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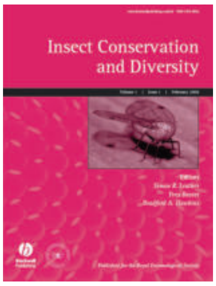

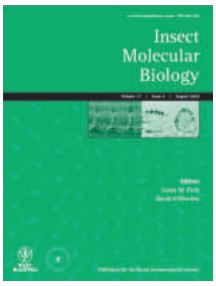

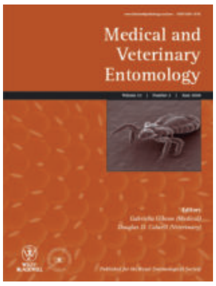

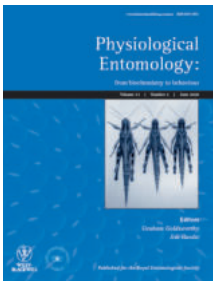

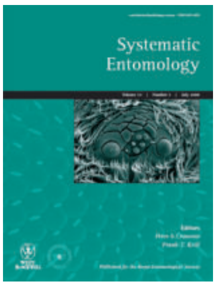

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Extatosoma tiratium nymph. Beth Ripper

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Bulletin of the Royal Entomological Society

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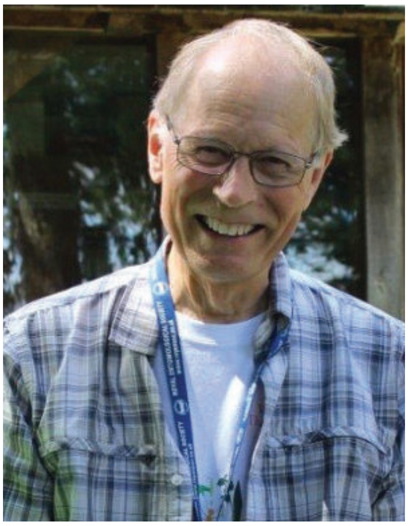
EDITORIAL



Welcome to the third edition of *Antenna* for 2017, we hope that you have had an enjoyable summer, filled with entomological delights.

It appears that this summer may have seen a slight media renaissance regarding insects. The first indication came whilst I was waiting for takeoff on board the aircraft that would transport me to my holiday on the Mediterranean coast. I was leafing through the inflight magazine when my attention was arrested; no, stopped in its tracks. There in front of me was an article entitled, 'How to throw an insect dinner party'. Now that is amazing, an article promoting insects as food in a magazine that normally offers advice on tourist destinations or holiday reading, the offered article being based on the Nordic Food Lab's recent book: "*On Eating Insects*". A curious start to my vacation, but wonderful to see the concept of insects as food being brought to the attention of such a wide audience. Later that month, I was listening to Radio 4 whilst having breakfast. It was a fascinating piece on the use of sound recorders to assess the structural state of wood paneling in stately homes. A technique that, it turned out, can also be used to detect wood boring insects. David Chesmore from York University explained how this technique could be used to monitor ancient timbers for a number of destructive beetles. The crunch of my muesli was accompanied by the scraping of anobid beetle larvae in ancient timbers. Then a few days later David Attenborough was on Radio 4 discussing our butterflies and 'The One Show' showed a series of short films on bee-hawk moths, chimney-wasps and solitary bees. I checked 'The One Show' website, and over the past two years they have shown fifteen short films dealing with invertebrates. Then Robin Ince and Brian Cox, of 'The Infinite Monkey Cage', debated "Will insects inherit the earth?" with Tim Cockerel, Amoret Whitaker and Dave Gorman. Furthermore, the famous tourist attraction 'Longleat' decided that this would be their 'Bug Summer' and imported a dozen giant animatronic insects from China to enhance the Estate, also hosting the BIAZA conference on Insect Conservation. So not only were there insects in the park, but also entomologists. Insects were creeping in, where big cats were once the main attraction. The second "*Beetle Boy*" novel was also published, ensuring another surge of interest among young people. So, overall, this summer saw a discernible increase in the public profile of insects. Simon Leather described the lack of awareness of insects as 'Entomyopia' (a limited awareness of insects as either pollinators or a nuisance). Could it be that the media have acquired new glasses with which to view the natural world? If so we hope they continue to visit the entomological optician.

So back to *Antenna*, we have another diverse issue to enhance your autumn reading. Edition three offers Australian stick insects from Beth Ripper, a fascinating exploration of insects associated with Bryophytes from Richard Jefferson, the curious tale of the Virginia silk worm from David Ransome & David Lees, and an outline of a bold large-scale experiment investigating the impact of increased carbon dioxide levels on trees and their associated insects from Liam Crowley. We feature the usual Society News, which includes reports from the PG Forum and the Big Bang Science Fair. We also reveal the winners of the student essay competition and the Wallace Award, and offer our congratulations to the recipients. We also offer six book reviews with another eight waiting for the next edition, with two more having recently arrived. One of the recent arrivals is an American student textbook by David Rivers entitled "*Insects, World Domination*". While insects certainly have achieved World Domination long ago, it appears that this summer entomologists in the UK have raised the public profile of insects and have taken a small step in this direction.

Peter Smithers

Guidelines for submitting photographs

To maintain a high quality we suggest that submissions for *Antenna* be presented via e-mail or on CD. Files must be in a PC-compatible format preferably in MS Word.

Electronic images can be embedded in the Word document but we will also require separate electronic images. These images should be at least 300dpi at an image size that is either equal to, or greater than the expected final published size.

Please do not submit images that have been printed from a computer on a domestic inkjet or laser printer. Even if the camera is a good one and photo quality paper is used, the graininess is very hard to deal with. If plain paper is used, the prints are virtually unusable.

Photos taken on film should ideally be submitted as slides or as reasonable sized prints for us to scan or alternatively they can be scanned in by authors provided the scanner is capable of scanning at up to 1200dpi.

If an image is intended for the front cover then the photograph should be in portrait format (i.e. the shape of the final image) and will need to be quite a large file size (at least 5,000kb) or a good quality slide or print.

To give an idea as to what happens when the image is not of sufficient size, take a look at these two photographs. One is 300dpi and the other is 72dpi.

300dpi

72dpi

CORRESPONDENCE

Green-veined White and Orange Tip sex imbalance

Dear Editors,

I have been breeding butterflies and moths for about 60 years, for many of those years on a professional basis.

Last year, I reared over 100 Green-veined White pupae (*Pieris napi*) along with 30 pupae of the Orange Tip (*Anthocharis cardamines*). The larvae of both species were reared in identical conditions and the pupae kept over winter in my garage.

This May, the *cardamines* emerged with a sex ratio of almost exactly half males and females. However, the *napi*, hatching over a similar time scale produced the following :- From 107 pupae, 105 were females and two were males. I have never before experienced such an imbalance of sexes.

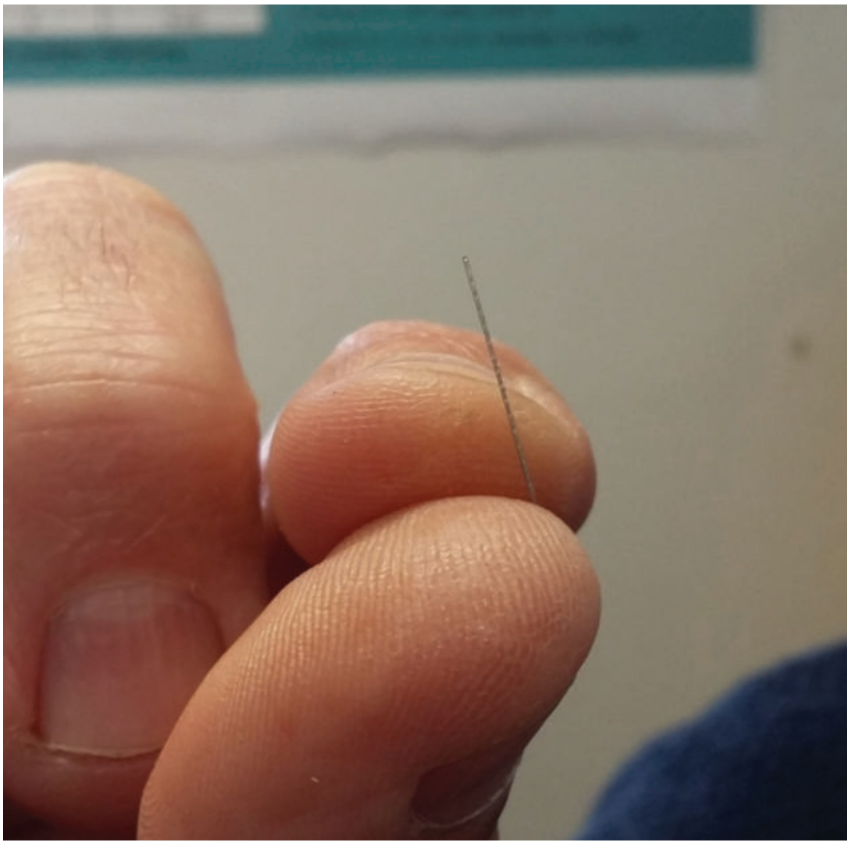
If anyone can shed any light on this occurrence, I would be very pleased to hear from them.

David Rushen
david.rushen@hotmail.co.uk

Hazards of entomology

Whilst walking in his garden in stocking soles, my recently retired colleague felt a sharp prick on the underside of his big toe. On examining it, he saw a small puncture wound but nothing else. Subsequently though, the toe became very sensitive and painful. At the time he was on new medication and went to his doctor to see about these strange symptoms. He was concerned because the jagging pain had moved to an adjacent toe, which was becoming inflamed. This went on for three weeks with marginal improvement and such heightened sensitivity in his second toe that it was a struggle to wear shoes. On the fourth week, a red swelling with a small blood blister formed on the top of his second toe. On pressing this and breaking the head, a glistening metallic point was seen and with surprising ease a 15 mm long entomological micropin removed. The pin had passed through his foot from the base of the big toe to emerge from his second toe! How the pin came to be in his garden, we can only surmise. It could be that it had stuck to his clothing whilst working in the lab and then fallen off at home.

AK Murchie, S Clawson



The offending pin that had passed through our colleague's toe.

Possum behaviour: wider implications

Readers may be interested in additional references to those cited by Professor Hugh Loxdale on possum behaviour in butterflies. These may be found in a paper that examines an extension of the behaviour from predator escape to mate refusal posture (Shreeve, T.G. et al. 2006. Phylogenetic, habitat and behavioural aspects of possum behaviour in European Lepidoptera. *Journal of Research on the Lepidoptera*, 39: 80-85). The predator escape implications of possum behaviour, in relation to adult hibernation and wing toughness, was discussed by Professors Paul Brakefield, Tim Shreeve and Jeremy Thomas in *The Ecology of Butterflies in Britain* (Dennis, R. L. H. ed. 1992. Oxford University Press) in chapter 5 on Avoidance, concealment and defence, page 98. A simple experiment in Bentley Wood near Salisbury in July 1983, much as carried out by Professor Loxdale, showed that brimstones can be laid flat on the palm of the hand and may remain inert for several minutes (illustrated in the *Entomologist's Gazette* 1984, 35: 7).

Both these references can be accessed from the following web sites
(http://lepidopteraresearchfoundation.org/journals/39/JRL%20Number%2039%2080_85.pdf;
https://openaccess.leidenuniv.nl/handle/1887/11028).

R. L. H. Dennis

Adult *Megacrania batesii*

Searching for stick insects in Queensland, Australia

Beth Ripper

Like many people, I was first introduced to stick insects at school… though unlike many people I quickly became absolutely fascinated by them! I marvelled at their stunning camouflage and incredible life stories. As a teenager, I joined the Phasmid Study Group and reared a number of different species in captivity. It wasn't until many years later that my childhood dream came true… in 2015, I was extremely fortunate to be awarded a Winston Churchill Memorial Trust Fellowship, which enabled me to travel to Queensland, Australia to study these amazing insects in the wild.

The aim of my eight week expedition was to photograph and collect data about stick insects (phasmids) in their natural habitats. I worked in a number of study sites, from Cedar Bay in the north-east to Conondale in the south-east, visiting a range of habitat types, including eucalypt woodland and tropical rainforest. For every phasmid found, I photographed the insect and recorded data about the location (including GPS location, site description, altitude, temperature and date/time). I noted details about the insect itself, including scientific and common names (if known), age code, sex code and breeding code of insect, and recorded other key observations, such as parasites, missing limbs and unusual colouration. In some cases, I also took photographs of the plant that the insect was found on, particularly if the insect had been feeding. We know very little about the foodplants of many phasmid species and this information can be extremely helpful in supporting conservation efforts and understanding the insect's role in the local ecosystem.

Stick insects can often be found in shrubs and bushes along existing

Onchestus sp. adult female - undescribed species.

walking trails and tracks, although it's extremely difficult to spot them during the daytime. It's much easier to find them at night when they emerge for feeding, moulting and breeding, and so virtually all of my fieldwork was conducted after dark. This certainly made for some exciting trips into the rainforest! At night, the boardwalks glistened with the eyes of huntsman spiders, and scorpions would scatter in the torchlight. I had to watch my footing to avoid snakes and flick leeches from my ankles on the muddiest trails.

Searching for stick insects is certainly a job for the patient. Finding them involves slowly and methodically studying vegetation – for example, two of us surveyed a 300m stretch of rainforest boardwalk in around 90 minutes. Only hand searching techniques were needed; this involved looking on top and underneath leaves, on stems and tree trunks, from ground level to around 10m height. It wasn't necessary to use beating trays or other more intrusive methods to find the insects – once you got your 'eye in' it was possible to spot them relatively easily.

Almost all of the work involved recording observations made in the field, although in some cases insects were collected so that they could be photographed further or to observe eggs produced overnight. No insect specimens were collected during this trip; however, the authorised collection of such specimens for lodging with research institutions can be incredibly valuable, helping to provide important information for species identification and conservation work. Permits are required for collecting insect or foodplant specimens in many areas of Queensland.

I thoroughly enjoyed the adventure of searching for stick insects in the rainforests at night time and had a few favourite finds. I was always excited to find nymphs or adults of *Onchestus rentzi*; these beautiful insects can have distinctive protuberances on their legs and head, and they show incredible intra-species colour variation, with mottled brown, green or 'lichen' variants. It was also interesting to see colour variation in other species; for example, *Anchiale briareus* nymphs are typically a bright, apple green colour but when found in large numbers the nymphs can exhibit a much darker mottled black or brown colouration called 'high density phase patterning'. Although I was searching for stick insects, it was amazing to see other stunning insects too, including katydids and weevils, cicadas, grasshoppers and crickets…

Virtually all of my searching was undertaken at ground level, with the exception of one site at the James Cook University research station in Cape Tribulation. The station has a crane, which enables researchers to be lifted into the rainforest canopy to undertake their surveys. Some of the rainforest trees are over 50m tall and floating above the canopy as the sun set was an incredible experience. It was fantastic to be able to search for stick insects in what would otherwise have been a completely inaccessible part of the rainforest. From the canopy crane, I was thrilled to find a beautiful female *Extatosoma tiaratum* nymph – one of the phasmid species I had reared in captivity as a child.

The eight week expedition seemed to just fly by. After each night out

Top left: *Anchiale briareus* nymph; Top right: *Anchiale briareus* male; Bottom left: *Anchiale* nymph eating shed skin; Bottom right: *Anchiale briareus* high density phase patterning.

Female *Extatosoma tiaratum* nymph

surveying, the day was spent catching up on sleep, typing up data, planning the next study site, preparing gear, buying provisions and travelling to the next camp site. It was important to be well organised, to look after the equipment and to ensure that data collected in the field was properly backed up.

Information and supporting photographs were collected for over 350 phasmid sightings. Highlights of the trip included discovering four phasmid species new to science, including three *Candovia* species and one *Onchestus* species. Species that are 'new to science' have not yet been formally described by a taxonomist and have no information published about them. Certain other stick insects found during the trip were similar to existing species and further work would be needed, possibly molecular work, to see if they are undescribed.

'This study of a wide range of stick & leaf insects (phasmids) from central and northern Queensland is one of the most comprehensive scientific studies on Australian phasmids [even worldwide] ever undertaken.'

Paul D. Brock,
Scientific Associate,
Natural History Museum, London

My aim was to ensure that the expedition could benefit others, and photos and data from the project will be used to inform a range of field guides and scientific databases. This will include the Phasmid Species File, a major taxonomic database of stick and leaf insects worldwide. I hope that this project will inspire others to build upon the research – phasmids are a very understudied order of insects and there is so much for us still to learn! I would love to encourage those with an interest in insects to follow their dreams in supporting insect conservation and contributing to scientific discovery. From a personal perspective, I also hope that I will have another opportunity to go in search of these beautiful and fascinating insects again soon…

To download my full expedition report, please visit:

www.wcmt.org.uk/users/elizabethripper2015

You can also read my expedition blog at:

https://phasmidexpedition.wordpress.com

Left: Example study site;
inset: Beth taking photos

Acknowledgements

I would like to say a huge thank you the Winston Churchill Memorial Trust for providing me with this fantastic opportunity. Many people helped to make the expedition a success and a full list of acknowledgements is provided in my expedition report. In particular, I would like to give special thanks to Paul Brock (Scientific Associate, Natural History Museum); without his input, the expedition certainly would not have been as successful as it was. I'd also like to thank my husband, Tim, whose support, encouragement and enthusiasm throughout the whole expedition was invaluable.

Sphagnum capillifolium (red bog-moss)

Insects and bryophytes

Richard G Jefferson

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Introduction

The British Isles has a remarkably rich and diverse flora of mosses and liverworts made up of species with contrasting geographical distributions ranging from Mediterranean-Atlantic to Arctic–montane (Blockeel *et al.* 2014).

There are 767 species of mosses and 298 species of liverworts (Blockeel *et al.* 2014) amounting to around 65% of the total European moss flora and 66% of the liverwort flora (Hill & Preston 1998). Britain has the richest flora of so-called Atlantic (Hyperoceanic) bryophytes in Europe, in terms of both number of species and their individual abundance (Ratcliffe 1968). One of their principal habitats, characterised by high humidity, are semi-natural mixed woodlands occurring in association with rock outcrops, gullies, block scree and steep slopes. This habitat is restricted to western Scotland, Wales, northern England and Ireland and has been described as Britain's equivalent of the tropical rainforests (Bain 2015).

The importance of bryophytes as a habitat and /or as food plants for invertebrates is arguably little appreciated, except perhaps in specialist zoological circles. In addition, invertebrates play a role in the sexual reproduction and dispersal of bryophytes, although to a much lesser extent than in flowering plants. This latter topic is not the focus of this article but good summaries are provided by Gerson (1982) and Glime (2014). A notable point is that bryophytes are often pioneers in plant succession and play a dominant role in influencing the colonisation, occurrence and composition of fauna in many environments (Uniyal 2000).

This article naturally concentrates on the class Insecta but other invertebrate groups considerably outnumber the insects worldwide in terms of the diversity of the bryophyte fauna (Glime 2014). These other faunal groups include the round worms (Nematoda), flatworms (Platyhelminthes), rotifers (Rotifera), water bears (Tardigrada), mites (Acari), segmented worms (Annelida), snails and slugs (Mollusca) and meiofauna, particularly Protozoa. The article is limited to terrestrial and wetland bryophytes but it is acknowledged that truly aquatic species may provide an important habitat for stream invertebrates such as caddisflies (Trichoptera), mayflies (Ephemeroptera) and stoneflies (Plecoptera).

The bryophyte fauna

Categories of association

Gerson (1982) defined four categories of association:

Bryobionts: animals which occur exclusively in association with bryophytes

Bryophiles: animals which are usually found on bryophytes, but may survive elsewhere

Bryoxenes: animals which regularly spend part of their life cycle on bryophytes

Occasionals: animals which may at times be found in bryophytes, but do not depend on these plants for their survival

This article only concerns itself with the first three categories but with a focus on Bryobionts and Bryophiles.

Types of association

There are a range of interactions between insects and bryophytes. These include:

- Food plant – direct consumption of leaves, capsules and spores, rhizoids, sap
- Feeding site – material within the moss/liverwort 'fabric' such as other prey organisms, algae, pollen, organic detritus etc
- Breeding/larval rearing site (nursery)
- Provision of nest material – e.g. ants, bumblebees e.g. moss carder-bee (*Bombus muscorum*)
- Sites for oviposition, pupation, shelter/refuge and ambush (predatory species) including the use of camouflage and mimicry, hibernation, aestivation.

Different species of bryophytes will offer a range of opportunities for insects, some being more attractive than others for one or more of the above functions.

Bryophytes will provide different environmental conditions, especially microclimate, compared to the surrounding habitat in which they occur. There may, for example, be key difference in temperature, moisture, humidity and wind flow velocity. In many environments, bryophytes will often provide a buffered temperature and humidity regime (Glime 2014, 2015, Vanderpoorten & Goffinet 2009). This environment will be favourable for a particular suite of insect species and may result in increased species diversity, especially in exposed and/or early successional environments.

The habitat in which a moss grows will also have an influence on which associates are present (Uniyal 2000). In the UK, for example, bryophyte-rich springs, seepages and flushes are often important insect habitats, especially for flies (Diptera) and beetles (Coleoptera). They are invariably small-scale features within other habitats but provide many niches and provide an important interface (ecotone) between groundwater, surface water and terrestrial habitats. They can be particularly rich in species of conservation value because they contain species from different ecosystems as well as habitat obligates (Boyce 2002).

Byrrhus pilula (a pill beetle)

Many more species use bryophytes as a habitat but do not feed directly on the plant parts. Direct consumption is remarkably uncommon. This has been attributed to their poor digestibility rather than due to their calorific value, which is comparable to that of flowering plants (Vanderpoorten & Goffinet 2009).

Bryophyte feeding species

Feeding may involve direct consumption of plant parts (leaves, thallus, rhizoids, spores) or tapping into the contents of cells using piercing mouthparts (e.g. Hemiptera).

A review of the literature (see reference list), including the Database of Insects and their Food Plants (DIFP) (Centre for Ecology & Hydrology), indicates that there are relatively few insects that directly feed on mosses and liverworts in the British Isles. This would also seem to be true in a global context. Appendix 1 lists those species known to feed on specific bryophytes but this is almost certainly not exhaustive. It should be noted that a number of species listed in the DIFP under moss genera or species have not been included in Appendix 1 as further research by the author has revealed that they are general associates rather than phytophagous, or are now known not to feed on bryophytes. Appendix 1 lists 73 species which is only a very small proportion (c 1%) of the British phytophagous insect fauna as documented by Ward & Spalding (1993).

A strong note of caution is required when considering Appendix 1 as there will be some situations where proven feeding has not been demonstrated. This will be the case where the presence of the larva amongst a moss or liverwort has been taken as a feeding association. The corollary may also apply in that there may be bryophyte feeders that have been overlooked. In addition, the list of bryophyte species food plants is probably not complete for most insect feeding species.

The small number of insects feeding on bryophytes is perhaps not surprising given that there is a strong relationship between vascular plant growth form or architectural complexity and the number of associated insects (Lawton & Schröder 1977) where, area for area, the architecturally complex trees support the greatest number of species and small, architecturally simple monocotyledonous herbs the least. Of course, growth form, size and complexity are not the only factors that will influence the number of insects exploiting plants.

What has apparently not been explored is the current nature of the patterns of insect groups feeding on bryophytes and how this has been influenced by the long history of bryophyte presence and evolution on land (probably from the Ordovician but possibly earlier) and the subsequent evolution of the more complex vascular plants and of phytophagous insects. Some progress has been made on this topic for vascular plants and phytophagous insects (Ward *et al.* 2003).

