Bulletin of the Royal Entomological Society Volume 43 (3) 2019

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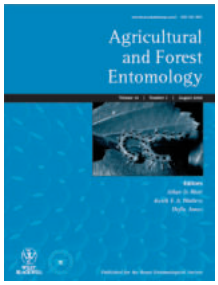

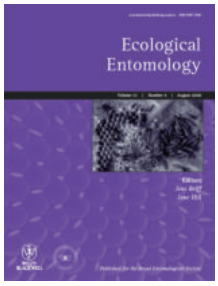

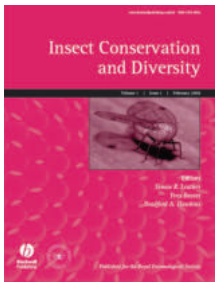

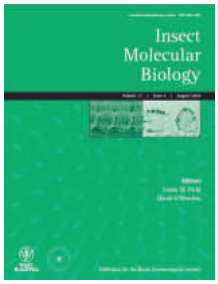

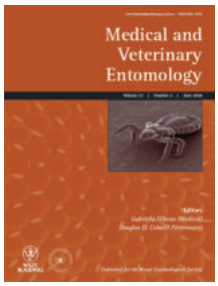

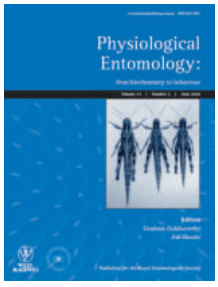

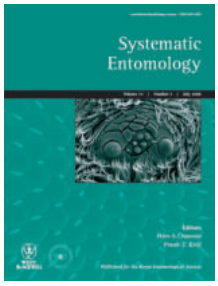

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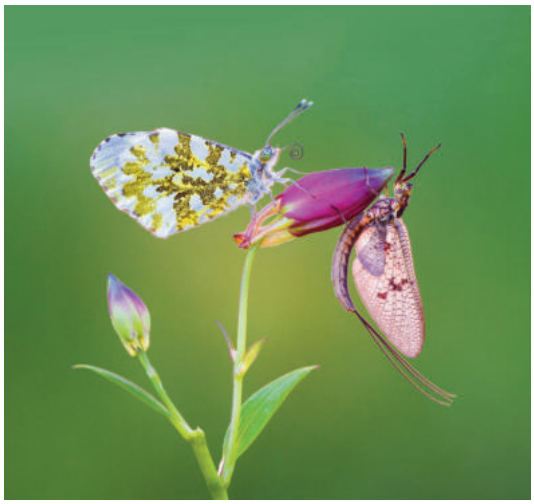

COVER PICTURE

NIW Photography Competition, 1st Prize: Petar Sabol – Orange-tip butterfly and mayfly sharing.

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EDITORIAL

As techniques enabling genetic modification (GM) become increasingly refined and accessible, exciting prospects for pest management emerge and emotions are stirred. In his third Research Spotlight, Stuart Reynolds discusses the issues raised by a recent paper advocating the control of malaria-transmitting mosquitoes using a GM fungus. I was very much hoping that Stuart's thought-provoking offerings would generate debate in the Correspondence section. Perhaps this will be the one. We have, though, had a letter in response to the article on invasive insects written by the editorial team of *Agricultural and Forest Entomology*. I am very grateful to our hard-working editors for their contribution to the new Journals and Library section. In this issue, the *Insect Conservation and Diversity* team discusses another controversial issue – ethics in entomology. Now, surely, that will get some of you writing in.

Gardeners may be lamenting the fast approach of autumn. Perhaps some readers have benefitted from the skills of the entomologists at RHS Wisley. They feature in the second of our enTeam articles. I invite you to let me know if your group would like to be highlighted. Talking of gardening, there have been several entries for the competition to design an insect-friendly garden at our Mansion House HQ. The results will be announced in the next issue. Competitions and awards feature strongly in this issue, revealing the winner of the RES/Marsh Christian Trust Award for Conservation and the winner of the 2010 Westwood Medal. Find out why this was delayed. The amazing winning entries from last year's National Insect Week photographic competition add a thrilling splash of colour, and the equally amazing winning student essays will get you thinking and laughing.

The Society has held a wide range of excellent meetings of late. Ento' 19 happened after copy-date, but we report on the Postgraduate Forum, the Verrall Lecture, the Northern Ireland Regional Meeting and five Special Interest Groups. John Cooper outlines a workshop (not organised by the RES) held in Kenya to train those running a butterfly farm for community and conservation benefits in how to deal with the problems of keeping captive invertebrates healthy.

Our Honorary Fellow interview is with entomological knight of the realm, Sir Charles Godfray (Mr Brown to me, but that's a long story!). Read about his life-long relationship with insects, his influence on environmental policy, his ideas as to how the Society could connect more with amateur entomologists, the tribulations of editing *Antenna* several years ago, what he thinks about aphids, and much more.

The Handbooks for Identification of British Insects celebrate their 70th anniversary this year. Their editors give an historical overview of these hugely valuable RES publications. No doubt you can identify several insects, but can you identify the wonderful RES staff? You can if you read this issue. Jim Hardie, Director of Science, and Luke Tilley, Chief Executive, are looking for volunteers to help provide an insect identification service for the public. Please read their article and offer to help out if you possibly can. As with any organisation, the more you put in, the more you get out.

Very many thanks to all contributors.

Richard Harrington

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

72dpi

CORRESPONDENCE

Where is the evidence that *Agrilus biguttatus* is an invasive pest?

Dear Antenna,

In your article about invasive insect pests featured in recent issues of *Agricultural and Forest Entomology* (*Antenna* 2019 **43**: 27-30), a short section was devoted to what UK Forest Research (FR) refers to as the two-spotted oak buprestid but which is better known to field entomologists as the oak jewel beetle *Agrilus biguttatus*. FR implicate this species in Acute Oak Decline (AOD) but I regard it as an innocent bystander, taking advantage of AOD but not causing it. The alleged pest status of this beetle appears to be based on rhetoric rather than science. It is of course right that FR should research its biology in order to clarify its role, but they appear to have declared it a pest and a symptom of AOD well in advance of any evidence.

Agrilus biguttatus is a long-established native species and therefore not an invasive alien. It has been known in Britain for 100 years or more and has not been regarded as a pest species by most entomologists and ecologists. Indeed, until relatively recently it was regarded as a rarity and of conservation concern.

I previously wrote an article for the *Arb Mag* addressing 'What do we really know about oak jewel beetle and acute oak decline?' (Alexander K., 2015, *The Arb Magazine* **169**: 50-54). I was targeting the Arboricultural Association, as arborists are at the sharp end of dealing with dead and dying oak trees. This review appears to have been ignored by FR, and the *Antenna* article repeats the FR rhetoric that the beetle is an important secondary pest of oak, strongly linked to AOD.

Agrilus biguttatus is in reality an early successional saproxylic, rapidly exploiting newly available, freshly dead or dying cambial tissues – the habitat is short-lived, and the beetle is relatively highly mobile as it needs to find potential larval habitat quickly, before this dries out and is degraded by other organisms. It is one of a broad assemblage of early successional insects exploiting freshly dead or dying oak cambial tissues, but it alone has been targeted by FR. Could it be that a combination of the *Agrilus* genus name – shared with the authentically invasive and destructive emerald ash borer, *Agrilus planipennis* – as well as experience from elm bark beetles has misled the researchers? All *Agrilus* species do not share the same biology, of course, as many are quite innocuous and there have been no previous concerns about any of our native *Agrilus* species.

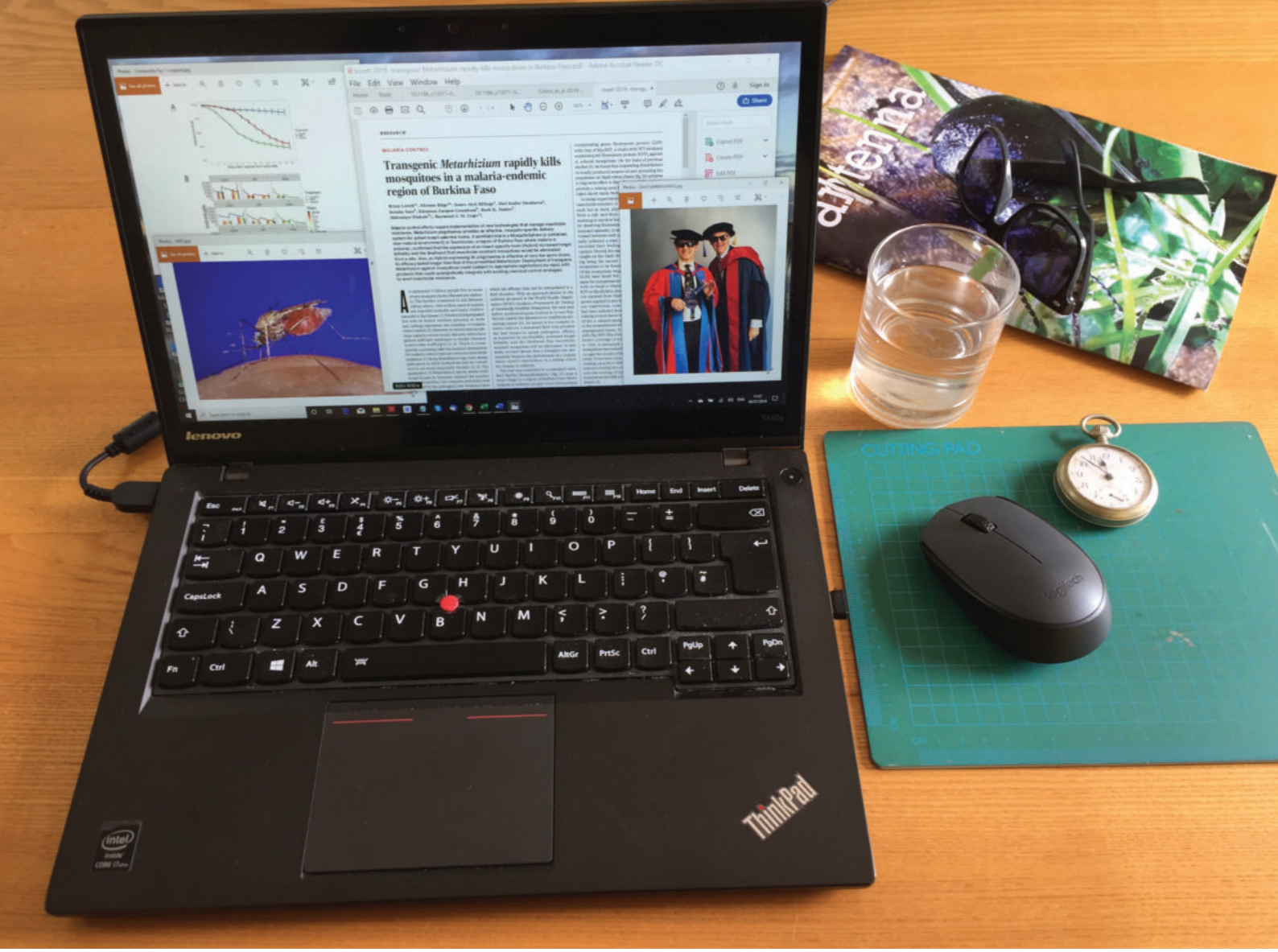
Agrilus biguttatus follows AOD, as AOD leaves a trail of fresh *A. biguttatus* larval habitat across the countryside. It has to follow rapidly, so it is no great surprise that there is a strong correlation between AOD and the presence of the beetle. Cause and effect, however, have not been demonstrated. Indeed, there are many oak trees exhibiting AOD symptoms where there is no evidence of the presence of the beetle. There is increasing evidence that the real issues are poor soil conditions – damaged by modern agricultural practices in particular – which stress the trees and make them more susceptible to potential pathogens such as bacteria. I believe that *A. biguttatus* should be declared innocent until scientifically proven guilty.

Yours sincerely
Keith Alexander FRES
Exeter, UK

Response to K. Alexander letter, *Antenna* July 2019

Acute Oak Decline (AOD) is a complex syndrome affecting native British Oak trees, involving a characteristic suite of bacterial pathogens, a range of environmental factors, and typically the presence of larval galleries of *Agrilus biguttatus*. *Forest Research* has never suggested that this beetle is an invasive species, but our work has determined that its distribution is thermally limited in the UK, with the potential to expand under a warming climate (the point being made in the *Antenna* article). The destruction being inflicted by Emerald ash borer (*Agrilus planipennis*) in North America is a very different situation, where an introduced species is able to attack and kill 'naïve' species of ash trees which have no co-evolved resistance. Conversely, our native oak species are well-defended against *A. biguttatus* (and other bark-boring beetles), so that only weakened trees may be successfully colonised. The terminology of the beetle as a secondary pest references the larval feeding damage that occurs once such trees are colonised, and which may contribute to the further decline of the tree. AOD symptomatic trees do not, however, always show the emergence holes of new adult *A. biguttatus*, and often galleries are overgrown with callus tissue indicating larval development has been halted by active tree defences. Ongoing research aims to better understand the relationship between the 'AOD bacteria', a suite of environmental drivers, insects associated with declining oaks (including *A. biguttatus*), and the trees themselves. This is a highly complex set of relationships, which are being investigated in a comprehensive, objective and empirically-driven manner, through a range of field, laboratory and cutting-edge 'omic' studies, by a consortium of dedicated researchers from across the government and university sectors.

Daegan Inward & Katy Reed
Forest Research



Malaria control: a genetically engineered fungus that kills *Anopheles* mosquitoes

RESEARCH SPOTLIGHT

Stuart Reynolds

Department of Biology and Biochemistry, University of Bath

For this issue's *Research Spotlight*, I've chosen to write about a recently published research paper (Lovett *et al.*, 2019) from the research group of Ray St. Leger at the University of Maryland, USA. It appears in the prestigious weekly *Science*, and addresses one of the biggest challenges for applied entomologists: how to control malaria mosquitoes. In our environmentally conscious times, the authors propose what seems like a great idea – biological control, using a natural enemy to kill a problem insect. The results are promising and the methods novel, yet also conventional in almost every way except one – the control agent is a genetically manipulated (GM) organism. I'll be asking if this is a good idea.

Controlling malaria

With more than 200 million cases per year and causing an estimated 10.2 deaths per 100,000 people worldwide (GBD 2016 Causes of Death Collaborators, 2017), malaria, caused by apicomplexan parasites of the genus *Plasmodium* and transmitted by adult female anopheline mosquitoes, is the world's most deadly vector-borne human disease. Sub-Saharan Africa is by far the worst hit region, and more than 90% of global malaria cases occur there (WHO, 2018). A massive US$ 4.3 billion was invested globally in malaria control and elimination efforts in 2016 alone (Haakenstad *et al.*, 2019).

How can the immense global burden of malaria be alleviated? Although the

disease is treatable, it's much better never to get it in the first place, especially since strains of *Plasmodium* have emerged in SE Asia that are resistant to all of the drugs that are used clinically to treat malaria, including those of choice, artemisinins (Fairhurst and Dondorp, 2016). The long-awaited malaria vaccine is now at last being deployed, but even when it is rolled out across the continent it won't completely eradicate the disease; it's expected to reduce the incidence of all malaria cases by only around 40% (WHO, 2019a).

