The effect of thermal Microclimates on the Nymphal development and abundance of the Common Meadow Spittlebug, *Philaenus Spumarius* (Hemiptera:Cicadomorpha: Aphrophoridae), in Hedgerows.

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THE EFFECT OF THERMAL MICROCLIMATES ON THE NYMPHAL DEVELOPMENT AND ABUNDANCE OF THE COMMON MEADOW SPITTLEBUG, *PHILAENUS SPUMARIUS* (HEMIPTERA: CICADOMORPHA: APHROPHORIDAE), IN HEDGEROWS

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ABSTRACT

Temperature plays fundamental roles in insect behaviour, ecology, and physiology, and influences development rates and distribution. Such data for the common spittlebug *Philaenus spumarius* (L.) is scarce, despite this species being an important vector for the bacterium *Xylella fastidiosa* in Europe. This study investigated the effect of thermal microclimates on nymphal *P. spumarius* through observations of temperature, abundance, and development on the north-west and south-east facing aspects of broadly east–west running hedgerows. Data were collected from the first appearance of spittle-masses in May through to the completion of nymphal development in July. Temperatures were higher on south-east facing aspects, except for early evening and overnight when north-west facing aspects were warmer. There was no consistent effect of aspect on abundance, however, numbers of spittle-masses peaked earlier on south-east facing aspects, and nymphs on south-east facing aspects developed more quickly compared to those on cooler north-west facing aspects.

INTRODUCTION

When considering impacts of climate change and weather patterns on insects, the importance of microclimates, as opposed to broader-scale ambient conditions, are increasingly being acknowledged (Duffy *et al.*, 2015; Pincebourde *et al.*, 2016). For insects, thermal microclimates are significant given they are poikilothermic and are therefore reliant on the external environment in regulating their body temperature (Wilmer, 1982; Rebaudo, Faye & Dangles, 2016). There are extensively documented effects of temperature on the chemical processes within insects, including digestion, metabolism, respiration, and consequently development (Clissold & Simpson, 2015; Bjørge *et al.*, 2018; Rebaudo & Rabhi, 2018).

Insects exploit spatial variation in microclimate through thermoregulatory behaviour, impacting their fitness and abundance in particular microhabitats (Cherrill & Brown, 1992; Heinrich, 1995; Logan, Wolesensky & Joern, 2007; Kenna, Pawar & Gill, 2021). Investigating responses of individual species to microclimatic variation will be important to gain understanding of how climate-change may impact species and community assemblages on a local-scale (Bernaschini, Valladares & Salvo, 2020; Pincebourde & Woods, 2020). Simulation models that combine published insect development rate responses with temperatures measured in the field have been produced, however, these often lack field observations on the insects themselves (Bernaschini *et al.*, 2019). Field investigations are required to advance understanding, especially regarding the influence of microclimates on pest outbreaks, with some species more likely to outbreak in warmer conditions associated with climate-change (Classen *et al.*, 2005; Ma & Ma, 2022).

Linear habitat features, such as woodland-edges and hedgerows, provide opportunities for studying impacts of microclimates (Bernaschini *et al.*, 2021). Those features orientated towards the south in the northern hemisphere, or the north in the southern hemisphere, will experience warmer average temperatures (Geiger, 1965; Chen, Franklin & Spies, 1995; Wright *et al.*, 2010). Whilst previous studies have looked extensively at the microclimates of linear habitats, few have done so in relation to insects specifically (Bernaschini *et al.*, 2019). Of those studies, it has been found that Orthoptera abundances and species richness are significantly greater on hedgerow sides that offer shelter from the prevailing wind and greater exposure to morning sun (Gardiner & Dover, 2008). Various butterfly species associated with hedgerows have also demonstrated greater abundance and preference for egg-laying on south-facing sides (Merckx & Berwaeters, 2010; Loeffler, Stuhldreher & Fartmann, 2013). Field investigations on the effects of fine-scale spatial variation in the thermal microclimates on the development rate of insects, is an under-developed research field (Bernaschini *et al.*, 2019). Hedgerows may provide a useful model system, whilst also being particularly relevant for insect pests associated with field margins.

