Bulletin of the Royal Entomological Society
Volume 43 (4) 2019

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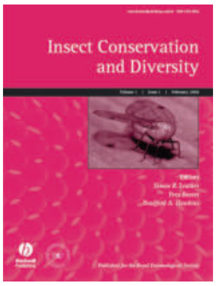

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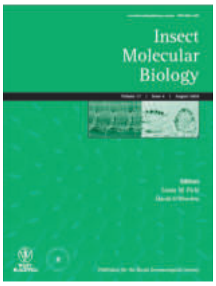

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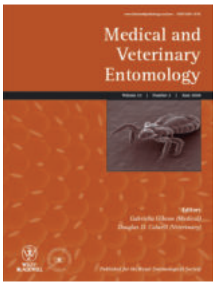

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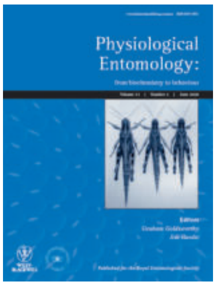

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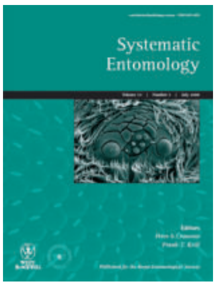

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Male Homerus Swallowtail nectaring in full sun on flowers of *Bauhinia divaricata* L.

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EDITORIAL

Hello and welcome to *Antenna* 43(4). By the time you receive this issue we'll be deep into the UK winter, with many of us looking forward to a seasonal holiday and some time to reflect on the last 12 months. It's certainly been a busy year for my own family, relocating over the summer following a job offer from Newcastle University. Though it was a hard decision for me to leave my post at Stockbridge Technology Centre in York, it's exciting to be back 'up North'. It was here that my entomological journey began under the supervision of RES stalwart, and the UK's leading authority on all things slug-related, Dr Gordon Port. I can still recall attending the PhD interview back in the early noughties, with no idea of the topic, and being delighted to hear that the organisms of interest had six legs instead of a single foot! It's also been another interesting year politically, with the less said on Brexit the better. Regardless of one's stance on the EU, there can be no doubt that continental entomology has taken great strides during 2019, with news released in September to confirm that the German Government has committed €100 million to insect protection. We'll feature more on this in the next issue, but still have plenty of entomologically-engaging content in the pages of 43(4) to keep you entertained and informed.

This Issue's Research Spotlight is particularly enlightening, with Stuart Reynolds brightening the dark winter nights with his article, 'A trick of the light? Artificial light at night, insects and spiders', a topic of increasing interest and one that featured in Callum Macgregor's 2017 Wallace Award winning thesis (see *Antenna* **41**(3)). At the time of writing in late Nov, ALAN and it's impact on insects was also in the spotlight of the national press, following the publication of 'Light pollution is a driver of insect declines' in the journal *Biological Conservation* (Owens *et al.*, 2019). Next up in a packed articles section is a look back at life as a PhD student in the 1950s by Helmut van Emden. This was a time far removed from the conveniences of modern technology that we rely on so readily today when searching for literature, analysing results, or typing and spell-checking a thesis. This is followed by an article on concerns for, and conservation of, the last two known populations of *Pterourus homerus* in Jamaica, provided by Thomas Turner and Vaughan Turland. We then head back to the UK for Jamie Robinson's overview of the insects (and other invertebrates) that one might expect to encounter, often as the bloodmeal, when out and about in the Scottish Highlands. In our final article of this issue, 'What has happened to our pollinators?', and in response to a recent Research Spotlight, Roger Morris and Mike Edwards argue that climate change may be playing a more prominent role than intensive agriculture in driving pollinator declines.

In addition to the above, this issue also features our usual Society News section, with the chance to delve into the life and works of *Antenna*'s very own Richard Harrington in 43(4)'s RES Honorary Fellow Interview. When not preparing this piece, Peter Smithers has been as busy as ever reviewing the latest entomological literature, the fruits of his labour being evident in the four book reviews featured. Amongst the pages of **43**(4) you'll also find several meeting reports, our meetings diary and a celebration of the many achievements of (John) Philip Spradbery, who sadly passed away in July this year.

Happy reading and season's greetings to all.

Dave George

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.

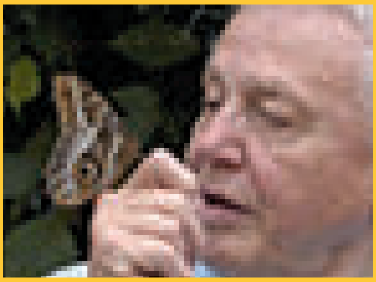
Electronic images can be embedded in the Word document but we will also require separate electronic images. These should be the full size image (.jpg or .tiff) from the camera even after the author has edited the file.

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.

If an image is intended for the front cover then the photograph should be in ***portrait format*** and again should be the full size image from the camera even after the author has edited the file.

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



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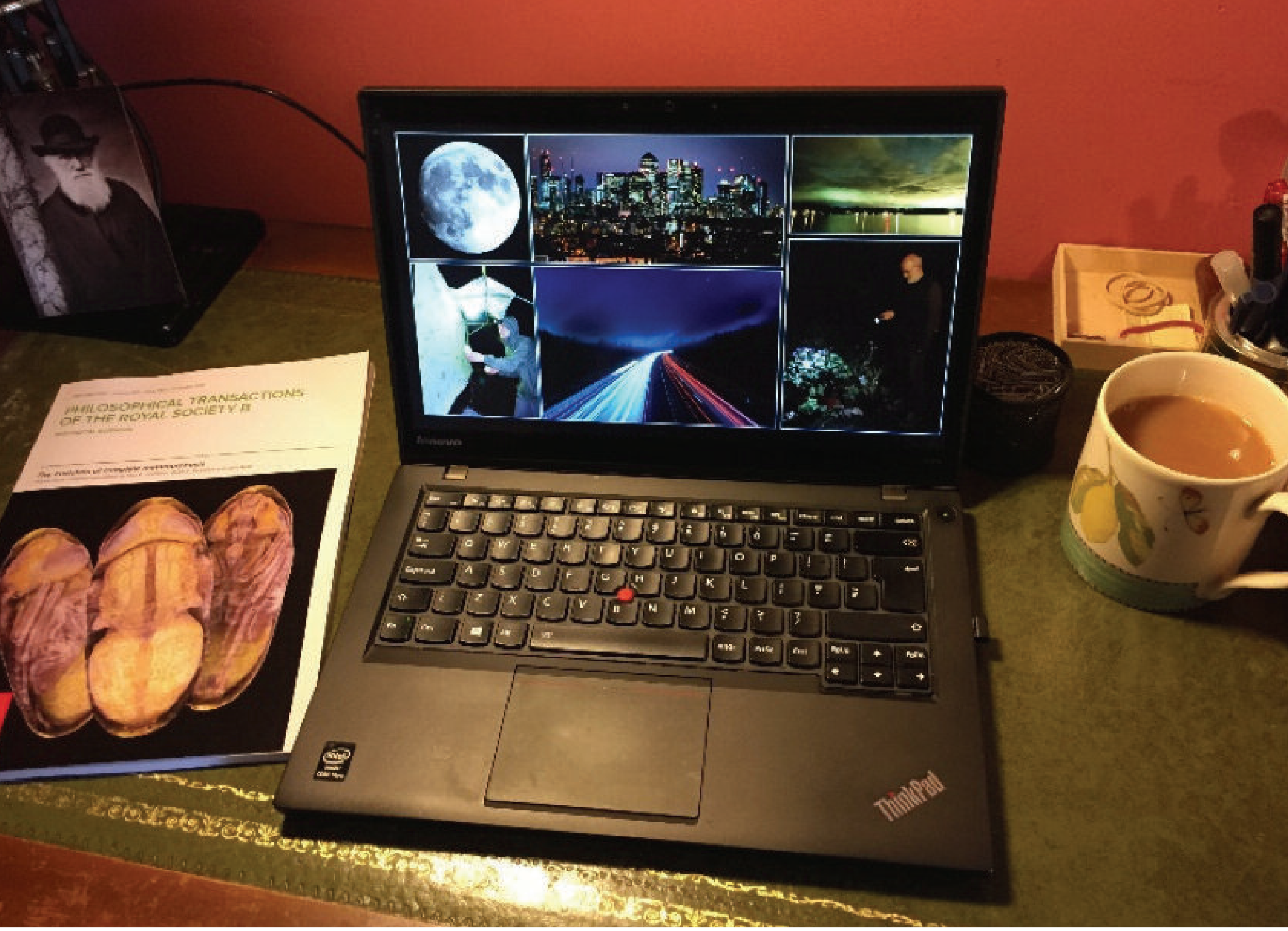

A trick of the light? Artificial light at night, insects and spiders

O Candle! Why does the moth love you?
Why is this restless soul devoted to you?
Mohammed Iqbal (transl. M.A.K. Khalil)

RESEARCH SPOTLIGHT

Stuart Reynolds

Department of Biology and Biochemistry, University of Bath

Unlike many other animals (including many insects) humans don't see well at the relatively low light intensities that typify what we usually call "night" (a period significantly shorter than the period between sunset and sunrise). Bizarrely, however, the daily rhythm of human activity isn't well synchronised with the rising and setting of the sun. Most of us don't wake up until well after dawn, and we typically stay up late into the night. To extend the length of the well-lit period ("day") in which both work and play can be pursued, humans have, for at least thousands of years, used indoor and outdoor light sources of one sort or another. But these lights were few, dim and local. It wasn't until the use of gas-powered street lighting (first used on a practical scale at Westminster Bridge in London in 1813) and later on, electric arc lights and incandescent light bulbs (various kinds of electric street lighting were introduced in different places from 1875 onward) that outside lights were installed in large numbers and left on for hours, showing the potential of city street lighting to turn the night into day.

Artificial Light At Night (ALAN) might well rate as one of the most important human inventions. But like most technological innovations, it has had unforeseen effects; there's now a lot of scientific interest in its collateral

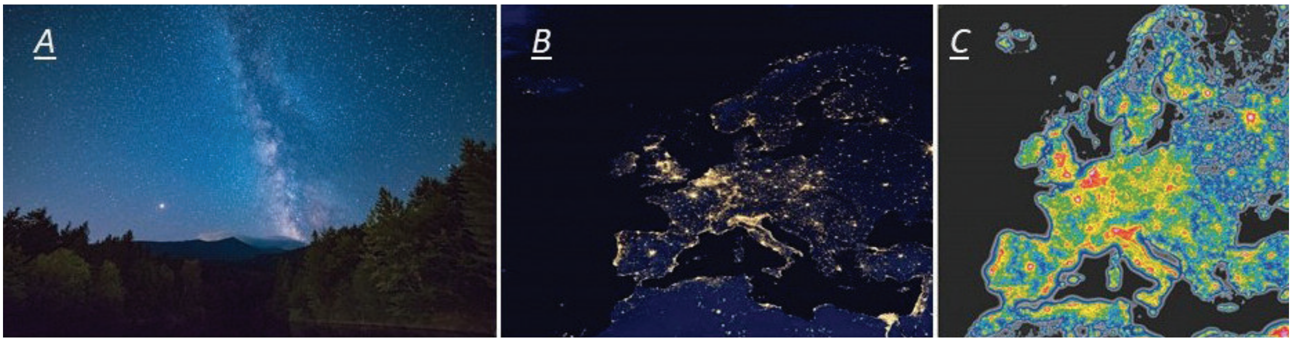

Figure 1. (*A*) What we now so rarely see; the Milky Way seen in a dark night sky in Macedonia. [Photo by Hristo Fidanov (Pexels)]. (*B*) Direct artificial light at night in Europe as it appeared from space on 27 March, 2012. This NASA image is derived from the Suomi National Polar-orbiting Partnership satellite. Image source: https://www.flickr.com/photos/nasacommons/15472779199/ [Public domain image]. (C) Skyglow intensity in Europe, mapped using the VIIRS DNB sensor on the Suomi National Polar-orbiting Partnership (NPP) satellite. Broadly, brighter skyglow is indicated by "hotter" colours. Image from Falchi *et al.* (2016). See the original paper for more detailed interpretation. [Creative Commons Licence 4.0 (CC BY-NC)]

medical and ecological consequences (see for example Gaston *et al.*, 2015; Gaston, 2018; 2019; Lunn *et al.*, 2017). All this adds up to the idea of "light pollution", in which light's effects are recognised to be both intentionally good and unintentionally bad.

Ever since its first introduction, the extent of ALAN has grown continuously, until now, in the twenty first century. Outside lighting is so ubiquitous that in the UK and Europe it's actually very difficult to find a place that is unlit at night (Fig 1). Increasingly, many people have never experienced skies that are completely free of stray light (Davis, 2016; see Fig 1*A*). Since the mid-1990s, a series of earth observation satellites bearing instruments that document terrestrial artificial light sources have been used to map the global distribution of ALAN in unprecedented detail. The resulting photographs have been widely reproduced and most people will have seen images like the one in Fig 1*B*.

Most readers will agree that although the artificially lit Earth looks beautiful, it is disturbing just how much light there is. According to Falchi *et al.* (2016), no less than 23% of the world's land surface between 75°N and 60°S is artificially illuminated to some extent. 88% of the area of Europe, and almost 50% of that of the United States is exposed to stray light from ALAN. Of course, this lighting mainly affects those places where there are most people: 83% of the world's population and >99% of Europeans and Americans are affected. [If you want to know how bad light pollution is exactly where you live in the UK, then visit the website of the Campaign to Protect Rural England (CPRE, 2016)]. The growth in outside lighting still continues. It has been recognised in recent years that it would be beneficial to reduce energy use, and low energy LED light sources have been widely introduced in outside lighting. At least some of the energy efficiency gains from LED technology have, however, been offset through the rebound effect or "Jevons paradox" (Ruzzenenti *et al.*, 2019), and the extent and intensity of light provision is actually increasing at roughly 2% per year (Kyba, 2018).

Humans generally see artificial lighting as a benefit (it means that you can see where you're going at night, and road safety is commonly cited as a strong benefit of ALAN), but it is now becoming increasingly evident that there are serious downsides to the lack of proper darkness at night. This isn't only a matter of it being hard to avoid the glare of an uninterrupted sight line to an actual light source; outside lighting also results in the reflection and/or diffraction of low levels of light almost everywhere, forming what is called "skyglow" (Fig 1C).

Stray night-time light isn't just an aesthetic nuisance, but actually causes adverse effects on humans, whose sleep patterns and general health are disturbed by exposure to night-time light, sometimes causing long term health problems (Stevens and Zhu, 2015). Light pollution isn't only a problem for humans either; supplying light when it would not normally be present also has the potential to disturb the natural world. Nocturnal animals (i.e. those normally active at night) are most obviously at risk, because the light can directly interfere with their ability to pursue their normal behaviour without injuring themselves (e.g. migrating birds are confused by lighthouses). But even strictly diurnal animals may suffer through the changed lengths of the day and night, cues that are often used to time their patterns of reproductive physiology, development and behaviour, leading to a direct loss of fitness. Beginning about 30 years ago, this subject has been extensively researched and reviewed. I can't provide an exhaustive bibliography here, but a series of papers by Kevin Gaston of the University of Exeter (2015, 2018, 2019) provides a very good introduction.

In this *Research Spotlight* article, of course, I'm particularly concerned with the effects of ALAN on insects. Naturally, entomologists have long been familiar with the idea that light and darkness are important for insects. Street lights are well known to attract moths and other nocturnal flying insects, and light traps of various sorts (e.g. Williams, 1948) have been used for more than 100 years to lure night-flying insects into the hands of both amateur and professional entomologists (see Fig 2). This tendency of nocturnal insects to fly towards artificial light sources (called positive phototaxis) is exhaustively documented but its mechanism is still not well understood (reviewed by Nowinszky, 2004). According to species, some insects flutter around light sources while others approach the light but then become immobile. These responses have been variously explained by hypothesizing that night-flying insects attempt to maintain a constant angle of orientation to the moon, orient to diffraction patterns from the open sky, or cast around because of photoreceptor desensitization. Different moth families are differentially attracted to different types of artificial light (which differ in the wavelength of light they emit), but we have no idea why this should be so (Somers-Yeates *et al.*, 2013). There's no need in any case to suppose that a single

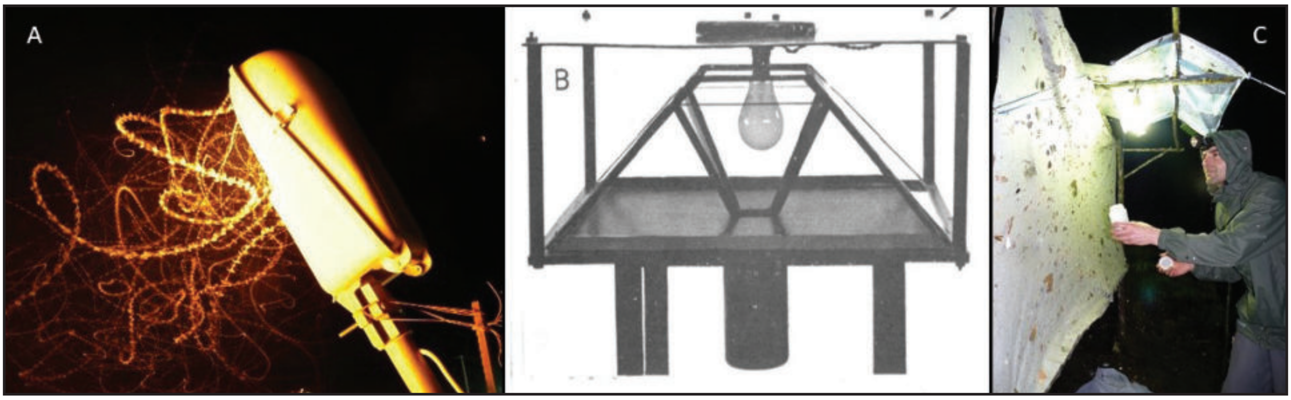

Figure 2. (A) Street lights attract night-flying insects. Multi-flash image by Nevit Dilmen [CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)]. (B) Many nocturnal insects are attracted to light, and this is used to study them: a Rothamsted "fixed" light trap (Williams, 1948). (C) Alessandro Giusti (Curator of Lepidoptera at the Natural History Museum, London) collecting moths in Borneo; image used with permission.

explanation will account for the behavioural response to artificial lights of all species of moths.

Regardless of how the attraction works, nocturnal insects like moths do approach street lights in large numbers, which effectively act as giant insect traps, hoovering up moths from a surrounding sphere that has a radius of 23 m (Degen *et al.*, 2016). Whether the light is an entomologist's trap or not, it is obvious that fluttering around, or being immobilized by an artificial light source is not time well spent for the insect. At best it is a waste of effort that would be better spent mating and egg laying; much worse, rows of street lights may act as barriers to migration and colonization of new habitats, and may also expose the insects to increased risk of predation by bats and other insectivorous predators (Cravens *et al.*, 2018). Diffuse illumination may also be harmful. For example, skyglow would be expected to interfere with dispersive behaviour in scarabaeid dung beetles, which navigate away from dung piles by skilfully orienting themselves with respect to the stars, especially the Milky Way (Dacke *et al.*, 2013).