Consequently, killing mosquitoes continues to be the single most important component in malaria control. It is universally agreed that control must rely on multicomponent strategies. WHO (2019b) lays great stress on Integrated Vector Management (IVM), which includes environmental management, and personal protection/preventive strategies, as well as insecticide use. But although environmental schemes like drainage, effective sanitation etc. (Walker and Lynch, 2007), larvicides (Killeen *et al.*, 2002), and biological controls of mosquito larvae for example by natural enemies such as nematode parasites (Abagli *et al.*, 2019) and even predatory fish (Roux and Robert, 2019) can all provide some protection (particularly in urban settings), these non-adulticidal interventions aren't sufficient on their own.

Thus, while we might wish it were not so, killing adult mosquitoes is overwhelmingly important. Synthetic chemical insecticides of one sort or another have been extensively used to control mosquitoes since the 1930s (when Paris Green was used), and this will almost certainly continue for the foreseeable future (Enayati and Hemingway, 2009). Widespread outdoor spraying of insecticides is not an option, not just because of their undesirable environmental effects (look at what happened with DDT!), but also because extensive prophylactic spraying is a sure way to ensure rapid evolution of resistance. It's much better to concentrate chemical treatments to the places where mosquitoes actually bite people. Indoor Residual Spraying (IRS) of pyrethroid insecticides on interior house walls is effective (Wagman *et al.*, 2018) and treated window screens and eave baffles might reduce the chemical burden and cost of such interventions (Chinula *et al.*, 2018). But so far, by far the most effective way to reduce the incidence of malaria has been to target protective efforts against mosquitoes to exactly the time and place when they are most likely to bite. *Anopheles* mosquitoes seek out their hosts at night and Long-Lasting Insecticide-treated Nets (LLINs) impregnated with a pyrethroid insecticide are a particularly effective and inexpensive form of protection (Lim *et al.* 2011); they have been used in Africa on an astonishing scale; between 2012 and 2017 more than 1 billion treated nets were distributed (WHO, 2018).

These two chemical approaches have together been outstandingly successful; it has been estimated that ~633 million malaria deaths were averted between 2000 and 2015, 68% of these due to LLINs and 10% to IRS. The importance of the entomological approach to malaria is dramatically shown by the fact that killing adult mosquitoes thus accounted for 4 in 5 of all the saved lives (Bhatt *et al.*, 2015).

Insecticide resistance

Unfortunately, however, as vector control efforts have become more effective, evolution has intervened in the form of insecticide resistance. The very fact that a high proportion of people's homes and beds are now protected has resulted in the rapid rise of pyrethroid resistance (Hemingway *et al.*, 2016; Ranson and Lissenden, 2016; Kisinza *et al.*, 2017). First detected in Côte d'Ivoire in 1993, resistance has since spread rapidly across Africa. Of course, pyrethroid resistance was always going to happen, because the almost universal deployment of an insecticide constitutes an extremely strong selection pressure on the target insect. A recent large epidemiological study by Kleinschmidt *et al.* (2018) has concluded that there is as yet no strong evidence that the efficacy of treated bed nets is compromised by mosquito pyrethroid resistance, but this must surely be evident soon.

It is thus that, despite decades of reducing the global burden of malaria, progress in controlling the disease is now faltering; WHO Director Tedros Adhanom Ghebreyesus recently warned that "no significant progress in reducing global malaria" was made in the period 2015-2017 (WHO, 2018). It's clear that resistance is spreading and, if left unchecked, may eventually render IRS completely useless and treated bed nets no better than untreated ones.

Novel control strategies

The usual strategy in the past when faced with resistance has been to switch to a new pesticide. This doesn't look like an option at the moment, as there isn't a suitable product waiting in the wings, and although there is now renewed interest in discovering new pesticide classes specifically for vector control, it will be years before these are available to use in the field (Hemingway, 2014; IVCC, 2014).

For many malariologists, the current talking points in mosquito control are non-traditional strategies. Notable among these is the release of genetically engineered mosquitoes into wild populations either simply to suppress insect numbers, or to cause the spread of genes that would prevent mosquitoes acting as hosts to *Plasmodium*. Such gene drives (Burt, 2003) are claimed by many to hold great potential to alleviate the burden of malaria and there is currently intense interest in developing the genetic tools for this (Hammond and Galizi, 2017; James *et al.*, 2018; Hartley *et al.*, 2019; Scudellari, 2019).

I don't want to say much more about this here, because this article isn't about gene drives, and I'll write about that topic on another occasion, but it's necessary to make the point that no gene drive is yet ready for widespread operational use against malaria mosquitoes, and important concerns about their environmental safety remain to be satisfactorily answered (Brossard *et al.*, 2019). The Royal Society (2018) has issued what I see as an excellent policy document that discusses the scientific concerns and specifically calls for an "amber light" for pilot scale research on gene drives to continue with caution. This seems to me very reasonable, in fact necessary. There is so much interest in gene drives that to forbid them without good evidence that they are dangerous would be a very bad idea.

Microbial control with an entomopathogenic fungus

But in the meantime, what are we to do about controlling malaria mosquitoes? It is against this background that the new paper by Lovett *et al.* (2019) describes research in which the authors

make a strong bid to revive the prospects for biological control of adult mosquitoes. Their paper describes the use of a GM entomopathogenic fungus to control malaria mosquitos at a site in the West African country of Burkina Faso, where malaria is endemic, pyrethroid resistance is common, and mosquitoes poorly controlled (PMI, 2019). The fungus they used is *Metarhizium pingshaense*, a close relative of that good old warhorse of biological control, the green muscardine fungus, *M. anisopliae*, the very first microorganism to be used as a practical microbial control agent (Metchnikoff, 1880). The taxon *M. anisopliae sensu lato* is currently recognised to comprise nine species (Bischoff *et al.*, 2009). Fungi of this genus have long been known to be entomopathogens, which, while being essentially non-pathogenic and non-toxic towards vertebrates (Zimmerman, 2007), are effective (but not very quick) at killing insects (Brunner-Mendoza *et al.*, 2019). An isolate of *M. pingshaense* obtained from an African soil sample efficiently kills mosquitoes, being rather specific towards this group of insects (Bilgo *et al.*, 2018a).

Previous work (Scholte *et al.*, 2005) had shown that when its conidia (spores) were presented on a black cloth lure inside rural houses in Tanzania, an unnamed isolate of *M. anisopliae* infected a significant fraction of *Anopheles gambiae sensu stricto* mosquitoes, reducing their survival time by more than half. Modelling suggested that this would lead to a 75% reduction in *Plasmodium* transmission intensity. This encouraging finding did not however lead to operational scale implementation of a *Metarhizium*-based biological control programme. Perhaps 14 years ago, before the widespread occurrence in Africa of pyrethroid resistance, the need for an alternative control strategy was not seen to be so great. Moreover, the relatively short life of the treated cloth lures and the low virulence of the *Metarhizium* isolate used by Scholte *et al.* (2005) were problematic. A fungus that killed mosquitoes more quickly and efficiently would have made the idea look much more attractive.

To address these limitations, Bilgo *et al.* (2017) constructed a GM fungus based on a local isolate of *M. pingshaense* (origin is important for registration purposes), which carries a gene encoding an insect-specific spider toxin (Hybrid [also designated "Versitude"]) that has dual channel-blocking activity towards insect voltage-sensitive neuronal potassium (K_V) and calcium (Ca_V) channels. The Hybrid toxin is active against a wide range of insects and increases the virulence of the fungus towards target

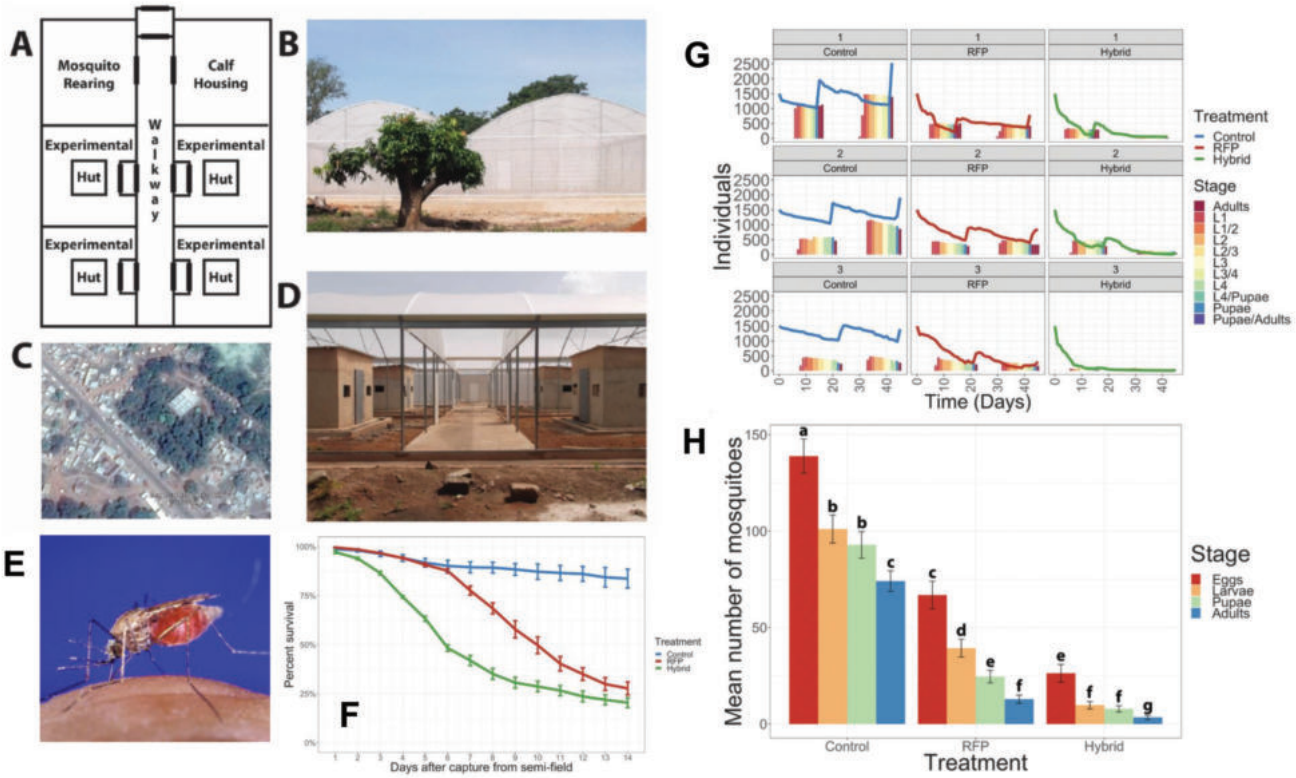


Figure 1. A Floor plan of the simulated domestic environment ("The MosquitoSphere") used to test the GM fungus. Each experimental compartment is 9.55 m x 9.1 m x 4.7 m. **B:** Side view looking at calf housing compartment. **C:** Google Earth image shows location of the installation in Soumousso, Burkina Faso. **D:** MosquitoSphere during construction, demonstrating location of experimental huts. Following construction, but before experiments were conducted, local vegetation was sown into experimental compartments. **E.** *Anopheles coluzzii*, formerly known as *Anopheles gambiae* M molecular form (Coetzee *et al.* 2013), belongs to the *Anopheles gambiae* species complex, comprising at least seven species. **F.** Survival of mosquitoes exposed to transgenic fungi in the semi-field trial. Survival curves for release–recapture experiments are shown. Mosquito survival (n = 100 mosquitoes per compartment) was scored after a single evening of exposure to control fungus (Mp-RFP – expresses red fluorescent protein) or toxin-secreting fungus (Mp-Hybrid). Controls exposed to neither fungus. Means ± SE (n=7). **G.** Semifield-established population counts of F1 and F2 offspring. Graphs depict population counts of F1 and F2 offspring after the release of 500 female and 1000 male mosquitoes. Bars represent visual counts of the number of individuals per day in compartmental breeding sites at each developmental stage; lines represent the number of adults in the entire compartment. Treatments monitored for two generations (45 days in duration). The results from three replicates (1, 2, and 3) are shown. L = larval instar. **H.** Effect of fungi on fecundity. The graph shows the mean numbers of eggs, larvae and pupae produced per individual female in laboratory experiments. Mean ± SE (n = 80 females, n = 70, and n= 71 for untreated, Mp-RFP, and Mp-Hybrid mosquitoes, respectively). Letters indicate significant differences among groups ($P < 0.05$). ([A-D] and [F-H] reproduced with permission from Lovett *et al.*, 2019; [E] Public domain image: Vectorbase: photo by James Gathany, Centre for Disease Control, USA).

insects but shows low mammalian toxicity (Fang *et al.*, 2014). The transgene does not affect the specificity of the host fungus towards host insects, which is due to other genetic elements in the fungal genome. The toxin gene is placed under the control of an insect haemolymph-specific promoter, so that it is not expressed except when in the insect host. Importantly, since neither of the toxin-targeted ion channels is a known target for existing chemical insecticide classes, the authors suggest that it should be active against all known insecticide-resistant insects, meaning that it should be particularly valuable when used in conjunction with existing control techniques (i.e. IRS and LLINs). Bilgo *et al.* (2018b) have verified exactly such a synergistic action between permethrin and Hybrid expressing fungus for a pyrethroid-resistant strain.

In their new paper Lovett *et al.* (2019) now use a semi-field scale trial to show that in a contained but near-natural environment, the toxin-expressing transgenic fungus effectively eliminates domestic populations of local insecticide-resistant *A. coluzzii* mosquitoes. The trial involved a realistic simulation of a domestic environment, in which mosquitoes were exposed to fungal spores only when they landed on fungus-treated black cloth lures within the test environment's simulated house (Fig 1). Although the control fungus (which was engineered to express the red fluorescent protein, RFP) also killed mosquitoes, because the toxin-expressing *M. pingshaense* displays greater virulence than the control (i.e. it is effective at lower spore doses), the toxin-expressing fungus-treated black cloths remained effective for longer than lures with the RFP (control) fungus. This meant that the GM *Metarhizium* was successful in extinguishing mosquito populations in three repetitions of the trial, the lures retaining their effectiveness over three mosquito population cycles, while the RFP fungus did not do so; exposure to toxin-expressing *Metarhizium* also reduced mosquito fecundity more effectively than did the control fungus (Fig 1).

While these experiments clearly show that the GM *M. pingshaense* performs more effectively than the RFP control under the conditions of the trial, this is well short of establishing that this would be true under operational conditions. To raise just one issue, for example, it remains possible that the range of spore concentrations on the black cloths within which the two fungal strains perform differently may be very narrow. Thus, further developmental work will be required to be sure that the GM fungus really is significantly superior to the unmodified form.

Will it work?