One such species is the common meadow spittlebug *Philaenus spumarius* (L.) which is a vector of the bacterial plant-pathogen *Xyelella fastidiosa* (Cornara, Bosco & Fereres, 2018). European economic losses to this pathogen in olives alone could top €20 billion over the next 50-years (Schneider *et al.*, 2020). There is research interest into the response of *P. spumarius* to microclimatic variation, because both vector and disease are expected to spread with climate-change (Karban & Strauss, 2004; Godefroid *et al.*, 2018).

Philaenus spumarius is thought to be one of the most polyphagous species, having been recorded feeding on over 1000 species plant globally, but being associated primarily with dicotyledonous herbaceous species (Stewart & Harkin, 2020; Thompson, Harkin & Stewart, 2023). Field studies in olive-growing regions have revealed the importance of field-boundary habitats to their nymphal development (Cornara, Bosco & Fereres, 2018). In olive groves, the nymphs are typically associated with herbaceous ground flora before adults disperse to feed on trees (Bodino *et al.*, 2020; Beal *et al.*, 2021). A recent citizen science project in Britain recorded nymphs feeding on a wide range of herbaceous plants associated with field margins, and also a number of woody shrubs and trees that are common in the hedgerow canopy itself (Thompson, Harkin & Stewart, 2023). There have been few field investigations of the effect of thermal microclimates on nymphal abundance and development rates of *P. spumarius*, particularly in countries where *X. fastidiosa* is not currently present (Chartois *et al.*, 2023).

Given a) the importance of field-margins and hedgerows as habitat for *P. spumarius*, b) concern about the spread of *X. fastidiosa*, c) lack of field-data on factors impacting the small-scale distribution and development of the *P. spumarius*, and d) the utility of hedgerows as model systems for investigating the effects of microclimate, this study brings these strands together. We investigated spatial and temporal variation in temperature, and the abundance and development of nymphs of *P. spumarius* on north and south faces of hedgerows at a field site in Wales, United Kingdom.

Methods

Study sites

The study site was at Fron Farm, Capel Bangor, Mid-Wales (UK) (British National Grid Reference SN665805; Latitude 52.406, Longitude −3.964). Six 75-metre sections were selected at altitudes between 40 m and 75 m (Fig. 1). The hedgerow sections were aligned along the contours of a gently sloping, south-east facing hillside, such that the predominantly south-east facing aspects were facing downslope (and north-west facing aspects were facing upslope). Sections 1–5 formed the boundary between sheep-grazed pasture and a farm-track. Section 6 ran parallel to a main road (the A44) with pasture to the north and a 5 m grass verge along the road (Fig. 1).

Based on the metrics developed by Garratt *et al*. (2017) all hedgerow sections were judged to be high quality with no gaps. The six sections were each dominated (>80% of length) by hawthorn *Crataegus monogyna*, with occasional blackthorn *Prunus spinosa*, hazel *Corylus avellana* and sessile oak *Quercus petraea*. Ash *Fraxinus excelsior*, holly *Ilex aquifolium* and dog rose *Rosa canina* also occurred in the hedge canopy but were rare. Of these species, all but sessile oak and holly are known to be hosts of nymphs of *P. spumarius* (Thompson, Harkin & Stewart, 2023). Species of herbaceous dicotyledons in the hedge-bottoms were typical of the habitat (Andrews *et al*., 1999; Cherrill *et al*., 2001). Species found in at least three of the six sections were: *Urtica dioica*, *Rumex* sp, *Ranunculus repens*, *Galium aparine*, *Plantago lanceolata*, *Silene dioica*, *Veronica chamaedrys*, *Fumaria officinalis*, *Epilobium* sp, *Filipendula ulmaria*, *Cirsium arvense*, and *Heracleum sphondylium*. In addition, *Rubus fruticosus* agg., *Lonicera periclymenum*, *Calystegia sepium*, and *Hedera helix* were noted as climbers from the hedge-bottom into the hedge canopy. Nomenclature for plants follows Stace (2010).

