in Denton, 2013) due to the grazing which produces "*closely grazed lawns*". The site which was home to three specimens (in Edinburgh Museum) taken by J.J.F.X. King on 2/8/1907 at Sway (SZ2899 and/or SZ2798) Ivan Perry suspects "*got grazed out of existence*". New Forest is an area extensively studied for centuries and there are no other records for *M.lateralis*. In Sherwood Forest Country Park (Nottinghamshire) the same lawns are achieved by Lawn Mowers (fig. 15)

Metapopulation 4: Home Counties

The metapopulation in the south east of England is diffuse (Figs. 9 & 12B), many records are from built-up suburbs to the west of London with a small scattering of sites to the south. Extending south east of the capital, towards Dover, is the North Downs in East Kent. Here the records lie exclusively on freely draining slightly acid loamy soils. To the west is a large sandy area on top of a moderately productive aquifer, clearly identifiable from the two distribution maps (Fig. 13) and lying between the Chilterns and the South Downs

The relatively high number of records from this region may be accounted for by "recorder effort", it being one the UK's most densely populated regions. Many records may be of dispersing and opportunistic individuals. Historic sites in East Kent were investigated in 2016 and no further records were made, indeed no Common Broom was found again in one site, presumably lost to road improvements and other changes.

Metapopulation 5: Thames Basin Heaths

Though a fifth metapopulation was suggested by historic records (figs. 11 & 12) when the above four were studied in 2018, the absence of recent records did not warrant its inclusion. It is clear however from very recent records (distribution map fig. 8) that this region supports a significant population.

European populations

The population dynamics in Europe are less easily studied as records are not so numerous. Though several countries report it as present in their Country Checklists (fig. 7) such lists do not specify georeferenced occurrences. The 63 non-UK records have been discovered through published papers and identification sites. Clusters are therefore difficult to estimate, the most clear (fig. 6) being north Portugal, north-west Spain and Saarland (a region of Germany adjacent to Luxembourg) westward into France..

Techniques

Recorder 6 biological recording database & spreadsheets, **NBN Atlas** (http://data.nbn.org.uk/) for UK *M.lateralis* records not managed by the Recording Scheme Organiser for the Micropezids & Tanypezids in the UK (D.Sumner) and **GBIF** (http://www.gbif.org/) for European records. Other records from literature searches, website trawls (diptera.info), published country lists and contributors to the Recording Scheme (directly and via **iRecord**)

Mendeley (http://www.mendeley.com/) for citation searches, organisation & collaboration,
iMatch 5 for image, project & document management.

Maps were prepared using **Quantum GIS** (http://www.qgis.org/), **TDWG** (Taxonomic Databases Working Group) **Ecoregions geospatial data** and **ISO standard 3166-1** (http://www.iso.org/iso/country_codes) for countries and **European Environment Agency** standards (https://www.eea.europa.eu/data-and-maps) for grids, colour themes, projections and extents. Full methodology available from the author. Caspar Mücher kindly provided the **LANMAP** geospatial dataset. Other GIS techniques via **Garmin Basecamp, OpenSource** maps, **Google Earth** and a **Garmin Montana** GPS device.

Soil data from **UKSO** at http://www.ukso.org using various data, the most useful of which were "Topsoil texture in Scotland" and the "Soilscape" data which provides a simplified method of soil categorisation for England. Various online tools for Grid Reference conversion, notably the **Batch Convert Tool** at http://gridreferencefinder.com/batchConvert/batchConvert.php which permits a copied spreadsheet list of Grid references to be converted to other formats, **Grid Reference Finder** at http://gridreferencefinder.com/ and **BSBI's Vice County** tool at http://herbariaunited.org/gridrefVC/

Image preparation using **Affinity Photo** and **Affinity Designer**.

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Datasets & further information

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