The smaller moths (Lepidoptera) make up 45% of the species in Appendix 1 (see Figure 1) with a high proportion belonging to the families Crambidae and Gelechiidae (see *Bryotropha* text box). A number of phytophagous insect orders and families that might potentially feed on bryophytes are absent, such as the weevils (Coleoptera: Curculionidae) (but note one species, *Tanysphyrus ater*, feeds on the floating aquatic liverwort, *Ricciocarpus natans*) and sawflies (Hymenoptera: Tenthredinidae), which collectively have around 750 species in the British fauna. There are no observations of gall-forming insects and it appears that the only gall formers of British bryophytes are nematodes and fungi (Spooner 2009).

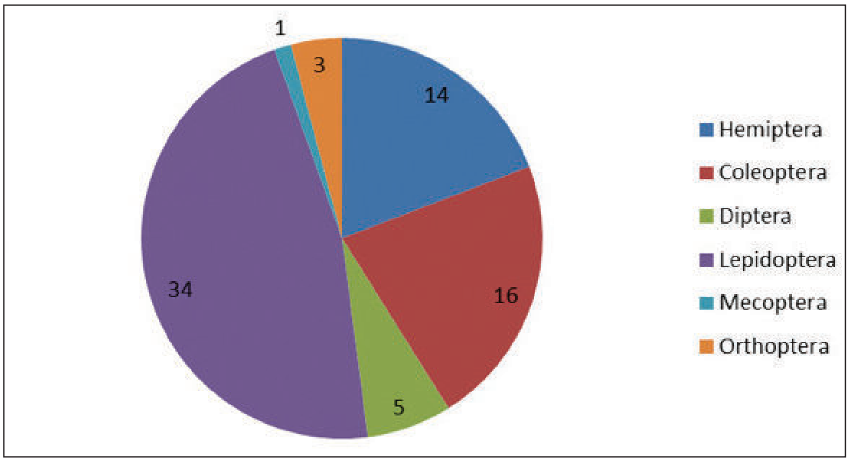

Figure 1. Number of bryophyte feeding species by insect order.

From a bryophyte perspective, one fact that stands out is the paucity of liverworts as food plants for insects listed in Appendix 1, although Fringed Heartwort (*Ricciocarpus natans*), is the host of a weevil (see above). The exception appears to be *Spania nigra*, the liverwort snipe-fly that feeds on thalloid liverworts (Appendix 1). There is, though, a measure of uncertainty with this feeding association. Various sources (e.g. Smith 1989) state that *S. nigra* mines the leaves of the liverwort Nees' Pellia (*Pellia neesiana*). Stubbs & Drake (2001) cast uncertainty over this suggesting that most species of Rhagionidae (snipe-flies) have predatory larvae and that the mines may be caused by a gall midge (Cecidomyiidae) of the sub-family Lestremiine. Barnes (1951), however, was not aware of any gall midge reared or recorded from bryophytes. Peter Kirby (pers comm) points out that two other species of Rhagionidae, *Ptiolina nigra* and *P. obscura* (Appendix 1) are associated with bryophytes (mosses) and some authorities separate out the plant-feeding species (family Spanidae) from the rest of the family which are predators. The nature of this relationship would repay further investigation.

The paucity of liverwort feeders in the UK could reflect a lack of knowledge although David Long and Sam Bosanquet (pers comm), liverwort taxonomic specialists, have indicated that they are unaware of any liverwort-feeding insects in Great Britain.

There are a few examples of insects feeding on liverworts elsewhere, such as species of Lepidoptera: Micropterigidae feeding exclusively on the great scented liverwort (*Conocephalum conicum*) (a thalloid liverwort) in Japan and eastern Asia (Imada *et al.* 2011). However, if liverworts are rarely utilised some explanation is required. Possible factors include the unsuitable plant 'architecture' or the few available feeding niches, nutritional quality, including digestibility or the presence of herbivore chemical defence compounds. For example, many liverworts contain aromatic terpenoids and phenols (Asakawa 2001).

Rhytidiadelphus squarrosus (springy turf-moss)

Other unspecified bryophyte feeders

Bristletails (Thysanura) and some springtails (Collembola) feed on dry moss (Gerson 1982). Other insect

The genus Bryotropha (Lepidoptera: Gelechiidae)

Etymology (Bryo from Greek bryos, bryon = moss; tropha = from Greek trophē = food)

A genus of small brown micro-moths with wingspans ranging from around 1 to 1.7 cm

There are 36 species in the western Palearctic. Most species appear to feed on mosses but are often polyphagous. There are 12 species in the British Isles of which 11 are moss feeders. The adults of the British species are on the wing between May and September and are all nocturnal and will come to light.

The larva lives in a silken tube spun to the host plant. Plant material and sand are often incorporated but not frass. When the larvae live in flat, stone-growing mosses, the tubes can be visible as pale lines within the moss. In most cases, however, the tubes are well hidden and only visible after parting the host plants. The larvae of most species are best searched for in the morning when the very fine strands of silk emanating from the larval tube are covered with dewdrops and show up like minute spiders webs. Without dewdrops, these strands are virtually invisible (Karsholt & Rutten 2005).

Pupation takes place in early spring (for univoltine species). Most species make a loosely spun cocoon covered with plant material and debris though *B. desertella* produces a firm sand cocoon.

orders with bryophyte feeders are the grasshoppers and crickets (Orthoptera) (Gerson 1982). Some ants (Hymenoptera: Formicidae) may feed on the spores of mosses, see for example Loria & Herrnstadt (1980), a non-British example.

General bryophyte associates

Many more species use bryophytes as a habitat but do not feed directly on the plant parts. Table 1 provides a summary of the main insect families that have species closely associated with bryophytes. Flies are arguably the insects most intimately associated with bryophytes, including in an evolutionary sense. Indeed Gerson (1982) makes the point that flies are the only insects to which mosses (Family Splachnaceae) have clearly adapted. Mosses in the family Splachnaceae are largely coprophilous and the spores are dispersed by the circular-seamed flies of the sub-order Cyclorrhapha which are attracted by aromatic compounds secreted in the highly coloured neck region of the moss capsule (Porley & Hodgetts 2005).

Larvae of Chironomids (Diptera) are very abundant in mosses. The crane-flies of several genera also live in and

Table 1: Some examples of bryophyte associates

Family	Feeding strategy and examples
Collembola (various families) (springtails)	Amongst mosses probably feeding on fungal hyphae.
Hemiptera: Hebridae (velvet water bugs)	Adults and nymphs are predatory or scavengers and may be found amongst mosses including *Sphagnum* spp.
Coleoptera: Staphylinidae (rove beetles)	Adults/larvae mostly predatory but some feed on fungi, algae and organic detritus. Some species may prove to feed on mosses. Bog-moss-dominated habitats are a rich source of species.
Coleoptera: Carabidae (ground beetles)	Adults/larva mostly predatory. Bog-moss-dominated habitats are a rich source of species.
Coleoptera: Dytiscidae (water beetles)	Larvae predatory, adults predatory or scavengers. *Sphagnum*-dominated habitats are a rich source of species *e.g. Hydroporus tristis* Paykull amongst bog mosses and other mosses in bogs and fens.
Diptera: Cylindrotomidae (crane-flies)	Three of the four British species in this family are moss associates and the larvae may all potentially feed on mosses (see Appendix 1).
Diptera: Limoniidae (crane-flies)	Larvae mostly feed in rotting vegetable material, fungi etc but some species may develop amongst mosses. A few are predatory and some are herbivorous.
Diptera: Tipulidae (crane-flies)	Larvae eat plant roots, other plant material or rotting wood and some species may develop amongst mosses including *Sphagnum* spp.
Diptera: Tabanidae (horse-flies)	Larvae mostly predatory except *Chrysops* spp. which are saprophagous.
Diptera: Dolichopodidae (long-legged flies)	The larvae of the majority are predatory and live in damp soil, mosses, rotting wood. Adults assumed to be predatory.
Diptera; Myceptophilidae (fungus gnats)	Most larvae are fungus feeders but a few are associated with mosses e.g. species in the genera *Gnoriste* and *Boletina.*
Diptera: Ceratopogonidae (biting-midges)	Larvae develop in a range of aquatic or damp habitats especially bogs and may be found amongst mosses.
Diptera: Chironomidae (non-biting midges)	Larvae develop in a range of aquatic or damp habitats especially bogs and may be found amongst mosses.

Catoptria falsella (common grey)

feed on mosses and other families with moss associates include biting-midges (Ceratopogonidae) and horse-flies (Tabanidae). Many beetles occur in bryophytes, especially rove beetles (Staphylinidae) and ground beetles (Carabidae) (see bog-moss account below) plus water beetles.

Species of springtail are often found in mosses across the world (Gerson 1982, Uniyal 2000, Glime 2014). They are known to consume a wide variety of food materials but especially fungal hyphae (Hopkin 1997). Some species feed on the living parts of mosses although there is no documentation of this from the UK, as far as is known. The author, using a Tullgren funnel, extracted two species of springtail (one from each of the superfamilies Poduroidea and Entomobryoidea) from the mosses (*Bryum argenteum*, *B. capillare and B. gemmiferum*) taken from the ledges and gullies of his greenhouse!

Bog-moss (Sphagnum spp) associates

There are 36 species of bog-moss (*Sphagnum* spp) in Britain. Of these, around 55% could be considered to be widespread and contribute significantly to wetland habitat 'fabric' (Blockeel *et al*. 2014, Rodwell 1991-2000). There are a considerable number of stenotopic insects that apparently utilise bog-mosses in mire and wetland habitats, including some of conservation concern (see conservation section below). It is though, in many cases, difficult to know the precise association of specific insects with bog-moss and some apparent associations described in the literature may be habitat-based and co-incidental.

As noted by Gerson (1982), the remarkable feature of bog moss species is that apparently very few species actually eat it, although the crane-fly *Phalacrocera replicata* (Diptera: Tipulidae Cylindrotomidae) ingests bog-moss and *Myzodium modestum* (Hemiptera: Aphididae) is the only British aphid that feeds on bog-moss (Appendix 1, Blackman 2010). It is conceivable though that the larvae of some other crane-flies and non-biting midges may ultimately prove to feed on bog-mosses.

This habitat feature includes flat 'lawns' of bog-mosses growing in very wet situations in topogenous mires, such as basin mires, water fringe mires and valley mires, and also hummock-hollow bog-moss-dominated communities in ombrogenous raised and blanket mires. A range of other microhabitats also occur in bog-moss-dominated mires including open water pools, grass, rush and sedge tussocks, ericaceous dwarf shrubs, litter and bare peat.

There are a diversity of beetles associated with bog-mosses, especially ground beetles and rove beetles but also water beetles. Representatives of the latter occur in a very wide range of aquatic and semi-aquatic habitats, from damp moss, peaty pools, streams and canals to coastal rocky shores and salt marshes. Bog-moss is a particularly rewarding habitat for water beetles (Friday 1988).

Other well represented groups include flies, including crane-flies (four families), long-legged flies and Chironomids, biting-midges and aquatic or semi-aquatic true bugs, for example, velvet water bugs. The uncommon fly (in Great Britain), *Pseudocoenosia abnormis* Stein (Diptera: Muscidae) has been reared from bog-moss (Glime 2015).

Homalothecium sericeum (silky wall feather-moss)

Conservation

All of the moss species that are recorded as insect food plants are widespread species in Britain (Blockeel *et al*. 2014). Of the specific bryophyte feeding insect species identified in Appendix 1, and that have had their conservation status assessed, 22 species (30%) are nationally rare, scarce or notable. Of these, 11 species are moths, one of which, the Scarce Brown Streak (*Aplota palpellus*), is listed on Section 41 of the Natural Environment and Rural Communities Act 2006 as a species of principal importance for the conservation of biological diversity in England (Priority species).

Bog moss-dominated habitats do support a large number of rare and threatened insect species including those listed as Priority species and Red Data Book species. These include the rove beetle *Lathrobium rufipenne*, the crane-flies *Idioptera pulchella*, *Phylidorea fasciata* and *Prioocera pubescens* and the horse-flies *Atylotus fulvus*, *A. plebeius* and *Hybomitra montana*. Wetland habitats with bog-moss are of course of considerable importance as habitats of conservation concern in their own right and provide important ecosystem services (UK Biodiversity Steering Group 1995a, Watson & Albon 2011).

Concluding remarks

A better understanding of bryophyte-insect associations overall could be a rewarding subject and scientific discoveries no doubt await!

An improved knowledge of which bryophytes are significant hosts for insects would be instructive. A detailed aside to this issue is the case of the Micropterigidae, an ancient (or basal) family of moths. In Britain, there are five species of which the larval food is unknown although the feeding site for *Micropterix aruncella* Scopoli has been described as the base of tussocks of cocksfoot *Dactylis glomerata* (Heath 1976). Imada *et al.* (2011) state that the family are either detritivores or bryophyte feeders so maybe bryophytes should be considered as potential larval host plants.

A fuller understanding of the life history of insect species of conservation concern associated with bryophytes would help inform their conservation. Finally, further investigation of the role of insects in bryophyte dispersal and reproduction would be an informative topic for research.

Acknowledgements

I am especially grateful to Peter Kirby for reviewing my initial list of bryophagous insect species and for adding many extra species and providing additional references and other useful information. Thanks are also due to Mark Hill for critically reviewing a draft from a bryophyte perspective. Jon Webb, Pete Boardman, Sharon Pilkington, Keith Porter, David Long and Sam Bosanquet are thanked for supply of information.

Scoparia ambigualis (chequered grass-veneer)

Tetrix undulata (common ground-hopper)

Tetrix ceperoi (Cepero's ground-hopper)

References

Asakawa, Y. 2001 Recent advances in phytochemistry of bryophytes-acetogenins, terpenoids and bis(bibenzyl)s from selected Japanese, Taiwanese, New Zealand, Argentinean and European liverworts. *Phytochemistry* 56, 291-312

Atherton, I., Bosanquet, S. & Lawley, M. eds 2010 *Mosses and liverworts of Britain and Ireland a field guide*. British Bryological Society, London

Bain, C. 2015 *The Rainforests of Britain and Ireland*. Sandstone Press Ltd, Dingwall

Barnes, H. F. 1951 *Gall midges of economic importance*. *Volume V. Gall midges of trees*. Crosby Lockwood, London

Blackman, R. L. 2010 Aphids – Aphidinae (Macrosiphini). *Handbooks for the Identification of British Insects* 2, Part 7. Field Studies Council, Shrewsbury for the Royal Entomological Society, London

Blackman, R. L. Aphids on the World's Plants: An Online Identification and Information Guide. [WWW document] URL: http://www.aphidsonworldsplants.info/ (accessed 11.11.16)

Blockeel, T.L., Bosanquet, S.D.S, Hill, M.O. & Preston, C.D. 2014 *Atlas of British and Irish Bryophytes.* Pisces Publications, Newbury

Boyce, D.C. 2002 A review of seepage invertebrates in England. *English Nature Research Report* No. 452. English Nature, Peterborough

Boyce, D.C. 2004. A review of the invertebrate assemblage of acid mires. *English Nature Research Report* No. 592. English Nature, Peterborough

Centre for Ecology and Hydrology, Biological Records Centre. Database of Insects and their Food Plants, [WWW document] URL: http://www.brc.ac.uk/dbif/hosts.aspx (accessed 11.11.16)

Cox, M. L. 2007 *Atlas of the Seed and Leaf Beetles of Britain and Ireland*. Pisces Publications, Newbury

Dolling, W.R. 1991 *The Hemiptera*. Natural History Museum Publications, Oxford University Press, Oxford

Duff, A.G. 2016. *Beetles of Britain and Ireland. Volume 4: Cerambycidae to Curculionidae*. A.G.Duff, West Runton, Norfolk

Emmet, A. M. (ed) 1988 *A Field Guide to the Smaller British Lepidoptera*. 2nd edition. The British Entomological and Natural History Society, London

Emmet, A.M. & Langmaid, J.R. 2002 (eds) *The Moths and Butterflies of Great Britain & Ireland*, 4, Part 2, Gelechiidae. Harley Books, Colchester

Falk, S. J., 1991. A review of the scarce and threatened flies of Great Britain (Part 1). *Research and Survey in Nature Conservation*, No. 39. Nature Conservancy Council, Peterborough

Foster, G.N. & Friday, L.E. 2011 Keys to adults of the water beetles of Britain and Ireland (Part 1). *Handbooks for the Identification of British Insects* 4, Part 5. 2nd edition. Royal Entomological Society, London

Fraser, F.C. 1959 Mecoptera Megaloptera Neuroptera *Handbooks for the Identification of British Insects* I, Parts 12 and 13. Royal Entomological Society of London, London

Friday, L. E. 1988 A key to the adults of British water beetles. *Field Studies* 7, 1-151

Gerson, U. 1982 Bryophytes and invertebrates In: *Bryophyte Ecology* ed Smith, A.J.E. Chapter 9 pp 291-332. Chapman & Hall/Springer, Netherlands

Glime, J. M. 2014 The Fauna: A place to Call Home. Chapter 1. In: Glime, J.M. *ed Bryophyte Ecology. Volume 2. Bryological Interaction*. E-book sponsored by Michigan Technical University and the International Association of Bryologists. [WWW document] URL: http://www.bryoecol.mtu.edu/chapters_VOL2/1-1AnimalGeneral.pdf (Accessed 11.11.16)

Glime, J. M. 2015 Aquatic Insects : Bryophyte Habitats and Fauna. Chapter 11-3. In: Glime, J.M. ed *Bryophyte Ecology. Volume 2. Bryological Interaction*. E-book sponsored by Michigan Technical University and the International Association of Bryologists. [WWW document] URL: http://www.bryoecol.mtu.edu/chapters_VOL2/11-3Aquatic%20Bryopyte%20Habitat%20and%20Fauna.pdf (Accessed 11.11.16)

Heath, J. 1976 (ed) *The Moths and Butterflies of Great Britain & Ireland*, 1, Micropterigidae – Heliozelidae. Blackwell Scientific Publications/The Curwen Press Ltd, Oxford & London

Heckford, R.J. 1999 Notes on the larvae of seven species of microlepidoptera (Oecophoridae, Gelechiidae and Pyralidae) not previously described in the British literature, together with the re-description of one and a further description of another. *Entomologist's Gazette* 50, 223-237

Heckford, R. J. & Sterling, P.H. 2002 The discovery of the larva of *Bryotropha dryadella* (Zeller, 1850) and larval descriptions of this species, *B. basaltinella* (Zeller, 1839), *B. umbrosella* (Zeller, 1839) and *B. senectella* (Zeller, 1839) (Lepidoptera: Gelechiidae). *Entomologist's Gazette* 53, 83-91

Heckford, R. J. & Sterling, P.H. 2003 The discovery of the larva of *Bryotropha politella* (Stainton, 1851) and larval descriptions of this species and *B. galbanella* (Zeller, 1839) (Lepidoptera: Gelechiidae). – *Entomologist's Gazette* 54, 223-226

Hill, M.O. & Preston, C.D. 1998 Bryological Monograph: The geographical relationships of British and Irish bryophytes. *Journal of Bryology* 20, 127-226

Hopkin, S.P. 1997 *Biology of Springtails Insecta: Collembola*. Oxford University Press, Oxford

Hutson, A.M., Ackland, D.M. & Kidd, L.N. 1980 Mycetophilidae (Bolitphilinae, Ditomyiinae, Diadociniinae, Keroplatinae, Sciophilnae and Manotinae (Diptera, Nematocera). *Handbooks for the identification of British Insects* 9, Part 3. Royal Entomological Society, London

Imada, Y., Kawakita, A. & Kato, M. 2011 Allopatric distribution and diversification without niche shift in a bryophyte-feeding basal moth lineage (Lepidoptera: Micropterigidae). *Proceedings of the Royal Society, Series B* 1721, 3026-3033

Karsholt, O. & Rutten, T. 2005 The genus *Bryotropha* Heinemann in the Western Palaearctic (Lepidoptera: Gelechiidae). *Tijdschrift voor Entomologie* 148, 77-207

Kimber, I. UK Moths: A guide to the moths of Great Britain & Ireland. [WWW document] URL: http://www.ukmoths.org.uk/ (accessed 11.11.16)

Kocarek, P., Grucmanova, S., Filipcova, Z., Braova, L., Plasek, V. & Holusa, J. 2008 Bryophagy in the groundhopper *Tetrix ceperoi* (Orthoptera, Tetrigidae): analysis of alimentary tract contents. *Scripra Facultatis Rerum Naturalium Universitatis Ostravensis* 186, 348-352

Lawton, J.H & Schröder, D. 1977 Effects of plant type, size of geographical range and taxonomic isolation on number of insect species associated with British plants. *Nature (London)* 265, 137-140

Loria, M. & Herrnstadt, I. 1980 Moss capsules as food of the harvester ant, *Messor*. *The Bryologist* 83, 524-525

Marshall, J. A. & Haes, E.C.M. 1990 *Grasshoppers and Allied Insects of Great Britain and Ireland*. Harley Books, Colchester

Porley, R.D. & Hodgetts, N. 2005 *Mosses and Liverworts*. The New Naturalist Library No. 97. Collins, London

Ratcliffe, D.A. 1968 An ecological account of Atlantic bryophytes in the British Isles. *New Phytologist* 67, 365-439

Rodwell, J.S. (ed) 1991-2000 *British Plant Communities*. Volumes 1-5. Cambridge University Press, Cambridge

Smith, K.G.V. 1989 An introduction to the immature stages of British flies. *Handbooks for the Identification of British Insects* 10, Part 14. Royal Entomological Society, London
Spooner, B.M. 2009 Galls of Bryophytes in Britain. *Cecidology* 24, 58-68
Sterling, P. H. & Heckford, R.J.2001. The discovery of the larva of *Bryotropha desertella* (Douglas, 1850) in Britain and a further note on the larva of *B. terrella* ([D. & S.], 1775) (Lepidoptera: Gelechiidae). *Entomologist's Gazette* 52,143-148
Stubbs, A.E. & Drake, M. 2001 *British Soldierflies and their allies. An illustrated guide to their identification and ecology.* British Entomological and Natural History Society, Reading
Telfer, M. [WWW document] URL: http://www.markgtelfer.co.uk/ (accessed 11.11.16)
UK Biodiversity Steering Group 1995a *Biodiversity: the UK Steering Group Report. Volume 1: Meeting the Rio Challenge.* HMSO, London
UK Biodiversity Steering Group 1995b. *Biodiversity: the UK Steering Group Report. Volume 2: Meeting the Rio Challenge.: Action Plans*. HMSO, London
Uniyal, P.L. 2000 Some aspects of bryophyte-Animal associations. In: Mukerji, K.G., Chanda, B.P. & Sharma, A.K. eds. *Glimpses in Botany*. Chapter 7, pp 121-128. APH Publishing Corporation, New Delhi, India
Vanderpoorten, A. & Goffinet, B. 2009 *Introduction to Bryophytes*. Cambridge University Press, Cambridge
Ward, L.K., Hackshaw, A. & Clarke, R.T. 2003 Do food plant preferences of modern families of phytophagous insects and mites reflect past evolution with plants? *Biological Journal of the Linnean Society* 78, 51-83
Ward, L. K. & Spalding, D. F. 1993 Phytophagous British insects and mites and their food-plant families: total numbers and polyphagy. *Biological Journal of the Linnean Society* 49, 257-276
Waring, P. & Townsend, M. 2009 *Field guide to the Moths of Great Britain and Ireland*. 2nd edition. British Wildlife Publishing, Rotherwick
Watson, R. & Albon, S. 2011 *UK National Ecosystem Assessment. Synthesis of Key Findings*, UNEP-WCMC, Cambridge