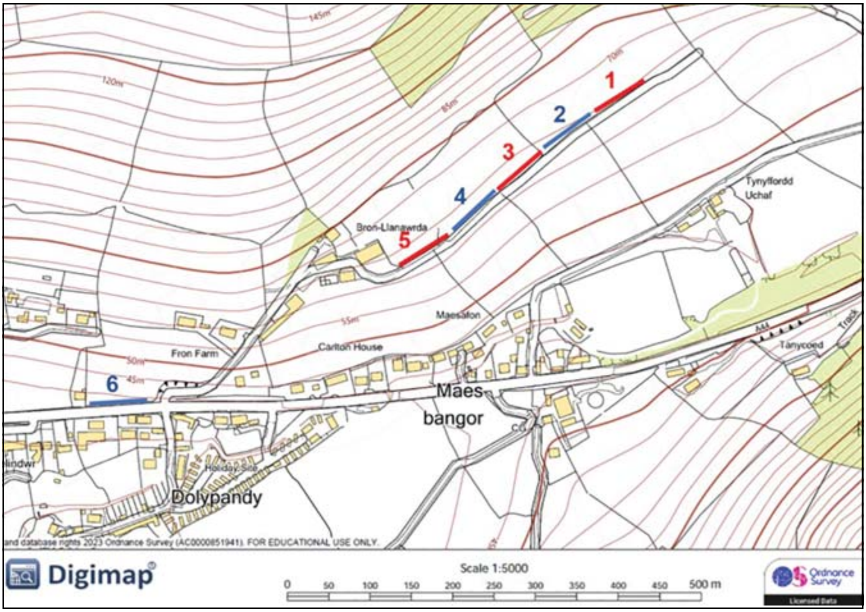


Fig. 1. Map of the hedgerow sections used for observing abundance of spittle-masses and development of nymphs. Sections 1, 3 and 5 (red) were used to monitor abundance of spittle-masses. Sections 2, 4 and 6 (blue) were used to monitor nymphal development, Brown lines show contours at 5 m intervals. Map created under licence using Digimap Ordnance Survey Collection, https://digimap.edina.ac.uk/.

No hedge management was carried out during the study which ran from early May to the end of July in 2021. Hedgerow height and width were measured at five regularly spaced points within each section at the start and end of data collection. Mean heights and widths across the six sections ranged form 266–286 cm and 207–231 cm respectively in May and grew to 317–343 cm and 231–308 cm respectively at the end of the study.

Temperature microclimate within hedgerows

Temperature measurements were taken by placing a Thermochron® temperature recording iButton® on opposite sides of each section at their mid-points. The iButton® sensors recorded temperature with a resolution of $\pm 0.5°$ C (in the range $-10°$ to $+65°$C). Each sensor was place halfway up the hedge in a thin white cotton muslin bag tied to the tip of a branch to reflect the tendency of spittle-masses to occur on young shoots. Placing the sensors in a muslin bag may have influenced the temperatures recorded, but this effect would have been similar for all sensors. The sensors were set to take measurements every 15-minutes for 24 hours, commencing at midnight each Tuesday and Friday for 12 weeks from 4 May to 23 July 2021 (hereafter referred to as weeks 1 to 12). These 12 weeks covered the nymphal development period during the study and are typical for the occurrence of nymphs in this species (Whittaker, 1973).

Data on regional weather was obtained from the UK Meteorological Office (Table 1). Daily minimum and maximum temperatures, rainfall, and wind speed were available at a weather station at Trawsgoed (British National Grid Reference SN675735; Latitude 52.343, Longitude -3.949) with an altitude of 63 m and 7 km from the study site. Daily sunshine hours were not available from this location and were obtained from a second weather station at Saint Harmon (British National Grid Reference SN996750; Latitude 52.364, Longitude -3.476) at an altitude of 291 m and 33 km from the study site. To allow direct comparison with the temperatures recorded from the hedge sections, data were summarised for only the two days per week in which temperatures were recorded (Table 1). Where rainfull was recorded as 'trace' a value of 0.01 mm was used to calculate the mean and Standard Deviation (SD).

Table 1. Daily weather data from Meteorological Office weather stations for the Tuesdays and Fridays in each month when temperature was recorded from hedgerow sections using iButton® sensors. Temperature, rainfall and wind speed are from Trawsgoed (7 km from the study site), while sunshine hours are from Saint Harmon (33 km from the study site). In each case the mean is shown with Standard Deviation in brackets (n = 8 in each case).