The development, reproductive physiology and behaviour of insects is just as vulnerable to disruption by ALAN as is that of larger vertebrate animals; this subject has been recently reviewed by Owens *et al.* (2018) and Desouhant *et al.* (2019). The vast majority of the documented effects are negative, i.e. exposure to light pollution decreases the fitness of insects and other arthropods. Many examples of the adverse effects of continuous illumination on insect fitness are known, and I'll mention just a few recent ones where the experimental design involved exposure to more or less realistic artificial lighting regimes. For example, van Geffen *et al.* (2014; 2015) found that ALAN disrupts sex pheromone communication and sexual behaviour in geometrid moths; Grenis and Murphy (2018) showed that the cutworm *Apamea sordens* grows more slowly when it feeds in conditions illuminated by streetlights, and that some of this effect is mediated through increased toughness of the plant on which it feeds; Durrant *et al.* (2019) have shown that low-level ALAN adversely affects cellular immune responses in the cricket *Teleogryllus commodus*, suggesting that such immunodepression might render insects more sensitive to pathogens and parasites than usual; and, sure enough, Kehoe *et al.* (2018) have shown that aphid–parasitoid population dynamics are sensitive to daylength alteration.

This kind of evidence (and more) has led Grubisic *et al.* (2018) to propose that ALAN may contribute to the much-vaunted widespread insect declines of recent years (see two of my other Research Spotlight articles in *Antenna*; Reynolds, 2019a; 2019b). I think that if there is such a connection, it will be very difficult to sort out a mechanistic explanation for any interaction between ALAN and the general level of fitness of natural insect populations – there are so many possible direct and indirect effects that the whole thing is much too complicated. Nevertheless, now that we have been alerted by phenomenological evidence that ALAN has negative effects on insect wellbeing, I think it is reasonable to say that we ought to take into account the welfare of insects when we install even more street lighting and other bright outdoor lights. After all, there are more insects than any other kind of animal.

But wait a minute! Surely, just as is the case for humans, there must be insects and other arthropods that actually benefit from ALAN? There are probably lots of examples, but in this case I am going to focus on one in particular: the benefits of ALAN to the nocturnal predators of flying insects, especially orb-weaving spiders. I came across this phenomenon for myself a couple of years ago when attending a conference. The meeting (the Ecological Immunology Workshop 2017) was held in the Youth Education Centre, Blossin, located near Heidesee, not far from Berlin, Germany. The Blossin centre, set in a rural location next to a natural lake, has dozens of outside lights set in the covered porches of its buildings. These lights provide a superb opportunity for the rather large araneid spider *Larinioides sclopetarius* (Fam. Araneidae). This orb-weaver (sometimes called the bridge-spider) is well known to build its webs underneath bridges and other human-built structures and is commonly found associated with water and (crucially in this context) artificial lights (Nieuwenhuys, 2013)[1].

[1] Unfortunately, there appears to be some uncertainty about the taxonomy of *L. sclopetarius*. A paper by Sestakova *et al.* (2014) has proposed that *L. sclopetarius* (Clerck, 1757) and *L. cornutus* (Clerck, 1757) are synonymous. This reassignment is, however, apparently proposed only on the basis of inspection of material from tundra locations in the Far East of Russia, together with a single specimen from Finland. This is a bit disturbing, as both spiders have world-wide distributions. Moreover, since *L. cornutus* is widely reported as occupying only natural habitats and being absent from urban light-associated locations (i.e. totally different from those in which *L. sclopetarius* has been collected in Europe and North America), there has to be some doubt about the matter. Perceptive readers will notice that this footnote has a strong bearing on the question of the evolutionary history of what I will continue here to call *L. sclopetarius*. What if *L. sclopetarius* actually represents an invasive subpopulation of *L. cornutus* that is already effectively distinct? It seems to me that the taxonomy of these two species of spider needs to be reinvestigated.

Figure 3. An orb web spider (*Larinioides sclopetarius)* that has set up its web close to an outside light at the Blossin Conference Centre (Heidesee, Germany), thus acquiring considerable success in capturing flying insect prey. The inset panel shows the same spider illuminated by the camera flash. Images by Gabriele Margos, reproduced with permission.

Entomologists at the meeting quickly noticed that underneath almost every single outside light at Blossin was a large and prosperous-looking resident *L. sclopetarius* sitting at the centre of its web, surrounded by the remains of the many insects that its web had captured (see Fig 3). It was immediately obvious that this spider benefits from its association with humans because the lights under which it chooses to live attract prodigious quantities of insect prey. The loss of fitness of the flying insects is the spiders' gain.

Checking up afterwards, I realized that this spider is actually well-known for its association with brightly lit human-built structures. Anja Kleinteich of Hamburg University notes (Kleinteich, 2009; Kleinteich and Schneider, 2011) that *L. sclopetarius* has all the characteristics of an invasive species, having accomplished the colonization of an empty new man-made niche in which light-driven availability of prey presented an open goal waiting to be scored.

The supersizing of the spiders' food supply presumably explains why *L. sclopetarius* does so well in brightly-lit locations close to water like Blossin. Twenty years ago, Astrid Heiling of the University of Vienna had already noticed that *L. sclopetrius* was more abundant on bridges across the Danube that were close to artificial lights; she showed that these locations both had a larger supply of potential prey, and that more prey was captured there (Heiling, 1999). There have also been reports that some other orb-web spiders are attracted to spin their webs close to light and that this is associated with enhanced prey capture rates (Adams, 2000; Ceballos *et al.*, 2005; Wilmott *et al.*, 2018), but *L. sclopetarius* is the best studied case.

While it might seem obvious that access to an enhanced food supply is bound to be a good thing, we ought to make sure that this is really the case for *L. sclopetrius*; not all invertebrates are limited by the availability of food. It's therefore reassuring that although *L. sclopetarius* spiders reared with a better food supply don't grow to be bigger than those given less food, nor do they lay more clutches of eggs, they do grow faster and lay more eggs per clutch, thus enhancing their lifetime reproductive output (Kleinteich *et al.*, 2015). But the enhanced food supply is probably quite episodic and unpredictable, depending, as it does, on the large-scale emergence of adult insects that have aquatic larvae. Kleinteich and Schneider (2011) looked at the relationship between the developmental progression of *L. sclopetarius* and food availability and found it to be highly plastic, with variable longevity, variable numbers of instars, and variable size increase in each stage. They argue that these characteristics are all pre-adaptations for the successful invasion of the spider into an unpredictable habitat like this. Incidentally, the functional response of other orb-weaving spiders to an enhanced food supply wouldn't necessarily share the same reproductive mechanism. The golden orb weaving spider, *Nephila plumipes*, for example, also benefits from a more abundant food supply in an urban environment; but in this case the well-fed spiders do grow bigger and have larger ovaries (Lowe *et al.*, 2014).

The astonishingly high occupancy rate by *L. sclopetarius* spiders in brightly lit man-made locations (Kleinteich, 2009, reports densities as high as 100 individuals per m^2 at various urban locations in Germany) calls for an explanation. How do the spiders find the sweet spots under the lights? Is this species in some way pre-adapted to be able to colonise this obviously non-natural niche? Or has the behaviour of *L. sclopetarius* actually changed through evolution to enable it to take advantage of the lights? Heiling (1999) showed that *L. sclopetarius* preferentially chooses to construct its web in a well-lit place, and that this preference does not have to be learned. She concluded that this spider has "evolved a specialised foraging behaviour that is tied to the behaviour of nocturnal insects which are attracted to artificial light". Heiling stopped short of suggesting that this is a new genetic trait due to natural selection of previously existing but rare, or mutated, genes and instead speculated that "…the active search for lit patches may be genetically determined. It is unlikely that this behaviour has evolved in response to the presence of artificial light, which may constitute a superstimulus for *L. sclopetarius*. Because this species is restricted to habitats near water, the spiders may have primarily used reflected moonlight as an indicator for high insect densities and thus as a cue to improve their foraging success."

Unlike Heiling (1999), however, I'm not so sure that pre-adaptation can be entirely responsible for the success of *L. sclopetarius*. Building a web that is located in a moonlit spot is quite different from selecting a spot that is within a few cm of a very bright artificial light! Even if there was some degree of pre-adaptation it is likely that, upon arrival in the new environment, strong competition between colonists to exploit the new way of life of feeding on a light-dependent food supply would drive further genetic change. The selective advantage of building a web close to a light is very strong, as the photographs of Fig 3 clearly show. Evolution can happen quickly (this is well known for invasions – Andrade-Restrepo, 2019), and *L. sclopetarius* has had almost 200 years (equivalent to 150-200 generations) to adapt to the presence of artificial lighting.

It seems highly significant to me that *L. sclopetarius* is reported by many commentators to live almost exclusively on human-built structures in cities and in the presence of artificial lighting (e.g. Nieuwenhuys, 2013). Moreover, its world-wide urban distribution argues for its invasiveness, probably due to human-mediated translocation. On the other hand, it is also described as numerous in Central Europe in "moist meadows with tall grass", where it evidently occurs only "secondarily on bridges, buildings and fences" (Araneidae-cz, 2019). If the colonization of brightly lit space was enabled by a rare genetic event (i.e. a single mutation) then such rapid adaptation through natural selection at a single locus would show up in the genomes of urban *L. sclopetarius* as a strong selective sweep (Smith and Haigh, 1974), while spiders of the same species occupying "natural" (i.e. not brightly lit) locations in Central Europe would not show this. Maybe someone should have a look?

Acknowledgement

I thank Gabi Margos for the images in Fig 3 and Peter Smithers for identifying the spider.

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Doing a PhD in the 1950s – no computers, photocopiers, pocket calculators and (in my case) no supervisor, almost

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"It beggars belief!" This was my reaction when checking the first experiment of my PhD time at Imperial College in the second half of the 1950s at Silwood Park. My supervisor (Professor Richards) had purchased a large number of Large Thorn Moth eggs for me to expose to predation in a field at different distances from the hedge (an early experiment on Ecosystem Services?). As the only available field was grazed short grass, I protected my egg batches from ruminants by four steel stakes with a wire fence wound around them. How was I to know the cows would take singular and specific objection to my stakes and back onto them with their tails raised – "it beggars belief!".

I dared not report to the Prof. that his expenditure now lay buried under cowpats. Indeed, I had no further supervisory contact with him until eventually I handed in my draft thesis for his comment. Instead I sought the help of fellow postgrad Trevor Lewis (later to be Head of Entomology and then Director at Rothamsted), who was working on thrips in a wheat field at Silwood. He agreed I could look for a project on his field, and so I looked for a herbivorous insect common on both the wheat and the surrounding grass verges. Enter aphids into my life – so often entomologists' careers are determined by the insects they studied for their PhD.

We postgrads really supervised and tried out ideas on each other. The research lab I was allocated was also used by Trevor Lewis and Peter Harris. Peter worked on Pine Shoot Moth, but later returned to Canada to become an international leader in the field of biological control of weeds. I couldn't have asked for two better supervisors.

Prof. Richards would bring visitors to the lab, departing with the misplaced introduction "I'll leave you with van Emden, who'll tell you about his work on predation of Lepidoptera eggs". This was long before upgrading meetings and annual reports, but I did decide to submit a report at the end of year one to make my supervisor aware that I had chosen a completely different road. I heard nothing in return.

My time as a PhD student was before computers, the internet, photocopiers or pdfs. If you wanted the copy of a recent paper you sent the author a "reprint request card" – pre-printed by

Fig. 1. Above, pen with tubular nib for use with below, plastic stencils (photo of pen courtesy of David Riches).

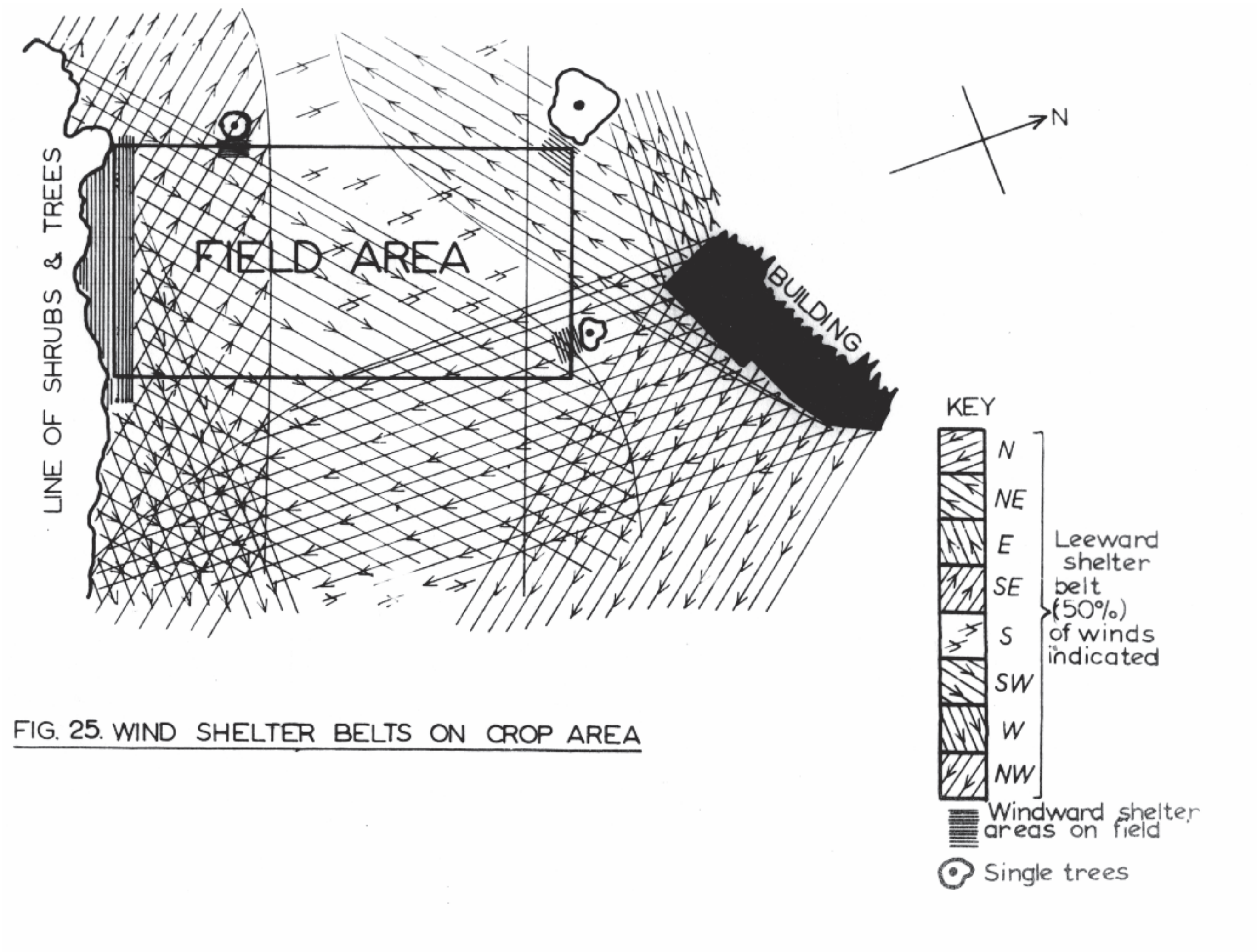

Fig. 2. A hand-drawn illustration from my PhD thesis showing stencilled lettering.

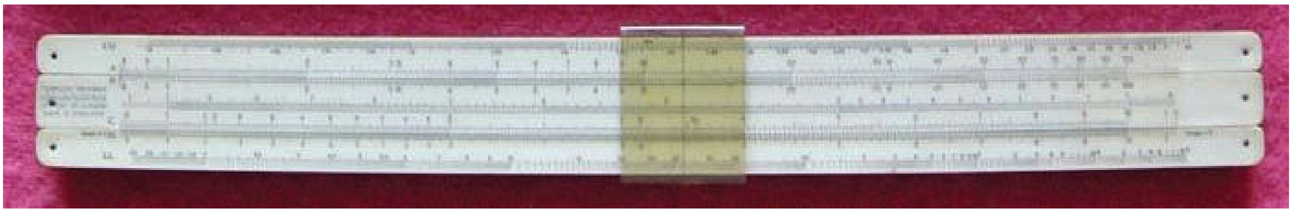

Fig. 3. A slide rule (photo courtesy of David Riches).

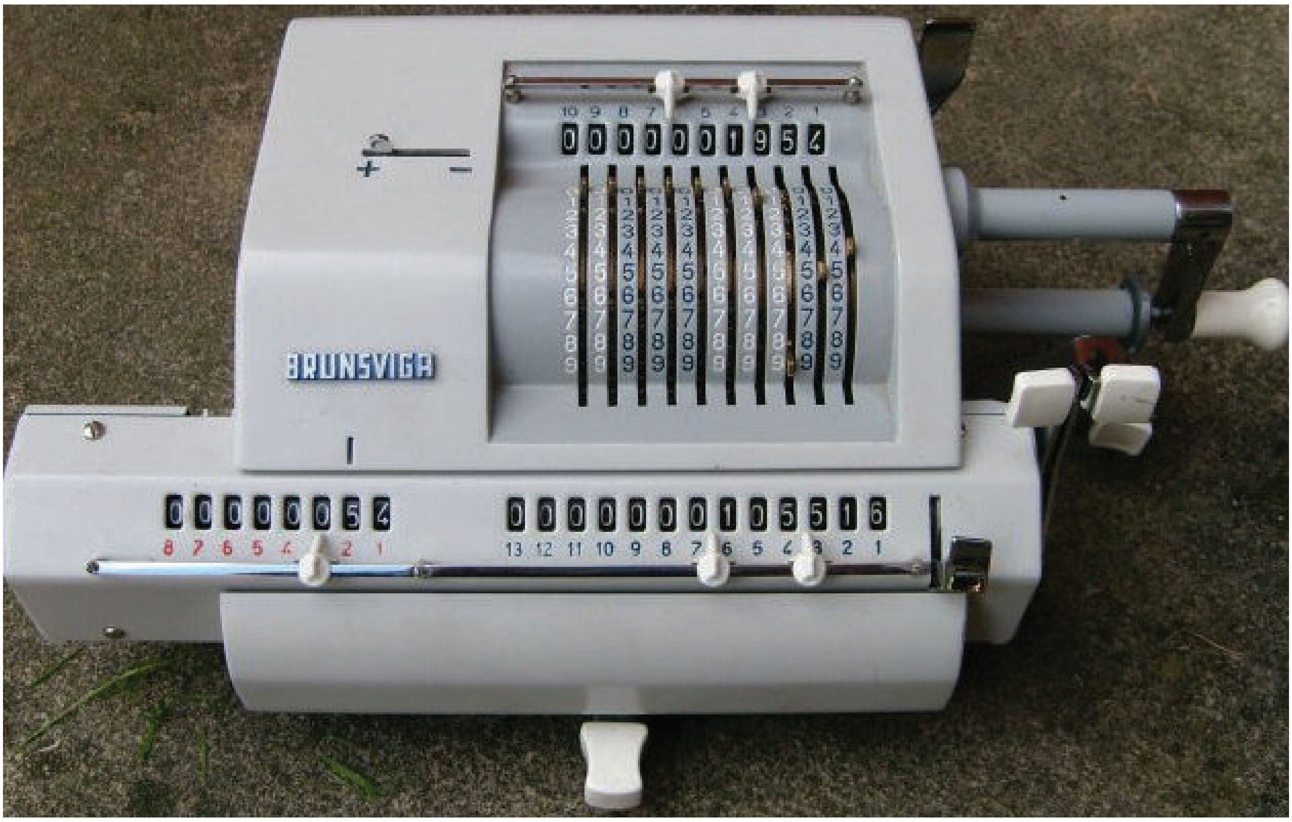

Fig. 4. A Brunsviga hand calculator (photo courtesy of Ingram Bromley).

the College except for the details of the paper. Authors usually received 50 free copies of their paper as well as the option to buy additional copies. For earlier papers, the only option was to obtain the journal and photograph the pages. No photocopiers and no digital cameras. You used roll film, which then had to pass through two liquids for developing and fixing the image, which was then projected through an "enlarger" onto photographic paper which finally was itself developed and fixed – all in the virtual dark with a dim red light. The darkroom in the Silwood basement was in regular use. Without the internet, there were also no literature searching facilities. The nearest things were abstracting journals such as the *Review of Applied Entomology*. So we all spent time regularly in the library, browsing the current issues of the journals we were mainly interested in. A computer literature search is no substitute for browsing if you have wider entomological interests than your PhD topic.