Appendix 1: Insect species recorded as feeding on bryophytes in the UK

Insect family and species (NB Recent introductions excluded)	Bryophyte host species. For English names of mosses and liverworts see Atherton *et al* (2010)	Distribution and status
Hemiptera: Tingidae (Lace bugs)		
Acalypta brunnea Germar	Various mosses on tree trunks	Scarce in Great Britain with a predominantly northern distribution
Acalypta carinata Panzer	Various mosses in taller moist vegetation	Uncommon but widely scattered in Great Britain
Acalypta nigrina Fallen	Various mosses *Polytrichum* spp, *Hylocomium splendens*	Confined to northern England, Scotland and Wales
Acalypta parvula Fallen	Various mosses in short dry vegetation	Widespread in Great Britain
Acalypta platycheila Fieber	Various mosses in dense vegetation around tree trunks *Pleurozium schreberi*	Very rare in southern and eastern England **(Nb)**
Derephysia follacea Fallen	*Climacium dendroides.*Widely polyphagous on a range of plants especially ivy (*Hedera helix*). Although sometimes found amongst mosses, there is a doubt as to whether there is a feeding association	Widespread but uncommon in England, Wales and southern Scotland
Hemiptera: Aphididae (Aphids)		
Decorosiphon corynothrix Börner	In humid areas on mosses. *Polytrichum commune, Rhytidiadelphus squarrosus, Atrichum undulatum*	No data/not assessed
Jacksonia papillata Theobald	Polyphagous on low plants especially grasses but including mosses	No data/not assessed
Muscaphis cuspidati Stroyan	*Brachythecium rivulare, Drepanocladus aduncus, Calliergonella cuspidata* The aphid can live below the water by using cuticular papillae to create a thin air layer around the body	No data/not assessed

Insect family and species (NB Recent introductions excluded)	Bryophyte host species. For English names of mosses and liverworts see Atherton *et al* (2010)	Distribution and status
Muscaphis escherichi Borner	*Eurhynchium* spp,*Hypnum* spp, *Mnium hornum, Kindbergia praelonga, Rhytidiadelphus* spp	No data/not assessed
Muscaphis musci Borner	*Amblystegia* spp, *Calliergonella cuspidata, Barbula* spp, *Brachythecium* spp, *Tortula* spp, *Kindbergia praelonga, Pseudoscleropodium purum, Bryum* spp *Hylocomium splendens, Mnium* spp, *Polytrichum* spp	No data/not assessed
Myzodium modestum Hottes	*Polytrichum* spp, *Racomitrium* spp, *Pohlia* spp, *Sphagnum* spp	No data/not assessed
Pseudacaudella rubida Borner	*Calliergonella cuspidata, Climacium dendroides, Dicranum* spp, *Hylocomium splendens, Mnium* spp, *Pleurozium schreberi, Polytrichum* spp, *Pseudoscleropodium purum, Thuidium* spp	No data/not assessed
Hemiptera: (Sternorrhyncha) Ortheziidae (Ensign scales)		
Arctorthezia cataphracta Shaw Alpine or Arctic ensign scale	*Racomitrium lanuginosum, Sphagnum* spp. Feeds on a variety of plants including fungi, mosses, grasses, forbs and shrubs. Dolling (1991) has cast doubt over the validity of the feeding association with mosses	Very rare in northern Scotland. Boreo-alpine species.
Coleoptera: Byrrrhidae (Pill beetles)		
Byrrhus arietinus Steffahny Northern Pill-beetle	Adults and larva feed on mosses	Scarce in the UK and primarily northern**. (Nb)**
Byrrhus fasciatus Forster	Adults and larva feed on mosses	Uncommon but widely distributed in Great Britain.
Byrrhus pilula Linnaeus	Adults & larva on pleurocarpous mosses	Widespread in the UK especially in England and Wales.
Byrrhus pustulatus Forster	Adults and larva feed on mosses	Uncommon but widely distributed in Great Britain.
Chaetophora spinosa Rossi	Adults and larva feed on mosses	Largely confined to southern England & Wales south of a line from the Wash to the Gower peninsular
Curimopsis maritima Marsham	Adults and larva feed on mosses in open dry habitats	Scattered distribution in England & Wales, primarily coastal
Curimopsis nigrita Palm Mire Pill-beetle	Adults and larva feed on mosses including *Dicranella* spp	Very rare. Restricted to wetlands in the Humberhead levels, north Lincolnshire**. (RDB)**
Curimopsis setigera Illiger	Adults and larva feed on mosses	Primarily coastal and rather scarce in England & Wales southwards from North Yorkshire **(Na)**
Cytilus sericeus Forster	Adults and larva feed on mosses	Widely distributed in the UK
Morychus aeneus Fabricius	Adults and larva feed on mosses near streams	Largely restricted to northern England and Scotland
Porcinolus murinus Fabricius	Adults and larva feed on mosses on sandy heaths and dunes	Uncommon in central and southern England from Yorkshire southwards (**Nb)**
Simplocaria maculosa Erichson	Adults and larva feed on mosses	Very rare. Restricted to river margins in the Humberhead levels, north Lincolnshire **(RDB)**
Simplocaria senistriata Fabricius	Adults and larva feed on mosses	Widely distributed in the UK but scarce in northern Ireland

Insect family and species (NB Recent introductions excluded)	Bryophyte host species. For English names of mosses and liverworts see Atherton *et al* (2010)	Distribution and status
Coleoptera: Limnichidae		
Limnichus pygmaeus Sturm	Adults and larva feed on mosses on water margins	Scattered distribution in England & Wales south of line from Flamborough Head to the Mersey estuary
Coleoptera: Chrysomelidae (Leaf beetles)		
Mniophila muscorum Koch Moss Flea Beetle	Circumstantial evidence that both larvae and adults feed on various mosses *Eurhynchium striatum, Rhytidiadelphus loreus, Rhytidiadelphus triquetrus*	Widely scattered but rather local in England, eastern Wales, Scotland and Ireland. but probably under-recorded (**NS**)
Mniophila bosnica Apfelbeck	Larvae and adults feed on various mosses	Very local in central and south-eastern England but distribution poorly known
Diptera: Cylindrotomidae		
Phalacrocera replicata Linnaeus	Larva feeds on *Sphagnum* spp and other mosses such as *Warnstorfia fluitans and Calliergonella cuspidata*	Scattered distribution in England, Scotland and Wales, with a preponderance of records from northern England. (**NN**)
Diptera: Tipulidae (Crane-flies)		
Dolichopeza albipes Ström	Larva feeds on the rhizoids of mosses	Widely distributed in Great Britain but rare in central England.
Diptera: Rhagionidae (Snipe-flies)		
Ptiolina nigra Zetterstedt Pale-fringed moss-snipefly	Mosses. Found at the base of oaks (*Quercus* spp) in parkland and on logs on wooded slopes	Scarce but widely distributed in Great Britain **(NR)**
Ptiolina obscura Fallén Black-fringed moss-snipefly	Mosses. Found under *Hypnum cupressiforme* on concrete and on tree branches	Uncommon but widely distributed throughout the British Isles **(NS)**
Spania nigra Meigen Liverwort snipe-fly	Thalloid liverworts *Pellia neesiana,* and the moss *Rhynchostegium riparioides*	Scattered distribution throughout Great Britain bur rather scarce (**NS**)
Lepidoptera: Oecophoridae		
Aplota palpellus Haworth Scarce brown streak	Larva feeds on mosses on walls, rocks and tree trunks. *Homalothecium sericeum, Hypnum cupressiforme, Orthotrichum* sp	Rare in southern England. **(RDB, S41)**
Lepidoptera: Gelechiidae		
Acompsia cinerella Clerck	On moss at base of trees	Widely distributed over all of the British Isles
Bryotropha affinis Haworth Dark Groundling	*Tortula muralis*	Widespread in England & Wales; local in Scotland & Ireland
B. basaltinella Zeller Thatch Groundling	In mosses on walls and buildings including *Syntrichia ruralis*	Local in southern England with a few scattered records from northern England (**Na**)
B. desertella Douglas	*Syntrichia ruraliformis, Homalothecium lutescens, Rhytidiadelphus squarrosus*	Mainly coastal in England, Wales and southern Scotland. (**Nb**)
B. domestica Haworth House Groundling	Mosses on walls including *Tortula muralis*	Common in urban areas England & Wales - very local in Scotland and ireland
B. dryadella Zeller Western Groundling	*Ctenidium molluscum, Barbula unguiculata, Barbula* spp, *Bryum* spp *and Homalothecium lutescens.*	Very rare in south west and southeast England (**RDB**)
B. galbanella ZellerPerth Groundling	*Dicranum scoparium*	Rare and largely confined to Scotland (**Na**)

Insect family and species (NB Recent introductions excluded)	Bryophyte host species. For English names of mosses and liverworts see Atherton *et al* (2010)	Distribution and status
B. politella Stainton Polished Groundling	*Rhytidiadelphus squarrosus.* Also feeds on grasses including *Poa* spp	Common in the north of Great Britain; local to rare in southern England and in Ireland
B. senectella Zeller Dull Red Groundling	Mosses on walls including *Homalothecium lutescens, Bryum* spp	Widespread in England & Wales; local in Scotland & Ireland
B. similis Stainton Obscure Groundling	Larva feed on various mosses on walls including *Bryum capillare, Grimmia pulvinata, Brachythecium rutabulum, Pohlia nutans, Syntrichia montana, Syntrichia ruralis*	Widespread but uncommon in Great Britain.
B. terrella Denis & Schiffermüller Cinerous Groundling	*Rhytidiadelphus squarrosus, Syntrichia ruraliformis, Hypnum jutlandicum, Calliergonella cuspidata.* Also feeds on the grass *Agrostis capillaris*.	Very common in the British Isles
B. umbrosella Zeller	On mosses growing on dunes and sometimes inland on walls including *Ceratodon purpureus*	Mainly coastal in British Isles. Uncommon inland (**Nb**)
Chionodes fumatella Douglas Downland Groundling	Mosses believed to be the food plant.	Well distributed but widely scattered in England and Wales and reaching parts of eastern Scotland
Lepidoptera: Crambidae		
Catoptria falsella Denis & Schiffermüller Chequered Grass-veneer	Larva on mosses on walls and old building *Tortula muralis*, *Tortula* spp, *Barbula* spp	Widespread but uncommon throughout Great Britain.
Catoptria lythargyrella Hubn Yellow Grass-veneer	On grasses or mosses	Migratory species – a few records from south-east England
Catoptria margaritella Denis & Schiffermuller Silver-stripe Grass-veneer	On mosses including *Campylopus flexuosus*	Locally common.in mire and heathland habitats in scattered localities throughout Great Britain
Catoptria osthelderi Lattin False Scotch Grass-veneer	On mosses	Migratory species – a few records from south east England
Catoptria permutatellus Herrich-Schaffer Scotch Grass-veneer	On mosses	Restricted to parts of north-eastern Scotland (**Na**)
Catoptria verellus Zincken Marbled grass-veneer	On mosses on trunks of apple, plum and poplar	Rare visitor or resident?
Eudonia alpina Curtis Highland Grey	The early stages are not described, but it is believed to feed as a larva on mosses.	In the Scottish Highlands, where it can be locally common and at lower elevations on the Shetland and Orkney islands (**Na**)
Eudonia angustea Curtis Narrow-winged Grey	*Pseudocrossidium revolutum, Tortula muralis* on dunes and old walls	Widespread but local in Great Britain and northern Ireland. Primarily coastal in the north
Eudonia delunella Stainton Pied Grey	On mosses and lichens on tree trunks	Rather local, occurring in various widely scattered wooded areas in England, Wales and southern Scotland (**Nb**)
Eudonia lacustrata Panzer Little Grey	On mosses on tree trunks or old stone walls	Widely distributed over most of the UK.
Eudonia mercurella Linnaeus Small Grey	Larva feeds on mosses growing on tree trunks and walls	Widely distributed over most of the UK
Eudonia murana Curtis Moorland Grey	Larva feeds on mosses on rocks and walls *Bryum capillare, Dicranum scoparium, Grimmia pulvinata, Hypnum cupressiforme*	Scattered localities in moorland in Scotland, Wales and central/northern England.
Eudonia pallida Curtis Marsh Grey	Believed to feed on mosses or lichens at ground level. It has been reared from larvae amongst the moss *Calliergonella cuspidata*	Widely distributed throughout the British Isles in mostly wetland habitats

Insect family and species (NB Recent introductions excluded)	Bryophyte host species. For English names of mosses and liverworts see Atherton *et al* (2010)	Distribution and status
Eudonia truncicolella Stainton Ground-moss Grey	On mosses growing on the ground	A moorland species, it occurs throughout much of Britain
Platytes alpinella Hübner Hook-tipped Grass-veneer	On *Syntrichia* spp and other mosses	Rather local and distributed mainly around the coasts of south and south-eastern England in sandy and shingle habitats (**Nb**)
Scoparia ambigualis Treitschke Common grey	On mosses	A common species throughout the UK
Lepidoptera: Pyralidae		
Aphomia zelleri Joannis Twin-spot Honey	Larvae feed on a moss on dunes	Extremely local restricted to Norfolk, Suffolk and East Kent (**Na**)
Synaphe punctalis Fabricius Long-legged Tabby	Larva feed on various mosses on the ground including *Hypnum cupressiforme*	Coastal habitats in southern Great Britain
Lepidoptera: Erebidae		
Thumatha senex Hübner Round-winged muslin	*Homalothecium sericeum*, *Dicranoweisia cirrhata* as well as lichens and probably algae	Uncommon but widely distributed throughout the UK but scarcer in Scotland and northern Ireland
Lepidoptera: Geometridae		
Martania taeniata Stephens Barred carpet	Likely to feed on moss capsules	Scarce with a scattered distribution throughout England north and south Wales and into Scotland and northern Ireland. **(Na)**
Mecoptera: Boreidae (moss-flies)		
Boreus hyemalis Linnaeus Snow flea	*Polytrichum commune.* Little is known about dietary preference, but larvae and adults appear to live exclusively on moss. Another possibility is that the species may be at least partly predacious.	Locally common but widespread in England, Wales and Scotland north of a line drawn from Margate to Plymouth
Orthoptera: Tetrigidae (Groundhoppers)		
Tetrix ceperoi Bolivar Cepero's Ground-hopper	Herbivorous on mosses (*Barbula* spp, *Bryum argenteum*, *Ceratodon purpureus*), algae and lichens	Primarily coastal and largely confined to southern England and south Wales **(NS)**
Tetrix subulata Linnaeus Slender Ground-hopper	Herbivorous on mosses (*Hypnum* spp), algae and lichens	Widespread in central and southern England and south Wales. Scattered in Ireland.
Tetrix undulata Sowerby Common Ground-Hopper	Herbivorous on mosses (*Hypnum* spp), algae and lichens	Widely distributed throughout the British Isles

Column 3 Conservation status

The latest assessment system for conservation status has two categories as follows:

Nationally Rare (**NR**) 1-15 10 km squares; Nationally Scarce (**NS**) = 15-100 10 km squares

However, not all species have been re-assessed using this new system and hence some have assessments using the former system as follows:

RDB: Rare. Species estimated to exist in 15 or fewer post 1970 10km squares

NN = Nationally Notable: occur in 16-100 10 km squares

Na = Nationally Notable: Uncommon in Great Britain and occur in 16-29 10km squares.

Nb = Nationally Notable (Nb): Species estimated to occur within the range of 30 to100 10 km squares.

Note: Aphids and Hemiptera; Orthezidae have not been assessed for status.

The Virginian Silkworm: From Myth to Moth

Or: How a Businessman turned into a Naturalist

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By 1600 *Bombyx mori* had long since been carried beyond its first home in China, where it had been domesticated for more than four thousand years (Shelagh, 2004). Since the sixth century AD the silkworm had been profitably cultivated for its silk in Persia and Italy (before that a local species, the lasiocampid moth *Pachypasa otus*, had been used in Europe: Good, 1995). During the sixteenth century, the silkworm had been introduced into France and Spain, and from the latter into Mexico where there may have also been pre-columbian silk production (Borah, 1943; Blomberg, 1997). *Bombyx mori* did not reach the Atlantic shores of North America, however, until the early-mid 17th Century.

In England the first records of silkworm cultivation date from the reign of Elizabeth I (Fig. 1), but at that time the activity was a pastime rather than a commercial undertaking. Yet, half a century later at Little Gidding in Huntingdonshire, John Ferrar in the 1650s was contrasting the 'European' with the 'Virginian' silkworm, both of which species, he claimed, his daughter was successfully raising. The breeding of an exotic silkmoth in Huntingdonshire this early in the history of sericulture in England has not been widely publicised and comes as a surprise. How did the 'Virginian' arrive there? And what species indeed was it?

The search for the answer to these questions began in 2012 in Providence,

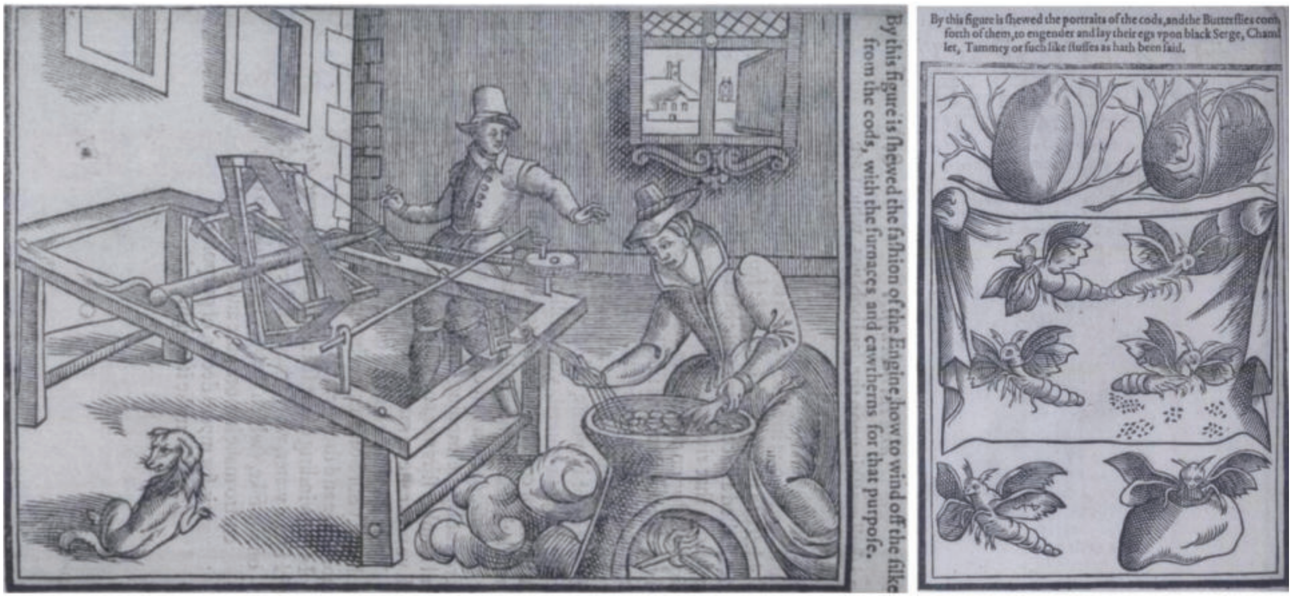


Fig. 1. Two of Geffe's (1607) more or less fanciful woodcuts of sericulture incorporating 'Vermis sericus' by Stradanus (left, a couple winding silk, and right, silkworm life history).

Fig. 2. (page 122) Facing pages of Mercator Atlas with marginal notes and drawings by (John) Ferrar

Rhode Island at the John Carter Brown Library. That summer Kimberly Nusco, one of the librarians, drew the attention of Janice Neri (now deceased) and Danielle Skeehan, library Fellows, to a book in the library's collections: a copy of the first edition of Wye Saltonstall's translation of Mercator's *Historia Mundi* or *Atlas*, published in 1635.

The library had bought the book in 1907 from Henry Stevens in London. In offering the book, Stevens had noted the "long MS Notes almost contemporary (1653-1654) relating to Virginia silkworms with drawings of them (Fig. 2). This MS matter seems to be original and in reading it, it appears not to have been written all at once, but to have been added to from time to time. I thought at first it might have been copied from Hartlib or Williams but I have been unable to identify it."

These comments and this failure caused Nusco to alert Neri and Skeehan to the volume. The former had studied insect illustrations in the 17th century, the latter was investigating early Atlantic printing and paper making. They soon identified the authors of these comments as John Ferrar and his daughter Virginia (Ransome, 2016). A report of their conclusions, appearing with illustrations in the library's Fall 2012 newsletter (Neri & Skeehan, 2012) caught the eye of DRR. He had edited the Ferrar Papers at Magdalene College, Cambridge, recognised the handwriting as indeed that of John Ferrar and, using not only Samuel Hartlib's work and other pamphlets of that decade but also the Ferrar papers at Magdalene (Ferrar Papers # 1187; Ransome, 1991), was able to set Ferrar's comments in context. Realising, however, that, in making detailed comparison of the 'Virginian' silkworm with the 'European', Ferrar was unlikely to be indulging in a flight of fancy, DRR made contact with DCL while based at Cambridge. This article is the result of their collaboration.

John Ferrar's interest in promoting sericulture in the colony

John Ferrar's lifetime coincided almost exactly with an English interest in silkworms, the mulberry trees they fed on, and the silk they produced. Ferrar's interest in the topic fell into two main phases: between 1619 and 1624, as essentially a businessman, and again from 1645 until shortly before his death in 1657 as a naturalist.

Chosen in 1619 at the age of thirty as the Deputy of the Virginia Company of London, John Ferrar undertook the day-to-day supervision of the company. Among his tasks was the diversification of the colony's economy. It had become almost exclusively, and dangerously, dependant on tobacco. Boat building and iron mining were among the industries he sought to foster; another was silk production.

Even a generation before Jamestown was founded in 1607, Thomas Hariot on Sir Walter Ralegh's expedition to Roanoke (Hariot, 1588) had reported "silke wormes fayre and great; as bigge as our ordinary wallnutts" and suggested both the planting of mulberry trees "for their feeding and nourishing" and the subsequent cultivation of the worms, so that "there will rise as great profite in time to the Virginians as thereof now to the Persians, Turkes, Italians and Spaniards." The suggestion did not fall on deaf ears. Already in England there were indications of an interest in the subject, and when James I succeeded to the throne, he soon noted, as Henri IV was already noting in France, the financial advantages to be gained from the cultivation of silkworms and the production of silk at home instead of its expensive importation from Italy (Potter, 2006).

Despite the royal encouragement, however, and the efforts of the Virginia Company, the enterprise failed both in England and the colony. Nevertheless, Ferrar stubbornly held to the notion of a silk industry. And despite the collapse of the Virginia Company in 1624 and the almost simultaneous bankruptcy of Ferrar's business partner, which in an age without Limited Liability threatened to engulf Ferrar also, he retained his enthusiasm both for Virginia (he named his daughter after the colony) and for silkworms.

and some Corne, which served well for the reliefe of his men, and afterward he furnished the Captaine with all things necessary. Hee as also Captaine *Smith* had a great desire to finde out veines of Gold and Silver, but both he and those that came after him were frustrated in their desire. Yet he sent a Ship loaden with Cedar to *England*. In the meane time *Powhatan* labourd to get some armes and munition from the English, which the Governours did very much suspect, as if the King with those armes intended to kill the English, or drive them out of the Country. But Captaine *Smiths* vigilance and watchfulnesse prevented him, so that he could effect nothing, and the English Colonie living here are now in a good estate increased to many thousands, and Kine, and Hogs, and Turkies aboundance, and all things plentifull, and no want but of good women, thick sowne, but thin come up.

Virginia so now flourisheth, that it victuals other parts.