Month	Daily minimum temperature C	Daily maximum temperature C	Daily rainfall total (mm)	Daily sunshine hours	Daily mean wind speed (knots)
May	6.3 (3.4)	13.4 (2.3)	10.2 (11.9)	4.6 (4.4)	5.9 (4.9)
June	6.7 (4.0)	19.8 (3.0)	0.3 (0.6)	8.2 (2.2)	4.3 (1.3)
July	12.0 (2.3)	22.0 (4.1)	0.9 (2.1)	7.1 (4.7)	3.5 (1.4)

Abundance of spittle-masses and development of nymphs

Abundance of spittle-masses and the development of nymphs were monitored on the woody shrub canopy. Spittle-masses in the shady hedge-bottom herbaceous ground flora were not counted because this environment was less likely to show consistent differences in microclimate between opposite sides of the hedge. However, the dates of first appearance of spittle-masses in the ground flora were noted.

Abundance and development were monitored on different sections (Fig. 1) because the latter involved destructive sampling. Monitoring of the abundance of spittle-masses was carried out on sections 1, 3 and 5. Starting at 10.00 h, spittle-masses were recorded every Tuesday and Friday for each of weeks 1 to 12. Observations were made by counting spittle-masses on the shoots of hedgerow shrubs. Adapting the recording method of other studies measuring insect abundance, each aspect of the three hedgerow sections was surveyed for 15-minutes (Garrett *et al.*, 2017). Estimates of abundance were made by counting spittle-masses whilst walking slowly along each section; a 75 m length being traversed in 15 minutes. Although spittle-masses occurred mainly at the growing tips of shoots, in dense areas, twigs were moved carefully to ensure thorough observation. Numbers of nymphs within individual spittle-masses were not recorded to minimise disturbance (Albre, Carrasco & Gibernau, 2020).

Monitoring nymphal development involved the collection of 10 spittle-masses per aspect from each of hedgerow sections 2, 4 and 6. To avoid exhausting local populations before the end of the study collections were made at two-week intervals as follows: 4 June (week 5), 18 June (week 7) and 2 July (week 9). Spittle-masses were collected whole by cutting the shoots on which they were found and placing each into separate labelled specimen tubes. Samples were frozen for subsequent determination of developmental stage. Identification of the five development nymphal stages followed Yurtsever (2000) and Stockmann *et al.* (2013). All nymphs were confirmed to be *P. spumarius*. A limitation of the study is that the species of woody shrub from which the spittle-masses were collected was not recorded.

Statistical analysis

Statistical analysis used the R package (R Core Team, 2020). The distribution of data sets was investigated using the 'ggplot2' package (Whickham, 2016). Data on abundance and developmental stage did not fit a Gaussian distribution and data were analysed using Generalized Linear Models (GLM) with quasipoisson distributions and 'link = log' funciton.

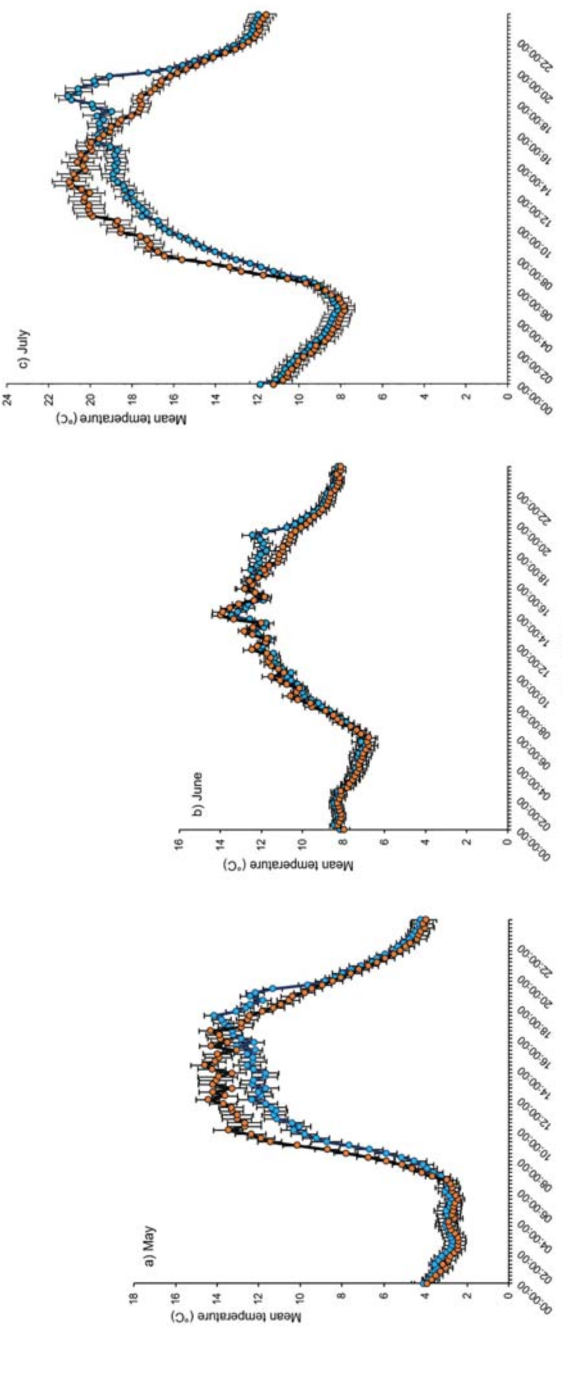
Before plotting of the data on abundance of spittle-masses, the mean of the counts from Tuesday and Friday was calculated for each week to give a clearer visual interpretation of the species' phenology. Data on developmental stage of nymphs was plotted as box-plots due to the ordinal nature of the observations.