What about illustrations for the thesis? These were hand-drawn in black Indian ink, on special white board (Bristol board) or more usually on blue-squared graph paper. Curves were drawn round the edges of special stencils or with a flexible lead-filled plastic ruler. What about lettering? Hand-lettering was acceptable, but most of us used special tubular pens of different sizes following size-matched letter-shaped holes in a plastic stencil (Fig. 1). Plastic stick-on lettering (Letraset) did not become available till later. The illustrations were then photographed using a special blue-insensitive film so that the blue lines disappeared (Fig. 2), and the necessary number of copies for the thesis were printed as enlargements. Washing between developing and printing was not always adequate, and fixer soon became less effective and required replacement, though you could only guess when this was necessary. Thus, some Figures in most theses of the day, including mine, have become disfigured with age by the appearance of brown patches.

What about calculations and statistics? No computers, not even hand calculators. It was not till 1973, long after my PhD years, that I bought an electronic hand calculator with just basic functions (not even a square root button) for over £200 – nowadays more powerful calculators are given away as free promotions. The tools we had were paper and pencil, a good grasp of mental arithmetic, logarithm tables and slide rules. A slide rule was an ingenious device of a central scaled ruler sliding in a groove within the scales on a fixed ruler (Fig. 3), and you could read off the results of

Fig. 5. A Roneo duplicator (photo courtesy of the Museum Centre in Hordaland, Norway).

multiplication and division, though with limited accuracy. We mainly used logarithm tables for squaring large numbers and square rooting. Double the logarithm and the antilog is the square of the original number. The statistical procedure for calculating the sum of squares of deviations from the mean, by adding the squares of the numbers and subtracting a correction factor, only came in with electric calculators. We actually subtracted the numbers from their mean and added their squares; this kept numbers smaller and they could often be squared and added mentally.

During my PhD time, Prof. Richards bought himself a Brunsviga (Fig. 4), a mechanical hand calculator. You slid levers to register your numbers and then turned a handle till a bell rang and then did one turn backwards. The answer to your multiplication or division appeared as a series of numbers in a sliding carriage. In nearly all these methods, including the Brunsviga, you were left to work out for yourself where to put the decimal place. When the Prof. brought an electric version of the Brunsviga (the Facit), the 25 cm long Brunsviga was moved to a small room, designated "the calculator room", on the top floor of Silwood House, and students and postdocs could book time on it. To give you some idea of how things have changed, my thesis contains a regression on only about 6 data points. This took me a full day's work, and the working stages covered about 4 A4 pages in pencil.

Now to the production of the thesis. No word processors, only the trusty mechanical typewriter. Most of us produced our thesis in handwriting, and then paid one of the departmental secretaries to type it. This actually speeded up the process of submission. Professionally trained typists could produce in a week what it takes a postgrad a month or more to produce with a word processor; moreover they corrected errors as they went along especially in Latin names of insects and in consistency of presenting the references. The several copies needed were often produced by loading the typewriter carriage with four sheets of paper separated by carbon paper, which left a progressively weaker impression down the stack as embossed metal letters hit the top sheet through a carbon ribbon. Corrections were complicated and obvious, since each copy had to be loaded separately for overtyping. A posher but more expensive technique was to load a wax sheet instead of paper, and use the type heads (with the carbon ribbon removed) to punch letter-shaped holes in the wax skin. This one copy could be corrected relatively easily by filling in the letters or words that needed correcting with a rapidly congealing liquid wax, and then typing the correction into it. The final stencil was then fitted onto the pad of a printing-ink-filled drum on a duplicating machine (usually a Roneo, though "other models were available") (Fig. 5). Sheets of paper were pulled through and ink forced through the letters as the drum was rotated. All copies were of equal quality, and you could make as many as you liked. All colleges had a bookbinding facility to produce a beautifully bound hard copy in the college strip of your text and Figures with gold-leaf lettering on the cover giving the title and the name of the proud author.

I submitted my thesis to Prof. Richards, and after quite a long time he returned it with the three-word approbation "Get it typed". I leafed through my manuscript and found zero comments, page after page. Yet somewhere around page 100 I found evidence that he had indeed been through it – he had corrected my mis-spelling of the pteromalid genus *Lygocerus*. It beggars belief!

Female Homerus Swallowtail nectaring on flowers of *Psychotria* sp.

Concerns for the last two known populations of *Pterourus homerus* (Fabricius, 1793) (Lepidoptera: Papilionidae) in Jamaica, and strategies for conservation

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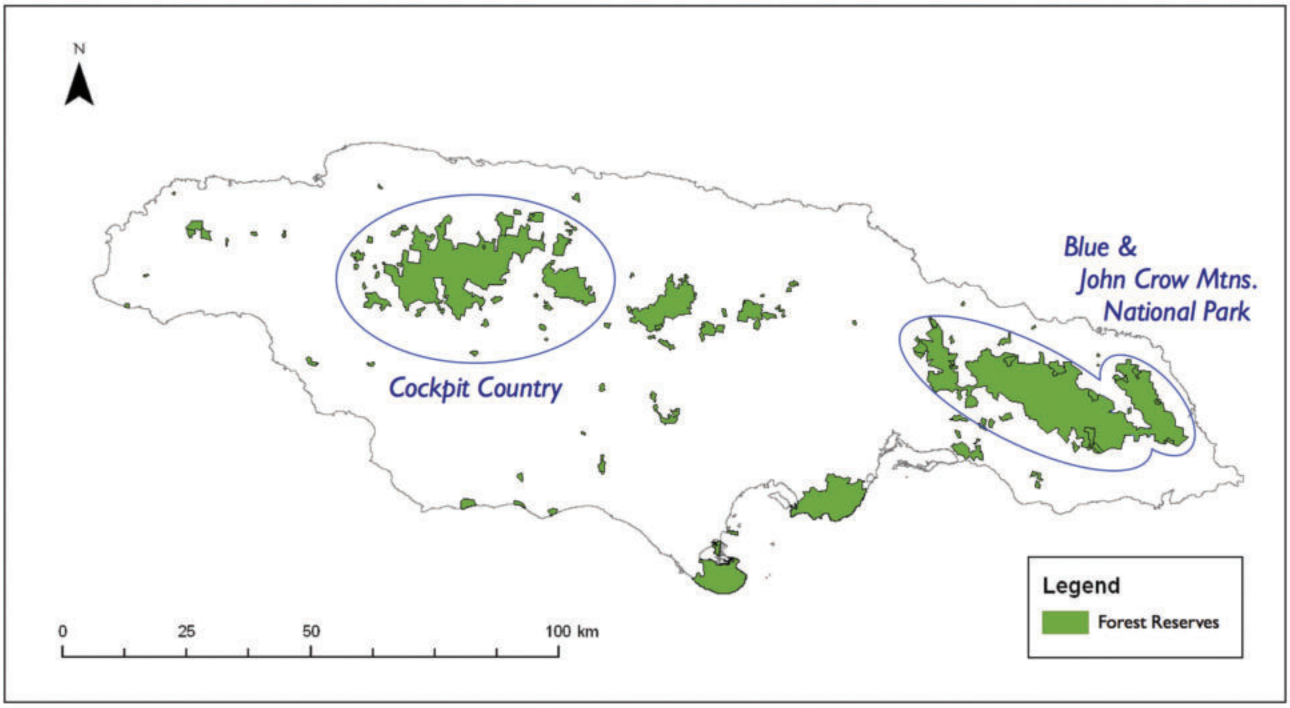
Background

Named in honour of the Greek poet, Homer, *Pterourus homerus*, the Homerus Swallowtail, is the largest butterfly in the western hemisphere, and one of the most endangered (Red Data Book, 1985, as *Papilio*; Collins & Morris, 1985). Confined to mountain forests of Jamaica, the battle for survival of *Pterourus homerus* continues in the face of habitat loss from expanding informal agriculture, animal grazing, logging, bauxite and limestone mining, and an ongoing fight against poachers. Protection in national law and its enforcement, as well as being listed in Appendix 1 of CITES, has not yet been enough to secure the future of this spectacular butterfly that few will ever get to see in the near inaccessible rugged interior of the island.

Many swallowtail species were originally described as *Papilio* Linnaeus (1758), but over time this genus has been divided, largely using morphological characters, but aided more recently by molecular studies, into a number of separate genera within the family Papilionidae. These changes in classification are discussed in *Swallowtail butterflies of the Americas* by Tyler, Brown and Wilson (1994) who apply common morphologies and already published generic names to their revision. In this they recognise *Pterourus* Scopoli (1777), with *Papilio troilus* Linnaeus as the type species, to be the group of swallowtails into which the species formerly known as *Papilio homerus* L. should be placed.

Destruction of closed broadleaf forest in Jamaica began with the arrival of the Taino Indians in approximately 700 A.D. (Walker 1992), continuing after establishment of the first Spanish

Male Homerus Swallowtail resting in shade on a cloudy afternoon.



The forest reserves encompassing the two remaining subpopulations of *P. homerus* (Map by Dr Susan Koenig, Windsor Research Centre, Trelawny, Jamaica).

settlements in 1509, and becoming extensive after 1655 with the arrival of the English. By 1983 only six percent of undisturbed primary forest remained (Olsen *et al.* 2002). This forest includes the western side of the John Crow Mountains in the east, and the Cockpit Country in west central Jamaica, where the last two known populations of the Homerus Swallowtail fly, and which are respectively referred to as the Eastern Subpopulation and the Western Subpopulation. Historically, the last known specimen from the now absent Central Subpopulation was collected in 1925, and it is evident that these three subpopulations are remnants of what was once a single population that extended across the island (Turner and Turland 2017).

In 1995 the World Resources Institute noted Jamaica as the country with the highest rate of deforestation (Eyre 1994; Evelyn and Camirand 2000), and in 2010 a United Nations Food and Agriculture Organization report concluded that only 80,000 hectares of primary forest remained there. Today, loss of closed broadleaf forest continues at an alarming rate, but with wide ranging estimates. The most recent figures are from the Jamaica Forestry Department, as presented in their National Forest Management and Conservation Plan 2016-2026 (2017), stating a loss of 4.1 percent of closed broadleaf forest between 1998 and 2013.

Behaviour

The Homerus Swallowtail is an obligate primary forest resident. It expands its range of occupancy within the primary forest during more favourable warmer and wetter summer months between April and October, contracting again in cooler dryer months of the year between November and March. Observations over many years confirm that the insect is very reluctant to cross open areas cleared of forest, always preferring canopy below its flight path (Turner and Turland 2017). The result is that as forest is cleared at the periphery of the habitat, a factor of particular concern in the Eastern Subpopulation, or as forest is fragmented, which is of particular concern in the Western Subpopulation, the territorial flight boundaries are progressively decreased.

By plotting former and present known flight boundaries it can be documented that in 1940 the range of occupancy for the Eastern Subpopulation extended to approximately 200 km^2. Due to deforestation, however, this range had been restricted to approximately 22 km^2 of undisturbed forest by 2017, a loss of territory of about ninety percent. Similarly, in the Western Subpopulation, the maximum known range of occupancy for adults in 1940 extended over 1,010 km^2, while by 2017 this had been reduced to approximately 500 km^2, a loss of range of occupancy of about fifty percent. The ranges of occupation in each subpopulation should not be equated to areas where breeding occurs, as this is restricted to a much smaller part of each territory.

Multiple challenges

The two remaining subpopulations of the Homerus Swallowtail face different survival challenges dictated by the terrain which they occupy. In the Eastern Subpopulation, which is in the Blue and John Crow Mountains National Park (also inscribed as a UNESCO Heritage site in July 2015), the single larval food plant used is the endemic *Hernandia catalpifolia* Britton and Harris (Hernandiaceae), known as Water Mahoe, a plant with pendant branches. This tree is most commonly found in close association with streams that descend the western flank of the 1,143 m high John Crow Mountains, which run southeast to northwest, meeting the eastern slopes of the Blue Mountains that run east to west. From these mountains flow several streams, many of which are individually named, that descend precipitously into the Plantain Garden River watershed to the south and into the Rio Grande River watershed to the north. *Hernandia catalpifolia*, an under-story tree, grows best under shade provided by taller forest canopy, and seeds from this larval food plant appear to be dispersed along the water courses by the current. However, the upper reaches of the Rio

The rugged and mostly impenetrable karst limestone topography of the Cockpit Country forests.

Grande River and the lower reaches of the Plantain Garden River are now largely deforested and the lack of a canopy inhibits successful growth of dispersed *Hernandia* seeds and further limits the flight range of adults which are reluctant to leave the forest. Of note is that oviposition has also been observed by both subpopulations on *Ocotea* sp., although larval development on this plant has not been recorded.

The Homerus Swallowtail's reliance on different summer and winter habitat also makes it vulnerable to change in either. When heavy cloud begins settling over the John Crow Mountains in September, leading to daily mists, and as the minimum nightly temperature falls to 20°C, adults leave territories occupied through the summer at elevations of up to 600 m. They move to areas as low as 220 m until the following April. When minimum nightly temperatures rise back above 20°C, they once again ascend the mountains (Turner 1991). Between 1991 and 1993 only 39 adults were observed at these lower elevations between October and March, as opposed to two hundred seen at higher climes between April and September during the same years (Garraway *et al.* 2008). This would suggest critically low population numbers at lower sites that may be especially vulnerable. Our observations over many years also determined that it is unusual to see more than three specimens in a month between November and February. Reduced canopy cover and thinning of forests may also be driving increased parasitisation in the upper Rio Grande river valley, where parasitic wasps have been documented infesting eggs of the swallowtail (Garraway and Bailey 1992). This seems not to be apparent higher up the mountain, at elevations of 685 m, along streams in densely shaded forest (Turner 1991).

The Western Subpopulation occupies areas of the Cockpit Country, a region of dense closed broadleaf forest. Most of this forest is within managed reserves and the extremely rugged and mostly impenetrable terrain is pitted with karst, steep-sided "cockpits" or arenas. These can be up to 120 m deep next to conical pinnacles of similar height, creating microhabitats where variations in edaphic factors from one aspect to the other permit the existence of a wide diversity of life.

For scientists, movement in this area is restricted to a few trails with limited observation points. The porous nature of limestone topography ensures there are no surface rivers, but caves and underground river systems abound. This underground network of water courses results in the Cockpit Country being the source of six major rivers and some 40 percent of Jamaica's exploitable potable water resource. Elevations of the main Cockpit Country forests are mostly between 500 m in the south to 300 m in the north.

Between April and November, the Homerus Swallowtail can be observed with limited frequency at restricted locations where males especially are attracted to flowers of a few available *Bauhinia divaricata* L. trees, with females sighted significantly less frequently (Turner and Turland 2017). The larval food plant in this subpopulation is the endemic *Hernandia jamaicensis* Britton and Harris, an erect tree growing to heights of 26 m or more, and not dependent on surface flowing streams. These plants are widely dispersed through the forest rather than concentrated in any one locality.

Male Homerus Swallowtail nectaring in full sun on flowers of *Bauhinia divaricata* L.

Eminent English botanist Dennis Adams (pers. comm.) opined that seeds of this tree were probably dispersed by fruit-eating bats, but researcher Susan Koenig at the Windsor Research Centre suggests that avian dispersal is more likely .

Already critically endangered, perhaps the greatest threat to the Western Subpopulation is the present fragmentation of forest. There are at least three large tracts of primary forest that have been separated from the main forests of the Cockpit Country by clearings created for agriculture, roads, and habitations. The resultant forest fragments now support even smaller populations of the Homerus Swallowtail and require urgent surveys to determine continuing presence of larval food plants, numbers of adults, and any deleterious effects of genetic isolation in these micro-populations. Design concepts are already postulated for the creation of wildlife corridors to rejoin these fragments to the main body of the Cockpit Country forest, but substantial and sustained sources of local and international funding will be required for detailed studies to fill the gaps in our knowledge of the life cycle and dependencies of the Homerus Swallowtail so that all conservation issues may be properly evaluated. Working solutions need to be developed in conjunction with all parties concerned.

Temperatures in the Cockpit Country may also be a limiting factor affecting the life cycle of *P. homerus*, falling to 20°C at night between December and March. During this period very few adults are seen, coinciding with low numbers of adults observed in the Eastern Subpopulation when experiencing similarly low temperatures.

Unanswered questions

The life history of the Homerus Swallowtail, from egg to adult, takes approximately eighty days and pupal diapause has never been documented in this species (Turner 1991; Garraway *et al.* 2008). So, one unanswered question, which applies to both subpopulations, is how does the Homerus Swallowtail survive during this low temperature period, spanning a window that would encompass two generations in warmer temperatures? While it appears that the Eastern Subpopulation survives the cooler months of the year at lower elevations in the upper reaches of the Rio Grande River valley and Plantain Garden river systems, there is no comparative information for the Western Subpopulation. How and where the insect survives the cooler and much dryer months in the Cockpit Country, with significantly lower humidity, is a critical factor for conservation planning. The removal of any forest from areas that this insect occupies during these months would undoubtedly be hugely detrimental to the survival of the species.