The Silke wormes with us in Europe have but one Bottome wherein they lye after they have Spun But these wonderfull Virginians have a double Bottome as you by this Figure and the First was you see all full of Silke both in and then in a Second Bottome the worme lyes

This is the forme of the Wild Naturall Silke Wormes Bottom in Virginia ten times bigger And NEW Waighter then 20 of ours of Europe &

This is the Fassion (in an Ovall frame) that the Naturall Silke Worme in Virginia makes her Silke Bottome: ours in the old World are of the Ovall manner: But there is great difference betwixt them: not only in largenes and Wayght: For these Virginia Bottomes doe way more then: 20: of ours in England or those of France Italy Spayne &

memento: the outward Slean Silke that is first spun about the bottome is not added to this Figure else the Bottome would be as big againe

And yeat the Sleave Silke was taken of from the out Side of the Virginia Bottome: but the 20: English Bottomes were wayed against it with all theire Sleave Silke round about them this is most true: I. F.

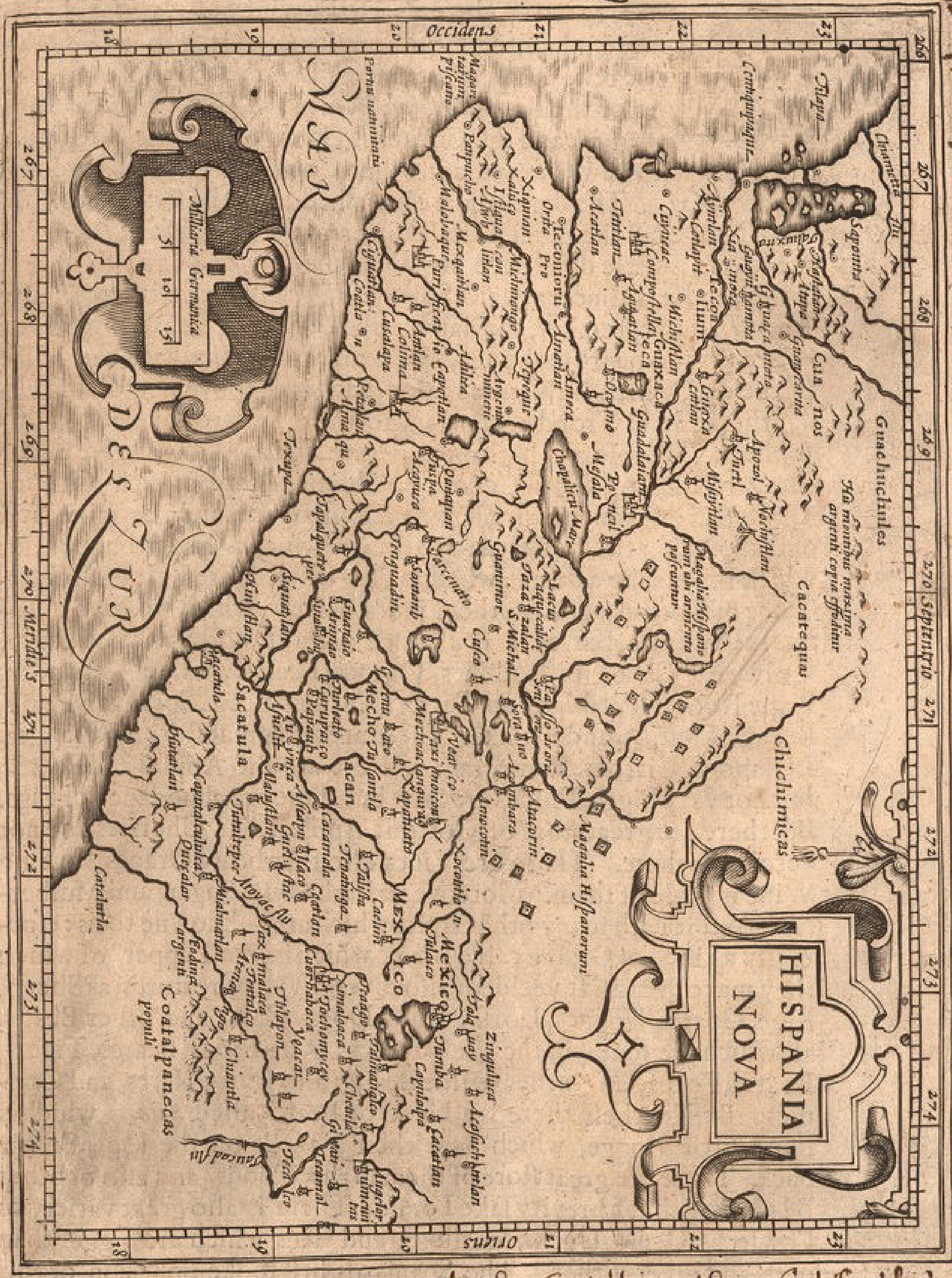
This is the Figure of our Silke Worme Bottome in Europe with there Sleave Silke about

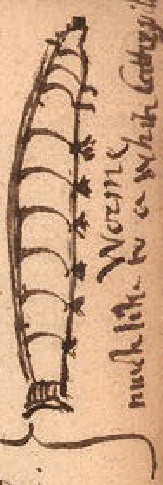
For these Virginians are the Wonder of the World and well may be So for they are for bignes of Bottome and waight of Silke Ten times those in proportion: and wch makes them more admirable, is that while those of the Old world are as we may Say but one Single Bottome in middest whereof our Worme lyes in a Skin, much after the manner wrapped up as this, in a kind of lumpe as it were nothing of Shape more to be desenned: These Virginia mighty Bottomes being almost ten Inches in there Compas round over the Middell and neere Six Inches in lenght. (besides there outward Sleave Loose Silke wch is not heere accounted for then the proportion every way would be much bigger) these I Say have with in the first Strong Incloseur a filinge of Silke much like the first outmost Sleave Silke and then in a Second Bottome with in the First in a Strong Compacted Compas of Silke the greate

The Greate Giantlike Worme lyes in his Silken Sell wrapped up as in a windinge Sheete in a Brownish Skinn as in the figure is Expressed there being noe more Shape to bee Seine: and After hee 40 days time of living and Feeding on the Mulbery tree leaves wch is the time from the first Comming out of there Eggs (and hatching) they then begin to Spin there Glorious admirable Silken Fleece: wch in 4 days they finishe with out and with in and then intombing them selves as you see in there Second Silken Dormitory, they slipp off the Skin they entered in with all and there lying 20: days the End of wch time they againe Skipp of another Skinn and by a Moysture that they Cast out of there Mouthe that Soe Soften the Close and Stronge that Soe in a Strange manner She Comes out: A Gallant Brave, Stately White Winged Silken Flye which like a Butter Flye &

like a greate Butter Flye in Shape with legs. Hornes, Eys, & Then the Male that is knowne by his much Shaking his Wings, doth presently running upp and downe find out the Femall and Soe Joyning tale to tale [illegible] as Butterflys doe and in a day or 2 parte and the Henn then out of her tale presently will lay her Eggs of a whitishe Culler in a round Sercell as bigg as a halfe Crowne peece Cloth one by one very artifficially Some 400: or 500: Eggs: and these are keep upon paper or Cloth where she lays them till 9 monethes after till the Mulbery leaves putt out for Foode And Note that these Silke Flyes never Come out either day or night [illegible]: but betwixt Sun rise and 9 a Clocke in Morninge not after till the next [illegible]

THE DESCRIPTION OF NEVV SPAINE.





The Shape of the Silke Wormes which Catterpil... much like to

Finding this trade to be met
Noe Witt, noe Strenght noe Purse, noe Stocke will neede
But Eyes and Hands the Wormes to guard and Feed.
And for all Tooles that apperteine there to
A Twelve penny Reele is all twill cost you:

July 1654 the Governor of Virginia and other Gentellmen there. Certifie that then the
Renowned Sr. Digg had soe happily brought the Silk designe to that pass wth
his two Armenians Skill. That he presented to them a bout one

hundred wayght of Excellent Silke in Skeynes to all there great Joyes
And there upon Enacted that whoe soe ever of the Collony should next
Spring make one hundred pounds waight of Silk should have for a gratuity of
his Industry Ten Thousand pound wayte of Tobacco: And now by the
undeniable proofe made before there Eys, they are all satisfied that the designe is
feazable, with much Easines and greate proffitt will arrise to all by the Trade
Soe that they resolved to proceede the thing with all diligence and readines

In the aftermath of the double collapse of the company and his personal prosperity, Ferrar withdrew with his mother, wife, son, and younger brother to Little Gidding, and was content, while his mother and brother lived, to follow their lead. After their deaths, respectively in 1634 and 1637, Ferrar began to cultivate his own interests once more. The Civil War forced this moderate royalist to retire for a couple of years to the Low Countries, but he was back by 1646 and once more took up his two enthusiasms, for the colony and the silkworm.

Breeding silkmoths at Little Gidding

By this time his daughter Virginia was almost twenty and enlisted as her father's ally in cultivating not only colonists of all ranks in Virginia but also silkworms at Little Gidding. There she had, we are told, a "young mulberry tree in her garden," and may well have had others. She carried on a correspondence with Virginians, some of them her kinsfolk who sent her specimens from the colony, including silkworm cocoons, or (as Ferrar called them) bottoms. Surviving evidence indicates that her correspondence was more truly her father's, as apparently were the map, broadsheets and pamphlets ostensibly created and written by her (Ransome, 2016).

We do not know when Virginia began to breed silkworms at Gidding. Little faith can be given to her father's statement in 1652 or 1653 that she had been "many a year a Mistris of Silkworms" (Hartlib, 1655: 10); it is unlikely that her cultivation of silkworms antedated the Civil War. (She was only fourteen when the king raised his standard at Nottingham in 1642.) Nor do we know when both 'European' and 'Virginian' silkworms were first to be found at Little Gidding, but it was certainly by 1653 and may have been three or four years earlier. In 1649 Virginia's cousin and close friend, Mary Mapletoft, departed for Virginia with her first husband; by 1651 she was married again, to Laurence Ward, and had sent Virginia "Ten rare Bottoms took from her Apple tree." - most likely in 1652, if her husband's letter to John Ferrar in early 1653 [Ferrar Papers # 1216] refers to them rather than to another consignment. A Ferrar kinsman sent another ten "which he found on stately Oakes and Shrubs that kiss the ground And Doctour Russell that learn'd Physitian" [sent yet more]. We are also told that Laurence Ward sent bottoms taken from the "Pohickerry" tree, and Mr. Wright yet others from a Cherry.

Ferrar, meanwhile, recruited for his silkworm project not only his own son John and a nephew Richard Farrar but, more importantly, Mary's brother, John Mapletoft (1631-1721). Like Mary, on the death of their father in 1635, Mapletoft had come to Gidding and been raised there. An undergraduate in 1648 and then a Fellow of Trinity College, Cambridge, he later became a fashionable doctor, a Fellow of the Royal Society, and lastly a clergyman. In the early 1650s he was still in the Gidding orbit, and Ferrar made use of his literary skill to polish "The History of the Silkeworme". Ferrar then edited it, underlining passages and at various times adding marginalia. The manuscript is undated but can be no later than 1654, for Ferrar in a marginal note refers to "S[ai]nt Andrues day last [30 November] 1653." The History may well be several years earlier, for the paper contains no information that relates to the Virginian silkworm.

In contrast the extended and somewhat repetitive notes that Ferrar penned in his copy of Mercator's Atlas (Saltonstall, 1635) concentrated on the Virginian silkworm, pointing out how it differed from the European silkworm. Ferrar was still eager to promote silk industry but, almost unawares, was transforming himself from a businessman into a naturalist. His descriptions are no longer merely mercantile, seeking economic profits, but essentially entomological, though admittedly unsystematic. Nevertheless, the descriptions he offered, when combined with the information from the Ferrar papers and the editions of the work that by 1655 had become *The Reformed Virginian Silkworm*, edited by Samuel Hartlib, make it possible to identify this Virginian silkworm (or at least the silkmoth most likely represented).

The clues that forward the search are to be found in Ferrar's remarks in The History of the Silkeworme about the 'European' silkmoth, and about the 'Virginian' in his copy of Mercator's *Atlas*. He contrasts the eggs, 'worms', and cocoons of the two species. The European lays eggs "300, 400, 500, all in the compasse of an half crowne & almost contiguous & all in a days space … about the bignesse of Turnep seed, round & flattish on both sides. When first laid whitish, then reddish, about the 5 or 6 day grayish, which colour they keep till the worme is hatched (& then the[y] waxe white againe)." In contrast the Virginian silkmoth's eggs "are grate like Fetches [vetch seeds] broun Culler Flattish and in 9 days there Eggs ha[t]ch."

As for the worms, The History of the Silkeworme opens with a long description of *Bombyx mori*: "…an Insect allmost two inch long when at her full growth, & the bignesse exceeds a swans quill, of a whitish colour, inclining somewhat to a pale blew, her sides powdered with little black spots aequally distant one from the other, not unlike small oiletts [eyelets]. The skin of her back, except when she's at full length or in progresse lyes in folds at severall distances as doth the Lobster armour [Ferrar underlines 'Lobster armour' and suggests 'Body of a Waspe"]. Towards her tayle is a little skinny excrescency fashioned like the prickle of sweet Brier [Mapletoft prefers this description to Ferrar's 'thorns point'] but not stiff. The skin of her head is gathered into pleats. Her ey[e]s are much controverted, though there want not probabilitys for the affirmative. An appearance of black streaks in their place in undeniable, which if its more remarkable your worme is male, if lesse female. The former part of the head (her supposed nose & mouth) resemble a Bee's. Her legs are 16, 6 of a lesser make, & sharper at the end, which are paced just under her head. At a distance follow 8 more, hairy round & flatt at the bottome. Not farre from these are 2 more, like the former save that they seeme to be the two sides of her parted tayle. She crawls much like a Caterpillar." In summary, Ferrar pens a drawing of this silkworm, whose shape, he says, is "much like to a white Cabbage", i.e. the caterpillar of a Cabbage White (Fig. 3).

In the Atlas, Ferrar offers no comparable description of the 'Virginian' silkworm, merely referring to it as a "Greate Giantlike Worme", clearly larger and longer than the 'European' one. His emphasis is on the cocoon (Fig. X, XI. XII), "ten times bigger And Wayghtier than 20 of ours of Europe." Moreover, "The silke-wormes with us in Europe have but one Bottome wherein they lye after they have Spun But thes wonderfull

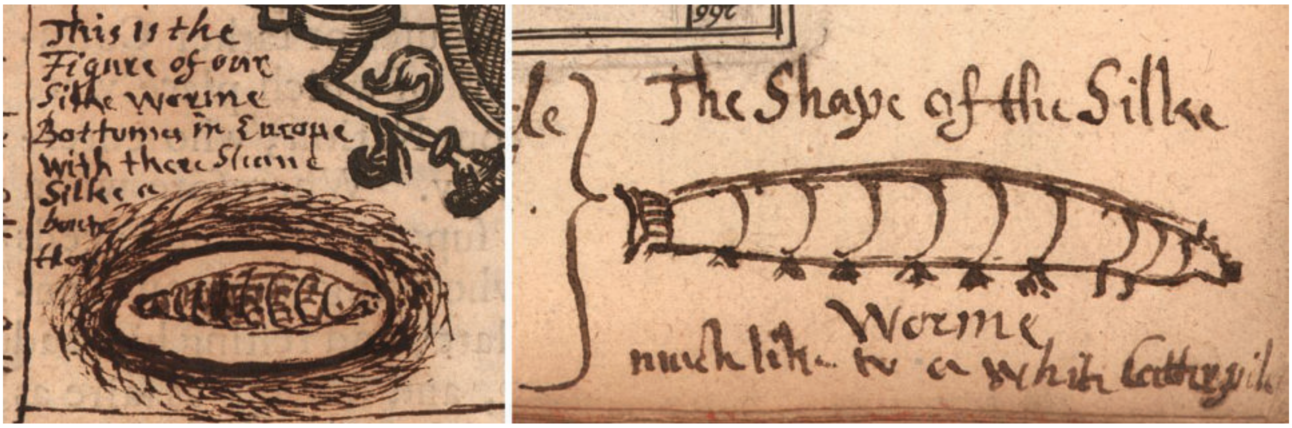


Fig. 3. Left: Cocoon of *Bombyx mori* with larva inside from Mercator Atlas showing single cocoon. “This is the Figure of our Silke Worme Bottom in Europe with There Skane Silken ….”. Right: crude sketch of larva of *Bombyx mori* from Mercator Atlas with perceived resemblance to Cabbage White larva.

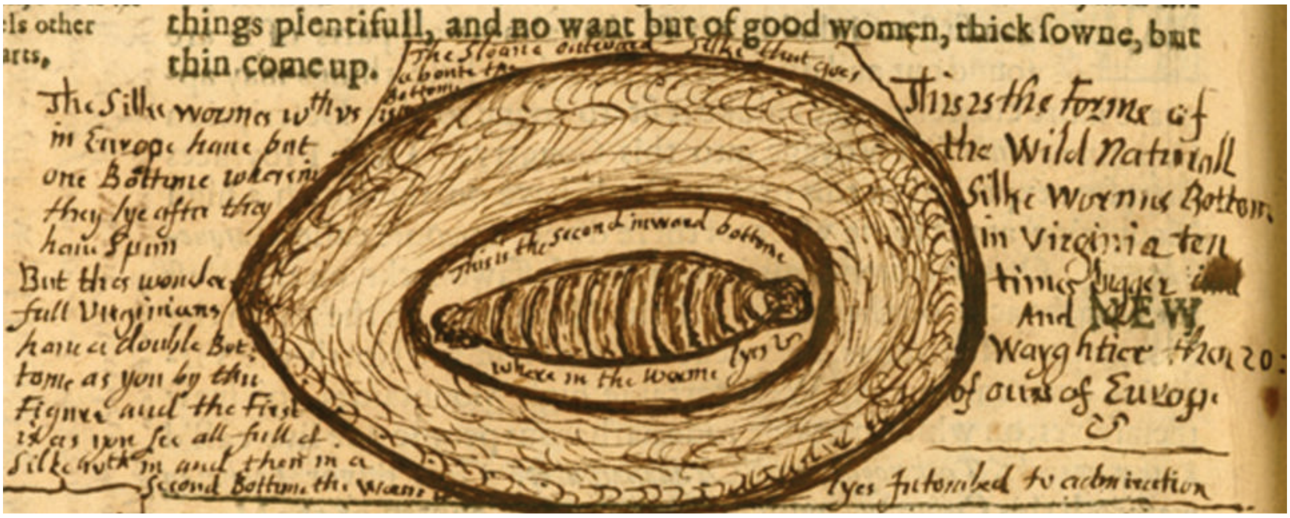


Fig. 4. “Double Bottom” apparently of *Hyalophora cecropia* with larva inside from margin of Mercator Atlas. “The is the Forme of the Wild Naturall Silke Worme Bottom in Virginia ten times bigger and Wayghtier than 20 of ours of Europe”

Virginians have a double Bottome … the First is …all full of Silke with in and there is a second [wherein] the Worme lyes Intombed to adniration.” Ferrar later explains that these double Bottomes (Figs. 4, 5) act “as a double defence that the Birds pick them not out” during their nine months of hibernation.

But interesting as these facts are, the identification of the Virginia silkworm depends on Ferrar’s brief account of the moth contrasted with his description of the ‘European’ moth, and more particularly on the information of the ‘Virginian’ moth’s host plants.

The ‘European’ moth emerges from its cocoon as “a white long-horned silken fly, covered all with a short soft downe. The male Fly … is known from the female by having a lesse body & the more frequent motion of his wings.” In the Atlas, Ferrar terms this silkmoth “A Gallant Brave, Stately White Winged Silken Fly much like a Butter Flye.”

The fashion of the Botome.

The Silke Bottome of the
naturall Worm in *Virginia*, found
there in the Woods, is ten Inches about,
and six Inches in length to admiration: & where-
as ours in *Europe* have their Sleave and loose Silke on
the outside; and then in a more closer covering they in-
tombe themselves. These rare Worms, before they
inclose themselves up, fill with Silke the great
emptinesse, and afterwards inclose them-
selves in the middle of it, so they
have a double Bottom.

Fig. 5. Poem by one of the Ferrars in form of “Silke Bottome” (Ferrar, 1655: 10).

The Virginian silkmoth emerges, however, from "her Mighty greate double Bottome and Comes out a most glorious painted Butter Flyes of Seve[r]all Cullers with mighty large wings and Bodys, and proceeds to copulation".

Host plants of the Virginian Silkworm

Its progeny, according to Ferrar and his informants, had a far more varied diet than the European silkworm that feeds almost exclusively on mulberry leaves, lettuce being acceptable as a substitute. The Virginian silkworm too ate mulberry leaves but was also found on other fruit trees, on apples and pears that had been grafted on native crab apples, on plums, cherries and persimmon, on poplar, dogwood, hickory, oaks and other shrubs.

These host plants, all named in the 1650s, permit a preliminary narrowing of the possible candidates for identification as the 'Virginian' silkmoth. These large silkmoths number six species, all from the family Saturniidae, four from the subfamily Saturniinae and two from Hemileucinae. It is of course possible that one or more of the Ferrars' kin and friends in Virginia encountered more than one wild saturniid species. They might have met the hemileucine (Hickory Horned Devil), but neither this nor *Anisota senatoria* is likely to represent 'the Virginian silkmoth', for Rosaceae trees are not among their host plants. *Hyalophora euryalus* can also be eliminated. It is nowadays distributed only in the western United States. The Luna Moth can be ruled out because of its relatively narrow host plant diet. *Antheraea polyphemus* is unlikely because of a smaller host plant repertoire. There thus remain two possible candidates: the Promethea Moth (*Callosamia promethea*) and the Cecropia Moth (*Hyalophora cecropia*), both of which are relatively polyphagous. Almost of all of the cited host plants, the five Rosaceae – crab, apple, pear, plum, and cherry – as well as the persimmon, poplar, dogwood, hickory and oak are shared by both species. However, mulberry is the host plant that gives the game away.

Only the Cecropia Moth will eat mulberry, but does not always do well on it. A detailed study of the feeding habits of the Cecropia Moth was conducted in Illinois (Scarborough *et al.*, 1974). More than 3,000 cocoons were observed in the wild, and detailed survival tests were conducted. Most of them were found on *Acer* (maple), *Betula* (birch), *Cornus* (cherry or dogwood), *Lonicera* (honeysuckle), *Malus* (apple), *Paeonia* (peony), *Prunus serotina* (black cherry), *Rhamnus* (buckthorn), *Rhus* (sumac), and *Salix* (willow). In laboratory tests, all that were fed on various species of hickory, cherry and dogwood, poplar, plum and oak as well as persimmon and the European pear survived, but only 70% survived on mulberry and fewer or none at all on other genera. Thus, while *Hyalophora cecropia* has a perfect score as the candidate for the Virginian Silkworm, the Promethea and Luna moths are also to be found on persimmon and hickory, and other Saturniidae species, including the Promethea and Cecropia, feed on fruit trees from the Rosaceae and beeches from the Fagaceae.

The Virginian silkworm as the Cecropia Moth

Ferrar's description of the Virginian silkmoth's eggs – brown and flattened like vetch-seeds – can be applied to the Cecropia Moth and almost as aptly to the Promethea. Oddly, considering the attention devoted to *Bombyx mori*, he does not describe in detail the larva, which can be up to 4.5 inches in length; particularly considering both the Cecropia and Promethea caterpillars sport remarkable, although very different, protuberances. Ferrar's illustration does reveal the double cocoon, which is a feature of the Cecropia. It has a multi-layered construction which probably helps to regulate moisture as in other silkmoths (Horrocks *et al.*, 2013), and – as Ferrar has remarked – also protects the cocoon from birds. The Cecropia breeds at only one season, and the cocoons could most easily have survived, during their nine-month diapause, the long sea voyage from Virginia to Little Gidding. It seems certain, however, that Ferrar exaggerated their size, writing that "These Virginia mighty Bottomes being almost ten inches in there Compas round over the Middell, and nere Six Inches in lenght bee sides there outward Sleave Loose Silke which is not here accompted for then the proportion every way would be much bigger."