Statistical analyses for the temperature data are not reported because the large sample size (total N = 27,648 observations) resulted in very high statistical power such that all contrasts were statistically significant (including those associated with very small effects of likely limited ecological significance).

Results

Hedgerow microclimate

Patterns of diurnal temperature variation across the six sections were broadly consistent, hence data for sections have been pooled for each month in Fig. 2.



Fiag. 2. The mean daily temperature (± Standard Error) at 15-minute intervals on north-west (blue) and south-east (orange) facing aspects of six hedgerow sections in a) May, b) June and c) July 2021. N = 48 for each mean and SE.

Temperatures on south-east aspects were generally warmer during the day, but warmer on north-west facing aspects in early evening and overnight (Fig. 2). The warmer evening temperatures on north-west facing aspects occurred because the arc of the sun led to sunlight striking the upslope north-west facing side of the hedge sections late in the day.

Differences between daytime temperatures on north-west and south-east facing aspects were less pronounced in June (Fig. 2b) compared to in May (Fig. 2a) and July (Fig. 2c). There was also less pronounced diurnal variation in June compared to May and July. The experience of working at the study site suggested that June was relatively overcast in comparison to May and July which could explain the differences between months. Daily sunshine hours recorded at Saint Harmon weather station were slightly higher in June than in May or July (Table 1). However, this weather station was 33 km distant and at a higher altitude than the study site which may explain the difference with the perceived weather on-site. The minimum and maximum temperatures recorded at Trawsgoed weather station, at the same altitude and 7 km distant, broadly paralleled those recorded at the study site (Table 1, Fig. 2).

Abundance of spittle-masses

The first spittle-masses in hedge canopies were recorded in the third week of May (Fig. 3). This coincided with the first appearance of spittle-masses on the herbaceous hedge-bottom flora.

Numbers of spittle-masses differed significantly between weeks ($F_{11,73} = 162.7$, $P < 0.0001$) and sections ($F_{2,73} = 64.6$, $P < 0.0001$). Numbers of spittle-masses on section 3 (Fig. 3b) were lower than on the other two sections (Figs. 3a, 3c). There was a significant interaction between aspect and section ($F_{2,73} = 26.4$, $P < 0.0001$). The north-west facing aspects of sections 1 and 3 had higher peak abundance than on their south-east facing aspects (Figs. 3a, 3b). In contrast, section 5 had a higher peak on the south-east aspect, than north-west aspect (Fig. 3c). There was also a significant interaction between aspect and week ($F_{11,73} = 7.49$, $P < 0.0001$). At all three sections, abundance on south-east aspects peaked earlier than on north-west aspects suggesting faster development.

Development of nymphs

A single nymph was found in each spittle-mass. Developmental stage differed significantly between aspects ($F_{1,163} = 14.9$, $P < 0.001$) and weeks ($F_{2,163} = 94.8$, $P < 0.0001$), but not sections ($F_{2,163} = 0.56$, $P = 0.58$). On all three sections, development was more advanced for spittle-masses on the south-east aspects (Fig. 4). This may explain the earlier peak in abundance of spittle-masses seen in Fig. 3. The difference between development stages on the north-west and south-east aspects occurred mainly in weeks 5 and 7, with the north-west specimens seemingly catching up with their south-east counterparts by week 9. However, the smaller difference in week 9 can be attributed to an artefact of recording, because spittlebugs were not counted after they moulted to the adult stage and left the spittle-mass.