Most malariologists consider that new vector control tools are urgently needed, and any that can be shown to be safe and effective should be considered. But it is too early to tell whether the GM *Metarhizium* pioneered by St. Leger's research group will actually meet these criteria. Its success in reducing vector populations within a contained semi-field setting is promising, but will it work under more natural conditions? Achieving a population crash in an experimental system is an important milestone, but it's just the first of many steps required to demonstrate efficacy in the field sufficient to justify an operational deployment on which lives will depend and millions of dollars will be spent. The most obvious limitation of the work reported by Lovett *et al.* (2019) is that no immigration of mosquitoes from outside the simulated domestic environment was permitted. This is an obvious next step.

I talked to Professor Richard Samuels (Universidade Estadual do Norte Fluminense [UENF], Brazil) who is enthusiastic about the future of biological control methods for controlling mosquitoes. He thinks that the potential benefits could be very great, not only for malaria control but for other insect vector-borne diseases too. Since 2008, Samuels has been using a native Brazilian strain of *Metarhizium anisopliae* (not genetically manipulated) in experimental work in Rio State, Brazil, to develop a rather similar biological control method against another mosquito, the Dengue and Zika virus vector, *Aedes aegypti* (Paula *et al.*, 2008; 2013, Silva *et al.*, 2018). The fungus is quite effective against *Ae. aegypti*, where it can reduce the number of *Aedes* eggs by more than half with fungus-impregnated traps containing a black cloth that is much smaller than the 4 m^2 ones used in the *Anopheles* study.

Samuels commented that Lovett *et al.*'s work is interesting but wonders whether it is really necessary to use GM fungus. Like me, he wonders if the "GM" label might prove to be a heavy public-relations burden for this promising technique to carry. Lovett *et al.* (2019) found that the GM *Metarhizium*-treated black cloths in their Burkina Faso experiments remained effective much longer than did the RFP controls, not because the spores survived longer but because of their greater virulence. "If this is the case", muses Samuels, "then maybe the benefits of the GM fungus might not be so great. Why couldn't you just use more non-GM spores in the first place?"

Environmental safety and ethics

Lovett *et al.*'s (2019) approach corresponds to what has been called the "inundative augmentation" version of biological control (Shah and Pell, 2003), where natural enemies, to which the target species is normally exposed only in insufficient numbers, are released into the environment to enhance the controlling population at the time they are needed. This strategy is widely used with entomopathogenic microbes; in effect, the control agent is used in much the same way as a non-persistent insecticide. Unlike so-called "classical" biological control, there is no expectation that the release should lead to establishment of a permanent population of the agent sufficient to control the target. Although it might be viewed as a disadvantage that a permanent reduction of the mosquito population is not achieved, so that repeat applications of the control organism are required, the contrary view is that failure to establish a local population is actually a benefit, as it means that the GM biological control agent does not "escape" into the environment, from which it can no longer be recalled. Lovett *et al.* (2019) point out that the application strategy they use makes it particularly likely that the fungus will not "escape", since conidia of the GM fungus persist for only a few weeks on the pre-prepared black cloth lures.

A point that Lovett *et al.* (2019) don't discuss in their paper, however, is that *Metarhizium* is a soil fungus, adapted to live in the rhizosphere (Hu and St. Leger, 2002). Thus, if unplanned leakage of the GM fungus does occur (perhaps associated with local manufacture or disposal of black cloth lures) it remains possible that the

agent could enter in the soil and remain there for some time. Hu and St. Leger (2002) were able to recover a genetically-marked strain of *M. anisopliae* from the soil 2 years after its release. Since the Hybrid toxin gene product is toxic to a wide range of insects, transfer of the transgene to other soil fungi could have potentially serious consequences. Although Hu and St. Leger (2002) found no evidence of recombination in the soil in their experiments (which used a different isolate of *Metarhizium*), the possibility of genetic exchange of the Hybrid transgene with other more or less closely-related fungi that attack other groups of insects with different specificity to that *M. pingshaense* should be positively excluded by appropriately designed experimental work.

Lovett *et al.* (2019) comment that, subject to appropriate registration, transgenic Hybrid-toxin-expressing *Metarhizium* could be rapidly put into use against mosquitoes on an operational scale. They note that since other *Metarhizium* biopesticides are already registered for agricultural use in a number of African countries, regulatory approval could well prove to be straightforward. They also note that the necessary products (i.e. fungus-impregnated cloth lures) can synergistically integrate with existing chemical control techniques to avert further development of insecticide resistance. It must be admitted that these are potentially strong points in favour of the toxin-expressing fungus.

On the other hand, a problem that is likely to arise early during development is the question of whether releasing a toxin-expressing GM organism into the environment is considered a good idea by local residents. Some form of public consultation is necessary. To date, most public debate of this question has centred on GM crop plants. The most widely grown transgenic plants are those that express the insect-specific *Bacillus thuringiensis* (Bt) toxin, so that in many ways, St. Leger's Hybrid toxin-expressing *Metarhizium* represents a public-interest issue that is quite similar. Transgenic crops are now widely grown in many parts of the world, including sub-Saharan Africa, and Burkina Faso, where Lovett *et al.*'s trials were conducted, is among the leading African adopters of GM agriculture, permitting a number of transgenic crops to be grown, and 0.4 MHa (7% of arable land) is already devoted to GM agriculture in that country (Royal Society, 2017).

However, GM crops don't get such a friendly reception all over the continent, as a glance at the internet reveals, and other African countries might view the prospect of using a GM control agent less positively. Moreover, it's also necessary to think about the attitudes of those who pay for malaria control. Since most countries with a high burden of malaria have limited finances available for malaria control, they are heavily reliant on international donors for funding. In Burkina Faso, for example, 44% of all malaria control expenditure during 2000-2016 came from development assistance (Haakenstad, *et al.*, 2019). It's well known that European countries are much less keen on GM than other regions of the world, and this might influence their attitude to paying for the use a GM fungus-based programme on mosquito control.

So is GM *Metarhizium* a good idea? Further developmental work is required to be sure that it is effective. It's also necessary to show that neither the toxin-expressing fungus itself, nor its transgene, will "leak" into the local environment. If it works and is ecologically safe, then the Hybrid-expressing fungus has potential great advantages, in that it can readily be integrated with existing methods of control and may help to delay or even reverse the spread of pyrethroid resistance. But in the end, approval will depend on the GM *Metarhizium* surviving an appropriate environmental risk assessment. Crucially, this assessment should be based on data, not opinion.

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I thank Ray St. Leger (University of Maryland, USA) for kindly answering my questions about his research group's work; I ought to admit that I have known Ray for many years and that he did his PhD in the Department of Biology and Biochemistry at Bath where I work (although not under my direction). I also thank Tariq Butt (Swansea University, UK), Keith Charnley (University of Bath, UK), Heather Ferguson (University of Glasgow, UK) and Richard Samuels (Universidade Estadual do Norte Fluminense [UENF], Brazil) for valuable comments and advice.

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Participants on the Kipepeo Workshop, with their tutors - Hussein Aden, Laban Njoroge, Margaret and John Cooper.

Invertebrate health and the contribution of butterfly farming to conservation: synergies on the Kenyan coast

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Butterfly farming has become a well-established mini-livestock industry since the oil crisis in the 1970s. Its origin in those difficult days is a happy example of a completely unintended consequence. A chain of events involving Israel, the USA, the Yom Kippur war and the oil-producing countries of the Middle East led to an oil embargo and the quadrupling of energy costs. Knock-on effects bankrupted the tomato-growing industry on the island of Guernsey, which was heavily dependent on heated greenhouses. David Lowe FRES, a Guernsey banker, had the inspirational idea of using them to breed and exhibit tropical butterflies. His efforts were a success and live butterfly exhibits or butterfly houses are now found throughout the world (Wikipedia, 2019).

This has been a welcome development. As Sir David Attenborough has said, "Watching butterflies is good for you". This view has been endorsed by Stephen Buckley, the Head of Information for the mental health organisation *Mind* (Butterfly Conservation, 2018). The exhibit industry has provided the opportunity to watch butterflies to millions, and presents unique facilities for public education on the value of insects and their importance for, and contributions to, conservation. It has also provided potentially sustainable livelihoods to rural farmers in tropical countries.

Despite these benefits, butterfly farming and the exhibit industry have attracted criticism. Concerns range from the impacts of exploiting wild populations, through the potential of introducing invasive species and diseases and damaging effects of butterfly releases on ceremonial occasions, to issues of alleged cruel treatment during breeding, transportation and confinement (e.g. Boppré and Vane-Wright (2012, 2019)). Both exhibitors and suppliers of live butterflies have also been blamed for neglecting to take sufficient advantage of the opportunities for synergies with scientific research, education and conservation. In this article we describe efforts to meet these critiques in association with the National Museums of Kenya, Nature Kenya, and a community-based butterfly farm on the Kenyan coast.

The farm is known as Kipepeo, the Swahili word for butterfly. It was launched in 1993 with a small grant from the Global Environment Facility, an international biodiversity conservation funding agency established during the Rio Earth Conference in 1992. Focused on Arabuko-Sokoke forest, famous for its endangered birds, Kipepeo sought to reverse hostile local

attitudes towards its conservation by enabling adjacent communities to benefit financially through the production of forest butterfly pupae for the exhibit industry in Europe and the USA. 2019 marks the 25th anniversary of its first shipment. It has since generated almost 2 million US$ in exports for Kenya and over 800,000 US$ for forest-adjacent farmers, all from an initial investment of 50,000 US$. Impacts on community attitudes to the conservation of Arabuko-Sokoke are harder to measure than dollar earnings, but surveys suggest these have been positive and Kipepeo farmers have been leaders in efforts to protect the forest from excisions (Gordon and Ayiemba, 2003) and seismic exploration for oil (the London Times, 2014). A butterfly inventory was carried out in 1993 before farming began; the rank abundances of harvested and unharvested species showed no changes when this survey was repeated in 1997, indicating no adverse impacts on wild populations (Gordon and Ayiemba, 2003).

The authors of this article first met when John and Margaret Cooper visited Ian Gordon in Kipepeo shortly after escaping the genocide violence in Rwanda in 1994. They rejoined forces in February 2018 when they organised at Kipepeo a "One-Day Workshop on the Health and Welfare of Invertebrates, Particularly Butterflies". The location was the grounds of the Gedi Ruins Historical Site, near the coastal town of Malindi in Kenya. The Historical Site consists of the remains of a Swahili town; from the 12th to the 17th century, Gedi was a thriving community on the coast of East Africa. The Workshop had been approved by the Director-General of the National Museums of Kenya, Dr Mzalendo Kibunjia, and it was run under the direction of staff of Kipepeo and Mombasa Butterfly House (MBH). The tutors and demonstrators were Mr Hussein Aden, Mr Laban Njoroge, Mr Mike Clifton, Professor John E Cooper and Mrs Margaret E Cooper. The lectures and practical sessions were conducted in a mixture of English and Swahili. This Workshop was primarily intended for the staff of MBH but also attracted others who work with invertebrates or have an interest in their care in captivity and their conservation in the wild. These included two Kenyan-registered veterinary surgeons involved in the licensing of animals and animal products. In all, 41 people attended.

Hussein Aden and Laban Njoroge search for larvae on a food-plant.

The first lecture, by Mr Laban Njoroge, provided an illustrated overview of invertebrates – their characteristics, varied life cycles and biology, importance in terms of biodiversity, and relevance to humans.

Margaret Cooper gave a lecture, mainly in Swahili, on "Sheria ya wadudu; invertebrate law". She started by reminding the audience that while the scientific descriptions and names of invertebrates are well defined, the terminology in legislation can be vague and variable. Invertebrates of various species fall into categories such as pest, pet, exhibit, research, wildlife, food source and, as such, can be regulated by different laws. For this reason, it is essential to read the definition section of any legislation to determine whether it is applicable in any particular circumstances. There are many aspects of law that can apply to invertebrates – keeping (pets, zoos, shops, research studies), conservation, trade, movement, veterinary, animal health, disease control, import/export, plant health, food safety, health and safety. While there is only limited legislation on the welfare of invertebrates (compared with vertebrates), conservation and trade laws (national and international) apply to many species, including butterflies, that are at risk of extinction. Biosecurity is also an important factor in international trade. Veterinarians attending the Kipepeo Workshop pointed out that they inspect shipments of butterflies prior to providing an export health certificate. Health and safety law is an important tool for protecting employees who work with invertebrates, some of which can cause injury, allergies or pose other risks.

In a presentation entitled "Invertebrate health", John Cooper outlined the long history of awareness of diseases in domesticated species, such as bees and silkworms. Two thousand years ago, for example, Pliny the Elder (23–79) wrote about brood diseases of honeybees. John applauded the studies of Louis Pasteur (1822–1895), a chemist by training, on the causes of morbidity and mortality of the Mulberry silkworm (*Bombyx mori*) – a species that he had never before seen until introduced to a colony by Jean-


Left: John Cooper teaches a registrant how to take a swab from fruit in the butterfly enclosure, watched intently by butterfly farmers; Right: Mike Clifton (right) demonstrates the anatomical features of a butterfly to two butterfly farmers, each equipped with a plastic hand-lens.

Henri Fabre (1823-1915), "the father of entomology". John stressed that, as in other taxa, diseases of invertebrates could be infectious or non-infectious and are sometimes multifactorial, involving a combination of pathogens, genetics and environmental stressors (Cooper, 1980). Investigations on, and diagnosis of, insect diseases follows a similar line to such procedures in vertebrate animals – history, assessment of environment, observation, clinical and *post-mortem* examination, and laboratory investigations (Cooper and Cunningham, 1991). Prevention of diseases depends upon the quarantining of incoming stock and subsequent good management. Once a disease occurs, even before a definite diagnosis is made, affected insects should be isolated and/or culled and every effort made to reduce overcrowding. Changes to the environment can often prove advantageous in disease control: for example, lowering of relative humidity to reduce transmission of bacteria and fungi (Cooper, 2012). Hygiene, including the careful and correct use of appropriate disinfectants, sterilising, and disposal of equipment between batches, is vital (Cooper and Dombrowski, 2012).

The final session of the morning comprised a description of the work of Kipepeo and of MBH by Hussein Aden. Hussein said that Kipepeo was established by Nature Kenya in June 1993 and is now administered by the National Museums of Kenya (NMK). It initially received a grant from the UNDP Global Environmental Facility (GEF) NGP Small Grants Program and subsequently from a number of sources, including Brookfield Zoo (USA), IUCN Netherlands Committee, USAID, and the Grassroots Grants Program of the Japanese Embassy. Hussein explained that Kipepeo involves farmers who live on the margins of the Arabuko-Sokoke Forest as an incentive for supporting its conservation. These people, a number of whom were present at the workshop, rear pupae of certain species of butterfly. The staff at Gedi purchase the pupae from the farmers and then pack them for dispatch to butterfly houses in Europe and North America. Kipepeo also runs a small butterfly house at Gedi, where visitors can see free-flying butterflies and ova, larvae and pupae, and purchase locally produced items, including honey.

The afternoon session comprised practical work. A tour to see live butterflies and to view enclosures was led by Hussein and members of Kipepeo staff. The guests were able to observe butterflies at different stages of their life cycle and were told about the food plants used to rear larvae and the management methods employed. Local farmers in the group answered questions, with debate about how best to exclude parasitoids, such as certain Hymenoptera, and predators, including Indian house crows (*Corvus splendens*). The question of hygiene, especially the safe disposal of empty pupal cases and possibly contaminated cage "furniture", was raised.