Progress

A welcome step in protecting populations of the Homerus Swallowtail was announced on 21 November 2017 in the Jamaican parliament by The Most Honourable Andrew Holness, Prime Minister, with the designation of the Cockpit Country Protected Area, which will be legally created following the ground-truthing of its proposed ~ 200 km boundary line. The Prime Minister stated to the house that "The goal of defining the boundary is to ensure forest conservation, protection of biodiversity, preservation and improvement of traditional livelihoods and the creation of new economic opportunities from heritage, health and wellness tourism and eco-tourism" and that "The Government is of the view that this area is too valuable in terms of its ecological and hydrological importance and uniqueness to allow mining which may result in permanent and irreversible harm and deprive future generations of the benefit of this national asset. While we will forgo the extraction of millions of tonnes of high-grade bauxite and limestone with potential earnings of billions of United States dollars, we cannot put a price tag on the loss to our water resources and biodiversity". Long-term advocacy efforts for a boundary to define Cockpit Country have been, and continue to be, supported by multiple local and international partners, notably including the International Association of Butterfly Exhibitors & Suppliers.

At this stage there remains much still to be determined, including whether, and to what extent, the habitat and known geographic range of the Homerus Swallowtail will gain fuller protection than current environmental legislation provides. Significantly, the proposed boundary within this legislation does not fully enclose the probable extent of recently identified micro-populations. Lenhert (2008) used mark and recapture techniques to estimate that there were no more than fifty adults of the Homerus Swallowtail in the Cockpit Country at the time of his study. However, as this work was undertaken within one of the forest fragments present, this number likely represents the size of that fragment's micro-population only, rather than the overall population of the Cockpit Country.

Conservational and cultural significance

In the IUCN Red Data List the Homerus Swallowtail is classified as "Endangered" (Turner 1983), though this status hasn't been revised since 1985. The Swallowtail and Birdwing Trust include the species in their top ten global priorities for conservation, with their concern for the species apparent through their funding efforts to protect it (e.g. with a key programme to compare the DNA of the Eastern and Western Subpopulations to determine if isolation is leading to inbreeding depression).

Seeing the giant yellow and black Homerus Swallowtail soaring above the forest canopy or flapping lazily along a sun-dappled forest path is an epic experience, though few are fortunate to have witnessed this. Watching males circling each other in territorial disputes, their wings audibly brushing, is unforgettable. The Homerus Swallowtail is also Jamaica's national butterfly and is regularly featured in tourism promotions for Jamaica. It has appeared several times on Jamaican postage stamps, the last in 2017 in a joint philatelic issue with Mexico also featuring the fabulous Monarch butterfly. It is also present on the Jamaican $1,000 bank note.

Closing remarks

This magnificent butterfly is a flagship species, deeply engrained not only in the national psyche, but recognised internationally. Preservation of the primary closed broadleaf forest habitats where this insect flies will not only protect the Homerus Swallowtail, but also numerous endemic plants and animals present in the same forest. Achieving this objective will require funding for ongoing research as well the continued involvement of already willing local authorities.

Acknowledgements

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The dark giant horsefly *Tabanus sudeticus*.

Midges vs horse flies and other Highland bloodsuckers

Dr Jamie Robinson

The Scottish Highlands are always associated with biting midges. However, they are not the only nuisance flies, or even the only group of annoying invertebrates, present; there exists a healthy population of other bloodsuckers, including horse flies, other tabanids, ticks, mosquitoes and keds. This article gives a whistle-stop tour of the species that you can expect to encounter in the region when enjoying a hike on the hillside.

Midges

Biting midges, *Culicoides impunctatus*, are said to cause a significant effect on tourism in the Highlands, as they can be unbearable. Recent warm summers have seen lower midge years, but this is only a relative comparison. A moth trap can still reveal a small teacup's worth of dead midges in the morning, even when populations are not high. Furthermore, other bloodsuckers seem to compensate with increased populations in years when midge numbers are low, though it's possible that other species simply appear more 'apparent' at these times.

There are now sophisticated traps that can help reduce midge numbers. There are also some good repellents on the market, though these do not seem to deter C. *impunctatus*. Even physically protecting one's extremities (arms and face) from their ravages has little effect – they simply resort to attacking the most vulnerable remaining feeding site – the eyes! A biting midge crawling into your eye is enough to deter the most determined hiker when a swarm appears. Sophisticated midge warnings are now issued, though these can be compromised by local conditions; a sudden drop in the breeze or a rise in humidity are enough to bring out biting midges in numbers.

Head flies

When weather conditions are less 'midge-friendly', the sheep head fly, *Hydrotaea irritans*[1], often takes over

A scanning electron micrograph of the prestomal teeth on the labium of *H. irritans* capable of scarifying already damaged tissue.

where the midges leave off, tolerating higher wind speeds. Head flies can be equally irritating to tourists when they form dense swarms, and their habit of congregating above the head induces an understandable fear of being bitten. Although not strictly capable of biting, this species is one of the few Muscidae that possess prestomal teeth on the labium, which can cause abrasions to skin and extract fluids from wounds, eyes and other sources of bodily fluids.

Horse flies

Horse flies dominate the low midge years, and there are two main culprits. One horse fly that is very noticeable is the dark giant horse fly, *Tabanus sudeticus*, said to be the largest and heaviest dipteran in Europe (being some 25mm long with a wingspan of up to 50mm). It has a very distinctive buzz when flying and hence is very noticeable. The males frequently appear on windows, although the female is not seen that often. It is quite common to be hit by flying adults although, speaking to stalkers and graziers, it thankfully does not seem to have a preference for human blood. Even so, there are records of this species attacking humans, so they are best avoided where possible.

A male banded horse fly *Tabanus bromius*.

Recent research by Caro *et al.*[2] has shown that zebra stripes can deter or interrupt attacks on zebras and horses by *Haematopota pluvialis* and *Tabanus bromius*. It is possible that *T. sudeticus* makes similar mistakes in attacking humans; the angular outline of a human does not fit the more rotund outline of deer or cattle suggesting that these 'hits' are made in error. Manitoba traps[3], on the other hand, which use a large black sphere, are extremely attractive to tabanids.

Cattle and deer show great alarm when horse flies are on the wing, the former often fleeing marshy wooded areas, "gadding" with their tails in the air. Colyer & Hammond[4] attributed this behaviour to the cattle warble flies, *Hypoderma bovis* and *H. lineata*, but these are now thought to be eradicated in the UK. Both roe and red deer are similarly affected in the presence of *T. sudeticus*, and show unusual behaviours to escape attacks, including breaking cover and fleeing in daylight.

The smaller banded horse fly, *T. bromius*, does not seem to cause such panic in cattle and deer, and so far has never attacked the author in Scotland! *Haematopota pluvialis*, on the other hand, can occur in large numbers, is silent when attacking, and can inflict a nasty bite, even through clothing! It can occur in such numbers that it is impossible to remain near lakes, rivers and marshes where *H. pluvialis* are active. It is not unique to the Highlands and I can recall retreating from rivers in Normandy when attacked by them.

Deer flies

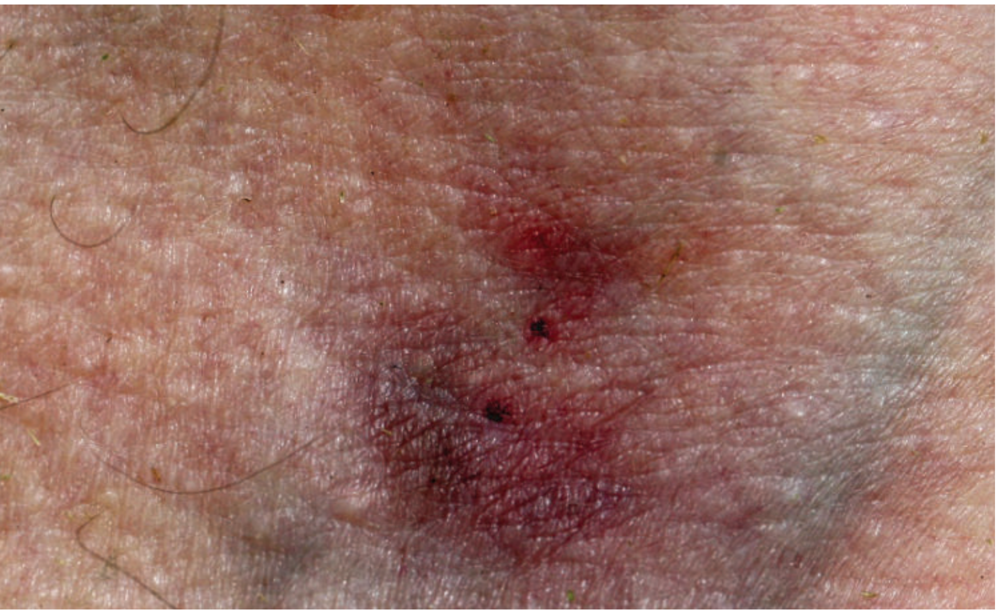
The Deer (or Thunder) fly, *Chrysops relictus*, is mostly found close to water. They have a distinctive wing beat and usually attack from behind, having followed a CO_2 trail, often targeting the head and neck as the preferred feeding spots. Like most tabanids the males are usually seen feeding on flowers.

Ticks

Ticks are prevalent in the Scottish Highlands, posing a significant risk of disease transmission. The castor bean tick, *Ixodes ricinus*, is widespread, particularly where there are deer. Bites can be frequent, as the author's own personal experience attests. Using a hand to rise from the heather once resulted in six ticks on one hand! The risk of Lyme's disease from tick bites can be high and necessitates frequent

Ixodes ricinus before (top) and after (bottom) feeding.

searches for ticks; I now use a permanent marker to show bite sites so that I can look out for the halo 'erythema migrans' that forms around a bite if Lyme's disease develops.



Near miss! Three bites by *Haematotopa* on an arm close to a vein, showing local haematoma which can cause severe reactions and can become subject to secondary infection.

Chrysops relictus, a sneaky biter.

The deer ked, *Lipotena cervi*, can be annoying if it gets into clothing.

Keds and warble flies

The end of the year sees one of the last of the active blood feeders in the Highlands make an appearance. The deer ked, *Lipoptena cervi*, has a nasty habit of dropping from trees and crawling, crab-like, inside clothing. Luckily, humans do not have enough hair to suit the habitat that the deer ked seeks and they depart without shedding their wings and settling down to feed. Deer are not so fortunate, and they can suffer heavy infestations. Keds are often seen in large numbers on the floor of game larders, having dropped from a deer carcass. Though less common, and again not a threat to humans, deer still also suffer the ravages of the deer warble fly, *Hypoderma diana*, which are often found in culled deer, both red and roe.

And finally…

Even having avoided the midges, horse flies, ticks, and other biting flies when out and about in the Highlands, at certain times of year you're not even safe in your hotel room. Mosquitoes also appear here in the autumn and *Culiseta annulata* can be a nasty bedroom surprise as they seek hibernation spaces after enjoying one last meal.

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What has happened to our pollinators?

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In a recent article in *Antenna*, Reynolds (2019) raises some important points about attributing cause and effect to the very obvious changes we see in our invertebrate populations. In so doing, he raises one possible cause: agricultural change, and especially the introduction of several generations of pesticides and herbicides. We wonder, however, if there are not several 'culprits' and one of the most serious is being overlooked?

Data availability

Before investigating 'culprits', the issue of data availability needs to be addressed. Unfortunately, there are very few long-term datasets collected in a rigorous and structured manner. Those assembled by the Rothamsted Insect Surveys (Woiwod, 1996) are likely to be the only data covering a sufficiently long timescale to record some of the critical changes in the agricultural and wider landscape. Pollinator data, by comparison, are nowhere near as robust. They mainly cover the past 40 years but, even so, on a yearly basis the volume is comparatively small and regional coverage varies from year-to-year/decade-to-decade.

The granularity of the data also depends upon the contributors because there are huge differences between the enthusiast who regularly records the 50 species that can be identified reliably from a picture and, in the case of hoverflies and bees, the 200 plus species of each that may require much more rigorous techniques (involving, for example, microscopy and often inspection of the genitalia). This granularity has a significant bearing on the data, although occupancy models go some way to addressing the problem (they are not fool proof though).

The sources of data are equally important when considering cause and effect. Most of the 'long-term' data come from what we term 'non-vocational specialists' i.e. many record invertebrates as a hobby but are often amongst the country's leading field taxonomists. They generally don't concentrate on agricultural areas and have not been sampling specifically to investigate changes in the arable environment; why spend your weekend in some dreary agricultural desert? As specialists we much prefer to go to nice places in order to see interesting insects!

Unlike most specialists, we do visit under-recorded areas in order to ensure better coverage by the schemes that we run (the Hoverfly Recording Scheme; Bees Wasps and Ants Recording Society). We can report that many areas are a desert as far as lots of invertebrates are concerned, especially hoverflies and solitary bees. The most productive places to record from are often overgrown churchyards or roadside verges; and they are pretty impoverished! The same applies to the arable prairies of The Wash as it does to the sheep-walks of Radnorshire or the southern uplands of Scotland – it is a struggle to find anywhere to record and when one does the lists are short.

So, even anecdotally we can be pretty sure that the areas that appear to be under-recorded are in fact desperately species-poor. A similar situation exists on the west coast of Scotland, where there is plenty of habitat, but it is very uniform, acidic and lacking in many of the species of hoverfly (e.g. the Syrphini) one might expect to see in richer areas.

Historic change and its relevance

The findings of studies such as Powney *et al.* (2019) can only address a part of the process of landscape change and cannot reflect the massive changes that took place between the 1950s and 1980s; the data are just not there. The most recent revolution in agriculture started with land drainage and conversion of pasture to arable systems in the 1950s. It was followed by widespread application of artificial fertilisers that eliminated the majority of our wildflower meadows. The growing problem of pesticides and herbicides in the 1960s was highlighted by Rachel Carson's *Silent Spring* in 1962. One might have thought that there would have been no invertebrates left after this period alone! At the time there were no recording schemes and no way of encouraging or compiling opportunistic data.

Yet, I (RM) still remember moth snowstorms in the 1980s and used to run a moth trap in urban London that was often heaving with catch – a count of 50-100 Garden Tiger Moths *Arctia caja* was not unusual, and several hundreds or even approaching thousands of Heart & Dart *Agrotis exclamationis*, or Large Yellow Underwing *Noctua pronuba*, was another regular spectacle. Equally, as I (RM) developed an interest in Diptera, any roadside verge with a few hogweed in flower lifted one's spirits – there would be flies to record – the 'hogweed fauna'.

Today, I (RM) cannot bear to run a moth trap because there is so little the following morning. What would such a catch have been in the 1950s? Why has there been such a dramatic change in an area that is completely buffered from agriculture by many kilometres of urban sprawl? We might put it down to greater urbanisation, but in the case of the moth trap it is on the edge of Mitcham Common, which is part of a much larger expanse of green (and wild) space extending several kilometres in three directions. Equally, why is it that Diptera numbers attending hogweed and other umbellifers have crashed? In only the last few days (mid-July, 2019) there have been video posts of large stands of hogweed with nothing in attendance apart from the ubiquitous *Rhagonycha fulva* (Hogweed Bonking Beetle). Observers from across the country are reporting much the same.

Are we reaping the whirlwind of agricultural intensification of the 1950s to 1980s? That seems unlikely. It is of course possible that modern pesticides and monoculture agriculture have had their impact in some parts of the UK, but we wonder if there is not a disconnect there too? The BWARS data are like the HRS data with the vast majority from 'nice places', south of a line between the Humber and the Mersey. In other words, not from the arable prairies of East Yorkshire, Lincolnshire and Norfolk, but from the nature reserves of southern and eastern England; many of which are a long way from high intensity agriculture. So, the trends we are seeing are within data that are not specifically from arable areas and as such we must take care not to place the blame solely on agriculture. To us, it seems that there are two separate debates and issues:

- The paucity of species and diversity in high intensity arable areas, and the effects this may be having on agricultural productivity. These areas are undoubtedly species-poor and it is possible to link agriculture to the problem. They are the expression of the agricultural revolution: desertified monocultures with few living animals. However, the data for these areas are comparatively weak and therefore it may be difficult to extract reliable trends for them using occupancy models.
- A frightening decline in invertebrate abundance and diversity in areas that are often far-removed from the effects of agriculture, many of which have been actively conserved for their biological diversity and scientific interest. For these, the data are more robust and are likely to figure strongly in occupancy models.

The problem starts with the focus on 'pollinators'. There have been times when one might read 'honey bees' rather than 'pollinators' or solitary/social wild bees rather than the broad suite of invertebrates that act as pollinators: many beetles, flies and moths are very important in their own right in this respect, although this requires a much more rigid definition of 'pollinator for what?'. In reality, we are witnessing the wholesale decline of invertebrates across a wide range of taxa, but with the concept of 'pollinators' providing a politically-expedient focal point.

Why are species expanding their range?

At this juncture, we might usefully pause and reflect: some invertebrates are declining, but others are expanding their range (some quite dramatically). Others still are becoming vastly more abundant but are not shifting their range that dramatically. Is there a disconnect between the two trends or are they linked? For this, we need to look at the biology of the animals concerned. In the case of hoverfly and aculeate Hymenoptera range expansions, the species on the move are primarily those with a southern and eastern distribution that are at the edge of their thermal range.

A classic example is the syrphid *Volucella zonaria*, a large hornet mimic whose arrival and spread are discussed by Morris & Ball (2004). There can be little doubt that this is a species that became established because of urban heat island effects and spread once the wider landscape achieved similar thermal conditions. Since that paper, it has spread further and was recorded in Glasgow in 2018 (Morris & Ball in prep.). A comparable example amongst the Hymenoptera is the European beewolf *Philanthus triangulum*. It is sobering to reflect that in the early 1990s this species was listed as Red Data Book 1 in Falk (1991) and was confined to a small part of the Isle of Wight. Recently, I (RM) observed a colony in excess of 500 burrows on Mitcham Common (south London) – a honeybee massacre was under way!

If, on the one hand, the climate has changed to such a degree that it has allowed a species (*Volucella zonaria*) that barely hung onto the south coast of England in the 1940s to rush across the country, could it not be that those same changes are having a profound effect on species that prefer what were once cooler and wetter climates? A little while ago, I (RM) realised that I had not seen the relatively ubiquitous hoverfly *Leucozona lucorum* on Mitcham Common since 2002! There are several records for the 1980s, a couple from the 1990s and that last one in 2002! It is an easily identified and unmissable species, as is the froghopper *Cercopis vulnerata* that was certainly present in 1984 in various locations (Hollier, 1984); it too has seemingly disappeared. In both cases, the habitat has not changed sufficiently to consider it the driving factor behind the disappearances. What frustrates me now is that I did not record more assiduously from my own 'patch'!

What are the differences between the expanding thermophilic species and the seemingly disappearing species? In the case of *L. lucorum*, its larvae are predators of aphids on a range of herbaceous plants. Such exposed larvae are not well-adapted to extreme temperatures (Rotheray and Gilbert, 2011) and adults are more frequently encountered in northern and western areas. There is growing evidence that another member of this genus (*L. glaucia*) has substantially disappeared from south-east England (Ball & Morris in prep.), so it is not unreasonable to suspect that a similar, if slower, decline is occurring with *L. lucorum*. There will be others.

Finding examples of declining species in the aculeates where this larval desiccation factor is a prime candidate for dwindling populations is not easy; the aculeates have largely by-passed such problems by the development of closed cells within nests. Nevertheless, there are candidate species for such northward range contraction, e.g.