Discussion

The south-east facing aspects of the hedgerows were on average warmer during daylight hours (Fig. 2). These findings are supported by previous studies in the northern hemisphere. Based on reviews of the evidence from field observations and

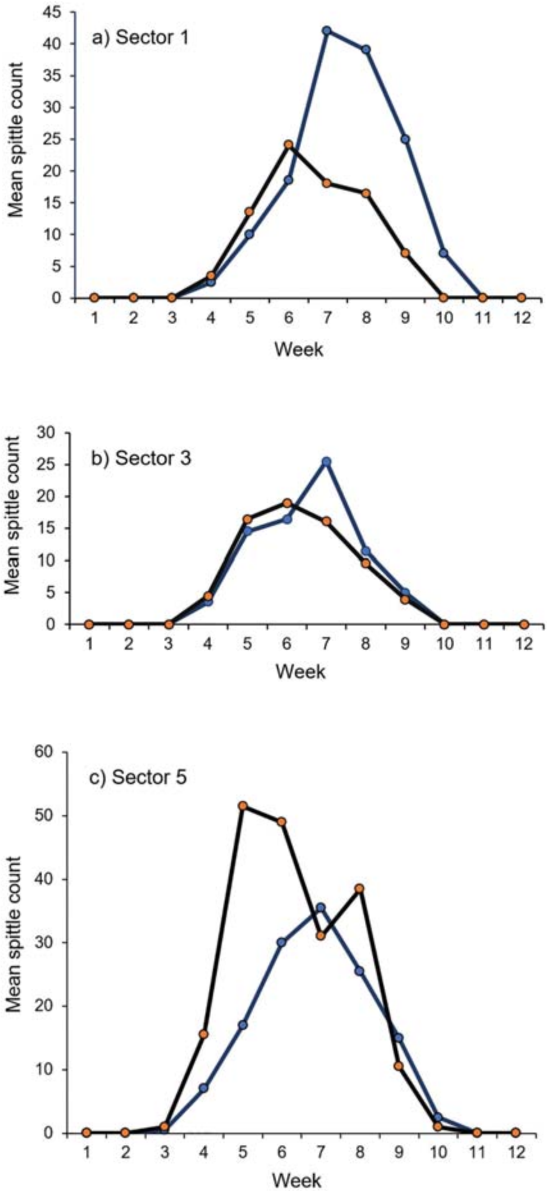


Fig. 3. The mean weekly number of spittle-masses observed on north-west (blue) and south-east (orange) facing hedgerow aspects for a) section 1, b) section 3, and c) section 5. Each point is a mean of the counts for Tuesday and Friday in that week.

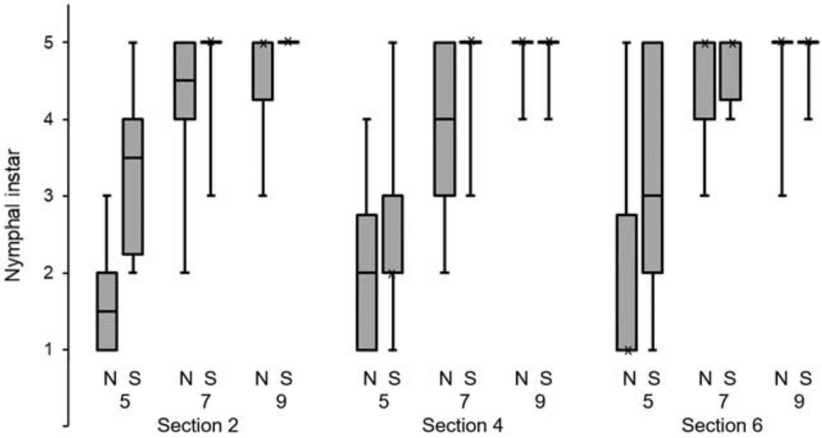


Fig. 4. Nymphal development stages on north-west (N) and south-east (S) aspects of three hedgerow sections for weeks 5, 7 and 9. Each box-plot is based on 10 spittle-masses (each containing a single nymph). The interquartile range is shown by the shaded box. In cases where the median coincides with either the first or third quartile, the median is identified with an x. The whiskers show minimum and maximum stages.