The programme for the rest of the afternoon focused on health, welfare and disease. The importance of introducing and adhering to codes of practice when managing invertebrates had been stressed nearly thirty years ago at a conference in London (Collins, 1990) and was endorsed by the production of codes of practice for inspectors under the British Zoo Licensing Act (National Federation of Zoos, 1990a,b). It is clear that ethics, as well as any legal constraints, should be considered an integral part of butterfly management (Cooper, 1990; Dombrowski and Cooper, 2012).

Laban Njoroge and John Cooper then demonstrated dissection and investigation of butterflies. The external and internal structure of these insects was explained, with reference to Laban Njoroge's lecture earlier in the day, and the various handouts in the registrants' pack – many of which depicted gross and microscopical anatomy of Lepidoptera and other taxa. John and Laban demonstrated the gross anatomy of a larva, a pupa and an imago and made smears of haemolymph for staining and microscopical examination. A range of portable microscopes was used, illustrating how relatively easily health studies could be performed in the field.

A final discussion included the need for more such training, via both hands-on workshops at Kipepeo and more in-depth scientific teaching about invertebrates at the National Museum of Kenya in Nairobi. The hosts at Gedi were thanked for their hospitality and the hard work that they had put into planning the day. Amongst those given special recognition were Shadrack Kombe from the Gedi Historical Site and interns Hilda Ben and Hudson Mkoka. Organisations and individuals who had helped fund the workshop, or gave material assistance in other ways, were also acknowledged, including the Zoological Society of London, the Veterinary Invertebrate Society, Dr John Ballany, Vetark Professional, Mr Paul Pearce-Kelly, Ms Sarah Pellett, Ms Sally Dowsett and Mrs Jeannie Knocker.

To the best of our knowledge, this workshop was the first attempt to involve veterinary scientists, as well as biologists and "farmers", in investigating the health and welfare of butterflies, thereby helping to improve product quality. However, interest in the health and diseases of captive butterflies is

not new. Entomologists who bred Lepidoptera for study or sale in the 19th and 20th centuries were very aware of the many threats to the health of their charges, ranging from parasitic wasps and flies to hypothermia (see, for example, Newman 1953). Research by far-sighted entomologists such as Brian Gardiner and Claude Rivers began to reveal a whole spectrum of micro-organisms that could affect butterflies, including bacteria, fungi, protozoa and viruses, and practical advice was formulated as to how to tackle these threats. In more recent years studies on organisms that infect invertebrates (including Lepidoptera), such as *Spiroplasma* and *Wolbachia*, have shown just how complex host–parasitoid relations are, and have produced many unexpected outcomes. For example, *Spiroplasma* is maternally inherited in the African queen butterfly (*Danaus chrysippus*) and kills all the sons of infected females (Smith et al. 2016), leading to distorted sex ratios and potentially to the disappearance of the species from certain locations.

There is considerable interest at present in the microbiota of insects as evidenced, for example, by a recent meeting in Liverpool (Reynolds, 2018). It was stressed at this meeting that, although we still know relatively little about how insects defend themselves against parasitoids, new techniques are changing conventional thinking. For instance, recent research using single cell transcriptomics and cell sorting has led to the recognition in some species of insect of several types of haemocyte. Nevertheless, knowledge of butterfly diseases remains rudimentary and there is a need for studies on free-living butterflies as well as those kept in captivity. The decline in the wild of certain species, such as the Monarch (*Danaus plexippus*), has prompted investigation of the possible role in mortality of pathogens, probably in combination with the effects of deforestation, predation, hypothermia and desiccation (Aguirre et al, 2004).

One of the butterfly farmers tries her hand with a field microscope.

In the report of the Liverpool meeting cited above it was suggested that perhaps the most cheering aspect of the current interest in insect–microbe relations is the involvement of people from many different disciplines – entomologists, parasitologists, geneticists, biochemists, molecular biologists, conservation biologists and both medical and veterinary pathologists. It is our hope that the Kipepeo workshop will contribute in a small way to this by stimulating more research on invertebrate health, both in the butterfly industry and beyond.

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ENTEAM

Richard Harrington

The RHS Entomology Team.
Left to Right: Stephanie Bird, Hayley Jones, Imogen Cavadino, Andy Salisbury, Fryni Drizou and Magdalena Boshoff.

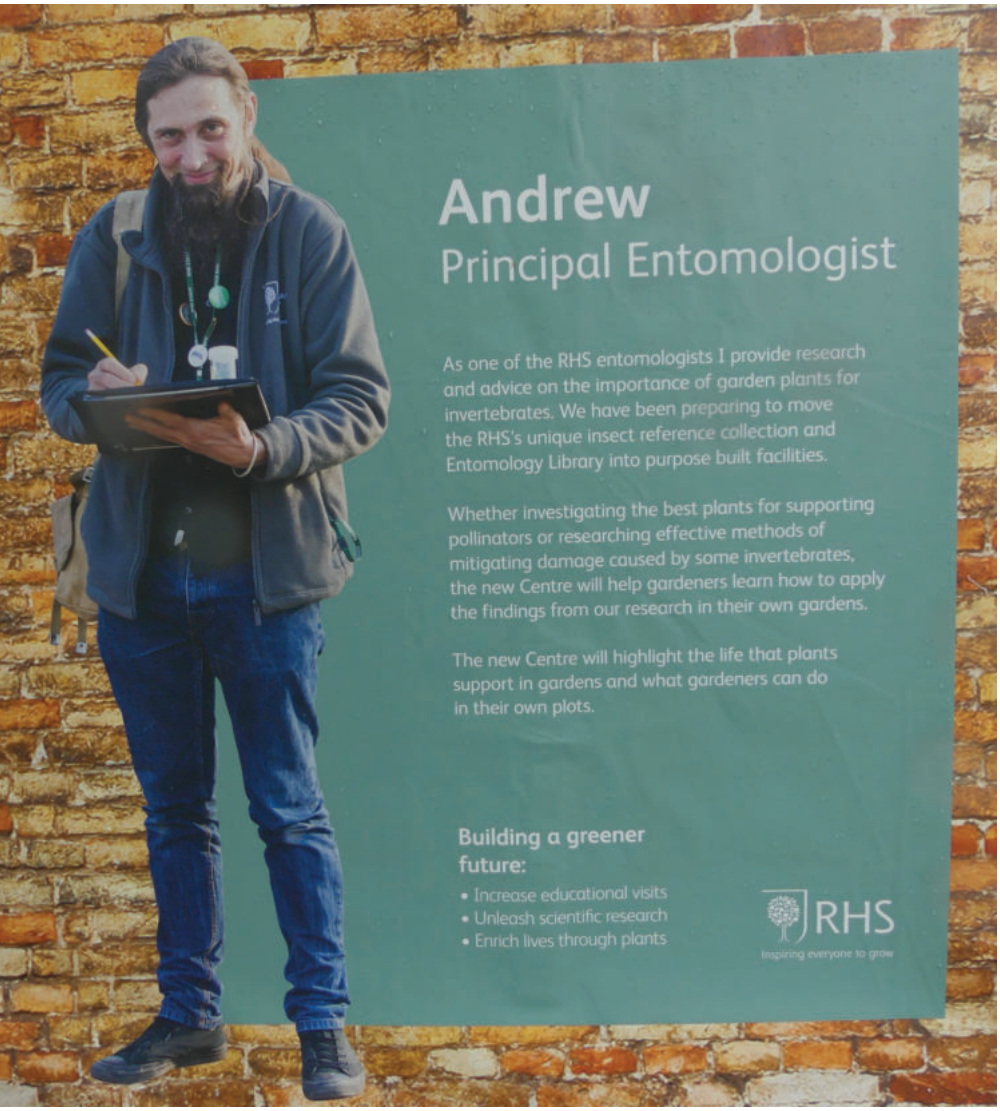
RHS Wisley

The Royal Horticultural Society's entomologists last featured in *Antenna* in 2012 (*Antenna* 36(2) 102–112). Then there were two of them plus a research assistant and a volunteer. Now they have grown to seven on site, with some co-supervised PhD students at various universities. They are in demand – the RHS has recently passed the milestone of half a million members, and private gardens occupy about 4% of the UK's land mass. The RHS itself owns five gardens, Wisley (Surrey), Hyde Hall (Essex), Rosemoor (Devon), Harlow Carr (North Yorkshire) and Bridgewater (Greater Manchester). RHS members submit roughly 5,000 queries a year to the team. They deal with these on a rota basis, which takes each of them roughly a day and a half a week from spring to autumn and a couple of hours a week in winter. They aim to provide a response within a week. These queries cover not only insects, but other invertebrates and, indeed, vertebrates. Their research, though, concentrates on invertebrates. The most frequent question is "what has eaten this?" and the most frequent answer is "slugs or snails". Chafer grubs in lawns also feature strongly, and a hot topic in recent years has been the caterpillar of the box tree moth, *Cydalima perspectalis* (Lepidoptera: Crambidae).

The 24-hectare site at Wisley is a fabulous and inspiring place to work. A new visitor centre has recently opened and a new science centre is under construction, with the expectation of occupation towards the end of 2020. Together, these projects represent a £100 million investment. In the meantime, the entomology team resides in the beautiful main house, looking like a half-timbered Tudor building but constructed between 1914 and 1916.

Principal Entomologist is Andy Salisbury, who has worked at Wisley for 21 years, during which time he completed a PhD at Rothamsted and Imperial College on scarlet lily beetle, *Lilioceris lilii* (Coleoptera: Chrysomelidae). Andy summarised the team's research mission as doing good science, getting it published and translating it for gardeners. He was the lead researcher in the well-publicised "Plants for Bugs" project, where native plants, near-native plants (from the northern hemisphere and closely

Hayley Jones and the model of the new science block.



Andy Salisbury's profile for all to see.

related to natives) and exotic plants were compared as hosts for invertebrates. Several trapping and observation methods were used. Results showed that the best strategy to encourage invertebrates is to plant a mix from different countries and regions, with emphasis given to natives to Britain and the northern hemisphere, although plants from the southern hemisphere can be used to extend the season and provide nectar and pollen for some specific pollinators. Andy has recently been looking at "green walls" for invertebrates, and hopes to engage an MSc student to investigate this little-studied vertical resource more thoroughly.

I asked Andy about the recent news of a webspinner (Embioptera) appearing at Wisley, the first time this order of insects has be found in Britain. They have now thoroughly colonised the tropical orchid service house. They are not pests and are neither being encouraged nor discouraged, but there are protocols in place to avoid them spreading beyond the service house.

Andy also manages an impressive insect collection, started by George Fox Wilson, the first RHS full-time research entomologist, around 1918. It comprises roughly 24,000 specimens, mainly from the UK and related to gardens, and is a useful reference resource for the team.

Agapanthus gall midge, *Enigmadiplosis agapanthi* (Diptera: Cecidomyiidae) was new to science when it was discovered in Britain in 2014 by the RHS. It is specific to *Agapanthus* and an important pest, causing economic loss to nursery growers and cut-flower specialists. Hayley Jones, who joined the RHS team soon after the discovery of the midge, has spent much time researching its biology and distribution in the hope of finding methods to control it. It lays its eggs on flower buds, into which the larvae bore, forming galls that stop the bloom from opening. It is a native of southern Africa and now occurs throughout southern England. Hayley was surprised that it can occur for a large portion of the year outdoors on evergreen *Agapanthus* in Cornwall. The other pests that keep Hayley and her student busy searching for sustainable control methods are the ubiquitous slugs and snails. Hayley has always been keen on enthusing young people about arthropods. She is a STEM (Science, Technology, Engineering and

Anna Platoni engaging the public on the topic of plant–virus–insect interactions at the Cambridge Science Festival.

Mathematics) Ambassador and works with the RHS Education Team. This includes running "slug workshops" for Key Stage 3 and 4 pupils.

One of Hayley's malacological PhD students is Imogen Cavadino. She is also supervised by Gerard Clover (RHS), Helen Roy (Centre for Ecology and Hydrology), Aileen Mill (Newcastle University) and Newcastle University's stalwart of the RES and slug-master general, Gordon Port. Imogen is using a citizen science approach to study slugs in gardens and encourage gardeners to think about slugs as individual species. She is particularly interested in the yellow cellar slug, *Limacus flavus*, and the green cellar slug, *Limacus maculatus*, neither of which is a garden pest and both of which may even be beneficial to gardeners. *Limacus flavus* is thought to have been introduced to Britain in the seventeenth century. *Limacus maculatus* didn't appear until 1970 but can hybridise with *L. flavus* and appears to be rapidly outcompeting it. Both are nocturnal, can be active throughout the year when temperatures are high enough, and can live for several years. Shining a torch around compost heaps, walls or near houses is a good search tactic. You can take part in the survey, which is hosted by iRecord, at www.rhs.org.uk/ slugsurvey. Imogen stresses the importance of invertebrate diversity in gardens and is hoping to understand better the reasons for decline of *L. flavus*. She aims to extend the survey to all slug species in due course.

The RHS's gardens have their own pest and disease problems. Fryni Drizou, who joined the team in June 2018, is first port of call in resolving them, using IPM methodologies wherever possible. She has a particular interest in non-native flatworms, as some species have been recorded in the RHS gardens. Much of Fryni's research is on *Phytophthora* fungi, and she is one of the RHS members of the EU project HOMED (https://www.efi.int/projects/homed-holistic-management-emerging-forest-pests-and-diseases), which aims to provide science-based, innovative, practical methods to assess and control emerging or invasive pests and pathogens threatening EU forests.

Collembola (springtails) are no longer considered to be insects, neither are they pests, apart from *Sminthurus viridis* which causes problems on alfafa and clover in Australia. They have been of interest to Steph Bird, who joined the team in 2015, since studying for her RHS-funded PhD at Roehampton University, supervised by the national recorder for Collembola, Peter Shaw. They are decomposers, and useful indicators of soil health and she would like to make an inventory of those present at Wisley. Steph wants to understand better the impact of garden management practices such as slug control on this beneficial group. She is also researching control of the box tree moth, including parasitoids and nematodes and wants to help the RHS develop an IPM approach to managing both the *C. perspectalis* and the fungal pathogen threats faced by box.

Resources for nematology in the UK have been greatly reduced in recent years, in spite of the importance of nematodes in agriculture and horticulture. Lien Boshoff has been charged with addressing nematode problems for the RHS and is sampling at Wisley to build up a reference collection. This is a huge undertaking, and she is starting by looking on plant roots and foliage, not in the soil. The main nematode query from the public involves stem and bulb eelworm, *Ditylenchus dipsaci*, which has a very broad host range including phlox and narcissus. Foliar leaf and bud eelworm, *Aphelenchoides* sp., comes a close second, often being found on chrysanthemums and begonia. Nematode-related symptoms can be mistaken for those caused by disease, and nutrient or environmental stress. For this reason their presence is often overlooked. Lien hopes that, once a good reference collection has been built up, nematology research can begin in earnest. Whilst some species of nematode are significant pests, others are valuable decomposers and Lien's mission is to make gardeners more aware of this very important group.