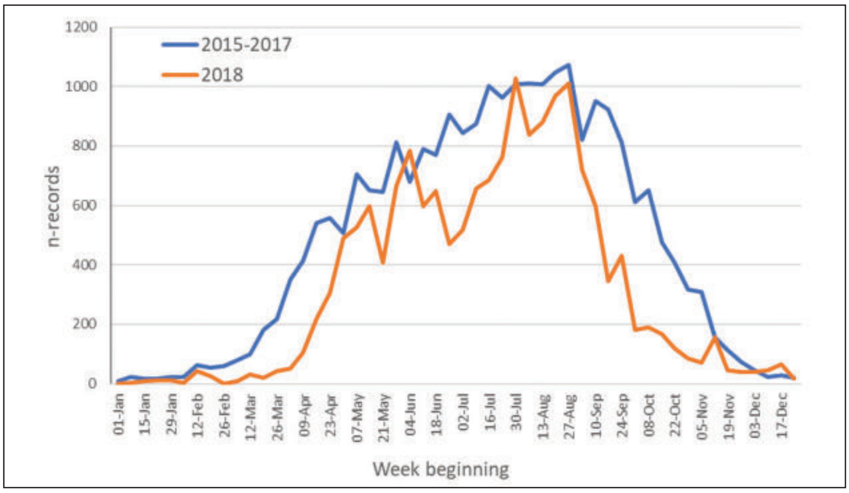


Figure 1. Numbers of hoverfly records extracted directly from Facebook and other social media in 2018 and compared against the average for the preceding three years (2015 to 2017). The impact of the heatwave is particularly clearly depicted, between week commencing 11 June and week commencing 2 July (but commenced around the 28 May).

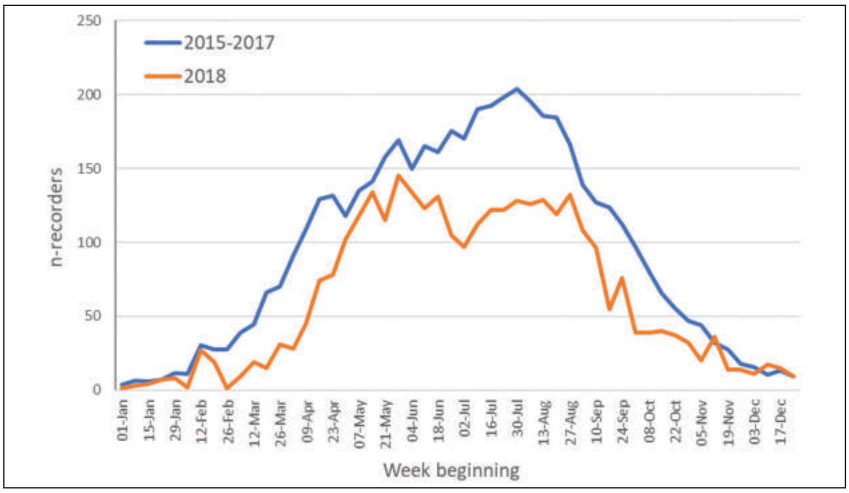


Figure 2. Numbers of contributors to the dataset used to construct Figure 1. The impact of the heatwave is more prolonged for contributors than in the hoverflies themselves (Figure 1). The disparity between the two graphs is largely because there is a small cohort of extremely active recorders and a much longer tail of intermittent recorders: the latter seem to have been particularly affected.

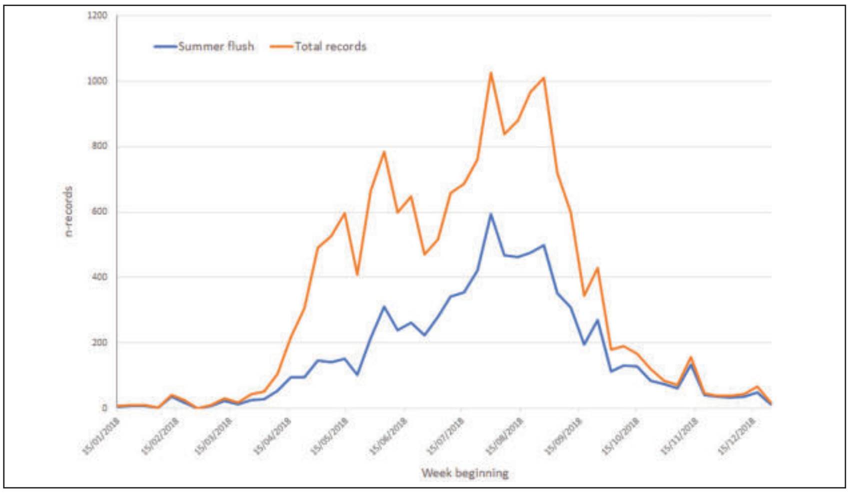


Figure 3. Contribution to the total dataset for 2018 made by 'summer flush' species comprising *Episyrphus balteatus* and the genera *Eristalinus*, *Eristalis*, *Eupeodes*, *Helophilus* and *Scaeva* (*pyrastri*). It is noteworthy that whilst the wider pool of species demonstrated a significant dip in numbers during the extreme heat event, these species showed a far less severe response (if any, because there is usually an early peak of *Episyrphus balteatus*).

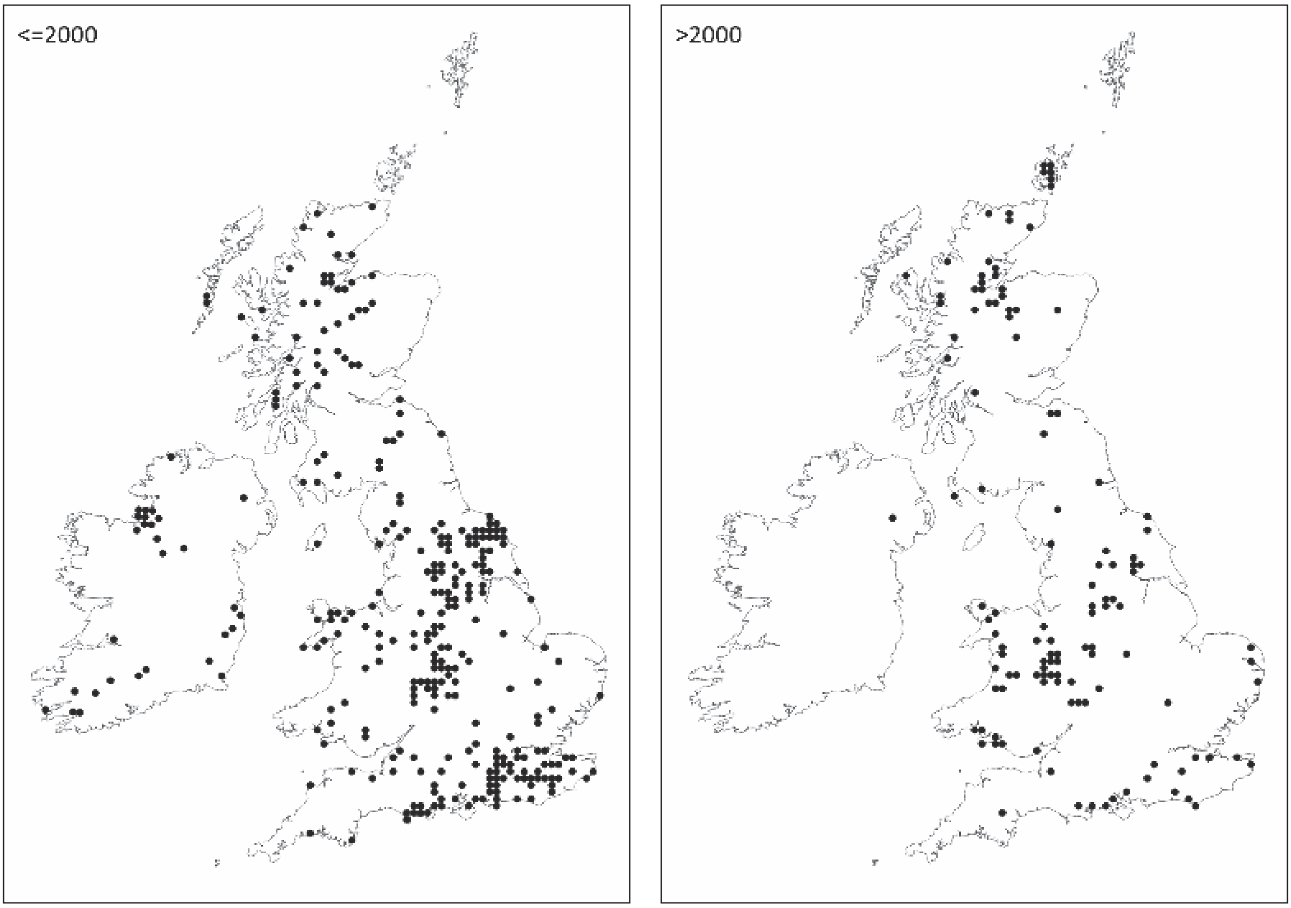


Figure 4. Distribution of the social wasp *Dolichovespula norwegica* before (left) and after (right) 2000.

Figure 5. Distribution of the social wasp *Dolichovespula germanica* before (left) and after (right) 2000.

Dolichovespula norwegica (Figure 4); a current project is looking at several species of social wasp (Vespinae) for just this reason. Interestingly, within this group there are both species apparently exhibiting a northward decline and species apparently exhibiting a northward expansion (*Vespula germanica*) (Figure 5).

The potential for sociality within the aculeates brings another factor into play when interpreting range changes. Several *Lasioglossum* species have a short social phase, with annual social nests. Some of these species, e.g. *Lasioglossum calceatum*, are facultatively social (Else and Edwards, 2017), others are obligate, e.g *Lasioglosum pauxillum*, one of the species noted in Stuart Reynold's article. This need to complete a nesting cycle with a worker generation limits the bee to situations where the growing period is long enough. There have been dramatic increases in the length of the growing period, and these have allowed *L. pauxillum* to complete its nest cycle in an apparently ever-increasing area of England. It helps greatly that this species is extremely catholic in its requirements for pollen, surviving in numbers in even the most apparently desolate arable areas. Being social with a long flight period this cannot simply be explained by the prevalence of oil-seed rape. Many of the declining bees are associated with plants which themselves are declining. Such plant declines unsurprisingly result from agricultural intensification (and abandonment), although they have nothing to do with poisoning by pesticides.

Other species, such as *Andrena cineraria*, also mentioned by Stuart, and *Andrena flavipes*, appear to have natural cycles of expansion and contraction. The reasons for these are not at all clear; the quality of data for both the insects themselves, and the potential factors affecting them, may not be present, let alone the mechanics for investigating any such links.

Developing evidence

Detecting incremental change is often very difficult without a high intensity monitoring programme. Range expansion is relatively easy, even using opportunistic data, but range contraction and population decline are far harder to detect without structured data collection. There are no such data for most invertebrates. We are therefore largely dependent upon anecdotal evidence, opportunistic data and the development of a conceptual model to explain a possible alternative reason for the declines in insects that have been reported in numerous studies.

In 2018 we saw what appeared to be a direct correlation between an extreme heat event and insect numbers. As the temperatures across Britain rose in late May and June, the numbers of records entering the HRS dataset declined dramatically (Figure 1). Why might this have been?

A first conclusion might be that the insects were sheltering from the heat and were therefore invisible to recorders. Consequently, the numbers of records would have diminished. There can be little doubt that this was part of the process – astute observers reported hoverflies landing and promptly disappearing under a leaf. However, as time progressed, it was apparent that even when conditions were favourable for recording, there were simply no flies to report. With such a situation, observers tend to lose enthusiasm too, and it is clear that the numbers of recorders also dropped off (Figure 2).

Once the heatwave abated, the numbers of active observers and hoverflies reported both rose again. However, by that time the composition of the assemblage had changed and the rise coincided with a period when numbers generally peak: around the time when the Eristalines (*Eristalinus*, *Eristalis* and *Helophilus*) are emerging and some partially migratory species (*Episyrphus balteatus*, *Eupeodes* sp. and *Scaeva pyrastri*) have a major impact on the numbers of records (Figure 3). So, we must treat the numerical element of the data with some caution and need to think carefully about the response of individual species and why it may have happened.

A useful example concerns the hoverfly *Rhingia campestris*. It is a widespread and often abundant species that is difficult to confuse with anything else other than *Rhingia rostrata*, which has undergone considerable range expansion in recent years (Morris & Ball in prep). Both species can be identified from photographs and are therefore useful study subjects because data can be assembled from a large community of observers.

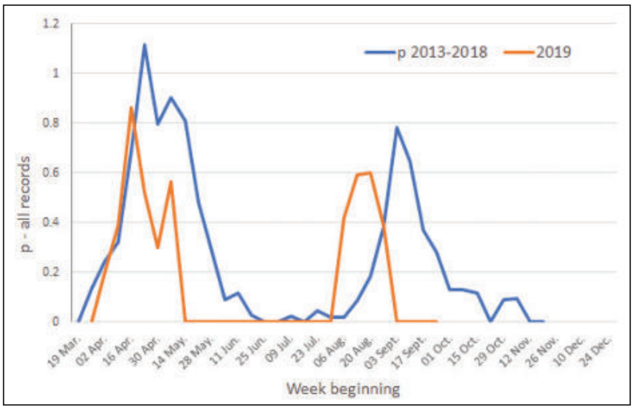
A link between *Rhingia campestris* and heatwaves goes back as far as 1948, when a crash in abundance was first reported (see Morris, 2019). In 2018, it became clear: the second generation of *R. campestris* was unusually small. This reduction in abundance seems to have continued into 2019, with data up to October 2019 suggesting that *R. campestris* had been observed in far lower numbers than expected from the previous 6-years of comparable data (extracted from social media) (Figure 6). However, the trend is bucked in Scotland, where numbers seem to have risen!

Rhingia campestris is a single example of a species that has demonstrated a strong response in 2019 that can arguably be linked to the 2018 heatwave. The data are at present incomplete and it is always possible that the argument will be confounded by new data. This risk seems unlikely, however, as our own observations tend to agree with the data. Furthermore, a single example of a clear negative signal does not mean that this is the entire explanation for the dramatic declines that we have seen. Nevertheless, it does provide a pointer for monitoring and wider investigation.

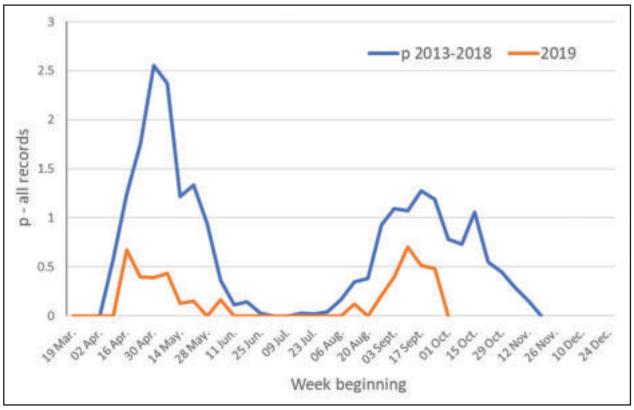
But why would unusually hot conditions cause such a response in *R. campestris*? Female *Rhingia* lay their eggs on blades of grass overhanging fresh cow pats (and probably other wet dung). The larvae, when they hatch, drop into the cow pat and proceed to burrow in. In very hot weather, the cow pat develops a hardened crust before the larva can make its entry: when it tries to burrow it fails, and consequently the next generation is interrupted. Similar arguments can be constructed for species that inhabit moist soil or small water bodies – if they are not there, the larvae cannot develop. At least some of the overall insect decline can probably be linked to temporary interruption of wet habitats. The more challenging problem is to understand the humidity gradients favoured by other animals; there is clearly plenty of research potential!

An alternative hypothesis to intensive agriculture

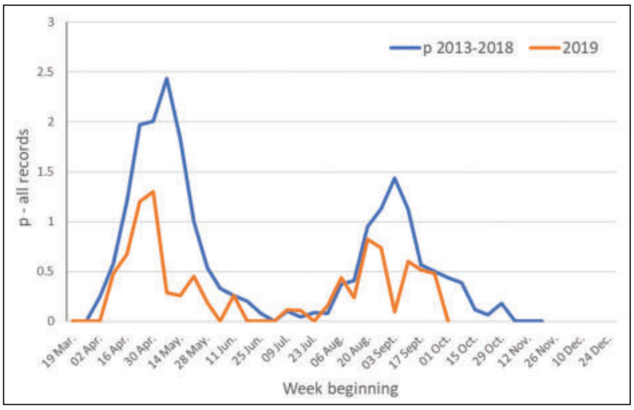
It seems to us that climate change is a far more compelling factor in the changing fortunes of invertebrates and especially 'pollinators'. Each time there is an extreme event there will be positive and negative responses, with thermophilic species benefitting and less heat-tolerant species declining. If



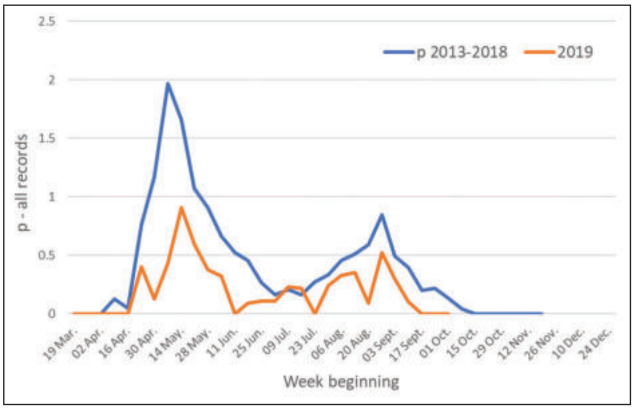
6a. South-east England.



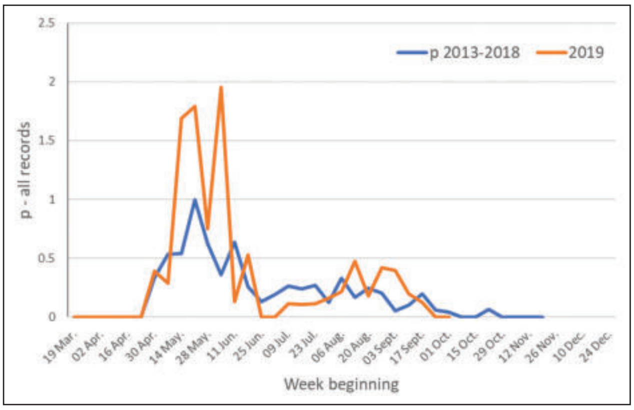
6b. South-west England.



6c. Wales and the Midlands.



6d. Northern England.



6e. Scotland.

Figure 6(a-e). 'Regional' *Rhingia campestris* records presented as the proportion of all records extracted from social media (primarily Facebook) in 2019 compared against the average for the period 2013 to 2018. The numbers recorded are substantially lower than the 6-year average, with the exception is Scotland, where the effects of the heatwave were probably not as pronounced and may have been positive for this species.

such events happen sufficiently frequently, they will gradually reduce the numbers of survivors on each occasion: in other words, 'death by a thousand cuts'. Species that are dependent upon wet habitats and humidity are most likely to suffer as a result of heat stress and drought. And, bearing in mind that the British Isles are an 'Atlantic' biozone, a predominantly warm and wet climate is being replaced by one that is hot and intermittently arid – suiting the aculeates far more.