Nevertheless, Ferrar was correct to describe the Cecropia Moth as 'a most Glorious painted Butter Flyes of Seve[r]all Cullers with mighty large wings and Bodys." It has a six-inch wingspan and is even more impressive (Fig. 6) than Ferrar's description of it. The female Promethea is also colourful (but not so the darker male), but this species is smaller, reaching only about 3.75 inches in wingspan and having less impressive eyespot-crescents within the basal areas of each wing.

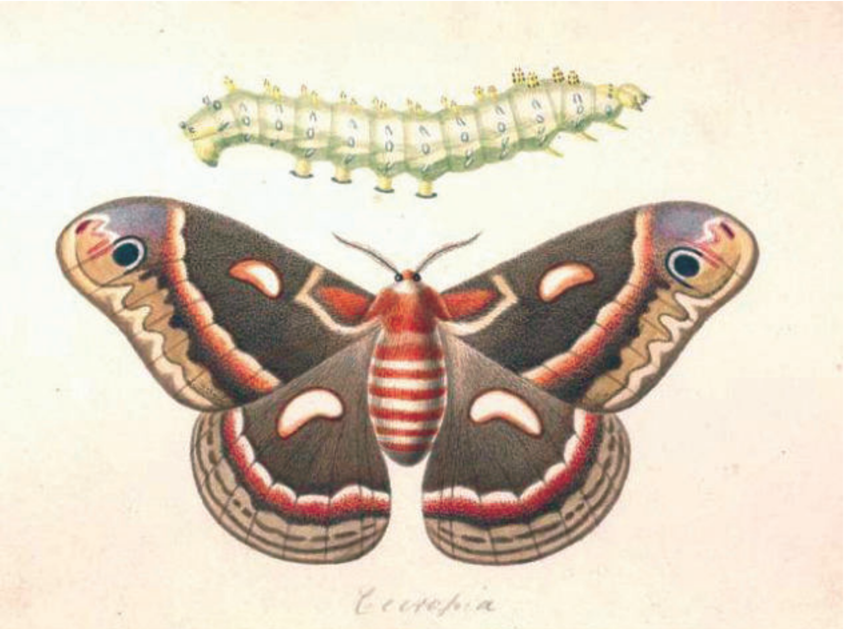


Fig. 6. Watercolour of female Cecropia Moth and its larva from 'The John Abbot Watercolors' at the Thomas Cooper Library of University of South Carolina.

Significance

The importation of an exotic silkmoth belonging to the family Saturniidae into England in the mid-17th century has apparently never before been noted, let alone described, either in informal or mainstream entomological literature. In entomological studies this greatly extends the history of the breeding of the species that we consider to be the Cecropia Moth, and predates by a generation Maria Sibylla Merian's famous and rather fanciful documentation of the life histories of large moths from Surinam. In addition this adds a footnote to the failed attempt to introduce domestic sericulture to the North American colonies in Virginia and Carolina. Although saturniid cocoons had long been used by some Amerindian tribes as ankle bracelets (Peigler, 1993), temporarily in the 1650s, thanks to Governor Digges and his two Armenians, silkworms were, it seems, successfully but briefly cultivated in Virginia. This activity happened two centuries before Trouvelot's experiments with wild silk (Verrill, 1865; Liebhold *et al.*, 1989) and was in large part thanks to the advocacy of John Ferrar, a failed entrepreneur but ultimately an unwitting entomologist.

Acknowledgements

We thank both Harriet Campbell Longley of the Natural History Museum is for her help in searching for illustrations and Leslie Tobias-Olsen for providing the image from the Mercator Atlas, courtesy of the John Carter Brown Library at Brown University. Ben Marsh helped greatly with insights into his research and references for his forthcoming study, tentatively entitled "Unravelling Dreams: Silkworms and the Atlantic World, c.1500-1840".

References

Blomberg, A. de Avila (1997). "Threads of diversity: Oaxacan textiles in context" in K. Klein ed., *The Unbroken Thread: Conserving the traditions of Oaxaca*, pp. 87-151.

Borah, W. (1943). Silk raising in Colonial Mexico. *Ibero-Americana*, **20.**

[Ferrar, J.]. Hartlib, S. (1652). A Rare and New Discovery of a speedy way ...For the feeding of Silk-worms in the Woods, on the Mulberry-Tree-leaves in Virginia.

Geffe, N. (1607). *The Perfect Use of Silk-wormes*. [Translation of work by Olivier de Serres, 1598].

Good, I. (1995). On the question of silk in pre-Han Eurasia. *Antiquity*, **9**: 59-68.

Hariot, T. 1588. A briefe and true report of the new found land of Virginia.

Hartlib, S. (Ed.) (1655). *The Reformed Virginian Silkworm*.

Horrocks, N.P., Vollrath, F. & Dicko, C. 2013. The silkmoth cocoon as humidity trap and waterproof barrier. *Comparative Biochemistry and Physiology* (A) *Molecular and Integrative Physiology*, **164**: 645-52

Liebold, A., Mastro, V. & Shaefer, P. W. (1989). Learning from the legacy of Léopold Trouvelot. *Bulletin of the Entomological Society of America*, [**1989**]: 20-22.

Neri, J. & Skeehan, D. (2012). "The Mystery of the Silkworm : conversations in the reading room and beyond. *I Found it at the JCB, Online Journal of the John Carter Brown Library*, **August 2012** : 8.

Peigler, R. (1993). Wild silk moths of the world. *American Entomologist*, **39**: 151-161.

Potter, J. (2006). *Strange Blooms: The Curious Lives and Adventures of the John Tradescants*.

Ransome, D.R. (1991). *The Ferrar Papers, 1590-1790* (1991, microfilm; 2008, online by subscription).

Ransome, D.R. (2016). "Virginia Ferrar, A Liberated Woman", *Records of Huntingdonshire*, **Oct. 2016.**

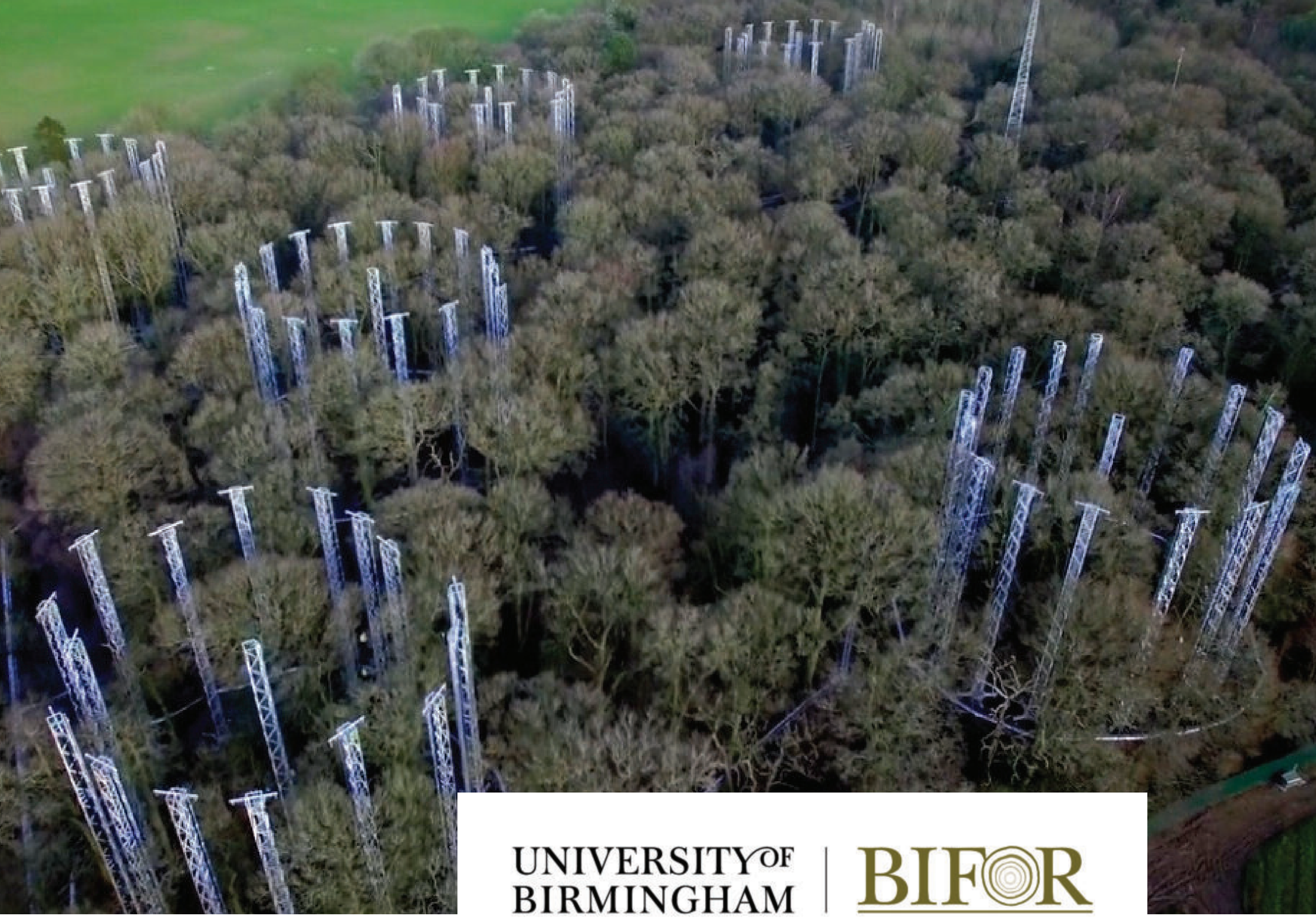
Saltonstall, W. (1635). *Mercator's Historia Mundi or Atlas*. [translation of a copy of the first edition of Gerhard Mercator's "Atlas or, A geographicke description of the world"].

Scarborough, A.G., Waldbauer, G.P. & Sternburg, J.G. (1974). Feeding and survival of *Cecropia* (Saturniidae) larvae on various plant species. *Journal of the Lepidopterist's Society*, **28**: 212-219.

Shelagh, V. (2004). *Chinese Silk: A Cultural History*.

[Stallenge, W., translator]. (1609). Instructions for the increasing of mulberie trees and the breeding of silke-worms, for the making of silke in this kingdome : whereunto is annexed His Maiesties letters to the lords liefetenants of the seuerall shieres of England, tending to that purpose. [Translation of a work of 1603 by Jean Baptiste Letellier].

Verrill, A.E. (1865). A new American silkworm. *American Journal of Science and Arts*, **34**: 228.



Bugs, bees, carbon and trees

Liam Crowley

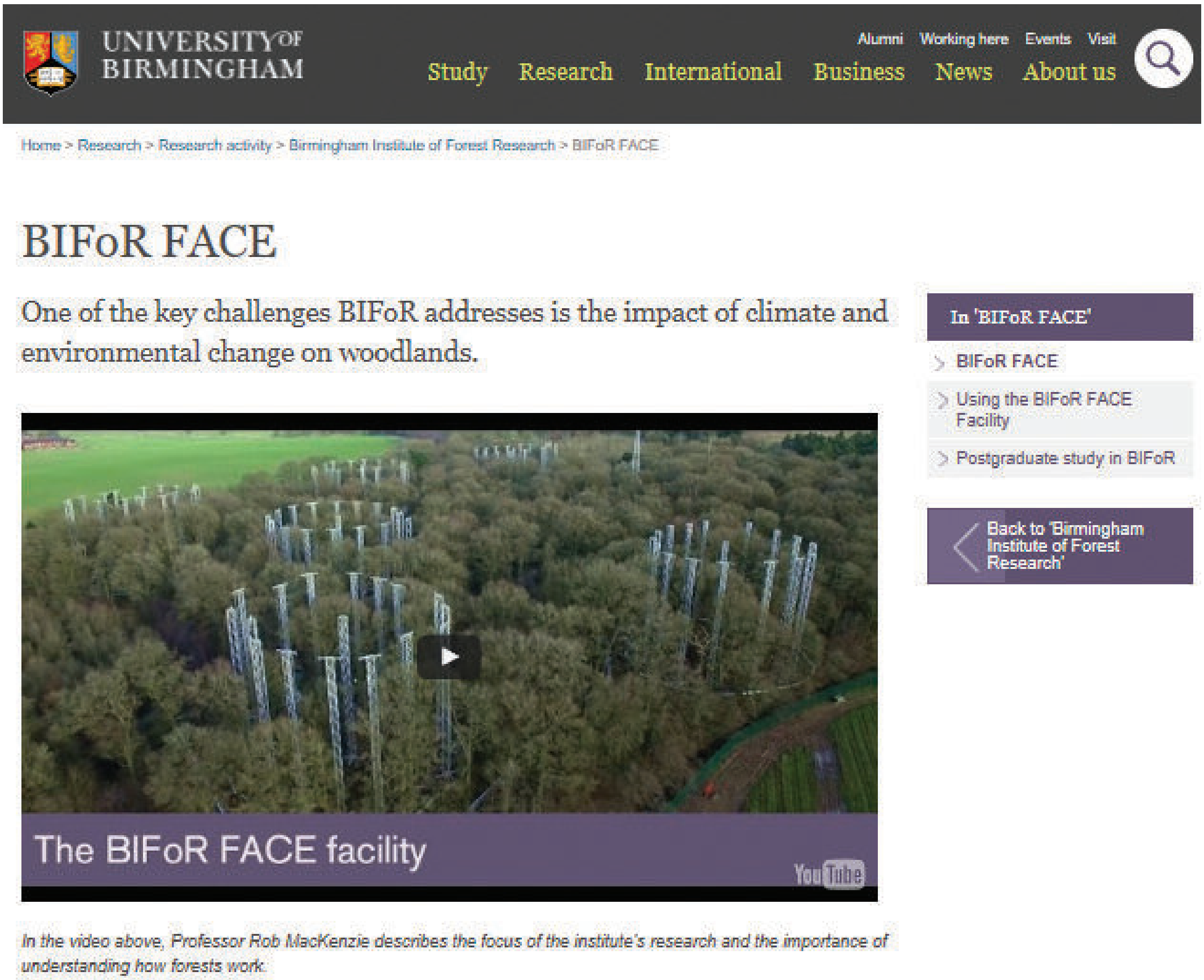
Introducing BIFoR FACE

If you go down to the woods today, you might be in for a surprise. I'm talking specifically about one very special wood in Staffordshire. A few miles west of Stafford, lies the new Birmingham Institute of Forest Research (BIFoR) experimental free-air Carbon Dioxide enrichment (FACE) facility. This state of the art facility sits at the cutting edge of ecological research, providing researchers the opportunity to peer into the future and gain an understanding of what our forests might look like in 50-100 years' time. This facility is playing host to an exciting new entomological research project, looking at how insects will respond to climate change and the consequences of this on the rest of the ecosystem.

The new institute at the University of Birmingham focuses on fundamental physical, biological, ecological, social and cultural research related to forested landscapes worldwide. The main research aims are to address two fundamental challenges:

1. The impact of climate change and environmental pressures on woodlands
2. The resilience of trees to pests and diseases.

So how does this relate to the FACE facility? It's all about carbon. We know that anthropogenic activities including combustion of fossil fuels and deforestation have, and continue to lead to an increase in the atmospheric concentration of carbon dioxide. This widespread and large scale



http://www.birmingham.ac.uk/research/activity/bifor/face/index.aspx

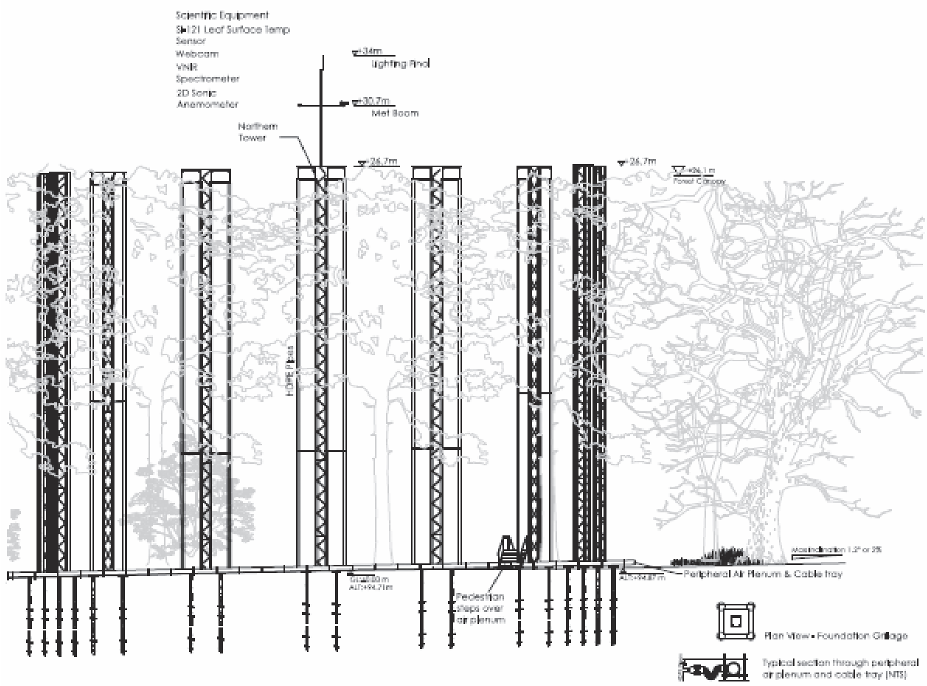
environmental change represents a significant factor influencing future ecosystems. To date, most climate change experiments have focused on temperature, but increasing CO_2 has its own direct role in global environmental change. The BIFoR FACE experiment is one of the world's biggest climate experiments, seeking to shed light on what impact these elevated atmospheric CO_2 (eCO_2) concentrations will have on woodland ecosystems by measuring the effects of controlled CO_2 fumigation *in situ*.

Whilst previous studies have begun to explore what effects eCO_2 will have on the environment and biological systems, this has never been tested at the ecosystem level in an open, mature, temperate woodland system. BIFoR FACE will address this over a 10-year time scale, using a £15 million facility to elevate CO_2, allowing detailed measurements of the responses across a range of research areas. This is a truly interdisciplinary research project, involving researchers from a multitude of areas from ecology and climatology, to mathematics and engineering; even public health and economics! The core focus of the project is to elucidate how the woodland responds to the CO_2 enrichment in terms of carbon storage, nutrient uptake, biodiversity and ecosystem function. These will be assessed and compared across three experimental plots which undergo CO_2 enrichment and three control plots exposed to ambient air. Air enriched with CO_2 to 150ppm above ambient (or ambient air in the case of the control arrays) is delivered to the plots via a 30m diameter ring of towers. These towers hold CO_2 delivery pipes which are opened and closed by valves depending on detailed feedback on CO_2 concentration and wind direction. There are a further three completely undisturbed 'ghost' plots, providing an additional level of control.

The experimental site is situated within a mature Oak woodland, characterised with English Oak, *Quercus robur*, 'standard' primary trees and a Hazel, *Corylus avellana* understory layer. Mature woodlands are highly heterogenous in terms of structure and species composition and as such contain highly complex ecological networks.

Insects under eCO_2

The BIFoR FACE project provides a unique opportunity to investigate how insect communities within mature, temperate, deciduous woodlands will respond to eCO_2. Further to this, the dominant role insects play in the functioning of terrestrial ecosystems will also mean that any responses experienced by the insect community are likely to also have major implications for the entire forest. Without knowing how insects respond to eCO_2, we cannot begin to understand or predict how the rest ecosystem will react. Due to forests being important components of global



carbon, nutrient and water cycling, as well as being home to more than half of all known species, you might say studying forest entomology is like studying the most important determinants of the most important ecosystem!

In September (2016), I commenced a PhD project at the University of Birmingham, jointly supervised by Dr Scott Hayward and Prof. Jeremy Pritchard in the School of Biosciences and Prof. Jon Sadler in the School of Geography, Earth and Environmental sciences. Based at BIFoR FACE, the title of my project is 'Are insects key drivers of change in woodland systems under climate change?'. This broad remit encompasses questions of how insect abundance, diversity, community composition and phenology will change under eCO_2, as well as more focussed investigation on the implications for insect-plant interactions including herbivory and pollination.

The close link between insects and the wider ecosystem, which, along with their short response times to environmental perturbations, means insects could provide the earliest and most detailed indication of climate change impacts. Subtle changes which are not easily detectable across the rest of the system may manifest in the insect community where they can be more easily distinguished.

My project can be broadly divided into three key areas. The first is to simply attempt to document the effect of eCO_2 on insect diversity, abundance, and phenology. This will be achieved through a detailed regime of sampling at monthly intervals throughout the three-year duration of my project (and beyond!). This will involve a range of sampling methods, from ground level to the top of the canopy, in order to capture as many different life histories as possible. The objective of this is to build a broad yet representative indication of the arthropod fauna and document any changes as the experimental treatments progress. Knowing if and how the insect community is changing is the first step to being able to predict how the ecological network might shift under eCO_2.

Secondly, I will focus in on how eCO_2 affects herbivorous insects through changing biochemistry in the plants they feed on. Changes in insect herbivore feeding traits (such as feeding rate), life history traits (such as development time) and interactions

a) Carabid beetle, *Abax parallelepipedus* b) Coloured water traps c) December moth, *Poecilocampa populi* d) Malaise trap.

with higher trophic levels (such as rates of parasitism) will be explored in-field. Simultaneously, the mechanisms driving these changes will be examined in the lab. Any changes in herbivores will feedback into the system through alterations in insect-mediated nutrient-cycling. This is an area which remains relatively unexplored, therefore I will seek to determine how eCO2 affects the biochemistry of insect feeding and frass production, which directly feeds back into to woodlands nutrient cycles.

A key aspect of these herbivory experiments will be distinguishing between differential responses between different feeding guilds, as well as even possibly species-specific responses. Aphid and leaf-miners have been identified as two groups of herbivore which are present in the woodland in large numbers, and therefore are certainly ecologically relevant. These two groups also represent two different feeding guilds with dissimilar life histories, thus potentially a highly informative comparison may be made between the two.

The final major focus of the project will be an examination of how the synchronicity of woodland plant-pollinator interactions is affected. eCO_2 is known to influence woodland plant phenology, which includes effects on flowering times. Data on the phenology of both the plants and their potential pollinators can be combined with data on the micro-climate of the site (such as canopy dynamics, light penetration and photosynthetic rates) to model how eCO_2 may indirectly impact on plant-pollinator interactions.

Through combining these different components, the project will identify key responses in woodland insect communities to eCO_2 and how these impact on the ecology of a mature temperate woodland. Performing this study within the FACE experiment provides 'real-world' data on a hugely complex, open ecosystem, thus informing us in a way which is not possible in the lab alone. After all, it's not every day that as an entomologist you can step into the future and see how insect communities have changed!

The results of the FACE experiment also have implications which reach far beyond the UK alone. Temperate forests represent a major ecosystem worldwide, and many of the findings will be applicable to many different environments making this experiment truly global. Forests are vital for biodiversity across the planet, and knowledge about how they will respond in the future has never been so important. It is a real privilege to be involved with genuine 'big science' which is so much more than my PhD project, and I look forward to providing updates as the project develops!







Society News

Royal Entomological Society Postgraduate Forum 2017

by Vicki Senior and Scott Dwyer

On February 2nd and 3rd 2017 the RES held its annual postgraduate forum at the University of Sheffield. The atmosphere buzzed, pun intended, with early career entomologists ready to absorb and share the current insect research happening across the UK. 2017 saw record breaking delegate numbers with a total of 64 delegates registered to attend. There was a fantastic share of knowledge across an impressive 28 poster presentations, 13 high-quality student talks and 5 invited senior entomologists who were invited to speak on our theme of 'entomology in the 21st century'. We tweeted throughout the day on the #RESPG17.