I didn't get to meet Anna Platoni as she spends much of her research time at the University of Cambridge, but I gather that she is working on relationships between bumblebees, tomatoes and tomato viruses. She is testing the hypothesis that, whilst the viruses can reduce the number of seeds a tomato plant can produce, they may be able to compensate for this by increasing the attraction of virus-infected tomato plants to bumblebees, thus increasing the number of pollination visits they receive.

Napoleon once described the English as a nation of shopkeepers. Perhaps we Brits are better described as a nation of gardeners. After all, The Union of Shop, Distributive and Allied Workers (USDAW) has 433,000 members against the RHS's half million. Those RHS members are served very well by the entomological and other teams at Wisley HQ, and the physical and mental wellbeing of the nation is all the better for that.

Society News

Council Matters

Timing of the Annual General Meeting

At March 2019 Council, the President put forward a proposal to move the Annual General Meeting (AGM) from a fixed date in June to being held at the Ento conference. The main reason for this is that attendance had declined in recent years and the President wished to make the AGM more interactive and representative of the Society. Dr Murchie commented that this was a recurrent issue since the move from London and had been discussed as part of an updating of the Bye-Laws in 2015. At that time Council had not changed the timing of the AGM for several reasons, including the reporting practicalities, the desire to utilise the Mansion House facilities and that currently there was no voting at the AGM, but rather a reporting of the results of any nominations or ballots. Prof. Field felt that holding the AGM at the Ento conference would also restrict attendance by some members, especially those who had retired and had to pay. Prof. Pickett mentioned that the Charity Commission filing deadline for the annual accounts must occur within six months of the end of the Society's financial year (end February). This means that the AGM would have to be held before the end of August, which would place restrictions on the timing of the Ento' conference.

Council agreed that there was a need to revamp the AGM to make it more inclusive. However given some of the difficulties, Council decided to keep the June date but open up the AGM electronically to Members who cannot attend physically. This will involve video streaming the meeting with questions submitted online. In addition, it was considered that in the future the Society could have an 'open day' aligned to the AGM for members to visit the Mansion House and new Insect Garden, when it is completed. Lastly, an information session will be held at the Ento' conference, where the summary presentations of the Society's business presented at the AGM will be redelivered and officers and staff available to answer any questions.

Governance Review

Dr Tilley (Chief Executive) said that he had been investigating the possibility of an external review of the Society's governance. He said that with new staff in place, now was a good time for reflection and that any review of the Society would be coming from a place of strength and positivity, building on past achievements. Such a review may cover the Society's charitable objectives and public benefit, Council and Committee responsibilities, skills and diversity of Trustees and Committee Members and risk management. He felt that a review at this time would align well with the broader entomological strategy that the Society is pursuing as part of the *Grand Challenges in Entomology* initiative.

Ento'20

Dr Murchie (Hon Secretary) reported that Ento'20 was planned for Penryn Campus of the University of Exeter and that preparation was underway. The date is likely to be the 25-27 August 2020.

Subscriptions

Prof. Pickett presented a report from Finance Committee. Despite investment funds dropping at the start of the year, they had now recovered. The Committee had however reluctantly recommended an increase in annual subscriptions for 2020 to keep pace with inflation. This was a 5% increase for Members and Fellows but the student rate will remain frozen.

Meet the Team

Left to right:

Fran Sconce – Outreach & Engagement Executive

Luke Tilley – Chief Executive

Val McAtear – Librarian

Kirsty Whiteford – Registrar

Jim Hardie – Director of Science (deals with insect identification enquiries)

Sue Ward – Administrator (mainly deals with new membership applications and membership database admin)

Kate Watkiss – Receptionist/Administrator (reception/secretarial duties and support for Sue with the membership database admin)

Monika Wielgus – housekeeper

AGM Award Presentations

The President, Professor Chris Thomas, the retiring Secretary, Dr Archie Murchie, and an appropriate bottle. (© Allan Watt)

The President and the two newly appointed Honorary Fellows, Dr Archie Murchie and Professor Lin Field.

Retiring Secretary, Dr Archie Murchie and his "farewell" cake, with new Secretary Dr Jenni Stockan and Registrar Ms Kirsty Whiteford. (© Allan Watt)

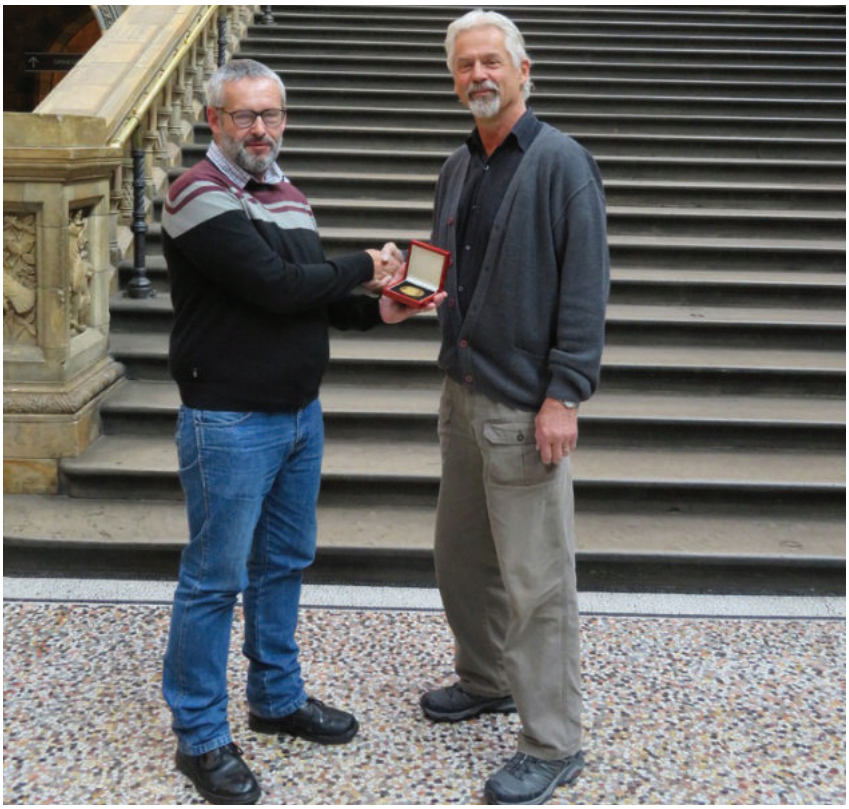
The President with Professor Michael Samways, this year's recipient of the RES/Marsh Christian Award for Conservation. On the right is Mr Nick Carter, a Trustee of the Marsh Christian Trust.

Westwood Medal

Dr Art Borkent (right) was the second recipient of the prestigious "J.O. Westwood Medal", awarded by the Royal Entomological Society for "The best comprehensive taxonomic work on a group of insects, or related arthropods". Art was given the award in recognition of his paper: Borkent, A. 2008. The frog biting midges of the World (Corethrellidae: Diptera). *Zootaxa* **1804**: 1–456.

Unfortunately, at that time (2010), he was unable to attend for a presentation and this was recently done by Dr Ashley Kirk-Spriggs (left), in the Central Hall of the Natural History Museum, London. Art (in collaboration with Patrycja Dominiak), is currently preparing the Ceratopogonidae volume of the Royal Entomological Society's *Handbooks for the Identification of British Insects* series.

Ashley H. Kirk-Spriggs
Senior Curator in Charge of Diptera
and Siphonaptera
Department of Life Sciences
Natural History Museum



Insect Identification by the RES

You may have noticed that the Society's website includes an 'Insect Identification' page. We have been offering this service to the general public probably since the Society began, but recently we have been accepting online submissions. People can send in pictures and details of insects that have caught their eye or have been 'annoying' them. Insect identification has been part of the remit of the Director of Science but, not surprisingly, the number of enquiries has grown and, if the Society is to continue to offer this facility, we need to involve more willing entomologists.

It would be useful if Fellows and Members could indicate an interest in supporting identifications and in which orders/regions they would be willing to specialise. The service is for anyone and we do get requests from across the globe. Over 30% of Fellows/Members reside outside the UK and their input would be particularly welcome along with those with experience abroad.

Many of the images submitted are readily identifiable whilst others are less so, but the majority of enquiries do not require species identification and the group/family is sufficient. Most enquiries are sent to satisfy curiosity but others are concerns about household pests, often unwarranted. People are very satisfied to hear that their fears of a cockroach invasion are probably just a single cockchafer, but equally to know that they need to effect some means of control if furniture beetles are appearing in large numbers. It can be very rewarding as it opens people to the joys of entomology and redresses the balance in confirming/informing that most insects are not harmful.

There are other identification services available online, such as NHM Forum and iSpot, but by offering this service the RES is brought to the notice of thousands of people who would not normally encounter the Society.

The system obviously differs from iRecord in that the majority of queries come from people with little or no knowledge of insects but, when the submission is of interest, they are encouraged to report the sighting to iRecord for inclusion in the BRC/NBN databases. It is thus an educational and useful service to entomology and the public.

The provision of this identification service forms part of the Society's activity for public benefit as an entomological charity.

Anyone interested in participating please contact Jim (jim@royensoc.co.uk) or Luke (luke@royensoc.co.uk).

Jim Hardie – Director of Science and Luke Tilley – Chief Executive

JOURNALS AND LIBRARY

Ethics in Entomology

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"Entomologists, with constantly regarding the beautiful structure of insects, acquire such a kind feeling for them that they seldom or never unnecessarily kill the objects of their study, and almost invariably take much more care than indifferent persons to avoid doing them any injury. And the various schemes which have been invented for killing insects in the most expeditious manner, prove, at least, that the entomologist is not willing to occasion them suffering." Newman (1841)

Entomologists have always valued insects highly, above all things (after all, they are frequently more relatable than our academic colleagues down the hall). But until recently, most of us would have said that the wider public did not share this sentiment, despite 30 years of conservation efforts since E. O. Wilson's wonderful call to arms for 'the little things that run the world' (Wilson 1987). That has all changed in the blink of an eye, with widespread public consternation over reported global trends in insect declines (Basset and Lamarre 2019, Cardoso and Leather 2019). Capitalizing on this out-pouring of public concern, and new-found societal interest in insects, will present incredible new opportunities to promote Entomology more broadly, but it is not going to come without challenges – some of which could reshape the discipline as we know it today.

As senior Editors at *Insect Conservation and Diversity* our *raison d'être* is to promote and disseminate a wider understanding of the importance and conservation of insects. A key foundation of this role, of course, is to ensure that we meet the highest ethical standards in research and publishing. In this regard, one emerging issue that we see is an increasing concern over the ethical treatment of insects in scientific research. Questions such as 'why do we need to kill rare insects if the goal is to conserve them?'; 'why do insects have to suffer cruelly as a result of our research?' and 'why do we need to kill so many non-target insects?' are only going to become more frequent, and more pointed, as public pressure to conserve insects mounts. This will inevitably influence how we go about doing our research, and publishing our results. Readers might well have heard the anecdotal stories of manuscripts reputedly being rejected from unnamed journals because the study methods had killed too many pollinator insects. Students of history might see parallels here in the shifting societal values that led to tightening of regulatory frameworks for the ethical treatment of vertebrates (since the 1980s) and more recently cephalopods and decapod crustaceans (since 2000).

It was with interest, therefore, that *Insect Conservation and Diversity* received a proposal from Bob Fischer (Texas State University) and Brendon Larson (University of Waterloo) to bring a philosophical and social sciences perspective to bear on the issues surrounding animal ethics, as they relate to entomology. The key thesis of Fischer and Larson (2019) is that it is time to consider whether the lives of individual insects matter. Yes, most entomologists value insects, in a broad sense, and indeed follow informal codes of conduct such as not indiscriminately collecting rare insects if this could plausibly lead to population decline or extinction. But these codes only consider insects as general exemplars of their species, or for their general instrumental value within ecosystems, and not as unique individuals (Fischer and Larson 2019). This is quite different from the way society, and science, view many vertebrate animals (think of all the cetacean or primate seminars you have seen, where each study individual is given a unique name). Individual vertebrates are recognised to be sensate, feel pain, reason, demonstrate unique behavioural personalities and, who knows, even have aspirations for the future. Do some, or any, of these considerations about individuals apply to insects? Fischer and Larson (2019) discuss the evidence for individual insects feeling pain, and question the degree of confidence we have in our understanding of insect consciousness. They argue that the case for pain sensation (if not some degree of consciousness) is not obviously any better for crustacea or cephalopods than it should be for insects, and it would be worth rethinking how our ethical codes might be modified to consider insects as individuals.

The foundation for the ethical consideration of individuals, is the so-called '3Rs' of animal use in research: (i) **replace** animals with non-living models, (ii) **reduce** the number of animals used, and (iii) **refine** animal care and use practices so that animals are better off (Fischer and Larson

2019). Demonstrably, many entomologists already do some, or all, of these things on a daily basis in their research. They are, however, not generally implemented or formalized with individual considerations in mind. Fischer and Larson (2019) make the point (which is worth quoting here) that "these guidelines probably would not take the same form as the ones found in vertebrate or crustacean ethical codes, as the difference in confidence about consciousness is relevant to the constraints placed on research: higher confidence in consciousness – and so in the capacity to experience pain – justifies more significant restrictions" (p.176). Accordingly, they propose "that entomologists should aspire to study insects without killing them, to reduce the number of insects they kill, and to refine their methods so that when they do capture or kill insects, they do so in ways that are sensitive to their subjects' well-being" (p.179). As we highlighted with a science haiku ('sciku') when this paper was published (twitter.com/InsectDiversity/status/1126014019062652928):

Because we love them
We need to think carefully
When we collect them

There are many practical ways in which these types of guidelines could be implemented. Lethal sampling methods could be replaced by non-lethal ones, where possible. Lethal approaches could also be modified or replaced with more specific and targeted approaches (e.g., pheromonal attraction). In a world of declining insect populations, it is worth reflecting on the long-term viability of mass trapping approaches that capture one or two orders of magnitude more non-target insects than the actual targets of interest. When such approaches are essential, Fischer and Larson (2019) argue that it would be easier to justify mass-trapping if the use of captured organisms was maximised, such as by creating a register of 'non-target' components of bulk samples that could be used in the future by other researchers. Of course, as we all know, museums around the world are already filled with bulk 'wet collection' accessions of tens of millions of specimens, and these are comparatively rarely used as a resource. Perhaps one outcome of formalizing a 3Rs framework would actually be increasing re-use of archived material. Advances in some or all of these areas would undoubtedly need major new investment in 3Rs strategies.

In the short-term, Drinkwater *et al.* (2019) suggest five pragmatic ways in which individual researchers can improve their own ethical approach to sampling, and reduce harm to insects: (1) conduct a power analysis to determine whether total sampling effort can be reduced; (2) if existing sampling methods have to be used, alter the deployment protocol to reduce by-catch; (3) change to more specific trapping methods to avoid by-catch; (4) make by-catch available for future use; and (5) minimize the suffering of insects during the collection process (modified from Drinkwater *et al.* 2019).