Thus, as climate change has become more obvious, we have seen the intensity and frequency of extremely hot years rising. Met Office data show that the ten hottest years ever recorded have occurred since 2000, but the trend for hotter summers was already apparent in the 1990s. It was this trend that seems to have triggered dramatic range expansion in species such as *Volucella zonaria* and *Philanthus triangulum*. Such a trend means that extreme events, even if short, may have a disproportionate effect on insects. In addition, whilst adult insects are the most visible stage, juvenile stages make up far more of the life cycle and may be substantially more vulnerable to desiccation. So, we should take note that if anecdotal observations in 1948 made a connection between heat/drought and the absence of *Rhingia campestris*, the likelihood of such effects is substantially greater under today's variable climate.

But prove it…

Current opportunistic observation provides some indications of the impact of climate change on invertebrate abundance and diversity. It is unlikely, however, that cause and effect will be completely resolved using such data alone. If it is considered to be of importance, then there is a growing case for developing a new range of research programmes focussed on the impact of climate change on juvenile stages. Some obvious questions are:

- Can we identify a range of taxa that are indicative of thermal stress and drought effects?
- What are the thermal stress tolerances of species showing signs of impact from drought?
- Which stage(s) in the animal's life history are most vulnerable to extreme heat or prolonged drought?
- Can we define guilds that will be most seriously affected by climate change?

If we can identify climate-sensitive guilds, can we start to predict what these effects will do to other ecological processes? For example, the Nematocera make up a substantial part of the food taken by a wide range of migratory waders during the breeding season. Heat stress may have serious consequences for this biomass and hence for bird breeding success. Perhaps some of the declines in breeding waders in southern England are more closely linked to climate change than habitat loss? If so, what are the consequences of effects on northern populations and are these already being felt? And then comes the big issue of pollinators – are the factors affecting declines in the Hymenoptera the same as those affecting the Diptera?

There are more questions than answers! Frustratingly, investigation of the issues is dependent upon skills that have been substantially lost from academia and now sit almost entirely amongst non-vocational specialists. Consequently, there will be a need to devise research programmes that involve a partnership between academia and non-vocational specialists. But, beware, non-vocational specialists have their own interests and are not necessarily a never-ending source of free labour and technical skills! Perhaps there will be a new golden age of insect taxonomy and biology in academia driven by the need to understand how climate change is affecting the world's biota!

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Society News

HONORARY FELLOW INTERVIEW

Richard Harrington

by Peter Smithers

Richard Harrington was well known to me several years before we eventually met, but it was not his many peer-reviewed papers on the biology of aphids that had caught my eye. It was a short piece in the correspondence section of an early *Antenna* (vol. 18(2), back in 1994). In it he had calculated the number of offspring produced by a single aphid and its subsequent generations if all the offspring survived. If this ran for 18 generations, which would be one year, how many aphids would there be? The answer was a staggering 7.6 x 10^{28} but because this number was so large, it was almost impossible to make sense of it. So, in order to give it some meaning, Richard calculated the depth that this number of aphids would produce. This was the fact that hooked me. They would cover the entire surface of the planet. What?!!!! But wait, it gets worse. The layer of aphids would have a depth of 149 kilometres. At this time, I was developing a talk for primary schools on the role that insects play in the natural world. In the talk I was using lots of numbers that the children could try to guess, so this staggering fact went straight in. It is a talk I still wheel out today, as this story of aphid armageddon is an attention-grabbing illustration of the reproductive power of insects.

I was meeting Richard on his home turf at Rothamsted which, despite being one of the UK's entomological hubs, I had never visited before. Back in the 1970s, when I was a young moth trapper, the name 'Rothamsted' was synonymous with the Insect Survey. The network of light-traps had almost legendary status among moth trappers, so finally walking into its home was a little like treading hallowed ground. Richard collected me from Reception and took me to the 'Lewis Restaurant' for lunch. "Welcome to Trev's café", said Richard. Named after former Director, Head of Entomology and President of the Society, Trevor Lewis, the nickname for the restaurant is common parlance amongst the dwindling band of older entomological staff at Rothamsted, and is now immortalised in Richard's part-autobiographical collection of poems about British butterflies (see *Antenna* 42(4) for a review). The inner man fueled, we adjourned to Richard's office to discuss his life in entomology.

How did your interest in insects begin?

"Brooke Bond tea cards played an important role. For the sake of younger readers, back then tea was always loose leaf and came in boxes. In each box was a card with an image on one side and information on the other. Brooke Bond also issued free albums that these cards could be stuck into. When I was eight, the current set of cards was on British butterflies, and I was an enthusiastic collector of the cards. One August Wednesday, the tea arrived with the groceries as usual and a card with a Large White on it emerged from the packet. That afternoon, the family was walking to the Weymouth coast at Portland Harbour. We were armed with crab nets ready to harass the marine life in the local rock pools, when a butterfly fluttered past and, as any young boy with a net in his hand would, I swiped at it. To my surprise, I caught it. To my further surprise, it was the very butterfly that was on the tea card that had arrived that morning, a Large White. This was the spark that kindled my interest in insects.

"Having discovered butterflies, I would cycle into the Dorset countryside in search of them, sometimes ten miles out, ten miles back. It was a different world and I was free to roam. "Just be home in time for tea", Mum would call. I can still recall where I caught each species for the first time. My first Dark Green Fritillary was especially memorable; it was caught on the Osmington White Horse, which commemorates George III's connection with Weymouth. The King was apparently annoyed that he was depicted riding out of the resort rather than into it, and legend has it that the horse's sculptor was so upset that he committed suicide and is buried at the end of the tail. Later that summer, a letter appeared in the Daily Telegraph, remarking on a decrease in the abundance of the UK's butterflies, so I wrote a response listing all the butterflies I had found. To my delight the letter appeared, credited to Richard Harrington, aged 8. My first publication."

School

"At Chickerell Primary School I was encouraged to follow my interest in natural history and was often asked about any interesting butterflies or birds I had seen. Even here, I was always looking for wildlife and I remember there being abundant slow-worms at the top of the school playing field.

"One afternoon at the age of thirteen, the family was visiting friends of my parents. I was bored and looking around for something more interesting than the grown-up conversation. I found a copy of the Imperial College prospectus, as their eldest son was applying for university. I recall reading about their Entomology courses and all the impressive staff that taught there – most of them Fellows of the Royal Entomological Society. I decided there and then that this was where I wanted to go.

"At Weymouth Grammar School we studied the new Nuffield biology syllabus, which focused on projects, experiments and observation. I really enjoyed this and when it came to my A-level project I decided to use an idea I had discussed with a friend of my dad, Victor Philpot. He was a physicist at the Admiralty Underwater Weapons Establishment on Portland, where dad worked, and he was hugely knowledgeable on Lepidoptera. I first met him when dad arranged for him to be the tester for my Cub Scout Collector Badge, which was on butterflies of course. As a result, he took me under his wing and I often helped him empty his moth trap and record the catch. He grew tobacco plants in his front garden, which attracted Convolvulus hawk moths that had migrated across the Channel. On a late-summer's evening, he would shine a light on the plants and we would sit and wait for the moths. All would be still, then one of the flowers would move backwards and, on closer inspection, a moth could be seen hovering in the shadows, barely visible, pushing its long proboscis into the flower. Victor had a great interest in a theory proposed by Eric Laithwaite, Professor of Heavy Electrical Engineering at Imperial College (another reason that I wanted to go there), that moth antennae act as dielectric aerials. The distance between the antennal pectinations indicated that they might be able to detect far-infrared radiation. His theory was that females emit far-IR, which attracts males. He also postulated that the UV light emitted by a moth trap passes through water vapour molecules and is converted to far-IR by a process known as Raman scattering, hence the attraction of moths to light. Victor suggested that we test this theory as part of my A-level project. A device was built in which female Lackey moths were placed. The openings were such that in one setting only pheromones could escape whilst the other setting allowed pheromones and infrared radiation to be broadcast. There was great excitement: which setting would attract the most male Lackey moths? Unfortunately, very few Lackeys turned up, so we never did find out. However, the school entered my project (on the basis of its experimental design) for the Prince Philip Prize for school science and it won second prize. I was delighted, and received a very nice certificate plus a copy of Lehninger's *Biochemistry* (slightly less delighted) – and the school received some money, I believe."

University

"Inspired by my find at auntie Joy's, I applied to Imperial college and was called to an interview, which I thought went well. I was delighted when I was offered a place even if I obtained just two E grades at A-level. This was almost certainly on the basis of discussing my A-level project.

"At Imperial I really enjoyed my course in Zoology and Applied Entomology and was strongly influenced by the knowledge and enthusiasm of Dick Southwood, Val Brown and Gareth Davies. Val was my personal tutor and, when third year projects came around, she put me in touch with Vic Eastop and Roger Blackman at the Natural History Museum, London as potential project supervisors. The project they offered was on Black bean aphid, testing whether different host plants affected morphology. I can't remember the outcome, but I did enjoy the work.

"Shortly after graduation, a PhD project came up at the at NHM with Roger, for which I successfully applied. This was to work on sexual morph production in aphids, especially the effect of photoperiod in species that had not been examined before in this regard. I chose to work on aphids that feed on soft fruits and selected six species with a range of life-cycle strategies. Tony Lees was my Imperial College supervisor and Jim Hardie, who worked with him, was an enormous help. The PhD viva was conducted by aphid guru Tony Dixon."

Rothamsted

"Following a lead from Roger, I was fortunate to be offered a three-year job at Rothamsted, starting on the very day that my PhD funding ran out. The job was funded by the Potato Marketing Board and involved working with Roy Taylor and the Rothamsted Insect Survey on the life cycle of *Myzus persicae* and the aphid's role in transmission of potato viruses. As this came to an end, I applied for many posts, including one in Belo Horizonte, Brazil, with EMBRAPA (Brazilian Agricultural Research Corporation). This was to devise a seed potato certification scheme for them. I had also applied for a job at Rothamsted and, when the job in Brazil was offered to me, I waited to hear how the Rothamsted interview had gone. The Rothamsted job also came through. It was a permanent role, while the Brazilian job was a three-year contract, one reason that the Rothamsted job won. If I'm honest, I'm not a particularly adventurous type, and preferred home territory.

"The Rothamsted Insect Survey post led to many collaborations, including with Jeff Bale (University of Leeds, then Birmingham) on cold hardiness in aphids. Jeff had found, through lab experiments, that aphids don't freeze until the temperature drops to around -30°C, so they should survive UK winters. On the other hand, my field observations following individuals on host plants through the winter revealed that they died at much higher temperatures. So Jeff conducted a further lab study and found that aphids died long before they reached their freezing point. Thus, the freezing point is biologically interesting but ecologically irrelevant. I think that this is a nice example of the importance of synergy between lab and field work. Indeed, it is also a good example of how observation can lead to testable hypotheses. Much of my work at Rothamsted was observational and correlative and, while some people don't like this approach, it has revealed patterns and relationships between, for example, weather and the abundance and diversity of insects, and has generated hypotheses that have been tested experimentally, giving new insights into factors influencing population dynamics."

You were with the Insect Survey for your whole career. How has it changed over the years?

"In some ways, hardly at all, and this is important. We keep the collection methods as stable as possible in order to standardise the samples. For example, when the tungsten light bulbs that are used in the moth traps became illegal, we had to obtain permission to order a fresh supply of bulbs from China to keep the data comparable. While the suction-traps are rarely moved to new locations, many of the light-traps have come and gone over the years. However, as we have always had large numbers of them and good geographical coverage, this has not adversely affected the capabilities of the data. Roy Taylor (whom many regard as the "father of spatial ecology") started the Insect Survey after obtaining funding in the wake of Rachel Carson's '*Silent Spring*'. The suction-traps were designed to monitor fluctuations in the numbers of aphids. If these changes could be linked to environmental factors, it would be possible to predict population increases by monitoring those factors. Advice could then be given to farmers and advisers on whether or not there was a need to spray against aphids, which should lead to reduced volumes of pesticides being applied.

"Over the years, the data have been used for a wide range of purposes, such as monitoring the spread of insecticide resistance and assessing the proportion of aphids that carry viruses. Once climate change was recognised as an important issue, our long-running data set was in even higher demand. There were European projects such as EXAMINE (Exploitation of Aphid Monitoring in Europe). This linked the UK with suction-trap networks in other European countries, to build a European database on aphids to link to land use, climate and pollutants, as possible explanatory variables in aphid population dynamics. The EXAMINE network was like a family; we always enjoyed our meetings and collaborations. Even after the project had finished, the networkers stayed in touch to exchange ideas, techniques, data and specimens. Another exciting collaboration was RUBICODE. I had read a paper by an Australian, Gary Luck, who had defined populations in terms of the ecosystem services that they provide. A 'service providing unit' was the population of organisms that provided a spatially- and temporally-defined service, and the idea was to look at the impacts of environmental changes on these 'SPUs'. I put in a bid for EU funding to explore this concept, but there was another similar project also applying for funding. The EU suggested combining the two. We did and this became RUBICODE. Luckily, I escaped the task of overall coordinator, this being done with excellence by Paula Harrison (then University of Oxford, now CEH Lancaster).

"We have worked with The Pirbright Institute to look at *Culicoides* midges as vectors of Blue Tongue disease. We supplied them with past samples of *Culicoides* from the suction-traps and found that the flight period of these flies went further into the winter months than they had previously thought. This had implications for the safe period in which livestock could be moved around the country.

"Now led by James Bell (I retired in 2015 on my sixtieth birthday – always my plan), the Insect Survey is exploring the possibility of automating insect counting and identification using robotics and micro DNA sequencers."

For a full account of the Insect Survey see Richard's article in *Antenna* 38(3), written to celebrate the group's fiftieth anniversary.

How did you become involved with the RES?

"While I was an undergraduate, Val Brown suggested I should join the RES. Shortly after joining Rothamsted, Trevor Lewis proposed me to sit on Council and I have been involved ever since. I have always encouraged younger people to get involved as I firmly believe that the more you put in to any organisation, the more you get out. We have some amazing student members. At the end of a recent Genomics SIG, two students asked me if they could organise the next meeting. They did, and it was fantastic. If Mendelssohn can compose the overture to *A Midsummer Night's Dream* at 17, students can certainly organise a SIG meeting and contribute in other career-enhancing ways to the RES.

"After my first term on Council, I joined Fellowship Committee under Van's chairmanship, and later chaired it myself. It introduced many new ideas such as the SIGs, regional meetings, the annual 'Ento' meetings and the glossy A4 *Antenna*. I stayed on this (which became the Membership Committee) for a quarter of a century, before the bye-laws on committee membership finally caught up with me, at which point I switched to the Meetings Committee and sat on the other side of the Council room table in an attempt to avoid confusing myself as to which meeting I was at.

"At a Verrall Supper, I was asked to take on the role of coordinating the SIGs. I must have had one or two beers, as I said "yes" immediately. In 2017 Lin Field twisted my arm to take on the editing of *Antenna*. I thought harder about this but realised that these two roles go well together. Writing up reports of the SIGs for *Antenna* keeps me informed in my retirement of the progress being made in a wide range of entomological fields, and keeps me in touch with many of the wonderful people I have been involved with throughout my career."

Have you always written poetry?

"This also started in my youth. I often wrote poems for family and Scouting occasions, and for the school magazine. When I retired, it occurred to me to combine two of my youthful pursuits and celebrate each British butterfly in verse.

"On most Wednesdays, I walk 16 miles through the National Trust's magnificent Ashridge Estate while my wife plays bridge. Ashridge is home to 34 of our 58 butterfly species and provides a perfect environment for poetic inspiration. I always carry a pen and paper and would write down couplets as they came to me (all my poems rhyme and meter properly – I'm not into airy-fairy, arty-farty free verse, which some might call "proper poetry"). It took eight months to write them all. The last one was the Large Heath, the only British butterfly I have never seen. I puzzled over what to write and finally decided that the poem would be about the fact that I had never seen it. While I have been an author on hundreds of papers, I think I can say that I have gained most long-term satisfaction from this book and from working with Van and other aphidologists to produce the book *Aphids as Crop Pests*."

As we closed the interview Richard said: "Looking back over my career, I have been dead jammy", but luck can be seen as the coincidence of preparation and opportunity and Richard was certainly well prepared which, being a life-long Scout, you might expect – although anyone who can buy a piece of amber containing an aphid on eBay and then discover that the aphid is a species new to science must have a little luck on their side.

Richard has been part of the Rothamsted Insect Survey from his first postdoctoral position to retirement and beyond (he remains a Visiting Worker), which has to be a remarkable accomplishment. Over this period, he has contributed to, and then overseen, its evolution as a data set of international importance, with multidisciplinary applications, and has then handed it on to a worthy successor in the form of James Bell. "Keeping the Insect Survey funded has always been a bit of a tightrope. Balancing the need for fundamental science with the practical needs of the growers and farmers is sometimes tricky". But it is tightrope that Richard has successfully traversed, safely navigating the complexities of a constantly changing funding landscape.

Although Richard describes himself as conservative (with a small c), he has embraced a diverse array of approaches to bring the Insect Survey into the 21st century and has secured its future. He has indeed been the custodian of one of the UK's great entomological assets.

The "Miroir d'Eau" is a very clever concept that alternately emits a cloud of water vapour or fills to form a film of liquid that reflects the Royal Palace like a mirror.

The sixteenth meeting of the European Association of Forensic Entomology – Bordeaux, France

Dr Andrew J. Hart [1] FRES and Dr Hannah Moore [2] FRES

[1] Forensic Services, Metropolitan Police Service, London, UK

[2] Cranfield University, Defence Academy of the United Kingdom, Shrivenham, Wiltshire, UK

The sixteenth meeting of the European Association of Forensic Entomology (EAFE) took place in Bordeaux, France on 5th-7th June 2019. It was organised by Jean-Bernard Huchet of Bordeaux University, who went to great lengths to ensure that the conference was a success. The Royal Entomological Society (RES) kindly awarded conference funds to two scientists with research experience in forensic entomology which supported their attendance at the meeting and enabled them to contribute to the conference. Hannah Moore is a lecturer with casework experience based in the Forensic Institute at Cranfield University, who gave a presentation entitled "Cuticular hydrocarbons from empty puparial cases for identification of species and geographical location". Hannah examined the chemical profiles extracted from puparial cases of seven Calliphorid and one Sarcophagid species using Gas Chromatography – Mass Spectrometry. The aim of this study was to establish species identification, as well as geographical markers of the same species. This work was co-authored with Falko Drijfhour from Keele University, Jens Amendt from Frankfurt University and his students Lena Lutz and Vicky Bernhardt. This work will subsequently be submitted for publication in a peer-reviewed journal later this year. Andrew Hart, a Senior Forensic Scientist at the Metropolitan Police Service, was co-author on a presentation with Martin Hall (Natural History Museum, London) and Meghan Beutler (Queen Mary University of London) entitled "The use of wing fray and sex ratios to determine the origin of flies at an indoor crime scene", in which they detailed the creation of a template to quantify the wing fray damage of blowflies found at the scene of indoor murders. By combining this with the sex ratio, it will be possible to establish the origin of a population of adult flies found at the crime scene. This work will also be submitted for publication in a peer reviewed journal if the readers are interested in learning more.