As coffee was drunk, early day discussions began, the posters went up and talks were loaded. At 11am we were ready to begin, and a warm welcome was given by Postgraduate Representatives to everyone in attendance.

Our first invited speaker of the day, Dr Ilik Saccheri, University of Liverpool, opened the forum with an engaging talk, presenting new information on the classic example of natural selection, the peppered moth. All melanic forms result from a single mutation event (a transposable element) in the early 1800s. Ilik entertained us with tales of how research really can be done anywhere - rearing moths in his back garden and hiring his children as research assistants!

Moving on to our delegate speakers, up first Robin Southon intrigued us from the start, with an unusual and brilliant talk title, 'Are male Hymenoptera just flying sperm?' describing his work on a paper wasp – and arguing the potential important roles of males in hymenopteran societies. Following was Callum Macgregor on his novel work using next generation sequencing to explore plant pollination networks in perhaps the more forgotten pollinators – moths. Concluding our first delegate session, Anthony Abbot described his investigation into the habitat requirements of a potential vector of the west nile virus in the UK – *Culex modestus*.

With the morning over, lunch and networking over an informal poster session ensued. Then, when we were full up on food and great conversation, we settled in for our second invited speaker. Dr Rosemary Collier, Director of Warwick Crop Centre, University of Warwick, gave a great presentation which discussed the history of IPM, new innovations and its future. She stressed the importance of new developments such as the implementation of camera technology which can aid in rapid detection of pests by sending photographs of traps to landowners and farmers.

Naturally leading on from this was a delegate session themed around pest control. Michelle Powell kicked us off with a novel control method for a serious pest of the honey bee. Thomas McDaniel, despite claiming the insect part of his talk was over after a few minutes, still engaged the entomological audience about using volatile organic compounds as a novel method of whitefly resistance.

After a well needed afternoon coffee break (and some donuts on the side) Amoret Whittaker took the stage for her greatly anticipated talk on forensic entomology – 'CSI: Crime Scene Insects'. Amoret took us through the fascinating applications of entomology to aid in solving crimes, from cases of murder, wildlife crime, drug trafficking and child neglect. Though often unappreciated, this talk highlighted the broad application of entomology and the great importance of insects to so many fields of study.

A single delegate talk of the day remained in which Katy Dainton discussed her work with Forest Research on finding new ways to tackle the most important economic pest for commercial forestry – the large pine weevil. This included telling us about her 'weevil arena'; although Katy claimed it wasn't as exciting as it sounds - we were inclined to disagree.

We ended the day with poster session and it was rewarding to hear so many great discussions between delegates and the genuine interest shown within and between disciplines. Delegates were reluctant to leave at the end of the poster session, but were quickly enthused at the prospects of our evening schedule.

We made our way over the Halifax Hall and relaxed conversation flowed in the bar before the conference meal and continued as people were seated, aided by wine which we were able to supply thanks to the generosity of our sponsors. Food and drinks were

Name badges ready for the 64 delegates upon arrival! Source: Melanie Brien

Delegates in deep discussion throughout the poster session   Source: Francisca Sconce

accompanied by an entomologically themed pub quiz, where competition between entomologists ensued over ‘guess the insect cartoon character’ and the unusual ‘guess the punch-line of these entomological jokes’. Our favourite was ‘What’s a dung beetles best chat up line? … Is this stool taken?’

The second day kicked off promptly with Professor Jane Hill from the University of York discussing what insects can tell us about climate change. It was a reminder about how drastic the impacts of climate change can be, with some butterflies shifting ranges of 1.75km a year in response. Jane touched upon her amazing insect conservation success story of the translocation of the Marbled white, *Melanargia galathea*, to new sites in County Durham. Although controversial such translocation may be a useful tool to conserve future insects threated by climate change.

Our first student talks on the second day were from Kris Sales, Matthew Hayes and Michelle Davis. Kris Sales aptly named talk ‘Putting the heat on insect reproduction’ discussed the impact of heatwaves on reproductive fitness. This was followed by Matthew Hayes telling us about the ecology of the charismatic Duke of Burgundy butterfly, a unique and poorly researched species suffering big declines due to specific habitat requirements not being met in management techniques. Next up was Michelle Davis, who told us about the conservation success story of the Marsh Fritillary and her research on understanding the post-reintroduction genetics of historic and reintroduced populations – a fantastic and engaging talk with humour throughout of tales of butterfly leg borrowing.

After a short coffee break we were back with our second invited speaker of the day, Dr Chris Hassall from the University of Leeds. Chris told us about dragonflies in the changing world and their use as barometers for global change – possibly a species to rival butterflies! We also welcomed Chris’s past biology teacher, along with current Biology A level students, to this session from Birkdale School; we hope they took home a bit of entomological inspiration!

Our final student talks of the day came from Robert Holdbrook, Charlotte Miller and Craig Perl. Robert from Lancaster University explained the effect of diet on host nutrient availability in Spodoptera. This was followed by Charlotte Miller from Queen’s University Belfast who gave us a talk on the immune tolerance in burying beetles, high fat diets seemingly leading to higher tolerance of bacterial infection, though death was still inevitable. Lastly, we welcomed Craig Perl from the University of Sussex talking about allometry and differential scaling in compound eyes of the visually guided wood ant, *Formica rufa*.

We then broke for lunch, during which we finished our voting for the best talk and posters of the forum. Afterwards we had an engaging publication workshop run by Professor Jane Hill, discussing the journey to publication, journal choice, open access, feedback and the review process. The key take home message was ‘publish early and publish often’.

This workshop was followed by Francisca Sconce from Harper Adams University and the Royal Entomological Society on how to engage outside of your current research and the skills that can be obtained from outreach in STEM (Science, Technology, Engineering and Mathematics), teaching, conferences and networking. The talk left student participants keen to engage within science beyond their PhD and gave us some great ideas for ways we can engage with the public!

Finally, Dr Luke Tilley, Director of Outreach from the Royal Entomological Society, summarised the societies aims, activities and meetings throughout the year in which we could get involved. Luke then awarded the prizes for the best talks and oral presentations of the forum.

It was a delight that the RESPG forum brought together researchers connected via entomology, provideding the basis for cross-disciplinary discussion, with entomologists from a vast array of backgrounds ranging from animal behaviour to biocontrol and from evolution to ecology.

We thank all the student delegates and invited speakers who attended the forum, the RES team and our sponsors, Syngenta, Koppert, Watkins and Doncaster and BugLife, who allowed us to put together a successful meeting. We hope that all those that attended enjoyed the meeting and we look forward to seeing you at the Royal Entomological Society Postgraduate Forum 2018, being hosted at the University of Warwick.

Talk and poster presentation winners at the PG Forum 2017   Source: Francisca Sconce

Dion Garett supervising microscopes Credit: Francisca Sconce

'Do you want to hold an insect?' Creating a buzz at the Big Bang Science Fair 2017

Francisca Sconce

Meeting a six-legged friend up close was a new experience for many visitors to the Royal Entomological Society's stand at the Big Bang Science Fair 2017, which took place from the 15th to 18th March at the National Exhibition Centre, Birmingham.

Our 'cutest' and 'friendliest' attraction was the leaf insect *Phylium philippinicum* and we also had sun beetles *Pachnoda marginata peregrina*, Madagascar hissing cockroaches *Gromphadorhina portentosa* and black beauty stick insects *Peruphasma schultei* for the more enthusiastic to handle. A female atlas moth *Attacus atlas* on display was an excellent 'hook' to our stand ('is that real?') along with a commercial buff-tailed bumblebee *Bombus terrestris audax* hive kindly supplied by Koppert Biological Systems.

Communicating science whilst having fun was our priority and we tailored each conversation to a visitor's particular knowledge level, which varied highly within the Big Bang's target age range of 7 – 19 years as well as family groups at the weekend. Our selection of live insect species allowed us to talk about hemi and holometabolous life cycles, mimicry, warning colouration and eusociality. We also showed how entomologists classify insect groups using the Society's new display box of preserved specimens from different insect orders. Sweep nets and the use of a pooter ('be sure which tube to suck!') demonstrated simple techniques to survey insects.

Insects of economic importance including diamondback moth *Plutella xylostella*, wax moth *Galleria mellonella*, large pine weevil *Hylobius abietis* and peach-potato aphid *Myzus persicae* were on view under microscopes, which inevitably prompted a microscopy lesson ('what do all these dials do?') as well as a discussion on different methods to manage pest insect populations. Entomopathogenic fungi species including *Metarhizium* spp. initiated conversations about biological control and Harlequin ladybirds *Harmonia axyridis* enabled us to speak about monitoring insects with citizen science.

75,000 visitors attended the Big Bang Science Fair 2017 which was 'the largest celebration of STEM in Europe'. Our team of staff, students and alumni from the Royal Entomological Society and Harper Adams University were busy talking about insects and handing out Society and Harper Adams materials including over 1600 copies of the Garden Entomology booklet. We also highlighted careers in Entomology using the Society's new 'How can you work with insects?' banner and publicised the return of EntoSci, the entomology conference for schools and colleges, which will take place at Harper Adams in April 2018.

Thank you to all involved with the stand, in particular to Liam Crowley and Scott Dwyer who were there for all four show days. We hope to return to Big Bang Science Fair in 2018, see you there!

Julian Beniers – insect specimen boxes Credit: Francisca Sconce

Liam Crowley – insect handling Credit: Francisca Sconce

Luke Tilley – bumblebee hive Credit: Francisca Sconce

Simon Leather – insect handling Credit: Scott Dwyer

Drawer and microscope table Credit: Francisca Sconce

Francisca Sconce, Liam Crowley – stand is ready Credit: Scott Dwyer

Banner display Credit: Francisca Sconce

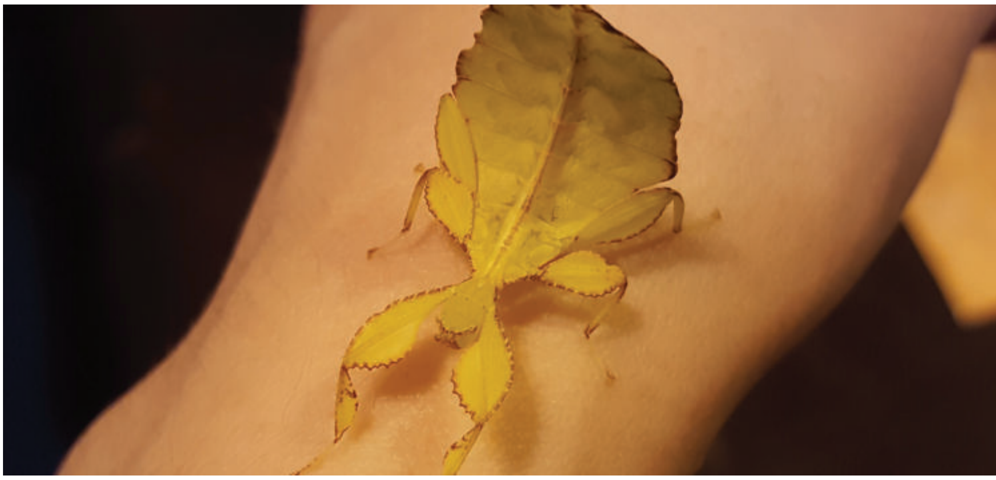
Stand crowd Credit: Francisca Sconce


Stand kick off selfie Credit: Liam Crowley


Atlas moth Credit: Francisca Sconce


Insect tanks Credit: Francisca Sconce


Sun chafer beetle Credit: Francisca Sconce


Leaf insect Credit: Francisca Sconce


Madagascar hissing cockroach Credit: Liam Crowley

Wallace Award 2016

With a change of format for 2016, four finalists were selected by the Wallace Award committee to present their PhD orally at Mansion House (either in person or via Skype) and discuss their work in conversation with the judges. The panel were extremely impressed by all finalists, both in terms of the theses they had produced and their presentation and discussion of their work in person. After much difficult deliberation, the decision was made to award the 2016 prize to Dr K B Rebijith, currently of the University of Cambridge. A summary of the impressive body of work that constituted Dr Rebijith's PhD is provided below, as are summaries of the PhDs of our other 2016 finalists.

WINNER

Molecular approaches in identification, diversity and management of important insect vectors, *Thrips palmi* Karny (Thysanoptera) and *Aphis gossypii* Glover (Hemiptera)

K B Rebijith
Kuvempu University

One of the main constraints in the successful production of vegetables in the tropics and sub-tropics are insect transmitted viral diseases. Sucking pests such as thrips and aphids are serious problems on a number of crops. Besides being direct pests, thrips and aphids transmit tospoviruses and potyviruses respectively, which cause significant crop loss globally. As the population explosion demands a substantial increase in food production, this can be attained only through the application of the modern biotechnology tools for the identification and management of insect pests of agricultural crops.

The first part of the investigation generated DNA barcodes for several species, and the analyses revealed the prevalence of cryptic species in thrips and aphids. Additionally, the species-specific markers developed in this study could successfully identify *T. palmi* and *A. gossypii* independent of life stages and sex. The vector status of *T. palmi* for Watermelon Bud Necrosis Tospovirus (WBNV) had not been proven to date through transmission studies. The current study unequivocally proved the vector status, and only adults, which acquired the WBNV during early larval stages, could successfully transmit the virus. The maximum transmission rate was observed after six days following inoculation and also proved the relative rate of WBNV multiplication inside the host tissue. These results will in turn help in further elucidation of the epidemiology of viruses, their management and serve as a potentially valuable tool in quarantine.

RNA interference, a sequence-specific gene silencing mechanism, has been harnessed as a useful tool in devising novel insect pest management strategies for various pests. We cloned, sequenced and synthesized double-stranded RNA (dsRNA) for Juvenile Hormone Binding Protein (JHBP), vacuolar ATPase-H (V-ATPase-H) and Odorant Binding proteins (OBPs) from *A. gossypii*. Bioassay results showed the effectiveness of diet mediated delivery of dsRNA for JHBP and V-ATPase-H, which silenced the above genes in turn, resulted in mortality. Interestingly, silencing of JHBP revealed the possibility of systemic spread of RNAi in *A. gossypii*. Whereas, partial knock down of the mRNA transcripts for AgOBP2 has clearly affected antennal response to physiologically relevant compounds. Thus, in aphids AgOBP2 play crucial roles in host seeking and detection of oviposition attractants. Based on our results we suggest that JHBP, V-ATPase-H and OBP2 could potentially serve as practicable targets for RNAi-mediated gene silencing in hemipteran insect pest control.

MicroRNAs (miRNAs) are small non-coding RNAs that regulate gene expression either by mRNA cleavage or by translational repression thus play an important role in growth and development. It is difficult to experimentally identify miRNAs and characterize their spatiotemporal expression in insects. However, we identified, characterized and validated miRNAs from both *T. palmi* and *A. gossypii*. The expression profiling of microRNAs employing real-time PCR revealed life stage specific functions such as metamorphosis as well as functions associated with growth and development. The microRNAs identified from this study not only provide an in-depth understanding of the biological and physiological mechanisms that govern gene expression but could also emerge as an invaluable tool (either synthetic or artificial miRNAs) in future pest management.

FINALIST

The effect of agri-environment schemes on farmland bee populations

Thomas J Wood
University of Sussex

Due to changes in agricultural practice during the latter part of the 20th century, most British farms support many fewer wildflowers than they used to. The wild bees that depend on these flowers have also become less frequent, with some declining to extinction over this period. Government funding is available to support farmers recreate bee-friendly flower-rich habitats, but there is a general lack of knowledge as to whether these schemes are actually benefiting bee populations on farmland.

Nineteen farms in Hampshire and West Sussex were studied between 2013 and 2015. Nine of the farms had created around six hectares of flower-rich habitat and ten farms had not. The first project focused on measuring whether the presence of this habitat resulted in a larger bee population. Bumblebees are large bees that live in social colonies with one queen and many daughter workers. They are the most common bees on British farmland and hence are a good study group. Bumblebees are mobile insects that are very good at finding flowers, and so simply counting individuals on flower patches might be a fair representation of their true abundance in the landscape. Because bumblebee colonies are essentially one family, daughters are closely related. Workers of four different bumblebee species were collected and the number of unique colonies on each farm was measured using genetic techniques. Farms with added flower patches had almost twice as many colonies present, with 212 colonies/km^2 compared to only 112 colonies/km^2. This was the first study to demonstrate an increase in bumblebee colony density in response to management, rather than just an increase in the number of observed bumblebees.

Whilst bumblebees are the most abundant bees on farmland, they only represent a minority of species, comprising 25 of the roughly 250 species of wild bee in the UK. On each farm, the diversity of bees was measured by regular walked surveys and also by using brightly coloured water traps into which bees fall and can subsequently be collected and identified. Bee diversity was high across the region with 112 species recorded. However, there was no difference in diversity between farms with or without flower patches.

Finally, a detailed study of which solitary bee species use plants in these habitat patches was carried out in order to better understand the most appropriate plants to include. Solitary bees were collected from all farms and the pollen they were collecting was identified in order to quantify their diets. Of the 72 solitary bee species recorded, only 35% of them used the plants present in the bee-friendly habitat patches for pollen. This investigation into solitary bee pollen diets was the first of its kind in the UK since 1968, highlighting the lack of detailed knowledge in this area.

The results of this thesis suggest that whilst the current design of the schemes is good for increasing the abundance of bumblebees, they do not seem to increase overall bee diversity, probably because their constituent plants are only attractive to a minority of bee species.

FINALIST

Diversity in emerging honey bee viruses

Gideon Mordecai
University of Reading
in collaboration with The Marine Biological Association

Pollination services by honey bees (*Apis mellifera*) are important to the environment and food security, but their health is under threat from an increasing range of pathogens and parasites. Widespread honey bee colony death over the past 25 years has been attributed to deformed wing virus (DWV), carried by the parasitic mite, *Varroa destructor*.

This body of work applied next-generation DNA sequencing to study this honey bee viruses. Importantly, a new strain of DWV was discovered. We now know that DWV is made up of at least three 'master' strains. The third strain of DWV was discovered in hives in Devon which succumbed to over wintering colony loss, so is likely plays an important role in honey bee colony collapse.

The realisation that the virus is made up of several different strains lead to a new method of protecting apiaries from disease. Molecular methods revealed a unique viral landscape in an apiary in Swindon, which has survived despite high *Varroa* loads. The study found that one infection by one strain of DWV prevented infection from a more harmful strain, which was not transmitted from the *Varroa* mites to the honey bees. The stable host-pathogen relationship was shown to persist over the period of a year. These findings led to the filing of a patent concerning the use of one virus to protect against another in social insects, which could provide a strategy for bee keepers to manage viruses in their hives. For example, a biological treatment for honey bees could be developed, in which a less harmful strain of a virus is applied to hives to protect against more harmful strains. A similar strategy is used extensively in citrus crops, but has never been applied in apiculture.

Additionally, a novel virus, named Moku virus, was discovered in the social wasp *Vespula pensylvanica* collected in Hawaii. Interestingly, the newly discovered virus was most closely related to slow bee paralysis virus, a lethal (but rare) honey bee virus. What's more, Moku virus was also detected in *Varroa* and honey bees, suggesting that transmission of viruses between insects is a threat to pollinator health worldwide.

FINALIST

Insect facultative endosymbionts: phenotypic effects and competitive interactions

Eleanor R Heyworth
University of York

The science of entomology is both deep and broad by the nature of those it studies. Insects inhabit almost every habitat and exploit almost any resource. They can be parasites, parasitoids, herbivores or omnivores, and while many are indispensable to the global ecosystem, others spread some of the most dangerous diseases facing human populations. There are so many aspects to study when insects are concerned that it can be easy to underestimate and to overlook the contributions of the invisible partners that are, at least in part, responsible for their successes.

Symbiosis is defined as a close relationship between two very different organisms and my work focuses on bacterial symbionts, which infect the majority of insect species worldwide. Non-obligate or 'facultative' symbionts are common in host populations, though not essential for insect survival. Instead, infections can affect host reproduction, defence, and behaviour, as well as affect the abilities of insects to spread human and plant diseases. The 'microbiome' is the total combination of microbes that an organism carries, and despite its vital role in immunity and development, little is known about how participating microbes interact, and how this affects the host.

I use the pea aphid (*Acyrthosiphon pisum*) as a simple model system to study symbiont-host interactions. My work explores both how single species and interactions between multiple species of symbionts affect host ecology. Aphid symbionts are relatively well-studied, and when I began my PhD the available evidence suggested that one species of symbiont conferred a specific trait or benefit to its host, such as higher resistance to a fungal pathogen. My work showed that a single species of symbiont can actually confer multiple benefits, raising questions about the specificity and redundancy of symbiont function in insect populations.

While much work has been done on the effects of a single symbiont infection, I also explored interactions between different bacterial species. I used ecological experiments alongside molecular techniques to measure host fitness and bacterial density under different conditions. My work was one of the first studies to show competition between symbionts, which then led to symbiont replacement and loss of infection. It implies that symbiont dynamics can be rapid, with competition occurring immediately after a new infection is established. Loss of symbionts likewise leads to loss of the traits they confer, painting a fluid and dynamic picture of symbiont-conferred benefits in host populations. My results also imply abilities of recognition and response between competing symbionts.

If symbionts are gained and lost rapidly, insect populations may essentially have access to a 'symbiont gene pool' and infection could depend on the prevailing needs of the host population, allowing insects to adapt rapidly to new predators, diseases or a warmer environment. Exploring symbiont effects in simple systems increases our understanding of more complex relationships, and leads to better knowledge about how microscopic partners have, and continue to, shape the world we live in.

Student Essay Competition 2016

1st Prize

Bombardier beetles: Superheroes of the insect world

Jonathan Smith

PhD student in the University of Leicester

An Orb-weaver spider sits in its web, waiting for its free food delivery. Suddenly, it feels vibrations in its web and immediately knows what's up: a struggling beetle just got caught in the predator's trap. *Dinner's ready!* It quickly approaches, seizing the chance to devour a new victim. As the spider attacks, though, the meal reveals a secret weapon. With a loud 'pop', the beetle's bum explodes, firing scorching heat and noxious chemicals right at the surprised spider's face. Not a fan of hot food, the predator hastily retreats, leaving the beetle to free itself of the pesky web and amble away. This was no defenceless prey; this was a badass Bombardier Beetle.

Thanks to being so diverse, beetles are an incredibly successful order of the insect family; almost one in four of all known species is a beetle[1]. Many different beetle species use nasty chemical defences, but Bombardier Beetles and their biological 'cannons' take the idea of chemical warfare to a whole new extreme. Species in the genus *Brachinus* (called *Brachinini*) shoot a biochemical spray at a whopping 100°C[2] – the temperature of boiling water – and swivel their 'gun turret' to aim the spray at the attacker's face. This barrage can kill small predators such as ants, and freaks out bigger critters such as frogs and mice, leaving the beetle to slip away unnoticed. It's basically a superpower. Understandably then, very few predators are brave enough to take on a Bombardier Beetle more than once[3].

Superhero origin story

Scientists have made big steps in uncovering the biological machinery behind the marvellous Bombardier Beetle's bottom. The internal chemical factory consists of four glands: two secretory glands that manufacture an explosive chemical cocktail, a reservoir that stores the cocktail and a reaction chamber that provides the ignition 'spark'. The chemicals in the cocktail are called hydrogen peroxide (what people bleach their hair with) and hydroquinones[2]. As soon as the beetle feels threatened, it squeezes the reservoir's stored cocktail into the reaction chamber, whose enzymes make things blow up. As the chemical cocktail sloshes in, the enzymes immediately break the hydrogen peroxide down into oxygen gas and steam, blowing out of the beetle's 'nozzle' like air from an untied balloon. Moreover, enzymes breaking down hydroquinones into quinones heat up the mix to scalding temperatures. Thanks to these explosive events, a loud, sizzling steam erupts from the nozzle at the attacker, who at this point is seriously considering a change in cuisine.