Ultimately, it is up to entomologists to forge a way forward. Fischer and Larson (2019) simply encourage us to view the 3Rs as relevant, and important, to the development of our discipline. So, go ahead and take up the challenge. Engage with Fischer and Larson on the philosophical and societal importance of ethics in entomology, and debate with your colleagues the appropriate framework and actions that should be taken to reduce harm and limit conservation risk.

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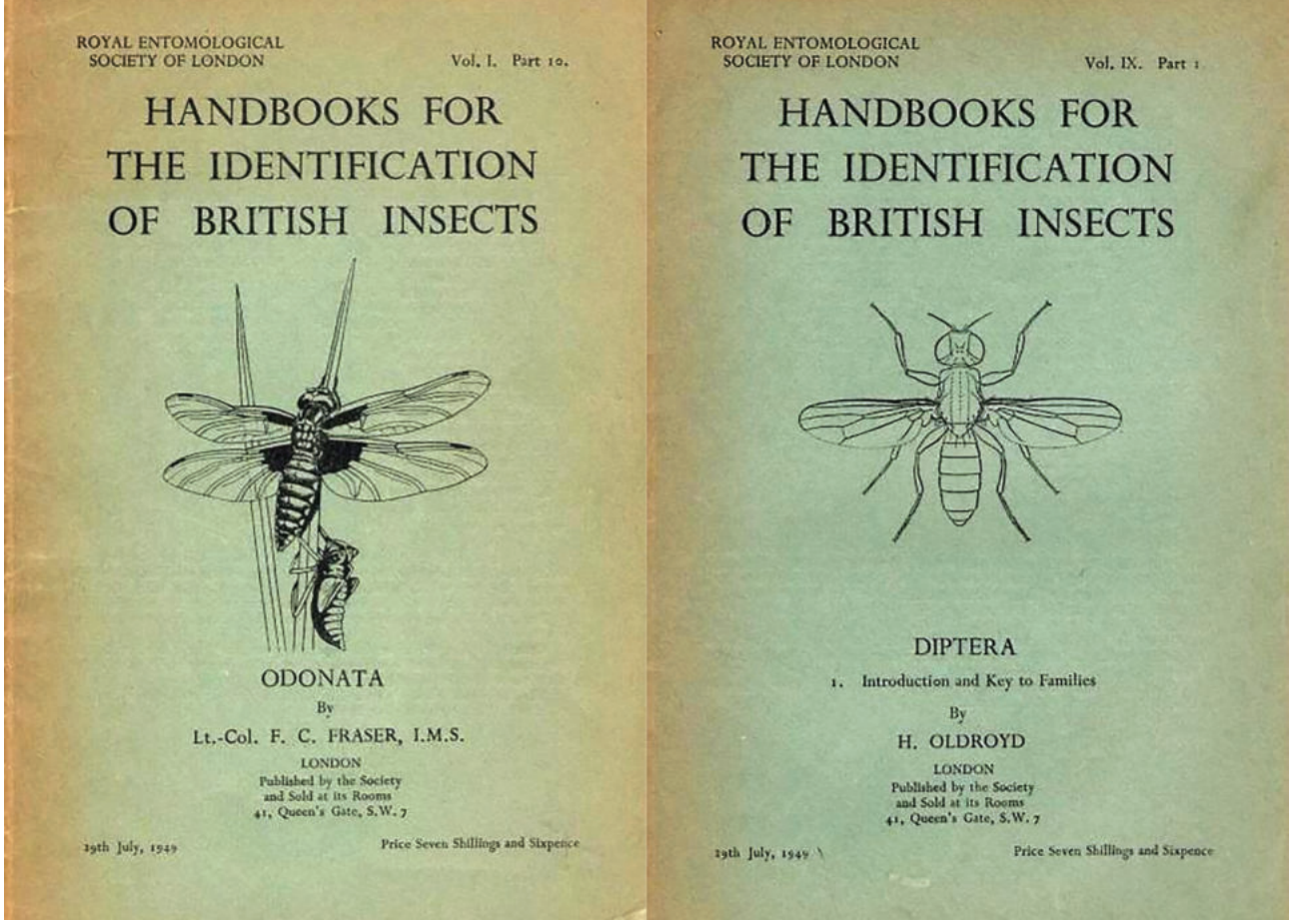


Fig. 1. The first published RES handbooks from July 1949.

RES Handbooks for the Identification of British Insects – 70 years of excellence, and a bright and varied future

Rebecca Farley-Brown, Lin Field, Beulah Garner and Andrew Polaszek

This year marks 70 years since the publication of the first RES handbooks; Volume 1 Part 10 *Odonata* by F.C. Fraser (1st ed.), and Volume 9 Part 1 *Diptera: Introduction and key to families* by H. Oldroyd were apparently published simultaneously on 19th July 1949 (Fig. 1). Ten days later, the third handbook, Volume 1 Part 5 *Dermaptera and Orthoptera* by W.D. Hincks, followed. These volumes essentially set the pattern for the almost 100 handbooks published subsequently. Until very recently, the handbooks were characterised by large blocks of text, hand-drawn diagrammatic illustrations, dichotomous keys, and the standard species-level accounts of distribution, seasonality and other life-history traits of importance and interest.

The aim of the handbooks is to provide illustrated identification keys to the insects of Britain, together with concise morphological, biological and distributional information. The series also includes several check lists of British insects. All books contain line drawings, with the most recent volumes, starting in 2007 with *The Carabidae (ground beetles) of Britain and Ireland* by M. Luff, including colour photographs.

The insect fauna of Britain is probably the best-studied on the planet, having attracted the attention of enthusiasts since the early 18th century or even earlier. Some of our most eminent scientists started as collectors and identifiers of insects, particularly beetles, including Darwin and Wallace.

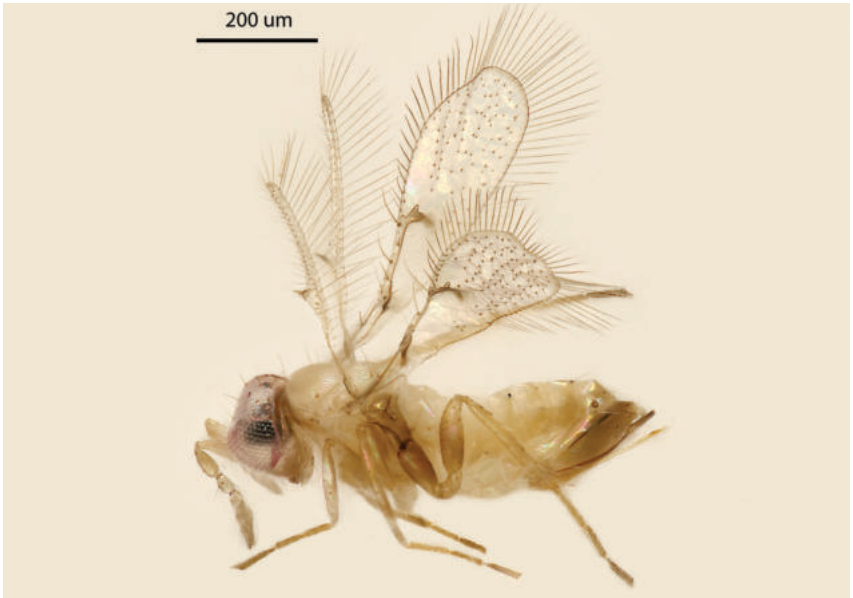


Fig. 2. *Pseudoligosita* sp., a trichogrammatid wasp, after DNA extraction and critical point drying (photo A. Polaszek).

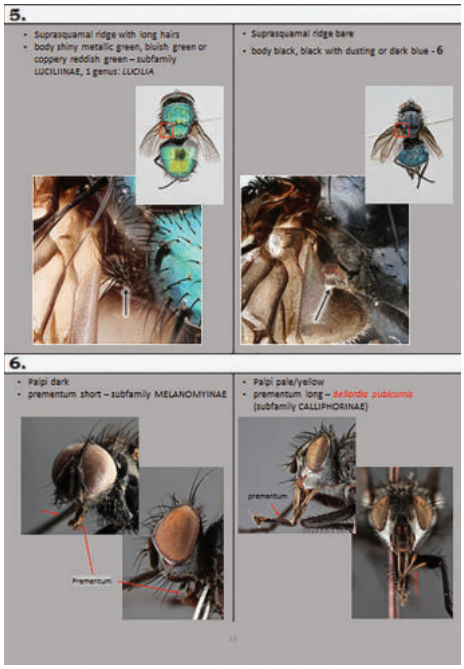


Fig. 3. Couplets from a pictorial dichotomous key to British Calliphoridae (Sivell, in prep.).

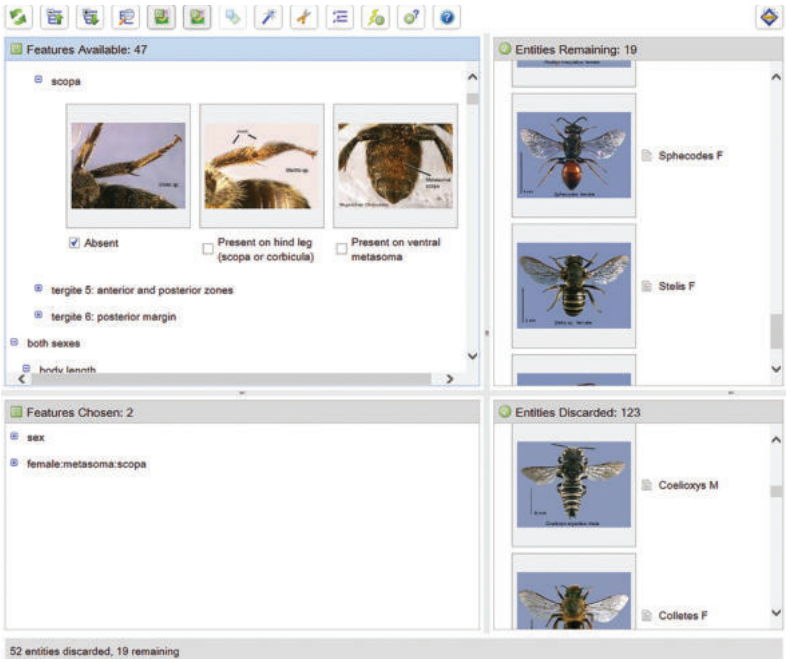


Fig. 4. Screen shot from multiple-entry Lucid© key to British bee genera (Polaszek, in prep.).

Providing enthusiasts, whether amateur or professional, with the means to identify British insect species has always been one of the Society's highest priorities. For about the first 50 years, RES handbooks conformed more or less to the standard layout described above. Colour printing would have made them prohibitively expensive, and photographs of the smallest species were impossible to render adequately because of depth of field problems. Within the last couple of decades microphotography in particular has been revolutionised by the development of focus-stacking (Fig. 2), and the cost of colour printing has fallen dramatically. These innovations, among others, have enabled the introduction of more colour illustration, including photographs, in more recently published handbooks, and certainly appear to be the way forward.

The ability to publish more colour photographs provides another opportunity: while almost every handbook published until now has included only dichotomous keys based on text, often very verbose and with few illustrations, we now have the option to publish largely pictorial keys, an example of which is in Fig. 3. This is from the forthcoming key to British Calliphoridae by Olga Sivell, something of a departure from our usual format. Another relatively recent innovation is the introduction of multiple-entry keys, such as those using Lucid© software. These have the advantage of allowing the user to select which character to study, or to allow the program to select the character with the most discriminatory power. A screen shot from the forthcoming key to British bee genera, which will contain both dichotomous and multiple-entry keys, is shown in Fig 4.

July 2019 saw the publication of our latest handbook – nearly 50 years in preparation. *British Coleoptera larvae* by Hammond *et al.*, edited by Barclay and Garner, was started back in the 1970s. The motivation to write the handbook was the bequest, by F.I. van Emden (1898-1958, and father of "our" H.F. van Emden) of 6,500 vials and 2,400 slides of beetle larvae to the Natural History Museum. After a succession of stops and starts, authors and reviewers, work on the handbook stopped for several years until the current editors took the task on in 2013 and brought it to completion (Fig. 5), finally fulfilling the requirements of F.I. van Emden's bequest.

Fig. 5. Hammond *et al.* 2019, edited by Barclay & Garner, *British Coleoptera larvae*.

Whatever appropriate new technologies come along to make the job of identifying our British insect species easier, wherever possible and appropriate, the RES will adopt those technologies, and adapt our methods of production and dissemination accordingly. We look towards the coming 70 years of RES handbooks, in whatever form they will take.

Details of the handbooks can be found at https://www.royensoc.co.uk/ publications/ handbooks.

SOCIETY MEETINGS

Postgraduate Forum

University of York, 21st-22nd March 2019

Molly Rogers

The Postgraduate Reps Adam Bakewell, Molly Rogers and Roberto Padovani welcoming delegates to the PG Forum.

The PG Forum provides an excellent opportunity for students to network with each other and share ideas. This year's forum was well attended, with representatives from more than 20 institutions across the UK and further afield. Both days played host to many discussions and led to numerous potential future collaborations.

We heard 18 student presentations and viewed 11 posters on a huge variety of subjects, from slug control to butterfly population dynamics. The standard of presentations was very high and the diversity of subject matter gave delegates an insight into a huge variety of unfamiliar fields within entomology.

Prizes were awarded for the top three talks and the top two posters, and these were voted on by the delegates. A list of the prize winners and the titles of their presentations can be seen in the box below. Congratulations to all of the winners!

We were very fortunate to welcome four fantastic plenary speakers:

Dr William Foster (University of Cambridge) opened the forum with an interesting and amusing presentation on the joy of insect watching. He discussed his work over the years on marine insects, a subject which was alien to many of the delegates, and later his work using aphids as a study system for social behaviour. William has enjoyed a long career at the University of Cambridge and his work as a curator of insects provided the delegates with an example of the variety of directions a career in academia can take you.

Dr Seirian Sumner (University College London) shared her adventures in #Wasplove and her efforts in convincing the public that wasps aren't all bad! Seirian does a huge amount of public engagement in entomology, and it was inspiring to hear about her work with Soapbox Science and the Big Wasp Survey. She also discussed her research into behavioural plasticity and social evolution, and delivered a fascinating and memorable presentation about the variation of social behaviour between different species of wasp, and why this makes them a perfect system to study the evolution of social behaviour.

Dr Kanchon Dasmahapatra (University of York) began the second day with a presentation about his research into the process of speciation, using heliconiine and ithomiine butterflies. He uses high throughput sequencing approaches to examine the genomes of the butterflies, and has found that some adaptive colour-pattern genes have been shared between species through hybridisation. Kanchon also spoke about his career progression, and gave the delegates some invaluable advice about pursuing a career in academia and what to expect when applying for grants and positions later on in their careers.

Dr Ailie Robinson (London School of Hygiene and Tropical Medicine) gave a useful insight as an early career researcher, having completed her PhD in 2017. She also mentioned how useful the PG Forum had been to her when she attended as a PhD student back in 2016. Her work currently centres around the biology and control of *Musca sorbens*, a fly species thought to be a vector of trachoma. Ailie also discussed her previous work on parasite manipulation, namely how *Plasmodium* can alter the odour compounds produced by humans in order to make them more attractive to *Anopheles* mosquitoes.