The meeting was attended by academics, their students and practising

The glamorous venue for the conference dinner set in an old theatre at "K Baroque".

forensic entomologists from around the world. A wide range of topics was presented both orally and as posters, including information on the development of forensic entomology in Lebanon looking at how we are going to encourage the next generation of caseworkers from research. As would be expected from a conference in Bordeaux, the food and drink provided were excellent and helped encourage lively discussions and debate on forensic entomology. The meeting was followed by a visit to Saint-Émilion located in the wine region which was listed by UNESCO in 1999. We were able to wander through the medieval city and enter the stunning underground monolithic church, after which we tasted a few fine vintages in the subterranean rooms of the local wine producers.

EAFE conference attendees at Bordeaux University.

The meeting was an excellent opportunity for generating potential international collaborations and for keeping up-to-date on the latest research in forensic entomology on a global scale. The authors would not have been able to attend without the generous support of the RES, for which we are both grateful.

Benin project 2018 Investigations of insect-based farming in Benin: Black Soldier Fly (*Hermetia illucens*) farming for livestock feed in Tanguieta, north Benin

Laura Riggi, Marthe Seater Jacobsen, Mariangela Veronesi, Melissa Lennartz-Walker

As a charitable organisation, a key focus of Bugs for Life (BFL) is understanding and promoting sustainable ways to adopt and integrate insect-based nutrition into our food production system. This can be in the form of rearing insects directly for human consumption, or for livestock feed. BFL is particularly interested in exploring how entomophagy can contribute towards food security in developing countries, where the availability of high-quality nutrition is of increasing concern.

Since 2012, BFL has been collaborating with partners in Benin and the UK, the latter to help generate funding to support project development and research. Our case study area is the Tanguieta commune, in the Atakora region of northern Benin. BFL, thanks to the support of many funders including the Royal Entomological Society, has over the years completed research into how traditional forms of entomophagy can play a key role in providing nutritional support in the region.

Building on these results, in 2018 we developed, in collaboration with local partners, a project plan that aimed to build a prototype farm for black soldier flies (BSF), with the intension of recycling organic waste to produce chicken feed and organic fertiliser for small rural communities in a manner that would be easily adaptable and affordable for local people.

The pilot project consisted of three phases:

1. To design, build and test a prototype BSF in Cotonou, the capital of Benin, in collaboration with Dr Djouaka from the International Institute of Tropical Agriculture (IITA);
2. To train BFL staff to farm and present prototype methods to Kosso villagers; and
3. To recruit local volunteers to complete further workshops in Cotonou, for further farm development in the target regions.

Stage 1

BFL collaborators at IITA previously obtained BSF cultures from Tanguieta (northern Benin) and tested farming methods used in Nigeria. These methods included the use a large outdoor netting design, containing small cages of various sizes for each life-stage of BSF. During the testing, chickens were fed with the larvae for examination of nutritional improvement and fecundity (Figure 1). Our objective was to optimize the existing model of breeding to facilitate collection of pupae.

During the first week of the project in November 2018, we built the new BFL design, focused on simplifying the IITA set-up in order to reduce costs and

Figure 1. BSF farm at the IITA centre in Cotonou: (a) adult BSF cage; (b) chicken feed experiment; (c) large outdoor cage where the BSF farm is set up; (d) team working on BSF farming at the IITA sorting out larvae from substrate manually; and (e) BSF larvae in their substrate.

Figure 2. Building and setting up of the optimized BSF farm. The aim here was to improve collection from manual harvesting to self-harvesting of the BSF larvae: (a) bucket prototype farm workshop with the IITA team; (b) adult egg laying cage for BSF; (c) profile view of the bucket self-harvesting method; (d) front view of the bucket self-harvesting method; and (e) prototype number 2 as an alternative to the bucket method.

improve adaptability for use in different small-scale rural communities. The design encompasses a simple, modified BSF bucket set-up for the larval stage, along with a mesh cage for the breeding adults (Figure 2). Once the farms were constructed, BFL tested the set-up over a 4–day period. This ensured that the BFL pilot project would support a full development cycle. The design worked, and the test was completed (Figure 2).

Stage 2

As the test unit contained only a small BSF sample from Tanguieta, more were collected in the north. Several target areas in Tanguieta were visited to locate BSF, e.g., butchers, abattoirs and market waste areas (Figure 3). BSF typically occur around organic waste produce.

Stage 3

On visiting the neighbouring village of Kosso, the Waama ethnic group was interested in BSF farming. BFL held a workshop in Kosso, to highlight the practicalities of the method, in addition to discussing design and maintenance of units over the long-term (Figure 3). Such community workshops resulted in significant interest and enthusiasm for the method. After building and testing the prototype farm, the prototype was delivered to our main base in the north of Benin, in the Attakora region.

Figure 3. Collection of larvae and community workshop in Tanguieta: (a) Laura collecting BSF adults near rubbish heaps; (b) meeting with delegates Ouro and Yatto from Kosso to discuss feasibility of integrating BSF farming in the Kosso community; (c) community workshop with all the village in Kosso; (d) collection of adult flies in Tanguieta; and (e) BSF pupae collected near the abattoir in Tanguieta.

After the workshop in Kosso two volunteers were asked to join us for a further, more advanced workshop at IITA, Cotonou; the delegates from Kosso, Ouro (administrative chief) and Yatto (a teacher and translator from Kosso), joined the workshop (Figure 4). The workshop lasted three days, and proved very successful. It was agreed with BFL that the Waama community would take the prototype farms up to Kosso to test in Tanguieta. It was also agreed that Kosso would test the method over a six-month period.

Acknowledgements

Thanks to our main collaborator at IITA, Dr Rousseau Djouaka. Dr Djouaka also works on the Aquaponics-based Insect Network (ABiNet) project. For further details please visit: http://bulletin.iita.org/index.php/2018/06/09/iita-hosts-launch-abinet-proposal-insect-driven-aquaponics-system/

Further reading

Riggi, L., Veronesi, M., Verspoor, R., Macfarlane, C. and Tchibozo, S. (2013). Exploring edible insects in Northern Benin, available at; www.bugsforlife.com

Figure 4. Cotonou work shop. From left to right: Yatto (Kosso teacher), Melissa (BFL), Claude (IITA technician), Mariangela (BFL), Ouro (Kosso delegate).

SCHEDULE OF NEW FELLOWS AND MEMBERS

as at 2nd September 2019

New Honorary Fellows
None

New Fellows (1st Announcement)
Dr Lakshmi Kanta Hazarika
Professor Robert D. Reed
Dr Somnath Roy
Dr Katarina Maryann Mikac
Dr Mayur Kumar Kajla

Upgrade to Fellowship (1st Announcement)
None

New Fellows (2nd Announcement and Election)
None

Upgrade to Fellowship (2nd Announcement and Election)
None

New Members Admitted
Dr Ainoa Pravia (as at 5.6.19)
Mr Michael John Pannell
Miss C Breeze
Dr Isaac L. Mathew
Dr Deepak Singh
Mr Tibutius Thanesh Pramanayagam Jayadas
Dr M Blaxter
Mr Tharsan Annathurai
Mr Philip Martin Schendel
Dr Thomson Paris
Mr Simon Paul Williams
Dr James Carolan
Mr Vaikunthavasan Thiruchenthooran

New Student Members Admitted
Miss Vivian Dutton
Mr Michael Day
Mr Charles George Rose
Mrs Ximena Cibils-Stewart
Ms Samantha Elizabeth Ward

Re-Instatements to Fellowship
Dr Thomas Charles Ings
Mr L H T Large
Dr Claire Carvell

Re-Instatements to Membership
None

Re-Instatements to Student Membership
None

Deaths
Mr T J Witt, 1982, DE
Ms D Clyne, 1981, AU
Dr D G Campion, 1962, UK
Prof. J M Crampton (Hon FRES), 1988, UK
Dr J P Spradbery, 1960, UK

SCHEDULE OF NEW FELLOWS AND MEMBERS

as at 2nd October 2019

New Honorary Fellows
None

New Fellows (1st Announcement)
None

Upgrade to Fellowship (1st Announcement)
None

New Fellows (2nd Announcement and Election)
Dr Lakshmi Kanta Hazarika
Professor Robert D. Reed
Dr Somnath Roy
Dr Katarina Maryann Mikac
Dr Mayur Kumar Kajla

Upgrade to Fellowship (2nd Announcement and Election)
None

New Members Admitted
Dr Renato Pereira Souza
Mr Arthiyan Sivasingham
Miss Sivabalakrishnan Kokila
Dr David Lohman
Dr Lionel Feugere

New Student Members Admitted
Mr Erik Tihelka

Re-Instatements to Fellowship
None

Re-Instatements to Membership
Miss Claire Jennifer Cresswell

Re-Instatements to Student Membership
None

Deaths
Dr C. J. Den Otter, 1989, NI

OBITUARY

In remembrance of

(John) Philip Spradbery

A passionate believer in entomological research for the public good

16th November 1937 – 11th July 2019

By Peter Cranston

John Philip (Phil to all) Spradbery died in July 2019, unexpectedly, while still at the height of his intellectual and practical prowess in entomology. He had been a Fellow of the Royal Entomological Society for almost 60 years, one of many such insect scientists trained in the UK with a long and illustrious career outside the 'home country'. Actually 'career' in the singular is misleading in that he had several, often concurrently: he studied social wasps throughout, but also in his productive life he worked on control of the sirex wood-wasp, control of old-world screw-worm and dedicated much of his later years to running a major entomological consultancy.

Following education at Wrexham Grammar School in North Wales, Phil was offered a scholarship to Jesus College, Oxford University, yet chose to study Zoology at Queen Mary College, London University. After evidently enjoying the student life, including playing rugby (see upper image), he gained first class honours. Phil then undertook a research project on locusts at the Anti-Locust Research Centre and was expected to move to East Africa to undertake a PhD on Red Locust under the formidable Dr DL Gunn. Fate intervened when entomologist Prof OW Richards recommended he'd do better to pursue his wasp work at Rothamsted Experimental Station. Phil said this was the best advice he ever followed.

His Ph.D. was awarded in 1963 for studies of the social wasps of Britain. This was the springboard to a career-long interest in wasps. In 1973, his 408-page book was very well reviewed in *Nature* and it remains the standard work in its field.

Phil's first strongly applied entomological success concerned the wood-wasp, *Sirex noctilio* (Hymenoptera: Siricidae), referred to hereafter as 'sirex'. The female wasp kills trees by injecting a toxic mucus and a fungus while laying her eggs deep in the hole that she has drilled. The species originated in Europe and northern Africa, and arrived in Australia in Tasmania in the 1950s, reaching Melbourne in 1961. Phil established that of the many wood-wasps globally, *S. noctilio* was the sole species that could kill live pine trees. It was threatening Australia's principal commercial plantation pine, *Pinus radiata*, by spreading at a rate of 35 km per year. Estimates of prospective losses come in the range $1–4 billion per 30-year plantation rotation.

The Australian federal agency for entomological research, then named the Entomology Division of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), quickly set up a unit at the Imperial College field station in Ascot (UK) to study sirex. In 1963 Phil was appointed as the research scientist to investigate wood-wasp taxonomy and their natural enemies. With a dedicated quarantine station and laboratory, Phil spearheaded a search for useful biological control agents for sirex in Australia.

When Robin Bedding joined Phil there two years later, he was astonished to see, in dozens of outdoor quarantine cages, hundreds of coniferous logs that Phil had already collected from many European countries. Part of Phil's challenging task was to collect logs from wood-wasp infected trees wherever they occurred and he continued in the next few years

skilfully finding, felling, logging and recording such trees in almost every country of Europe, as well as in Morocco, Turkey and Japan, and organising their transport back to the CSIRO Sirex unit. Phil did this for several months of each year, and Robin recalls always looking forward to his return to study and experiment with the quarantine cages, containing both wood-wasps and their fascinating insect parasitoids.

The parasitoids included species of ichneumonid wasps of various sizes. The large ones belonged to the genus *Megarhyssya*, being able to drill through wood to paralyse and lay an egg on sirex larvae deep inside, with the rather smaller *Rhyssa* species similarly attacking larvae, but nearer the surface. When the eggs of these parasitoids hatch a week or so later, the resulting larvae suck the immature sirex dry. The smallest parasitoid, *Ibalia* (Ibaliidae) was most successful and was observed to visit a sirex drill hole and oviposit within the developing sirex egg. But it was not that simple: Phil also found an ichneumoid hyperparasite of the parasitoids in the genus *Pseudorhyssa*, which would complicate straightforward biological control. Phil and his team elucidated the biology of these and other prospective control agents and even developed a transparent apparatus from which parasitoid oviposition and subsequent parasitic development could be observed. Promising insect parasitoids were sent to a unit established in Tasmania where they were bred up and tested in the field. Thus, in 1971 Phil left his base in England and relocated to Tasmania to complete his studies on the sirex-parasitoid complex.

Largely as a result of these studies, Robin Bedding used Phil's meticulous collections to find some 30 species of insects from 31 tree species and 29 countries from which he studied and described seven new species of parasitic nematodes. One of these nematodes and several insect parasitoids successfully controlled sirex in eight million hectares of pine forest in Australia, New Zealand, Brazil, Argentina, Chile and Uruguay at a then estimated saving of around $100 million per year. Sirex arrived in northern USA and Canada in 2005 and, although largely limited at present to the north-east, is feared capable of spreading to over 100 million hectares of diverse pines; if not controlled it could cause damage valued at upwards of US $17 billion a year.

All the studies on sirex were published in appropriate and well-cited literature, and then Phil moved on to another economically-damaging insect problem: the Old World screw-worm, *Chrysomya bezziana* (Diptera: Calliphoridae) that caused debilitating and lethal myiasis via larvae feeding on living flesh. The New World screw-worm, *Cochliomyia hominivorax* had been well studied since 1935, when 13% of 3.2 million infected cattle died in Texas alone. However, there was little understanding of the biology and potential control of C. *bezziana*. Australia had, and still has, no screw-worm flies, but its presence in northern neighbour Papua New Guinea (PNG) was of major concern. With PNG only 150 km from mainland Australia at its nearest point, and with adult flies capable of migrating up to 100 km and island-hopping through the Torres Strait islands, a major threat to Australia's tropical and sub-tropical cattle ranching was on the doorstep. As such, the potential economic damage to Australia had been calculated: screw-worm establishment could cost upwards of AUS $1 billion of damage each year to livestock alone. In 1973, in a proactive effort that also aided PNG, Phil was invited to establish a CSIRO laboratory in Port Moresby, the capital and access city to the great tropical island. Phil and his colleagues reviewed all previous studies of New World screw-worm (taxonomically in a different genus but expected to have similar biology), especially noting successes and failures in a programme that did eventually eliminate C. *hominivorax* completely from the USA, Mexico and Central America.

In Port Moresby, Phil's team studied potential control, particularly the release of sterilised males that had found eventual success in the New World. Females mate only once, and if the sterile males are competitive in matings with the females, swamping the population with sterile males should result in females laying only sterile eggs. To this end, Phil's team improved on the artificial mass rearing of these flies, which in the wild fed as larvae only on living flesh. Yields improved, but more importantly the quality of males was much increased. Cultivated (and sterilised) males had to be as large and active as the wild males to compete efficiently with them. Sterilisation by gamma irradiation needed to be of short enough duration not to damage but still sterilise them. Phil's team found quality to be much more important than quantity and achieved this by consistently improving the rearing techniques and culture medium. A prototype facility produced and processed 30 million quality sterilised flies per week. Release of sterile flies, pre-chilled, from aircraft led to higher survivorship and better targeting.

Phil's team produced an amazing 70 publications on screw-worm, including substantial manuals of operations and diagnosis, also writing on a trap best able to detect the flies in the field. Phil was an author on all of these works and sole author of 20, some of which were very substantial. Importantly, this CSIRO team paved the way for detecting screw-worm if and when it arrives in Australia, and established a primer for rapid response with a proven method for its eradication.

On completion of the screw-worm project in 1985, Phil returned to Canberra to head a group working with 'Insects Affecting Livestock and Humans' within CSIRO's Division of Entomology, where he was a Senior Principal Research Scientist. However, three years later he opted to leave the payroll of the CSIRO but remain as an Honorary Research Fellow to enable greater scientific freedom. This gave him the opportunity to write-up and publish more of his research results and, finally, to consolidate his personal research interest in the complexities of social life in the European wasp, *Vespula germanica* (Hymenoptera: Vespidae).

It was in this role that Phil achieved much fame amongst the wider public in Canberra. In its native range *Vespula germanica*, as European readers will know, produces relatively small nests with only one queen, largely because the contents of its nest die off with winter cold. In Tasmania, however, where this wasp arrived first in Australia, nests survived the milder winters and got bigger and bigger, with multiple queens and many thousands of workers. The biggest nest that Phil found there was apparently as large as a small car! The inevitable spread northwards on the mainland took *V. germanica* to Canberra, where a naive local population was alarmed, and thus Phil became a guide and mentor to government and public. His formal title was chief of the 'European Wasp Awareness and Insect Identification Service', but he was known informally as 'Dr Wasp' or 'Wasp Man'. He fielded more than 10,000 hotline phone calls, spoke to schools and was a media favourite. Phil appeared on science and popular TV and radio, on commercial media as well as the Australian Broadcasting Corporation (ABC). On hearing of Phil's death, veteran local radio journalist Genevieve Jacobs, who interviewed Phil on air frequently, lauded him as "An old school CSIRO scientist who was a passionate believer in scientific research for the public good". Amongst other recognition of his science was the award in 1992 of a D.Sc. from the University of London. Internationally, in 1998 his advice was called upon by the United Nations' agencies, the Food & Agriculture Organization (FAO) and the International Atomic Energy Agency (IAEA), that were attempting to eradicate screw-worm fly from the Middle East following an overwhelming outbreak in Iraq in 1996.

He was actively working up to his untimely death, as shown in the accompanying image. He reported to one of his colleagues as recently as April 24. "The wasp studies are proving frustrating as usual. But, as the man said: There are no failures in experiments, only discoveries you weren't expecting. How true! Better than getting all depressed! This year I have dug up 26 nests so far compared with 19 last year and seven and eight in previous years. So, an abundance of material. Another season should see the magic light shine brightly at the end of the tunnel! Then I'll give another talk at the Botanical Gardens!"

Phil always had at heart a concern for entomological science in Australia, notably through its flagship establishment, the CSIRO. Although honorary (i.e. no longer salaried) from 1988 onwards, he lobbied for expanded insect research of national concern. Following the departure of the last great CSIRO chair, Neville Wran in 1991, Phil rallied against the effects of the cyclical funding cuts imposed from successive governments. With such concerns he did more than complain: in 1993 he established a scientific consultancy company, XCS Consulting Pty Ltd, which included over 60 scientists and technologists, many of whom had 'retired prematurely' from CSIRO or were made redundant during one of the repeated cycles of budgetary 'restraints'.