Ready, aim, FIRE!

It's impressive just how precisely Bombardier Beetles, particularly the *Brachinini*, aim their jets. When attacked by Wolf spiders in one study, every shot by the Bombardier Beetles hit their attackers at full blast; they were even able to aim towards their own front legs[4]! This incredible aim is possible because they have an intricate bottom, comprised of a flexible abdomen and a fancy set of deflector plates directing the flow[5]. Thus, sneaking up on them from any direction would be a pretty bad idea.

Given the bizarre way that Bombardier Beetles superheat and expel the spray, it's natural to wonder: "Why doesn't this weapon fry the beetle too?". It turns out that these beetles have the insect equivalent of 'blast walls' surrounding their reaction chamber, so it's much easier for the vapours to surge through the nozzle rather than into the beetle[3]. Weirdly too, each blast of gas actually stops chemicals from entering the reaction chamber, shutting down the reaction. This happens roughly 500 times per second – too fast to see with the naked eye – and possibly stops the reaction chamber from having a meltdown[6]. In fact, this makes the Bombardier Beetle's bum really more like a machine gun than a cannon.

Every beetle has its Kryptonite

Like all superheroes, the Bombardier Beetle isn't invincible. Some cunning Orb-weaver spiders dump extra webbing on the beetle's gun nozzle, immobilising it and rendering the artillery useless[7]. Blue Jays have also figured out that jiggling the beetle under their wings protects them from its spray and soon leaves it drained of ammunition[8] – a bit like the local bully holding you in a headlock until you give them your lunch money. Worrying as this may be, vulnerability to these tactics is a price worth paying for otherwise being virtually 'predator-proof'.

Of course, scientists don't play around with Bombardier Beetles just for 'funsies'. There are real ways we can use this research to improve our own technology. For one, the hard-core ways that the beetle protects itself from its own chemistry might help refine our own explosion containment systems. Furthermore, understanding the biochemical reactions could let us design new, efficient propellant systems[3]. In light of these potential technological contributions, it's clear that, one day, everyone will owe a huge amount of respect and admiration to the Bombardier's bum.

References

1. Hunt, T. *et al.* A comprehensive phylogeny of beetles reveals the evolutionary origins of a superradiation.. *Science* **318**, 1913–1916 (2007).
2. Aneshansley, D. J., Eisner, T., Widom, J. M. & Widom, B. Biochemistry at 100{degrees}C: Explosive secretory discharge of bombardier beetles (Brachinus). *Science* **165**, 61–63 (1969).
3. How some beetles produce a scalding defensive spray. *MIT News* Available at: https://news.mit.edu/2015/how-bombardier-beetles-produce-defensive-spray-0430. (Accessed: 7th April 2016)
4. Eisner, T. et al. Effect of bombardier beetle spray on a wolf spider: repellency and leg autotomy. *Chemoecology* **16**, 185–189 (2006).
5. Armitage, M. H. The spray nozzle of the bombardier beetle, *Brachinus favicollis* Erwin. *Bull. South. Calif. Acad. Sci.* **103**, 24+ (2004).
6. Arndt, E. M., Moore, W., Lee, W.-K. & Ortiz, C. Mechanistic origins of bombardier beetle (Brachinini) explosion-induced defensive spray pulsation. *Science* **348**, 563–567 (2015).
7. Eisner, T. & Dean, J. Ploy and counterploy in predator-prey interactions: Orb-weaving spiders versus bombardier beetles. *Proc. Natl. Acad. Sci. U.S.A.* **73**, 1365–1367 (1976).
8. Eisner, T., Eisner, M. & Aneshansley, D. Pre-ingestive treatment of bombardier beetles by jays: food preparation by 'anting' and 'sand-wiping'. *Chemoecology* **15**, 227–233 (2005).

2nd Prize

My life as a cat flea, Ctenocephalides felis

Christopher Edwards

Harper Adams University

It feels like a lifetime waiting within my silken cocoon hidden in the cat's bed, I'm a pre-emerged adult cat flea and I've been thinking about how I got here.

My parents and generations of relatives lived on the old cat, its bed near the Aga. Our only function is to reproduce, and this activity requires regular blood feeds from a permanent host. After an orgy of multiple mating, my egg was laid along with about 24 others that day; like many parasites fleas produce lots of eggs as losses of juveniles are expected. My pearly-white oval egg, about 0.5mm long fell from the sleeping cat onto the bedding, an old woollen jumper. Beneath the cat was perfect, warm and dark. Hatching was easy using my 'egg tooth' to pierce the shell and wriggle out, I was a 2 mm long bristly, apod larva. Being negatively phototactic and positively geotactic I quickly burrowed beneath the woollen jumper and entered the understorey; a world that was warm, humid and dark, everything I could wish for. The floor was layers of old yellowing musty newspaper, covered with a tangled jungle of organic debris, cat hair, dried cat food, soil and faecal particles. Above me fragments of dried flea faeces (flea dirt) were trickling through the canopy, adult fleas consume an awful lot of blood daily and the faecal overflow of blood ensures that we are provided for. The blood particles were voraciously consumed along with a few nearby flea eggs (we do have cannibalistic tendencies), the ingested haem turned me brown.

I was not alone, herds of plump *Acarus siro* mites were nibbling food particles and the fungal fruiting bodies that grew on the cellulose of the newspaper. *Dermatophagoides* and *Glycyphagus* dust mites were recycling squames and fragments of moulted larval and nymphal 'skins'. Close by, predatory *Cheyletus eruditus* mites had ambushed a few *Acarus* mites, piercing them with their chelicerae and sucking out their body fluids; their deflated dry bodies drifted about, gradually disintegrating. The all-blood diet enabled me to quickly develop through two larval stages in 10 days, becoming a third stage larva about 5 mm long. In the debris were egg capsules of the cestode *Dipylidium caninum*, fleas are an intermediate host of this tapeworm, so I might as well consume an egg and be one of the 2% that contains the cystercercoid as an adult.

By the late third stage it was becoming more urgent to form a protective cocoon as unfortunately other larvae had shown increased cannibalistic tendencies, and also by coincidence the faecal blood supply had dried up. I found an undisturbed space within a matrix of fibres that enabled me to assume a more upright position, with the silk from my salivary glands I spun a loose and sticky cocoon that was soon camouflaged with dirt and debris. Other larvae that pupated 'naked' had desiccated or were cannibalised. Within the cocoon I underwent metamorphosis forming an exarate pupa and finally after the pupal-imaginal moult remained within the cocoon as a quiescent pre-emergent adult.

So that's my story so far and I'm still waiting. Recently the old cat had 'the one way trip' to the vets and was gone; the basket was moved to the shed and it's so much colder here than in the nice warm kitchen. The average survival of pre-emerged adults is only a few months in present conditions, so it's not looking good for me. But at least delaying emergence until an adequate host stimuli should improve my chances of a successful host attack.

Without warning I sensed a nearby warm body and the concurrent repeated pressure on the cocoon stimulated my rapid emergence, and I ascended through the woollen canopy. Using my antennae, simple eyes and sensilium I detected CO_2 gas, air currents and passing shadows that enabled me to orientate myself towards the source; at last a potential host. My powerful legs have a specialised energy storage mechanism and its sudden release allowed me to 'jump with style' towards the source; a visiting spaniel puppy who fortunately had taken great interest in sniffing and pawing the old cat's bed. The bristles on my legs enabled me to snag the pup's hair and I quickly moved towards the warm and dark skin surface; this was the place my streamlined, smooth and shiny body was made for. I weaved effortlessly between the hair shafts instinctively finding the thin abdominal skin. Now it was time to feed piercing the skin with my maxilla, engorging took five glorious minutes. But something was wrong, my muscles went into a tetanic spasm and I became paralysed, the puppy had been treated with a systemic insecticide. My first feed was to be my last.

3rd Prize

Job Opportunity for an Adventurous Insect

By Jennifer Rasal
University of Liverpool

Are you a louse who is bored with your host? Do you fancy a change of habitat? This is a rare and new opportunity for an insect. As the insect group invests in its expansion into the marine environment it is looking for new members to take up the exciting position of: Blood sucking lice, true parasites of marine mammals, working in the *Anoplura* family branch. The louse who applies for this position must be adventurous, hardworking and adaptive to the different requirements and pressures that will be necessary to each situation. This particular job advert will cover the position available in the parasites for the fur seal department.

Background

As insects we are the most diverse group of animals on the planet, yet there is one area which we have not yet fully exploited – the marine environment. The *Anoplura* family are one of the first groups of insects to take the plunge and have moved into the marine world. They took a huge risk and are proud to say they have made a success by living on a variety of marine animals, including seabirds and marine mammals. They are now ready to expand their family's coverage and are looking to recruit more insects to join their colonising team.

Working conditions

The insect that takes up this position must be resilient to a wide range of working conditions, the hosts available are often diving animals, penguins, fur seals, elephant seals, cormorants etc. The job is high pressured, as the diving animals can reach depths of 500 metres, and the insects conducting this work will need to be able to withstand a wide range of temperatures. The *Anoplura* family prides itself on being able to work in temperatures right down to -20 C, you would be required to cope with the temperature found in the polar regions as well as the subtropics. Training for this is limited and you would be expected to self-evolve in time. Typical working time is 24 hours 7 days a week, the *Anoplura* are a family and they work as a family and you never take time out from being a family.

Salary

There will be unlimited blood available courtesy of the host, but each louse is asked to control their feeding and take only around 0.003ml of blood each day. This will prevent the host from developing health concerns due to low iron concentrations. A healthy host makes for a happy home. You'll be able to feed directly from small blood vessels of the host mammals, on condition you can provide your own feeding apparatus.

Prospects

The prospects available long term largely depend on the host that you will be assigned to. Due to the nature of the marine environment there will be little opportunity to change your host once you have moved in. As such your future will be determined by the host, the standard coevolution of parasite and host apply. As the host evolves over time to cope with its residents, you will be expected to co-evolve to manage whatever strategy your host may choose to peruse to evict you. Long term this could lead to some very advantageous adaptations which is wholeheartedly encouraged by the *Anoplura* family who have already adapted to extreme pressures and temperatures. Although new host opportunities are scarce there will be a chance during the breeding season to move between copulating couples and mother and cubs.

Location

Each host offers a variety of locations, the most popular being the pinnipeds. On starting the work you'll be housed on the dorsal surface in what we term the 'nursery'. This area is under more favourable conditions and is perfect for young recruits. Upon promotion you'll be able to move to the belly of the host, a more social area for the *Anoplura* family's workers. There is also the opportunity to move out to the outlying district of the pinnipeds flippers, very popular with more established lice. There will also be occasion to holiday at the host's eyelids and nostrils.

Benefits

There are many benefits for the lucky louse that joins the *Anoplura* family. The marine environment has not yet been fully explored by insects and we are hoping to expand and create new niches for insects. As our insect families evolve and overcome the elemental factors of the marine environment we will be able to colonise more areas of this lucrative habitat.

We look forward to receiving your application, and for you to join us on our aquatic journey.

Runner up

I hate bugs and wish they would go away forever

Jeffrey Smith (ages 5 and 25)

Stanford University

I've always had a love-hate relationship with insects, in that while I love them, they hate me. One fall day, early in first grade, my teacher took our whole class outside for reading time. I, and a group of equally rambunctious five-year-olds, decided that the large leaf pile on the edge of the woodlot would make the perfect reading nook. Sadly, we were second in reaching this conclusion, and were promptly greeted by a swarm of wasps (*Vespula maculifrons* I believe). The battle that ensued was wholly lopsided and left the school nurse's office looking and sounding more like a M*A*S*H triage scene than a quiet, suburban elementary school.

When my mother arrived at school to collect me, I proclaimed, in a state of wasp-kinin induced deliria, that, "I hate bugs and wish they would go away forever." Now that I am pursuing a PhD studying insects, my mother has become quite fond of this story, using it liberally and with great effect to embarrass me. While I have come to appreciate insects, I would like to take a moment and go back and ask, what would the world have looked like if the bugs, in fact, went away forever.

Scene 1: Insects play key roles in food webs

Setting: Jeffrey's bedroom, the morning after 'the incident'

Characters: Jeffrey, Mom

Jeffrey: My whole body hurts.

Mom: You poor thing, let me put some cream on the stings, it will make you feel better.

Jeffrey: This means I don't have to go to school today right!?!

Mom: I guess…

Jeffrey: Mom?

Mom: Yes, sweetie?

Jeffrey: Where are all the birds? They usually wake up when I do, but I don't see any, I don't even hear any of them.

Mom: Well you wished they would all go away forever, don't you remember?

Jeffrey: No I didn't, I just wanted the bugs to go away, I like the birds.

Mom: Well when all the bugs disappeared the birds had nothing to eat, so they all flew away.

Jeffrey: Why didn't they just eat other food; I always see them by our bird feeder? Couldn't they just eat seeds and plants?

Mom: For a little bit yes, but eventually birds need to eat insects because they have lots of protein, especially the baby birds. It's like how you have to drink milk to grow up to be big and strong, baby birds have to eat caterpillars. At some point 98% of all birds have to eat insects!

Jeffrey: Oh, I see…

Mom: Go back to bed, you need your rest

Jeffrey: Okay… *[falls back asleep]*

Scene 2: Insects provide vital ecosystem services on which humans rely

Setting: The dining room, lunch time

Characters: Jeffrey, Dad - AKA "Best Dad in the world" – has mug to prove it.

Jeffrey: *[Walking downstairs]* Dad, I'm hungry!

Dad: Okay let's get you some lunch, you haven't eaten anything all day.

Jeffrey: I want peanut butter and jelly!

Dad: I know… *[rolls his eyes and starts making a PB&J sandwich for the 400th straight day]*. Is orange jelly okay?

Jeffrey: Why can't I have strawberry? I always have strawberry!

Dad: I'm sorry Jeff, but when you wished away all the bugs you wished away all the strawberries.

Jeffrey: What do you mean? That doesn't make any sense!

Dad: Well you see, strawberries need bees and other insects to pollinate them, without insects they can't make any strawberries.

Jeffrey: But what about oranges?

Dad: Not all plants need insects to pollinate them; oranges don't need bees like strawberries do.

Jeffrey: Well, I guess if all I have to give up is strawberry jelly I can still live without bugs.

Dad: But it's not just strawberries, it's also apples, mangos, kiwis, avocados, and many, many more foods, not to mention the coffee that you see mommy and I drinking every morning.

Jeffrey: Oh I see… *[scene fades]*

Scene 3: Insects should be conserved on intrinsic merit

Setting: The backyard, after dinner

Characters: Jeffrey, Katie – archetypal little sister

Katie: Let's go catch fireflies! They're my favorite and we can put them in jar and make them light up!

Jeffrey: We can't.

Katie: What do you mean?

Jeffrey: Well I wished them all away.

Katie: Why would you do that?

Jeffrey: Because I thought that all bugs were bad, but I think I might have been wrong.

Katie: You're always wrong about everything.

Jeffrey: I'm sorry.

Katie: It doesn't feel like summer without the fireflies. Insects are so cool. Remember the butterflies and beetles we saw at the museum last weekend? They were so pretty, why would you want them to go away.

Jeffrey: I *know*… I wish I could bring them all back *[curtain]*

Runner up

Soldiering on

Thomas Aspin
University of Birmingham

YES!!! I cried with relief, bringing four hours of suffering to an end. The architect of my torment had been sitting innocently on my lab bench, unfazed by the piercing beam of the microscope light, like a hardened soldier trained to withstand relentless interrogation.

The soldier in question was of the entomological variety, a larva of the family Stratiomyidae, or soldier flies so named because of the resemblance of their dorsal patterning to military camouflage, and of the fearsome spines present on certain adults. The eccentric military naming theme is more than skin-deep: common names for UK species include the Long-horned General (*Stratiomys longicornis*), the Ornate Brigadier (*Odontomyia ornata*) and the Twin-spotted Major (*Oxycera leonina*). Three hours into identifying my specimen and I would have happily settled for a lesser-warted Lance Corporal.

I should point out at this stage that insect identification is not my background. I am a physical geographer by training, more comfortable measuring river flow than picking through invertebrates. My PhD examining the impacts of drought on chalk stream insects has forced me to adapt quickly and pushed me out of my depth numerous times. 'Soldierflygate' was just one instance.

My identification breakthrough came when I stumbled across a website dedicated to dipterology (the study of flies and midges), where users can post their dipterological conundrums on an online forum. Here was a fly enthusiast's haven; a dipterist's mecca; a sanctum for the proprietors of very bountiful specimen collections and very bare social calendars. I had found my calling.

After examining the photos of the offending specimen I had posted an expert on the forum informed me that I had a common or garden *Oxycera*. The spidery coronet of float-hairs was the initial clue, and the ventrally emarginate apex of the last abdominal segment the confirmation. Apparently. Roughly translated it had a hairy backside with a notch in it.

At the time, my identification of a single specimen did not seem much to show for four hours' work. However, six months on and with my dataset taking shape, that initial investment has paid dividends. My samples have revealed *Oxycera* as a recurring denizen of drying streambeds, to the extent that it represents a statistically significant indicator species (taxon) of these habitats. The resistance of *Oxycera* to drought stress is consistent with its reputation as a habitat generalist, able to tolerate steep moisture, salinity and temperature gradients (Rozkošny, 1997) owing to a thick, calcareous cuticle (Lock *et al.*, 2013). If, as predicted, climate change increases the prevalence of intermittently dry freshwater habitats, it may be species like *Oxycera*, thick-skinned in both morphology and character, that hold the blueprint for success at this land-water interface.

As generalists become more dominant among the insect life of streams, so they may become more prominent among entomologists. Specialising in either obligate aquatic or obligate terrestrial species may be of little use when semi-aquatic habitats are the order of the day. However, as I learnt six months ago, a paucity of published information on semi-aquatic taxa makes them a challenging prospect. To continue to work with them I'll need a thick skin. Luckily I know an old soldier who might be able to offer some inspiration.

Lock, K., T. van Haren, D. Tempelman, F. Cherot and T. Adriaens (2013). Distribution and ecology of soldier fly larvae captured in Flemish waters (Diptera: Stratiomyidae). *Bulletin de la Société royale belge d'Entomologie*, 149, 150-159.

Rozkošny, R. (1997). Diptera Stratiomyidae, Soldier Flies. In: *Aquatic Insects of North Europe- A Taxonomic Handbook, Vol 2* (Ed Nilsson, A.N.), pp 321-332. Apollo Books, Vester Skerninge, Denmark.

Runner up

The Tale of a Spider

Krisztina Fekete

Natural History Museum

…she wasn't feeling too well today.

She got used to that strange, blunt pressure around the top of her abdomen now.

But it was something else, that bothered her.

She wasn't really acting like herself lately. It was an undefinable feeling that somehow she was being manipulated. Manipulated to do things she didn't intend doing. She felt like being a puppet, or someone's marionette dummy. How could this be possible?

While her neighbours carried along doing normal spider-business, spinning standard insect-catching webs, she was creating something else. And she didn't know why….. all she knew that it was this urge inside, a sudden, weird and unstoppable need to go and start weaving….yes, a COCOON WEB!

Round and round, back and forth, back and forth. Is it strong enough now?

After 10 hours of relentless weaving the web is ready now. Beautiful, strong and purpose-built. But for whom?

She feels tired. She must rest. Let's just sit on this web for a while…. just for a little while…

Then- ….. darkness.

Fascinated by this behaviour? Welcome to the compelling world of host manipulation by parasitoids.

Allow me to introduce you to a koinobiont spider ectoparasitoid – an Ichneumon wasp (in this case our wasp is from the Genus- *Acrodactyla*), which specialises in using spiders as the food source for their larvae.

The story above describes the last day of the spider host parasitised by a larvae of such wasp.

The female Ichneumon skillfully chooses its spider-host, then temporarily paralyses it. After laying a single egg onto the dorsal surface of the spider's abdomen the host recovers and resumes its activities while the larva grows. The host is eventually destroyed and consumed by the growing larva- the expression parasitoid is used to describe this phenomenon. Koinobiont parasitoids allow the host to continue on living, feeding and developing until the larva ready to pupate.

Web-building *Tetragnatha* sp. being parasitised by *Acrodactyla* larvae (K.Fekete, 2016)

But that is not the whole story!

This tiny larva has evolved mind-blowing strategies,- still not fully understood,- which are used to re-programme the spider's web making process. The reason for this is cunningly obvious- SURVIVAL! The cocoon web is simpler, stronger and provides better chance for the pupa to survive inside it against the challenging weather conditions and enemies. The parasitoid pupa is surprisingly vulnerable to heavy rain!

The cocoon web construction contains a few reinforced elements, such as an extra strong central hub and frame, but on the other hand some of the components are reduced e.g. web spiral.

The three different web types (normal orb, resting web and coon web) are not surprisingly showing differences between the breaking force of their radial and frame threads. If it was a competition for the title: Most Durable Web,- the cocoon web would be a clear winner. The tougher structured cocoon webs provide better resiliance and therefore better protection for the pupa.

The exact mechanism of manipulation is thought to be chemically- rather than physically induced. Even if the larva is removed before its pupating time the spider will still proceed to construct a coccon web.

Still, there is so much to learn about these host manipulative mechanisms. What is clear from this example is that these parasitoids possess an extremely sophisticated mechanism whereby they are able to control the behaviour of a much bigger organism they entirely rely on for their survival.

I think we can agree that host manipulation is nothing short of being an ingenius phenomenon.

So, I m afraid, our spider did not stand much of a chance from the moment the female Ichenumon wasp laid an eye (and an egg) on her……

References

Korenko, S., Korenková, B., Satrapová, J., Hamouzová, K., and Belgers, D., (2015) *Modification of Tetragnatha montana (Araneae, Tetragnathidae) web architecture induced by larva of the parasitoid Acrodactyla quadrisculpta (Hymenoptera, Ichneumonidae, Polysphincta genus-group)*, Zoologica Studies, Issues 54:40

Korenko, S., (2016) *Web architecture alteration of the orb web weaving spider Metellina merianae (Araneae, Tetragnathidae) induced by the parasitoid Megaetaira madida (Ichneumonidae, Polysphincta group)*, Arachnology Letters, 52: 35-37

Souza HS., Messas YF., Masago F., dos Santos ED., Vasconcellos-Neto, J., (2015) *Paracyphononyx scapulatus* (Hymenoptera, Pompilidae), a koinobiont ectoparasitoid of *Trochosa* sp. (Araneae, Lycosidae). Journal of Hymenoptera Research 46: 165-172.