All of the plenary talks were very inspirational, and delegates had the chance to discuss their ideas and ask for advice from these experienced scientists.

We are very grateful to our sponsors, Koppert and Watkins and Doncaster, for their support, without which we wouldn't have been able to have made the forum the success it was.

Prize Winners

Talks:

1st – Jordan Cuff (Cardiff University) – A rapid streamlined protocol to determine macronutrient content in macroarthropods

2nd – Robert Paton (University of Oxford) – Reproductive interface between the vectors *Aedes aegypti* and *Aedes albopictus*: competition, coexistence and epidemiology

3rd – Stephanie Rogers (University of Cambridge, Entocycle) – Plasticity in the melanisation of *Harmonia axyridis* pupae in response to temperature

Posters:

1st – Theodora Commandeur (Newcastle University) – Chronic bee paralysis virus: transmission and infection routes

2nd – Imogen Cavadino (Royal Horticultural Society) – Garden gastropods: slug and snail diversity in UK gardens

How dung beetles orientate

Verrall Lecture 2019 by Prof. Marie Dacke

University of Lund, Sweden

Archie K. Murchie

(Honorary Secretary)

On Wednesday 6th March 2019, Dr Tim Littlewood (Head of Life Sciences) gave the Verrall Lecture audience a warm welcome to the Natural History Museum. He explained the importance of the Museum's entomological collection, going right back to Hans Sloane's day. He said that of Sloane's thousands of insect specimens, sadly not many remain, which was due to an unfortunate tale of rivalry, drunkenness and mis-curation. However, Tim informed the audience that matters have since improved at the Museum. The Society's President, Prof. Chris Thomas, gave a brief introduction to the speaker. Prof. Marie Dacke is a neurobiologist based at the University of Lund, Sweden and, impressively, winner of the Ig Nobel prize (achievements that make people laugh, and then think) for her work on dung beetles. She has previously spoken at the Society's Insect Behaviour SIG (see *Antenna* 42(3), which has a dung beetle (and elephant's foot) on the cover).

Prof. Dacke explained that dung beetles are found in all continents except for Antarctica. Approximately ten percent have followed a strategy of taking dung, rolling it away and burying it. Dung pats can attract hundreds of beetles in a day, so competition for dung is intensive. Beetles can also steal from their rivals. It is therefore important for the beetles to maximise the distance from the dung pile to get away from competitors. The most efficient path is a straight line. This seems simple but can be a difficult task. Prof. Dacke showed a video of humans unsuccessfully trying to move backwards in a straight line. People lost in forests and deserts will typically wander in circles. Dung beetles, on the other hand, have an active compass system. Teasing apart the mechanisms underlying this compass system has formed the basis of much of Marie's research.

The first step was to examine the importance of the sun for orientation. Many animals use the sun as a compass. Marie explained that she won the Ig Nobel for putting little caps on beetles to prevent them seeing the sky. The classical way to prove that the sun is used for navigation is to use a mirror. Sure enough, the beetles reversed direction when a mirror was used as a false sun. In addition, when the sun is not visible due to clouds, the beetles can use polarised light. Circles of polarised light emanate from around the sun. This can be tested using a polarising filter. When the filter was rotated, the beetles changed direction by 90 degrees. Further to these cues, the beetles can use light intensity and colour. Beetles can

L to R, RES President Chris Thomas, Chris Lyal (NHM), Marie Dacke (Verrall lecturer) and Tim Littlewood (Head of Life Sciences, NHM).

also use a wind compass when the sun is directly overhead making it difficult for them to differentiate sunlight-directional cues. Dung beetles thus have a dynamic system depending on circumstances. However, they use one cue at a time for orientation, following a set hierarchy. There was no indication of landmark orientation nor notice taken even of elephants (the original source of the dung in many of Marie's studies). Marie did touch upon how dung beetles cope with obstacles, showing how a forest dung beetle dragged the dung ball, with a leading leg that was used to pull itself over sticks and branches.

What about low light levels? How do they face this challenge? The dung beetles that Marie studies have eyes both on top and on the underside of their head. She does not yet know what the ventral eyes are for, but it could be flight or ground orientation. The eyes of nocturnal species are larger. These beetles can orientate using the moon, as well as the much weaker polarisation patterns at night. Without the moon, beetles can orientate using the stars. Marie demonstrated the importance of the Milky Way for beetle orientation, using the planetarium in Johannesburg, whereby the 'stars' could be turned off one by one. Also, in October in South Africa the Milky Way is close to the horizon and the beetles cannot use it for navigation, whereas in February the Milky Way is higher in the sky and the beetles orientate as normal.

Ninety percent of Europe is light polluted. Surprisingly, there was no difference between the beetles' performance in light-polluted areas and in the wild. The beetles use a snapshot compass. During a little rotation dance on top of the dung ball, they take a snapshot of the visual cues used for orientation. It seems that beetles can use artificial light sources for orientation, although this is only possible for short movements.

Marie finished her talk by explaining some of the applied aspects of her findings. She mentioned the mechanisms that bees use to navigate, and risks to pollinators by factors that impinge on these. Her work is also relevant to improving navigation sensors in mobile phones and other devices. The step-wise process by which beetles take information from the environment and process it into a single output has relevance for artificial intelligence systems, which need to follow a similar process.

After an enthusiastic question and answer session with the audience, the President thanked Marie for her elegant work and fascinating talk. He then presented her with the President's Medal on behalf of the Society. The audience retired to the Verrall Supper and I know continued to enthuse about the fascinating world of dung beetles and their compasses.

Left: Marie Dacke with a 'capped' dung beetle in the background. Dung beetles wearing such caps cannot orientate using sunlight; Right: Marie Dacke with the President, after receiving the President's Medal.

Insect Data Special Interest Group

University of Hull, 23rd October 2018

Jenni Stockan

Convenor James Gilbert opened the inaugural Insect Data SIG by outlining some of the data challenges in entomology, from the sheer diversity of disciplines to peculiarities unique to insect data. These include taxonomic difficulties and underrepresentation of insect data in broader databases. He asked how we might best use new and improving resources, such as published databases and increased capacity, generation and storage, to maximum effect. Every delegate then presented a two-minute flash talk to describe their background and interests, the types of data they work with and the issues and challenges this involves. This was a useful way to identify common problems in relation to insect data but also to spot networking opportunities based on shared interests.

The first plenary was from David Roy (Biological Records Centre) who discussed the importance of trait data for ecological understanding. Using a theme of 'past, present and future', he highlighted some of the large-scale and long-term issues associated with trait data. For example, we can use past data to explore phenological changes. However, care must be taken in interpretation of these changes without fully understanding the mechanisms involved; something the BRC database does not capture. At the present time, recording schemes provide opportunistic recording possibilities or more structured monitoring. How the data have been collected has implications for how they can be exploited. In the future, we are likely to have new challenges such as how to incorporate data from remote sensing and image recording, which may demand new or agreed vocabularies. There is also the issue of open versus closed access to data.

Our second plenary speaker, Jo Judge (National Biodiversity Network) outlined NBN's vision to collate and share biological data to educate and inform environmental management. However, to do this they are faced with multiple challenges. Only around 10% of the data held by NBN are on invertebrates and little of these come from academic institutions. As David also touched upon, there are emerging problems centring on how new recording methods (e.g. molecular identification) can be incorporated into the database. Jo also highlighted future development plans, which included interactive tools (e.g. the ability of users to flag errors), customisable user pages, tracking and feedback processes and identifying geographic and taxonomic gaps in the data.

Jo Judge discusses the opportunities and challenges offered by insect data on the NBN.

The remainder of the day was given over to discussion sessions. In the first session, we were asked to consider four questions: what problems are specific to insects; how can this group feasibly help; what do we want to get out of the day and out of the SIG?

Over lunch we had the opportunity to view posters. Damian De Marze presented a summary of Fera's aphid monitoring work and the benefits for agriculture. Rowan Edwards (Edwards Ecological and Data Services Ltd) described the challenges associated with digitising the Linnean taxonomic system. Rebecca Kinsella (University of York) highlighted the potential of historic abundance datasets to study biomass change in flying insects. Steven Dupont described the Natural History Museum's Interactions Bank which seeks to integrate species distribution and trait data to understand how these interact with each other.

For the afternoon discussion, delegates divided into three groups. The first considered plans for future Insect Data SIG meetings and how the RES could help facilitate these. One option discussed was the inclusion of a dedicated session at a future Ento meeting. A second group discussed skills and resources relating to museum collections and recording data – in particular, how recording schemes could learn from each other and the importance of harvesting additional data alongside routine collection. The third group discussed traits and trait databases, which seemed to interest a great many of those present. It was felt that a review of the current trait data as well as developing standardised methods for recording traits (particularly variation) and a central repository would be useful for researchers in this field.

A wine reception was laid on for those able to stay after the main meeting. Finally, it remains for me to thank James Gilbert and his colleagues at the University of Hull for hosting a well-organised and thought-provoking meeting.

Aphid Special Interest Group

Rothamsted Research, 3rd – 5th April 2019

Richard Harrington

The first meeting of the Aphid Special Interest Group was held at our Queen's Gate HQ on 14th March 1989 and was attended by 72 people, eight of whom were present at the latest incarnation. In 2015, we joined forces with the INRA (French Institute for Agricultural Research) French Aphid Research Network (BAPOA) for an excellent meeting in Paris. The Rothamsted meeting was the return match. Okay, Harpenden isn't quite Paris, but we were able to offer a very enjoyable and successful meeting, scientifically and socially. What I hadn't taken on board when booking the dates was that the meeting fell just a few days after the original Brexit date, and I had great fears over the potential impact on cross-channel travel. In the end, of course, Brexit didn't happen then, but Eurostar managed to achieve with a strike what Brexit couldn't. Our French friends rallied and made last-minute rearrangements.

Nearly eighty people from ten countries attended the meeting. There were 32 talks and 20 posters, so only a brief sketch of the excellent science is possible here, and only presenting authors are mentioned. Abstracts are available at https://www.royensoc.co.uk/special-interest-groups/aphids. Ten years or more ago, such meetings would have had a strong taxonomy component. Not any more – but there was one presentation in this area, from Mariusz Kanturski (University of Silesia), concentrating on antennal sensilla of the Lachninae. Mariusz also presented work on the morphology, histology and ultrastructure of the reproductive system of the pea aphid, *Acyrthosiphon pisum*. Whilst a series of taxonomic presentations has been known to be somewhat soporific, their lack is a sure sign of the inadequate funding of taxonomy, skills in which are so fundamental to the rest of aphidology.

So, what aspects did feature? The most-mentioned aphid award goes to *A. pisum*, with the peach–potato aphid, *Myzus persicae*, coming a distant second, this perhaps reflecting a bias towards fundamental molecular work (the pea aphid genome has been available for longest and is best understood) as opposed to more immediately applied studies. The latter were not absent, though. James Bell (Rothamsted Research) provided a summary of the potential for automatic identification of aphids in the field. Steve Foster (Rothamsted Research) described the problems with aphid control following the ban on neonicotinoid insecticides and, with that in mind, Ramiro Morales-Hojas (Rothamsted Research) is studying the genetic structure of cereal aphids in the UK with a view to understanding dispersal dynamics to assist decisions on the use of the increasingly limited control options. Beth Moore (University of Aberdeen) plans to assess the role of climate and land-use in driving patterns of genotypic diversity and insecticide resistance in a range of aphid species. John Pickett (Cardiff University) is investigating new opportunities for biocontrol using his signature "push–pull" system. Estelle Postic (Agrocampus Ouest Rennes) is studying trophic webs of aphids and parasitoids with a view to improving aphid control in strawberry greenhouses whilst Amandine Cornille (CNRS Orsay) is studying the population structure and genetic diversity of the rosy apple aphid, *Dysaphis plantaginea*, in order to reconstruct its invasion history in Europe. Joe Roberts (Harper Adams University) is aiming to test the hypothesis that plants with partial resistance will slow down aphid development and increase their susceptibility to biocontrol agents. Dion Garrett (Rothamsted Research) is studying the biology, migration and population structure of the currant–lettuce aphid, *Nasonovia ribisnigri*, using landscape genomic approaches, including the spread and evolution of cultivar resistance. Hana Platková (University of Ostrava) is studying the density and diversity of aphids through vertical gradients in temperate floodplain forest tree canopies in Moravia. Jurij Danilov (Vilnius University) described the first examples of sexual forms of *Cinara piniphila*, which is a pest of *Pinus sylvestris*.

Several presentations involved aphid stylets which, of course, draw sap from plants and convey viruses between plants and are hence the prime organs of damage. Gaël Le Trionnaire (INRA Rennes), Marilyn Uzest (INRA Montpellier) and Sylvie Hudaverdian (INRA Rennes) are developing and experimenting with CRISPR-Cas9 technology to knock out the stylin-01 gene, which produces Stylin-01, thought to be the receptor for non-persistent viruses in the acrostyle at the tip of aphid maxillary stylets. Early indications are that *A. pisum* lineages with stylin-01 knocked out have a reduced capacity for transmitting *Cauliflower mosaic virus*. Maëlle Deshoux (INRA Montpellier) is studying the role of the acrostyle through characterising Stylin-01 and Stylin-03 in *M. persicae* and silencing the genes responsible for their production. Results point to the acrostyle being involved in aphid–plant compatibility. Yvan Rahbé (INRA Lyon) has identified the complete set of cuticular proteins from the stylets of *A. pisum*, finding new cuticular protein classes. Nadine Douglas (University College Dublin) is using mass spectrometry to characterise the proteomes of watery and gelling saliva of an *A. pisum* strain virulent on otherwise-resistant *Medicago truncatula*. Numerous candidate proteins have been identified for future RNAi-based pest control strategies. Torsten Knauer (Max Planck Institute) is using stylectomy to obtain pure phloem sap from single sieve elements of *Trifolium pratense* infested with different *A. pisum* strains and has analysed the amino acid composition to see whether results from a single sieve element are representative.