mathematical simulations of incident isolation on east-west orientated olive hedgerows in southern Europe, Connor *et al.* (2014) and Trentacoste, Connor & Gómez-del-Campo (2015) demonstrated greater insolation on the south-sides compared to their north-facing sides. They also find support from studies on northern-hemisphere woodland edges, such as Matlack (1993) and Geiger (1965), who recorded greater temperatures on south-facing aspects in eastern USA and Germany, respectively. In woodlands, edges of different aspect can be ranked in order of increasing annual insolation as follows: N < NE and NW < E and W < SE and SW < S (Geiger, 1965; Forman, 1995). This ranking is consistent throughout the year, except for mid-summer when increased canopy interception (and the sun's position in the sky) leads to comparable inputs at S, SE, SW, E and W facing edges (which still receive more light than NE, NW and N facing edges) (Forman, 1995, p. 87).

The spittlebug lays its eggs on its host, utilising crevices in bark when ovipositing on shrubs, and in leaf litter on the soil surface (EPPO, 2020). Eggs hatch in spring and the nymphs disperse to locate a suitable feeding point. Feeding nymphs are relatively immobile, and local abundances and developmental rates are likely to be influenced by choice of oviposition site, date of egg hatch, selection of feeding site, temperature, food quality and nymphal survival.

Despite the differences in temperature, the abundance of nymphs did not differ consistently between north-west and south-east facing aspects (Fig. 3). Intuitively we had speculated that there would be higher numbers on the warmer south-east facing aspects, perhaps due to differential movement of first instar nymphs to warmer feeding sites, and/or a preference for maternal females to oviposit on the sunny side of the hedge. Studies of female oviposition behaviour and nymphal dispersal from egg-laying site, however, are lacking.

Studies in warmer Mediterranean and semi-arid climates found fewer nymphs in years when temperatures exceeded the optimum for development and survival (Karban & Strauss, 2004, Antonatos *et al.*, 2021, Chartois *et al.*, 2023). The spittle-mass buffers the nymph against temperature fluctuations and desiccation (Sahayaraj *et al.*, 2021), but hot weather can impact survival, particularly when humidity is low (Karban & Strauss, 2004). In our study, temperatures were less extreme (Table 1, Fig. 2) and are unlikely to have influenced survival, although there was an effect of aspect on development rates (Fig. 4).

Nymphs on south-east facing aspects were at a more advanced stage of development than those on north-west facing aspects (Fig. 4). This may explain why abundance peaked earlier on south-east facing aspects (Fig. 3). Temperatures on south-facing aspects were typically closer to the optimum for development during daylight hours (Chmiel & Wilson, 1979; Antonatos *et al.*, 2021) suggesting that temperature differences were the most likely cause. However, differences in food quality between hedge aspects also need to be considered.

The nutritional content of xylem fluid can be influenced by soil fertility (Hartley & Gardner, 1995; Wood & Jones, 2020), but this is unlikely to have impacted the nutritional value of xylem fluid on north-west and south-east facing aspects of the hedges in our study. The hedges were comprised of a single row of shrubs – such that nymphs on north- and south-facing aspects were feeding on opposite sides of the same plants. Water loss through transpiration of leaves on south-east facing aspects may, however, have been greater than on north-west facing aspects, such that flow rates of xylem fluids may have differed between sunny and shady sides of the hedge (Hirons & Thomas, 2018, p. 253).

Woods & Jones (2020) found that body size of *P. spumarius* differed between species of host plant. The hedgerow shrubs in our study were predominantly hawthorn, although we did not record the species from which spittle-masses were collected. We cannot, therefore, rule out that the direct effects of temperature or nymphal development rates, may have interacted with the unquantified effects of nymphal diet.

The common meadow spittlebug is the subject of increased research interest because of its role as a vector of *Xylella fastidiosa*. This bacterium multiplies within the xylem of plants, eventually blocking them, and potentially causing the death of the plant. *Xylella fastidiosa* has caused substantial losses of olive trees in the Mediterranean region (Cornara, Bosco & Fereres, 2018). Given the extremely broad range of plants upon which *P. spumarius* feeds and its widespread occurrence in northern Europe, there is a risk to native flora should the disease spread. Although *X. fastidiosa* has not been recorded in the UK, an understanding of the ecology of the spittlebug vector is desirable in anticipation of its arrival.