Besides this extraordinary career in entomology, there was very much more to Phil. He was a very social scientist, as demonstrated at the funeral service by the empathy and tales of his family, his many friends and erstwhile colleagues. Wherever he went, and he worked at least for some period in 35 countries, and in PNG for a decade, he sailed a yacht. He was commodore of the Canberra Yacht Club for a period and, when on land, he preferred to drive a sports car. He even brought his UK Austin Healey 3000 Mk III with him when he arrived in Australia. He always tended a garden, for fruit and vegetables in his Canberra backyard with flowers out the front. He even won an award for his garden in the inaugural Canberra Gardens competition. He enjoyed his wine, and the company he shared it with both at home and at the local yacht club. He was a rounded man, taken too early from us. His legacy will last as long as there is a discipline of entomology.

Acknowledgements

This tribute stems from a eulogy presented by Phil's long-term collaborator Robin Bedding (FRES) at the memorial service in Canberra on 22nd July 2019. Some embellishment was provided from an interview with Genevieve Jacobs, and by memories of other colleagues including Roger Farrow. The whole was assembled by Peter Cranston (FRES).

Further Information / References

https://csiropedia.csiro.au/sirex-wasp-eradication/

https://the-riotact.com/farewell-philip-spradbery-an-old-school-csiro-scientist-and-european-wasp-warrior/312872

Book Reviews

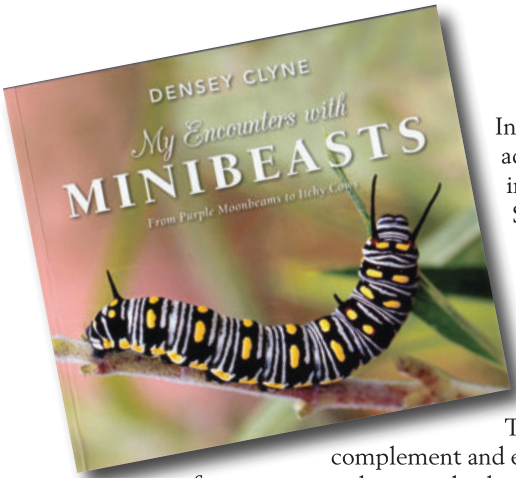
My Encounters with Minibeasts: From Purple Emperors to Itchy Cows

Densey Clyne

New Holland Publishers

ISBN 978-1-92554-617-0

£44.99



In this book, Densey Clyne invites the reader to accompany her on thirty-four short adventures, each a personal reminiscence of an encounter with a species or group of invertebrates which she introduces as if the reader were standing in the field at her elbow. Some are hunts with a quarry in mind, others are walks to see what can be found, whilst some are musings, a chance to talk about some curious or fascinating piece of natural history. All result in a series of invertebrate portraits that are finely observed and beautifully detailed, but delivered in a relaxed and informal style. There are introductions to katydids and mantids, an overview of insect sex, moulting, maternal behaviour in spiders, cicadas, mason wasps, termites, net casting spiders and mistletoe moths, to name but a few.

The book is lavishly illustrated with photographs of a wide range of invertebrates that complement and enhance the text. I assume that these are all taken by Densey Clyne, as she was a pioneer of insect macro photography, but there is no mention in the book of who they should be credited to.

While the invertebrates described are primarily Australian, with forays into south-east Asia, this does not detract from a more global appeal, as Densey's easy style draws the reader into each encounter and leaves them with their curiosity seriously piqued, irrespective of where they are.

'*My Encounters with Minibeasts*' is the latest in a long list of books that Densey has written, and to have been published at 96 years old might be an entomological record. Densey Clyne has produced an exuberant entertainment that spotlights the fascinating nature of the insect world, a spotlight that will enthuse future generations of Australian entomologists and a broader readership around the globe. We wish Densey a very happy 96th birthday and look forward to her next invitation to walk at her elbow.

Peter Smithers

The Beetles: poems in praise of beetles

Poems by Peter Brown

Illustrations by Fran Evans

Published by Signspeed.com

£5.00

Peter Brown loves to play with words and images. In these poems, he often links the insect order with the pop group of the same name. He closes his introduction with the call, "Let's make the beetles the fab four thousand", and on the back cover depicts four beetles walking over a zebra crossing. There are fourteen poems that vary in length, each dealing with a single species. The introduction is a brief biography of the author plus an illustration of the important parts of a beetle.

The poems possess a hint of classical romanticism, a style that hints of a previous age when insects were more abundant than they are today. They are also sprinkled with humour; the poem about the dock beetle is a conversation between a dock plant and a doctor, while the ladybird poem refers to the old nursery rhyme "There is no fire, don't fly away. Your house is fine, your children play". They all possess a lyrical charm and a generous dose of natural history. Each one outlines an aspect of a species' biology, the random movement of whirligig beetles "a darting bullet in perpetual doubt", the feeding habits of great diving beetle larvae "I am a sigmoid assassin", or the life cycle of the oil beetle.

The illustrations possess a wonderful delicacy that captures the character of each species and often, like the poems, with a hint of humour. They offer an aesthetic which makes the book extremely attractive and at the same time provide biologically accurate images that allow anyone to identify these insects in the field.

The Beetles is a book that will entertain and inform both poetry lovers and natural historians. This delightfully quirky introduction to UK beetles is sure to be a hit with all who read it. We love it, yea yea yea!

Peter Smithers

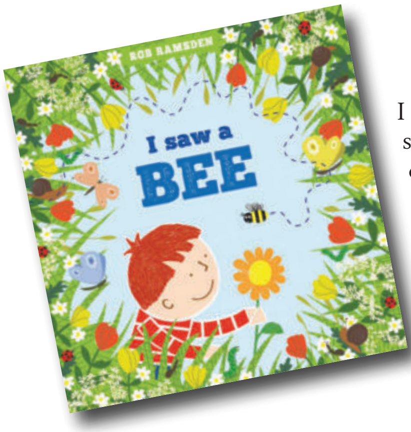
I Saw a Bee

Bob Ramsden

Scallywag Press

ISBN 978-1-912650-03-3

£11.99



I saw a bee is a charming story of discovery that is aimed at very young children. The story is spread over sixteen pages, each simply-illustrated with bright and colourful images. The story charts a child's discovery of a bee, their initial fear but then the arousal of their curiosity, which leads to the discovery that bees are our friends. This is a simple bedtime story with an important message. At a time when insects are in steep decline, ensuring that the next generation has a positive attitude to the natural world is imperative. Here is a book that will initiate that mind-set. Parents, grandparents and children will all enjoy reading or listening to this over and over again.

Peter Smithers

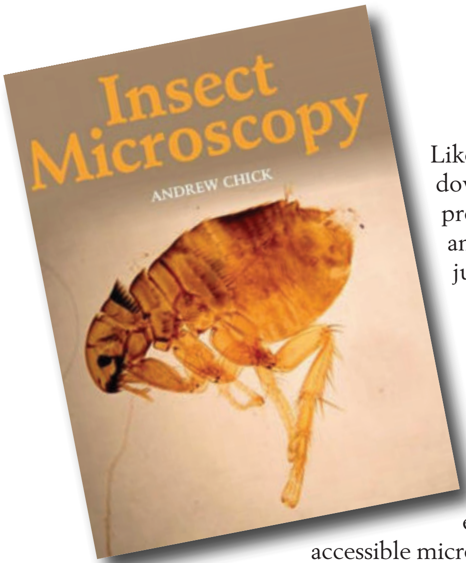
Insect Microscopy

Andrew Chick

The Crowood Press

ISBN 978-1-78500-201-4

£16.99



Like many entomologists, I spend not inconsiderable amounts of my time peering curiously down a microscope, though I would not consider myself in any way an expert in the preparation of the subjects in question. *Insect Microscopy* was a helpful 'refresher' for me, and will be a useful and accessible introduction to the subject for hobbyists or students just starting out.

The opening chapter, 'The Insects and their Relatives', provides a quick introduction on what insects are, their classification and life cycles, with brief mention of non-insect hexapods and other arthropods, without getting bogged down in detail. It also outlines some common collecting and euthanizing equipment, and runs briefly through how to go about identifying your subject.

The following chapters focus on different kinds of microscope, other equipment you might need, and different media that can be used for mounting specimens for examination under high powered microscopes. The overview of the most common and accessible microscope types will be useful for readers just starting out, outlining the differences between them, their uses, and providing helpful information on what features to look for, though it might have been helpful to include a brief section on microscope use. The subsequent chapters on equipment and media are relatively comprehensive for an introductory book. The next chapter, on dissection, is comparatively brief but again provides a good overview, though pictures providing examples of some of the procedures or techniques may again have added value.

'Compounds, Chemicals and Potions' runs through some of the most commonly used chemicals used in the preparation of slides. It is well laid out and thought through, with the various mixtures defined, instructions on their preparation provided and safety considerations included. The chapter segues smoothly into one on 'Slide Mounting', which provides selected common methodologies tried and tested by the author and which can be applied across groups. Lists of steps are presented clearly. Photographs with examples from the author's work have been included, although I feel that this chapter, in particular, would benefit from inclusion of photographs of key steps in the mounting processes to go along with the instructions, rather than just those of the finished product.

The book wraps up with chapters on publishing one's findings (which includes basic introductory information on manuscript preparation and the publishing process) and another on a broad range of further reading. Sandwiched between the References and Index is a simple identification key to identify adults of some common terrestrial invertebrate groups to order.

The book is well-referenced, and text is interspersed with comments from the author on their personal experience. Most chapters include a highlighted box with either a summary or some interesting consideration. Colour figures are used throughout, and although sometimes these could provide examples of processes, overall it is gratifying to see what typical end results could look like. In addition to aspects of personal safety, it is also good to see, at various points, mention made towards disciplined collection and killing of insects, and the foresight and consideration that should be given to this.

Insect Microscopy provides a fantastic introduction and starting point to an important aspect of entomology. It gives ample, clear guidance on some common basics without assuming extensive existing knowledge, and signposts sources which can provide further detail for those wishing to learn more. It is a well-constructed, helpful book that was a relatively quick and very interesting read. I, for one, am more than pleased to have added a copy to my reference library, and to which I am sure I will be referring again.

Jennifer Banfield-Zanin

Diary

Details of the Meetings programme can be viewed on the Society website (www.royensoc.co.uk/events) 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.

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

Insect Genomics Special Interest Group
Monday, 6 January, 2020
Lancaster University, Lancaster

PG Forum
Thursday, 20-21 February, 2020
University of Bristol, Seminar Room G13/14, Life Sciences Building, 24 Tyndall Avenue, Bristol, BS8 1TQ

Verrall Lecture
Wednesday, 4 March, 2020
The Flett Theatre, Natural History Museum, London, SW7 5BD

Forest Insects and their Allies Special Interest Group
Thursday, 2 April, 2020
The Mansion House, Chiswell Green Lane, St Albans, Herts, AL2 3NS

Insects as Food & Feed Special Interest Group
Tuesday, 21-22 April, 2020
Natural History Museum, London, SW7 5BD

EntoSci20
Thursday, 30 April, 2020
Harper Adams University

Annual General Meeting
Wednesday, 3 June, 2020
The Mansion House, Chiswell Green Lane, St Albans, AL2 3NS

National Insect Week
Monday, 22 June – Sunday, 28 June, 2020

Ento '20
Tuesday, 25-27 August, 2020
University of Exeter, Penryn Campus, Penryn, Cornwall, TR10 9FE

Pollinators in Agriculture meeting in collaboration with the AAB
Wednesday, 11-13 November, 2020
Copthorne Hotel , Slough

NON-SOCIETY MEETINGS

XXVI International Congress of Entomology, Helsinki, Finland, 19-24 July, 2020
'Entomology for our planet'

For full details on all meeting please visit
www.royensoc.co.uk/events

author guidelines

We are always looking for new material for *Antenna* – please see below if you think you have anything for publication

AIMS AND SCOPE

As the Bulletin of the Royal Entomological Society (RES), *Antenna* publishes a broad range of articles. Articles submitted to *Antenna* may be of specific or general interest in any field related to entomology. Submissions are not limited to entomological research and may, for example, include work on the history of entomology, biographies of entomologists, reviews of entomological institutions/methodologies, and the relationship between entomology and other disciplines (e.g. art and/or design).

Antenna also publishes Letters to the Editor, Meeting Reports, Book/App/Website Reviews, Society News, Obituaries and other items (e.g. selected Press Releases). *Antenna* further includes details of upcoming entomological meetings in its Diary Section and features information and reports on RES activities including National Insect Week, Insect Festival and National, Regional and Special Interest Group meetings. Details of RES Awards and recipients are also covered, as is notification of new Members (MemRES), Fellows (FRES) and Honorary Fellows (HonFRES).

READERSHIP

Antenna is distributed quarterly to all Members and Fellows of the RES, as well as other independent subscribers.

INSTRUCTIONS FOR AUTHORS

Standard articles are normally 2,000-6,000 words in length, though shorter/longer submissions may be considered with prior approval from the Editorial Team. The length of other submitted copy (e.g. Letters to the Editor and meeting reports) may be shorter, but should not normally exceed 2,000 words. The use of full colour, high quality images is encouraged with all submissions. As a guide, 4-8 images (including figures) are typically included with a standard article. Image resolution should be at least 300 dpi. It is the responsibility of authors to ensure that any necessary image permissions are obtained. Additional supplementary material may also be submitted for consideration for publication on the members' area of the RES website.

Authors are not required to conform to any set style when submitting to *Antenna*. Our only requirement is that submissions are consistent within themselves in terms of format and style, including that used in any reference list.

PAGE CHARGES

There is no charge for publication in *Antenna*. All articles, including images, are published free-of-charge in full colour, with publication costs being met by the RES for the benefit of its membership.

REVIEW AND PUBLICATION PROCESS

All submissions are reviewed and, where necessary, edited 'in-house' by the *Antenna* Editorial Board, though specialist external review may be sought in some cases (e.g. for submissions that fall outside the Editorial Board's expertise). Receipt of submissions will be provided by email, with submitting authors of accepted articles being offered the opportunity to approve final pdf proofs prior to publication. Where appropriate, authors will be requested to revise manuscripts to meet publication standards.

SUBMISSION PROCESS

All submissions should be sent electronically to 'antenna@royensoc.co.uk', preferably in MS Word format with images sent as separate files (see above). Image captions and figure headings should be included either with the text, or as a separate file.

EDITORIAL BOARD

www.royensoc.co.uk

Royal Entomological Society
– Society Awards –

For more details on these Society Awards please see www.royensoc.co.uk

THE ROYAL ENTOMOLOGICAL SOCIETY STUDENT AWARDS

Award Criteria: Any article about an entomological topic that would be of interest to the general public. The article to be easy to read, in a popular style and no longer than 800 words.

Prize: Winner £400, runner up £300, third place £200, all three articles published in *Antenna*.

THE L.J. GOODMAN AWARD FOR INSECT BIOLOGY

Award Criteria: For advancing the education of the public in the knowledge, understanding and appreciation of all aspects of insect physiology and behaviour, thereby promoting the control and conservation of insect species.

For promoting research into aspects of insect physiology and behaviour through online, digital or printed material.

For supporting exhibitions, meetings, lectures, classes, seminars and courses that widen the understanding of insect physiology and behaviour.

Grant: No individual award shall exceed £3,000 and not more than £6,000 shall be awarded each year.

THE MARSH AWARD FOR INSECT CONSERVATION

Award Criteria: For an outstanding contribution to insect conservation; on the basis of 'Lifetime Achievement', or 'Considerable and Exemplary Contribution' to a significant project or undertakings. In exceptional circumstances two prizes may be awarded to reflect each criterion.

Prize: £1250 and certificate.

THE ALFRED RUSSEL WALLACE AWARD POSTGRADUATE AWARD

Award Criteria: For postgraduates who have been awarded a PhD, whose work is considered by their Head of Department to be outstanding. The research involved should be a major contribution to the science of entomology.

Prize: £800 plus certificate, plus one year's free membership. The winner will also be invited to present their work at a Society Meeting.

J.O. WESTWOOD MEDAL – AWARD FOR INSECT TAXONOMY

Award Criteria: The best comprehensive taxonomic work on a group of insects, or, related arthropods (including terrestrial and freshwater hexapods, myriapods, arachnids and their relatives). Typically, this will be a taxonomic revision or monograph.

Prize: A specially struck silver gilt medal inscribed with the winners name. Also costs incurred in attending the International Congress of Entomology, European Congress of Entomology, or other major meeting (specified by the adjudicators) to present his/her work.

RES JOURNAL AWARDS SCHEME

Award Criteria: The best paper published in each Society Journal over a two year period. Each of the Society Journals participates biennially.

Prize: £750 and certificate for each participating Journal.

THE WIGGLESWORTH MEMORIAL LECTURE AND AWARD

Award criteria: The outstanding services to the science of entomology. The award will be made to a researcher who has contributed outstanding work to the science and who best reflects Sir Vincent Wigglesworth's standards of personal involvement in every aspect of his/her research.

Prize: A specially struck gilt medal inscribed with the winner's name. Also the costs of attending the International Congress of Entomology to give the Wigglesworth Lecture.

BOOK PURCHASE SCHEME FOR FELLOWS AND MEMBERS IN DEVELOPING COUNTRIES

Award Criteria: To provide assistance in purchasing specialist taxonomic books, that will assist in the identification of insect groups being studied in developing countries and their regions. Applicants will be required to demonstrate need and specify particular texts.

Prize: Any one applicant may be awarded up to £250 in a three year period. The Society will purchase the texts awarded and send them to the applicant. The applicants may, themselves, provide any additional funds in excess of the amount awarded.

OUTREACH AND CONFERENCE PARTICIPATION FUNDS

Award Criteria: ORF: Grants to support activities which further the Society's aims. This may range from, help to purchase equipment, to help in funding expeditions/meetings. CPF: Grants to assist applicants who are participating in a meeting or conference in some way, e.g. presenting a paper/poster.

Prize: ORF: Monetary grant. CPF: Monetary grant.

MARSH AWARD FOR EARLY CAREER ENTOMOLOGIST

Award Criteria: For an early career contribution to entomological science that is judged to be outstanding or exemplary with single or ongoing impact on the science. The award is 'open' and not restricted to any particular discipline or specialised area of entomological science.

Prize: £1250 and certificate.

Royal Entomological Society
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Tel: +44 (0)1727 899387 • Fax: +44 (0)1727 894797
E-mail: info@royensoc.co.uk

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 attached entry form, and submit it with five copies of your entry to:

The 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 e.g. student I.D. card

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 2019. The winner will be announced in the Spring 2020 edition of *Antenna* and on our website.

PLEASE CUT AND RETURN THIS PORTION WITH YOUR ENTRY

Article title: ______________________

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Student name: ______________________

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Address: ______________________

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Telephone: ______________________

E-mail: ______________________

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Name of academic institution:

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