Takasuka, K., Yasui, T., Ishigami, T., Nakata, K., Matsumoto, R., Ikeda, K., and Maeto, K., (2015) *Host manipulation by an ichneumonid spider ectoparasitoid that takes advantage of preprogrammed web-building behaviour for its cocoon protection*, Journal of Experimental Biology 2015 218: 2326-2332

Miller JA, Belgers JDM, Beentjes KK, Zwakhals K, van Helsdingen P. (2013) *Spider hosts (Arachnida, Araneae) and wasp parasitoids (Insecta, Hymenoptera, Ichneumonidae, Ephialtini) matched using DNA barcodes* Biodiversity Data Journal. 2013;(1):e992

SCHEDULE OF NEW FELLOWS AND MEMBERS

as at 3rd May 2017

New Honorary Fellows
None

New Fellows (1st Announcement)
Mr Jia Hui Li
Professor James C Nieh

Upgrade to Fellowship (1st Announcement)
None

New Fellows (2nd Announcement and Election)
Dr Binu Antony
Dr Hannah Elizabeth Moore
Dr Jeffrey M. Marcus
Professor Ratnayake Kaluarachchige Sriyani Dias
Dr Rajendramani Gnaneswaran
Mr Martin Williamson

Upgrade to Fellowship (2nd Announcement and Election)
Dr Lara Ellen Harrup

New Members Admitted
Mr Barry Phillip Warrington
Mr Benjamin Christie
Mr James Calow
Ms Andreja Kavčič
Dr Krishna P Srivastava
Mr John Christopher Beaufoy

New Student Members Admitted
Miss Siobhan Anne-Marie Hillman
Mr Matthew Timothy Hamer
Mr Paul Thomas James Brett
Ms Danielle Klassen
Mr Arran James Folly
Mr Andris Simon Ernstsons
Mr Mohamed Khadar Abdi Mohamed
Mr Ayman Ahmed

Re-Instatements to Fellowship
None

Re-Instatements to Membership
Mr Frazer Hamilton Sinclair

Re-Instatements to Student Membership
None

Deaths
Professor E R Nye, 1957, New Zealand
Dr R E Lewis, 1960, USA
Mr H Wainman, 1979, UK
Mr C A Collingwood, 1953, UK

SCHEDULE OF NEW FELLOWS AND MEMBERS

as at 7th June 2017

New Honorary Fellows
None

New Fellows (1st Announcement)
Mr Graham Leslie Smith
Mrs Janice Mary Smith

Upgrade to Fellowship (1st Announcement)
None

New Fellows (2nd Announcement and Election)
Professor James C Nieh

Upgrade to Fellowship (2nd Announcement and Election)
None

New Members Admitted
Mr Richard Kenneth Halfpenny
Miss Elizabeth Deakin
Dr Marcus James Guest

New Student Members Admitted
Miss Harriet Horsler

Re-Instatements to Fellowship
None

Re-Instatements to Membership
None

Re-Instatements to Student Membership
None

Deaths
Mr E T Bezant, 1953, UK

Book Reviews

Beetle Queen

M.G. Leonard

Chicken House

£ 6.00

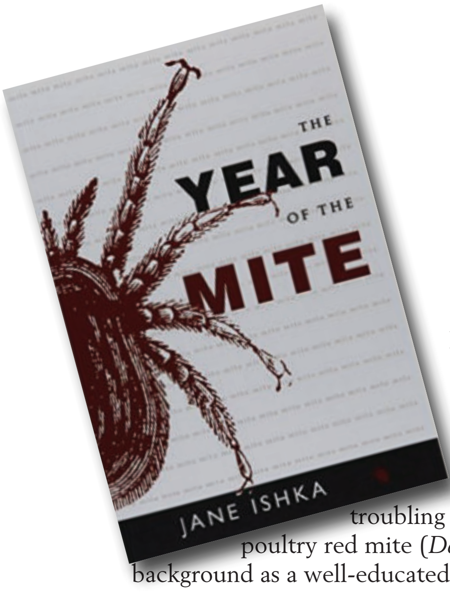
ISBN 978-1-910002-77-3

Darkus and his coleopteran sidekick Baxter are back. Along with his friends Bertolt and Virginia he must try to unravel the fiendish plans of his now arch-enemy Lucretia Cutter and stop whatever it is she is planning while saving his father once again. The story quickly gathers pace, leading the trio to new friends and old enemies. A frantic dash across the globe to Los Angeles ensues and leads to a final showdown with Lucretia that leaves you on the edge of your seat.

'Beetle Queen' brims with more of the fast-paced coleopteran action that we loved in 'Beetle Boy', and just like 'Beetle Boy' is littered with real entomology. Latin names abound and snippets of insect science are slipped into the plot; a discussion of insect photonics in chapter one, entomophagy in chapter nine and the use of pooters in chapter twenty-seven. The plot roars to a climax that sets the scene for the final book. Disaster is averted but not for long, everything is in the air and Darkus and his pals still have everything to fight for.

If you enjoyed 'Beetle Boy', then 'Queen' is unmissable. It's a must for any proto-entomologist in your family. M G Leonard continues to enchant, educate and inspire the next generation of entomologists. The final showdown in the form of 'The Battle of the Beetles' is eagerly anticipated.

Peter Smithers



The Year of the Mite

Jane Ishka

Paperback: 222 pages

Publisher: Bitingduck Press (February 4, 2016)

Language: English

$14.99

ISBN-10: 1938463439

ISBN-13: 978-1938463433

I first met Jane Ishka in 2013 during a visit she was making to the UK from her home in the US. Having spent an interesting afternoon discussing bird mites and the topic of human infestation, I was pleased to learn that she was planning to publish an account of her own experience in this area in Year of the Mite – a book detailing Jane's prolonged battle with gamasoidosis, a little-known human ectoparasitosis that seems to be gathering in significance. Jane recounts this experience with an open, honest, occasionally humorous, but troubling read, outlining over 222 pages her year spent trying to overcome not only an infestation of poultry red mite (*Dermanyssus gallinae*), but also the preconceptions of a dismissive medical profession. With a background as a well-educated scientist, the author adopts a pragmatic approach to ridding herself of red mite, though the challenges faced in doing so will shock all but those with personal experience of this mite.

This book highlights the potential impact that gamasoidosis can inflict upon an individual and those around them, this being exacerbated by the lack of support available for sufferers of 'non-standard' ectoparasitoses and the current paucity of scientific understanding on this topic. Though the latter is beginning to be addressed through large collaborative projects such as COREMI (see http://www.cost.eu/COST_Actions/fa/FA1404), full recognition of this condition is likely to be some way off. Thankfully, through sharing her own experience in Year of the Mite, Jane Ishka offers valuable and much needed moral support to those undergoing their own battle with gamasoidosis, as well as a level of practical assistance through inclusion of the authors own 'do's and don'ts' where treatment approaches are concerned.

Though confirmed cases of human attacks by *D. gallinae* (and indeed other bird mites) are still relatively rare, Year of the Mite represents a hard hitting, blow-by-blow reminder of just how significant such cases can be when they do occur. Though seemingly 'extreme' to the lay reader, with implications of infestation including social isolation, staggering financial costs of treatment and even family breakdown, it's worth noting that Jane's ordeal is worryingly 'normal' for those unlucky enough to encounter these mites as bedfellows. Whilst perhaps reassuring for those reading this book with a personal interest, Year of the Mite should also serve as a call-to-arms and entomological eye-opener for those reading as acarologists, healthcare professionals, or representatives of the pest control industry.

As highlighted in Year of the Mite, the full significance of *D. gallinae* to human health is likely to be underestimated, masked by a combination of challenging diagnosis, symptoms that closely match other more common dermatological/psychological conditions, and the pre-held misconception that species such as *D. gallinae* are unable feed upon humans. Our attitudes towards these mites, and indeed gamasoidosis itself, will need to change if we are to better understand, prevent and treat human infestations as a potentially emerging/escalating health concern. Year of the Mite provides an important step in this process, fully and frankly documenting the implications of human infestation for the first time.

Dave George
Stockbridge Technology Centre

Britain's Spiders. A field guide

Lawrence Bee, Geoff Oxford & Helen Smith
Princetown University Press (as part of the WildGuide series)
£24.95
ISBN 978-0-691-16529-5

Previous invertebrate guides in this series have dealt with smaller groups (hoverflies being the largest at 283 species), for which they have provided information in a variety of formats that enabled individual species to be identified. *Britain's Spiders* deals with 670 species and presented the authors with a considerable challenge, a challenge that they have risen to magnificently.

They clearly state in the Introduction that this guide will not enable the identification to species of all the UK spider fauna, but it will allow field biologists to determine the family in all cases and the genus in many. It opens with a quick photographic guide to the families based on body shape and proportions, which is followed by the Introduction which explains the scope and limitations of the guide and how to use it. There is then a section that shows how to tell spiders from other invertebrates, a photographic guide to spider anatomy, an illustrated glossary, a comprehensive introduction to spider biology and spiders and people. The guide then offers a series of practical chapters dealing with how to find and collect spiders, a detailed guide to the UK families plus a photographic guide to webs and egg sacs.

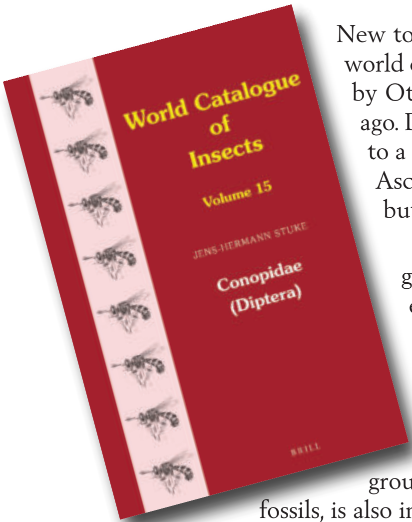
The main bulk of the book then comprises a series of detailed species accounts. Each family has a brief introduction, giving the number of genera it contains. Each of these genera are then described and the number of species they contain are given, along with an indication as to whether it can be identified by eye, with a hand lens or if microscopical examination is required. Where microscopical examination is needed, identification can be accomplished by reference to previously published works. For each species there are notes on habitat and where to look within it, a description of the species morphology, the names of similar species, a distribution map and details of its conservation status plus a chart showing when it is adult, with a colour-coded guide to the sample size used to generate the chart. There are also details of the size of both sexes which are presented as both numbers and a life size scale bar. Each species account is accompanied by high quality photographs showing males and females plus colour variations where these are significantly different. As with previous wild guides there are also tables that summarise the genera, offering details of habitat and distinctive morphological characters in a handy rapid access chart. These accounts are then followed by an introduction to the ethics of fieldwork and the spider recording scheme. The final section deals with legislation and conservation providing a comprehensive table of all the known UK species. This offers details of ease of identification, the percentage of 10 Km square in the UK that each species has been recorded from and details of its conservation status. The guide ends with a selection of useful books and websites for further reading, acknowledgements and an index.

Britain's Spiders draws together a wide range of information that has previously been scattered through the literature, plus a host of field observations that have been part of arachnological field lore. It is a colourful introduction to the study of spiders that offers the assembled information in a wide range of formats that will enable both experienced arachnologists and beginners to rapidly home in on the information that they require to identify UK spiders. This is a guide that will revolutionise the study of British spiders, allowing confident field identification of many species and encouraging a new cohort of natural historians to take a closer look at these extraordinary creatures. The authors are to be congratulated on the completion of a herculean task that has made spiders accessible to a wider audience.

Peter Smithers

Conopidae (Diptera)
World Catalogue of Insects volume 15

by Jens-Hermann Stuke,
Published 2017 by Brill, Leiden/Boston. 354 pp. + xxxviii.
Price £119.00
ISSN 1398-8700, ISBN 978-90-04-27183-8 (hardback), ISBN 978-90-04-27184-5 (e-book).

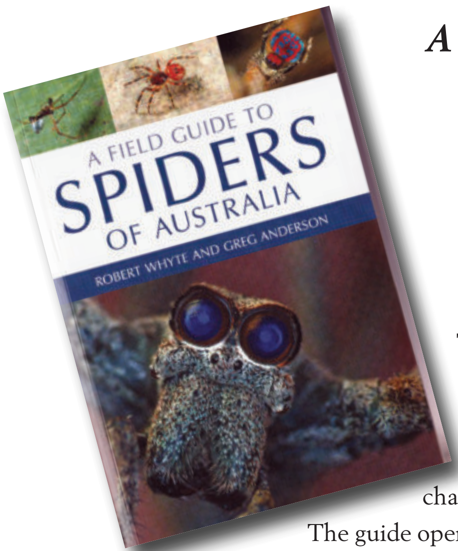


New to this series of world catalogues of insect families published by Brill, this is the first published world catalogue of this interesting family of largely parasitic, wasp-mimicking flies since that produced by Otto Kerber, the first person to extensively study the taxonomy of this group, almost 100 years ago. During the intervening years, the number of described species of this family has almost doubled to a current total of over 800. In the past Conopidae have usually been considered to belong to the Aschiza group of families, largely because of the superficial similarity of the adults to hover-flies, but they are now considered to belong to the acalyptrates.

This book begins with a large introductory section including explaining the systematics of the group and listing the geographical distribution of the individual genera, and also some explanation of the content of the catalogue. There is also a list provided of host species on which the eggs of Conopidae have been found, including doubtful records which are indicated by a question mark preceding the host species name. The large, distinctive and mainly tropical genus *Stylogaster*, sometimes treated as a separate family, is retained here as a subfamily of Conopidae as the author does not think there are clear reasons for separating them and expects that some differences of opinion are likely to continue concerning the status of this group. The extinct subfamily Palaeomyopinae, comprising two genera described from Baltic amber fossils, is also included. The author agrees with the recent phylogenetic studies by Gibson and Skevington by splitting Zodioninae as a distinct subfamily from Myopinae but disagrees with this by not separating Sicinae as a subfamily and also by not dividing the subfamilies into tribes. Also, no genera are divided into subgenera in this catalogue. The names of tribes which have previously been used are listed as synonyms under the appropriate subfamily, one of many examples of how this catalogue is more thorough than most, and has sought to include all taxonomic names applied to this family and references to where they were originally described. In a few cases the author has if anything been a little excessive in terms of the amount of information which has been included; it seems unnecessary to include a list indicating which bioregions "boundary countries" belong to since the distributional records of each individual species are also given in the main part of the catalogue, where they are also listed according to their bioregions. He has also been very thorough in painstakingly including references for all published distributional records for each country: therefore, a single entry for a common and well-recorded species can take up to five pages, and there are 90 pages of references at the end of the catalogue. Helpfully, type depositories have been provided, and any published host records are also listed for each species.

There may be some criticism that this catalogue contains more detailed information than is necessary, and that it is more long-winded than it needs to be, but for this type of work it is preferable to have this detail rather than having too little information. The author deserves to be congratulated on his exceptional thoroughness, and his exhaustive searching through the relevant literature to compile this generally excellent catalogue.

Nigel Wyatt



A Field Guide to the Spiders of Australia

Robert Whyte & Greg Anderson
Published by CSIRO
464 pages
AU$ 49.95 (£29.00)
ISBN 9780643107076
web site arachne.org.au

This field guide is a bright and colourful introduction to a vast and intriguing fauna.

In the introduction the authors set the scene by stating that there are more unknown than known species of spider in Australia, with 4,000 described species out of an estimated total of between 15,000 and 20,000. Despite these daunting numbers the authors invite the reader to put their prejudices to one side and become acquainted with Australia's charismatic and often enigmatic spiders.

The guide opens with brief sections covering how species are identified, a history of Australian arachnology and spider anatomy. There is then a chapter offering an outline of features to look for when determining the identity of a spider. These are broken down into sections covering, behaviour, eyes patterns, spinnerets, location, webs, burrows, egg sacs & leaf curlers. The rest of the book offers a photographic tour of the families found in Australia. This begins with those commonly encountered and is divided into 37 Araneomorphae families and 9 Myglomorph families. These are then followed by descriptions of 39 uncommon families.

Each of these family sections are illustrated with a series of high quality images that offer an insight into the family's diversity. The images are accompanied by an outline of the family biology and details of habitat and distribution. The book concludes with an index of common family names and a conventional index. There is also a family tree which shows the relationship between the families dealt with in this volume.

The authors enthusiasm and fascination with spiders is more than apparent, they excite and entice the reader to delve deeper into this arachnological box of delights. This field guide is a must have for any Australians with an interest in invertebrates as it offers an easily assessable introduction to spiders as a group and a user friendly map to the biological labyrinth of Australian arachnology. It will also be of great interest to arachnologist globally, as a guide to the families of the Australasian region. Even if you never plan on visiting Australia this book is a fascinating insight into spider diversity and is well worth buying just for the photographs. While this book will be some peoples worst nightmare, for many more it will be a revelation, a window into the astounding world of Australian spiders.

Peter Smithers

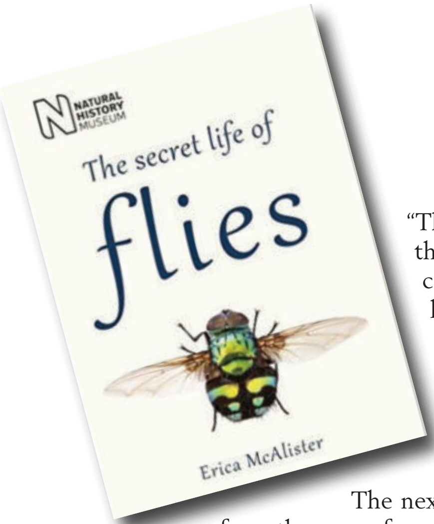
The Secret Life of Flies

Erica McAlister

Published by The Natural History Museum, London

£14.99

ISBN 9780565093365



"The Secret Life of Flies" does exactly what the title implies, it reveals many things about flies that the average entomologist may not have been aware of and that a wider readership will certainly have not known. It could have been sub-titled, "Everything about flies you wanted to know but were afraid to ask". This is a book that is full of encounters with flies that you may be familiar with and some that you almost certainly won't, but they are all fascinating, bizarre, intriguing and often surprising.

The introduction offers an overview of the Diptera and a glimpse of the author's life at the museum, but also stamps the book in no uncertain terms with the author's passion, enthusiasm and authority on the subject.

The next chapter deals with the immature stages and opens with the emergence of a cranefly larva from the anus of a police dog ensuring that the reader is braced for the unexpected as subsequent chapters become curiouser and curiouser.

The book then plunges into detailed accounts of the ecological roles undertaken by flies with subsequent chapters dealing with pollinators, detritivores, coprophages, necrophages, vegetarians, fungivores, predators, parasites and sanguivores. Each of these chapters examine the families that are involved in these roles, offering details of the lives of some of their most charismatic members. These include the giant timber fly *Pantophthalmus bellardi* with its 8.5cm wingspan, the terrible hairy fly that lives on bats and consumes any guano that may stick to them, the fruit fly *Goniurellia tridens* that has evolved images of spiders on its wings, the family Perissommatidae that have four eyes on their head and the outrageous stalk eyed flies of the family Dinopsidae.

Throughout "The Secret Life of Flies", Erica McAlistair does not shy away from the use of technical terms, the book is littered with them, but each one is carefully explained thus making further reading about flies more accessible to readers who are new to the subject. She offers not only a comprehensive insight into the diversity of dipteran biology but also a glimpse into the distant dimly light and unexplored corners of this order, providing an indication of the vast amount we do not yet know or understand about this fascinating group. In the epilogue, the author discusses recent molecular work that indicates that the number of species of Cecidomyiidae in Canada alone may rise from 6,000 to 16,000, suggesting that the Diptera may yet challenge the taxonomic dominance of the Coleoptera.

Erica McAlistair dispels the popular perception that flies are dull, disease-carrying intruders and reveals them to be a carnival of colourful characters with important roles to play in natural systems.

"The Secret Life of Flies" is an irreverent tour of an amazing order, an encyclopaedic collection of stories, anecdotes and musings presented in the author's own uncompromising style with just a hint of English eccentricity.

Peter Smithers

Diary

Details of the Meetings programme can be viewed on the Society website (www.royensoc.co.uk/meetings) and include a registration form, which usually must be completed in advance so that refreshments can be organised. Day meetings typically begin with registration and refreshments at 10 am for a 10.30 am start and finish by 5 pm. Every meeting can differ though, so please refer to the details below and also check the website, which is updated regularly.

Special Interest Group meetings occupy either a whole day or an afternoon (check www.royensoc.co.uk/meetings for details).

Offers to convene meetings on an entomological topic are very welcome and can be discussed with the Honorary Secretary.

MEETINGS OF THE ROYAL ENTOMOLOGICAL SOCIETY

2017

Sep 6 **Film Night**
Films: "Sticky", "Dreams of the Last Butterflies", and "Small Talk Diaries"
: Conservation Education Centre, Bristol Zoo, Guthrie Road, Bristol
Tickets available from Tim Bray (tbray@bristolzoo.org.uk, T: 0117 4285474)
For more information regarding the films, contact Peter Smithers (psmithers@plymouth.ac.uk).

Sep 12-14 **Ento' 17 Annual Science Meeting and International Symposium**
Entomological Networks: Ecology, Behaviour and Evolution
Venue: Newcastle University
Convenors: Gordon Port, Darren Evans, James Gilbert
Symposium speakers:
Lars Chittka (QMUL), Sheena Cotter (Lincoln), Mathieu Lihoreau (Toulouse), David Shuker (St Andrews), Allen Moore (Georgia), Yoshifumi Yamawaki (Kyushu), Ramiro Morales-Hojas (Rothamsted)

Sep 23-24 **Bristol Insect Festival**
Venue: Bristol City Museum
More information from psmithers@plymouth.ac.uk

Oct 24 **Insect Pollination SIG**
Venue: National Museum of Scotland, Edinburgh
Convenors: Drs Jenni Stockan (jenni.stockan@hutton.ac.uk);
Michael Garratt (m.p.garratt@reading.ac.uk)
Confirmed speakers: Dr Adam Vanbergen (NERC Centre for Ecology and Hydrology); Dr Lorna Cole (SRUC).

Nov 1 **Orthoptera SIG**
Venue: Neil Chalmers Room, Natural History Museum, London
Convenor: Bjorn Beckmann orthoptera@ceh.ac.uk

2018

Mar 7 **Verrall Lecture by Dr Amoret P. Whitaker, University of Winchester**
Fabulous Fleas
Venue: Natural History Museum
Convenor: Dr Archie K. Murchie
Due to their parasitic lifestyle, the much maligned flea has always had a close association with humans. However, it has also been celebrated in poetry, art and entertainment. This talk will consider some of the many ways in which this fascinating insect has been portrayed - including their use in flea circuses, as curiosities and as love tokens.

Other Meetings

2017

Sep 4-8 **26th International Conference of the World Association for the Advancement of Veterinary Parasitology (WAAVP 2017)**
"Combating Zoonoses: Strength in East - West Partnerships"
Venue: Kuala Lumpur Convention Centre, Kuala Lumpur, Malaysia
For further details please visit: www.waavp2017kl.org

2018

Jul 2-6 **European Congress of Entomology**
Venue: Expo Convention Centre, Naples, Italy

RES STUDENT AWARD 2017

Write an entomological article and WIN!

REQUIREMENT

Write an article about any Entomological topic that would be of interest to the general public. The article must be easy to read and written in a popular style. It should be no more than 800 words in length.

WHO CAN ENTER?

The competition is open to all undergraduates and postgraduates, on both full and part-time study.

PRIZES

First Prize: A £400 cheque and your article submitted for inclusion in *Antenna*.

Second Prize: A £300 cheque and your article submitted for inclusion in *Antenna*.

Third Prize: A £200 cheque and your article submitted for inclusion in *Antenna*.

ENTRIES

You can send electronically via e-mail to: **kirsty@royensoc.co.uk**

Alternatively, complete the entry form, and submit it with five copies of your entry to:

The Deputy Registrar,
Royal Entomological Society,
The Mansion House,
Chiswell Green Lane,
St Albans, Herts
AL2 3NS

For further information telephone: 01727 899387

Please include:

- Your name and address (including postcode)
- Your e-mail address
- The name and address (including postcode) of your academic institution
- Evidence of your student status

THE JUDGES

The judges panel will be made up of three Fellows of the Royal Entomological Society. The judges decision is final.

CLOSING DATE

The closing date for entries is 31 December 2017. The winner will be announced in the Spring 2018 edition of *Antenna* and on our website.

PLEASE CUT AND RETURN THIS PORTION WITH YOUR ENTRY

Articletitle: ______________________

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Studentname: ______________________

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Address: ______________________

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Telephone: ______________________

E-mail: ______________________

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Name of academic institution:

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