The present study shows that small scale variation in temperature did not influence local abundance of spittle-masses, but there was an effect of aspect on development. Plants in sunnier and warmer locations might be more vulnerable to *X. fastidiosa* because of the earlier appearance of mobile adults that could transfer the bacterium between plants. Studies of this nature can also provide insights into potential ecological impacts of climate-change (Bernaschini *et al.*, 2019; Godefroid *et al.*, 2022). The insect's responses to small-scale spatial variation in temperature suggests that initial responses to climate warming are likely to be seen in terms of relatively subtle changes in timing of development, rather than dramatic changes in abundance and distribution.

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BOOK REVIEW

The Moths of Lancashire by S. Palmer & B. Smart. Pisces Publications, Newbury, 2024. 662 pp. Hardback. £37.95. ISBN 978-1-913994-13-6.

There is a school of thought that suggests the age of publishing hardcopy distribution atlases of fauna and flora is past, as access to 'live' websites which can be constantly updated make them irrelevant. Indeed, there is a new crop of excellent county moth websites which are increasing in number. However, this magnificent new volume from the highly respected moth experts Steve Palmer and Ben Smart, demonstrates just why the hard-copy volume still has an extremely important role to play and should be on the bookshelf of any serious moth enthusiast. Aside from the pleasure of flicking through pages of such a volume and landing on unexpected nuggets of information (less easily done on screen), one of the main advantages is how a book can act as a 'snapshot' of the status of the moth fauna at a point in time. It is much easier to understand how populations are changing when the status at a particular time is highlighted and supported by historic data and text explaining how this status has been changing prior to that time.

In addition, *The Moths of Lancashire* continues the progression in quality, both in data and in the means of publishing, that can be traced over the years that county faunas have been published. The authors set out to produce a history and distribution for all species of both micro and macro-moth ever recorded in the county of Lancashire up to and including the 2022 season (although an additional 11 species added to the county list in 2023 are included in an addendum – a reflection perhaps on how quickly populations are changing and also on just how popular moth recording has become recently). For the 1,570 species in total that are included, the admirable aim to include colour photographs of each species using images only of examples from the county has created an excellent record of the fauna. Not only are there excellent images of adult moths but also of larvae and habitat shots for some. These images are accompanied by clear, colour distribution maps and phenology graphs. Some of these images (perhaps especially of the larvae) will be very useful, particularly to micro-lepidoptera recorders across the country and the ability to include colour imagery on every page reflects both the reductions in cost in publishing techniques that digitisation has brought along with excellent sponsorship in this instance.

Aside from each species account, as you might expect, the introductory chapters cover a definition of the county (based on the two vice-counties 59 and 60), a brief history of moth recording and recorders of importance locally and then sections on moth habitats, covering climate, geology and history, and then summaries of particular habitat types with examples of important sites and their associate moth fauna.

After the species accounts, appendices listing sources, rejected records and the like are complimented by a section on field work, how to do it and how to get involved, which is a nice touch. If I have one small criticism it is that I would have preferred to see some of the more interesting stories about some species to have been pulled out into the introductory chapters. For example, the strange story of *Euclemensia woodiella* might have been better in a general section along with discussion on other unique or interesting aspects of the moth fauna from this part of the north west of England. Although species characteristic of the moth habitats covered in the introductory chapters are mentioned, it might have been instructive to have also had a section pulling out which species are special in this part of England and why, particularly for those of us not that familiar with the county. Such a section could also have highlighted which species may or may not be being impacted by climate change or other collective pressures, such as urbanisation or intensive agricultural practices.

With approximately 2 million moth records incorporated for this one county and the contributions having been received from over 2,000 recorders, those studying the moths of Lancashire are very well served by this publication. The authors and publishers should be congratulated on the excellence of the information but also the quality of the printing and the Tanyptera Trust and National Museums, Liverpool also praised for their support and funding which has enabled it to be produced to such a high standard. I fully recommend this to any moth recorders whether local to or visiting Lancashire or not.

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