Top of the topics was interactions between aphids and their bacterial symbionts, much of this work being at the molecular level. Tsutomu Tsuchida (University of Toyama) considered the role of symbionts in body colour and its ecological significance; Chen Luo (Université Côte d'Azur), their role in coping with abiotic and biotic stress through producing phenoloxidases in the haemolymph; Hubert Charles (INSA Lyon) their role in coping with a nutritionally unbalanced diet, and Mariska Beekman and Helena Donner (Wageningen University), their role in compromising biocontrol of aphids in greenhouses. In relation to the latter, Christoph Vorburger (ETH Zürich) explained that rapid counter-adaptation of parasitoids to the presence of symbionts can occur, and how his laboratory experiments have shown, for the first time, that parasitoid pre-adaptation can improve aphid control. *Anoecia corni*, the dogwood–grass aphid, spends the summer months underground on the roots of grasses, surrounded by a considerably more diverse microflora than above-ground species. François Renoz (Université Catholique de Louvain) tested the hypothesis that this species would acquire a richer bacterial diversity. Whilst new symbiont genera were found, more work is required. Ailsa McLean (University of Oxford) considered the roles of different phenotypes of a single facultative symbiont, *Spiroplasma*, which manipulates reproductive strategies by male-killing and confers protection against hymenopterous parasitoids and fungal pathogens. There were no apparent trade-offs between these functions, suggesting that the different phenotypes are evolving independently. Studying another type of interaction between symbionts, Gaurav Pandharikar (Université Côte d'Azur) found that infection with facultative symbionts decreases the efficiency of nitrogen-fixing *Rhizobium* bacteria in the root nodule. Inès Pons (Université Catholique de Louvain) studied how the symbiont *Serratia symbiotica* infects aphids. Cultivatable symbionts colonised the aphid digestive tract and then multiplied exponentially. They immediately protected against parasitoids, but there was a fitness cost. The bacteria could be extracellularly transmitted via the honeydew and phloem or horizontally transmitted between aphids; the first time this has been shown. Corentin Sochard (INRA Rennes) presented early stages of his work looking for co-adaptation between aphids and their symbionts, testing the hypothesis that the "holobiont" (the combination of the aphid and its symbionts) constitutes a unit of selection, rather than the individual organisms evolving independently. All work on symbionts requires reliable protocols for their introduction and elimination from aphids. Stéphanie Morlière (INRA Rennes) optimised techniques for injection of haemolymph harbouring facultative symbionts or antibiotics and achieved 84% and 80% success rates respectively for symbiont introduction and elimination. Mélanie Ribeiro Lopes (INSA Lyon) reported a newly discovered cell-death process involved in the deterioration of bacteriocytes containing the obligate symbiont *Buchnera aphidicola*. Her work charted the stages of bacteriocyte death, revealing mechanisms by which bacteriocyte cells and *Buchnera* numbers are controlled. She also annotated the apoptosis (cell death) pathway in *A. pisum* and found a large number (compared to other studied insects) of Inhibitor-of-Apoptosis Proteins (IAPs), suggesting a possible mechanism whereby apoptosis is prevented in bacteriocytes.

There were several presentations on host-plant–aphid interactions and host-plant resistance. Tom Pope (Harper Adams University) studied the landing behaviour under glass of the English grain aphid, *Sitobion avenae*, on a range of winter wheats and found that *cv.* Maris Huntsman was preferred over modern varieties, which may explain reduced direct damage from *S. avenae* since the 1980s. An understanding of why Maris Huntsman is favoured may prove useful in breeding programmes. Having screened over 1,000 wheat lines, Gia Aradottir and Amma Simon (Rothamsted Research) discussed the potential of resistance to the bird cherry–oat aphid, *Rhopalosiphum padi*, and *S. avenae*. Antibiosis and antixenosis were found in lines of *Triticum monococcum* in the laboratory and field, although there was an interaction with drought. The hope is that such resistance can be introduced into modern wheat (*T. aestivum*) varieties. Hana Platková (Crop Research Institute, Prague) tested six wheat varieties on life-cycle parameters of the rose–grain aphid, *Metopolophium dirhodum*, finding that varieties tolerant to drought were less resistant to aphids. Helmut van Emden (University of Reading) revealed how far it was possible to change the host-selection responses of the polyphagous *M. persicae*, oligophagous cabbage aphid, *Brevicoryne brassicae*, and monophagous lupin aphid, *Macrosiphum albifrons*, by rearing them on Brussels sprouts (*M. persicae* and *B. brassicae*) or lupin (*M. albifrons*) and transferring them to tomato after one day on artificial diet with or without the addition of tomatine, a secondary compound characteristic of tomato. The influence of tomatine on host-selection was greatest for *M. persicae* and virtually zero for *M. albifrons*. Although *B. brassicae* specialises on plants containing glucosinolates, it was able to feed to some degree on tomato after a day's exposure to tomatine. In another presentation, Van revisited his famous

asexual lineage of *M. persicae* which had been reared on artificial diet since 1976 and considered why aphids performed less well on the diet than on plants. Adding sodium acetate (a precursor of alarm pheromone) to artificial diet brought development time and adult weight close to values when reared on plants. His lineage, and a culture of the same lineage kept at Imperial College, died out suddenly after 33 years, raising the question of whether such continuously parthenogenetic lineages have a limited life span.

Chris Bass (University of Exeter) is investigating the role of cytochrome P450s in driving host-range expansion and xenobiotic resistance in *M. persicae*. He has characterised the mutational events leading to overexpression of three P450s and worked out the role that each has played in conferring resistance to xenobiotics, and how this might have facilitated the move of *M. persicae* to tobacco by detoxifying nicotine. Michael Giolai (John Innes Centre) linked electrophysiological assays to recent progress in spatial transcriptomics to study features of the response of *Arabidopsis thaliana* to *M. persicae*. Matteo Gravino (John Innes Centre) showed that oligogalacturonides enhance *A. thaliana's* resistance to *M. persicae* and that this response is mediated by calcium-dependent protein kinases that are known to be involved in immune signalling. Four presentations considered mechanisms underlying host-plant adaptation in the *A. pisum* complex. Jean-Christophe Simon (INRA) is using population genetics and transcriptomics approaches to identify candidate salivary genes which might control plant adaptation in different biotypes. Felix Feistel (Max Planck Institute) is studying the role of toxic quinolizidine alkaloids (QAs) in a biotype specialised on species of *Genista*. Eight QAs have been found in plants but not all are present in the phloem sap and in aphid honeydew. Maria Paulmann (Max Planck Institute) is studying the role of forisomes, which block sieve elements threatened by loss of phloem as a result of aphid feeding, in legume defence against aphids. She found that forisome reactivity depends on the plant–aphid biotype interaction and hence may play a role in *A. pisum* host-race maintenance. Forisomes change their configuration in a Ca^{2+}-dependent manner. Using live *in vivo* images of aphid-induced calcium signalling responses, Joshua Joyce (John Innes Centre) is beginning to unravel some of the key features of these signals and their role in determining aphid–host compatibility. Varvara Fazalova (University of Oxford) estimated mutation rate and genome-wide differentiation to test the view that speciation in *A. pisum* is very recent. It appears that divergence began longer ago than the 8,000 to 16,000 years previously estimated based on an unusually high mutation rate in the aphid's *B. aphidicola* complement.

Julie Jaquiéry (INRA Rennes) is using combined quantitative genetic and population genomic approaches to unravel the genetic control of shifts towards permanent asexuality in *A. pisum*. She has found that permanent asexuality is determined as a recessive character by a single locus and identified a 2.5 Mb region responsible on the X chromosome. Hugh Loxdale (Cardiff University) was as challenging as ever, arguing the case that there is no such thing as a generalist, since each species fills a unique, multi-dimensional ecological niche. He also presented re-analysed Rothamsted data showing that ten major pest aphid species appear not to be as polyphagous as previously thought. Mariusz Kanturski (University of Silesia in Katowice) gave a fitting tribute to the great aphidologist Ole Heie. Mariusz is organiser of the next International Aphid Symposium in 2021. Maurice Hullé (INRA Rennes) presented the web site "Encyclop'Aphid", a fantastic new resource covering all aspects of aphidology – see https://www6.inra.fr/encyclopedie-pucerons_eng/.

Roger Blackman's presentation was called "How (or why) do they do that?". Roger's long career (and beyond) in aphidology has left him with unanswered questions, such as why chromosome numbers differ so much in some genera but remain stable in others, and how viviparous aphids feed their embryos. Roger is a guru to many and I could sense a relief that there are fundamental questions to which even he doesn't have an answer.

A most convivial conference dinner was held at the Aubrey Park Hotel. Surreal blue lighting didn't do wonders for the photographs, but the food and atmosphere were excellent and the bar stayed open very late. Roger Blackman (my PhD supervisor at the Natural History Museum, incidentally) and Helmut van Emden were presented with BAFTA's (British And French Teams Aphidologists) Golden Aphid Award for lifetime achievement in aphidology, recognising the huge benefit that their work has been to almost all aphidologists the world over.

The meeting concluded with a fabulous 40-minute film by Urs Wyss (Kiel University) on "The dangerous life of the linden aphid *Eucallipterus tiliae* in the lime tree microcosm". To see its life-cycle and battle with predators in such high quality on the big screen adds a whole new dimension to our appreciation of its biology and ecology. I was rather amused by the obvious sympathy amongst the delegates, most of whom are employed



Left: Invited speakers and convenors; Middle: poster session; Right: conference dinner.

to solve aphid pest problems, for the aphids rather the natural enemies. It was a bit like watching a film of a tussle in the Masai Mara between a lion and an impala, in which we would mostly be rooting for the latter.

This will, I hope, not be the last joint RES/BAPOA meeting. We currently plan to hold them every four years, midway between International Aphid Symposia. The Aphid SIG may well meet on its own in the even-numbered years, but under new management. Having retired four years ago I am gradually slipping out of date with who's who and what's what in aphidology. Gia Aradottir has kindly and enthusiastically taken up the mantle.

Many thanks to my co-convenors, Jean Christophe Simon (INRA Rennes) and Simon Leather (Harper Adams University) and to INRA and the RES for generous financial and logistical support for the meeting.

Arthropod Cuticle Special Interest Group

Micro-Ct And Other Novel Methods Of Imaging In Entomology

Natural History Museum, 16th April 2019

Richard Harrington

Many years ago, I studied for my PhD at the splendid venue for today's meeting. In the basement was the Electron Microscopy Unit. Watched over carefully by its pioneering Head, Don Claugher, I would coat my subjects (the back legs of sexual female aphids) with gold and drop them to frightening vacuums, focus, press the button and hope for the best. How times have changed! Today's Head of what is now the "Imaging and Analysis Centre" at the Museum, Alex Ball, outlined current techniques available. No longer is gold coating required in order to suppress charging of the specimen, even with an insect on a card-point on a pin. Photogrammetry allows construction of a 3D image from a series of 2D images taken from various viewpoints. Reasonable results can be obtained very cheaply using mobile phones and inexpensive software. It is even possible to 3D-print the results. The method can be adapted for use with computer-controlled scanning electron microscopes which can be programmed to take the required images automatically. Much of the meeting focussed on the rather more expensive and complex methodology of micro-CT (Computed Tomography) scanning. The principle is the same as CT used in hospitals to view our internal organs and structures, but at a microscopic scale, the sample rotating rather than the X-ray generator. It combines a series of X-ray images taken from different angles and uses computer processing to create slices that can be viewed from any orientation and can also be reassembled to give a 3D image.

Specimen preparation is key. Brian Metscher (University of Vienna) discussed his favourite techniques for fixing (e.g. air drying; ethanol), staining (e.g. phosphotungstic acid) and mounting (e.g. low melting temperature agarose; Lego bricks; thermoreversible gels which gel when warm and melt when cold) specimens prior to CT scanning. He pointed out that cyber images make museum specimens shareable without risk to the original specimen. With the same purpose of accessibility in mind, Steen Dupont (Natural History Museum) gave a micro-CT-free presentation on digitising museum specimens and label data by conventional photographic means. A system called ALICE enabled the digitisation of 27,000 specimens in 39 days at a cost of about 50p per specimen, each specimen taking about 30 seconds to deal with. With 80 million objects in the Museum, 32 million of them being insects (including 25 million pinned and 2.5 million on microscope slides), it will take a while to complete the task. Indeed, the task will never be complete as further improvements in techniques are inevitable and specimens will need digitising again.

Daniel Martín-Vega (Universidad de Alcalá, Madrid) used micro-CT-based virtual histology to study the metamorphosis of blow flies (Calliphoridae) of medical, forensic and veterinary relevance. The method made it possible to assess the stage of development of various organ systems at 10% intervals during development within the puparium, potentially improving the accuracy of estimation of colonisation-time and hence time since host death. There was much

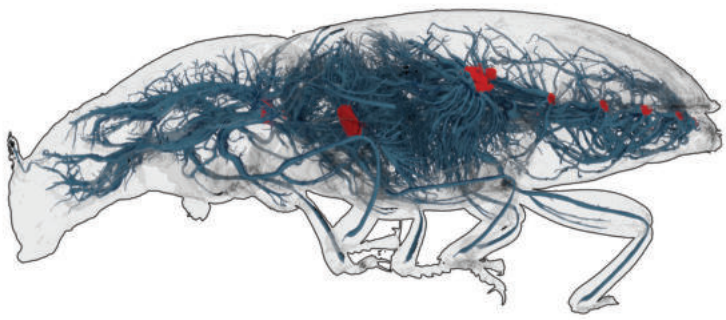


Fig. 1. Micro-CT image of the tracheal system of *Tenebrio molitor*. © Marcin Ra (Museum and Institute of Zoology, Polish Academy of Sciences)

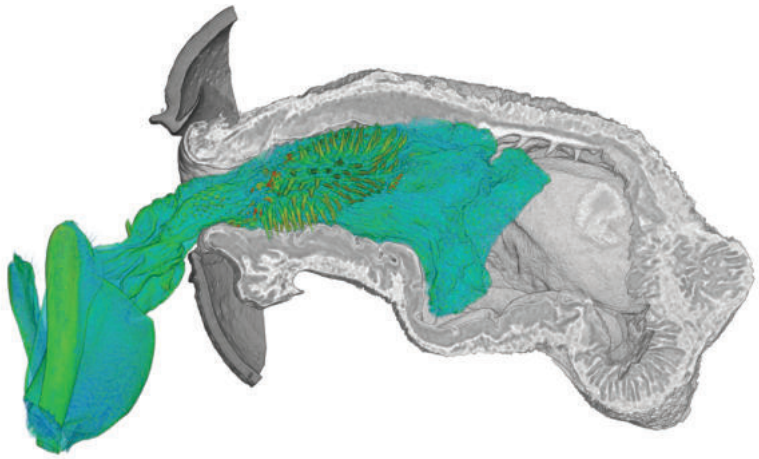


Fig. 2. X-Ray micro-tomography reconstruction showing the penis of the cowpea seed beetle *Callosobruchus maculatus* (colour) inside the female reproductive tract (grey) during mating.
© Liam Dougherty (University of Liverpool)
First published in Dougherty, L.R. & Simmons, L.W. (2017) X-Ray micro-CT scanning reveals temporal separation of male harm and female kicking during traumatic mating in seed beetles. *Proceedings of the Royal Society B* **284**: 20170550.

Fig. 3. *Megaphragma longiciliatum* (Trichogrammatidae) (Oman).
Photographed with confocal laser microscopy by Andrew Polaszek (Natural History Museum)
Yellow – strongly sclerotised cuticle; Blue – weakly sclerotised tissues; Scale bar 0.1 mm

discussion around the nature and function of a gas bubble that forms in the puparium. Daniel also compared the alimentary canals of Calliphorids and Oestrids (bot flies and warble flies), finding, for example, that in *Oestrus ovis*, the canal is vestigial from early in development. It is hoped that such comparative studies will provide new insights relevant to anatomical, developmental, evolutionary and biomedical research.

Remarkable micro-CT images of the tracheal system of beetles (Fig. 1) were shown by Marcin Ra (Museum and Institute of Zoology, Polish Academy of Sciences). Winged beetles such as *Tenebrio molitor* have a higher volume of tracheae per unit mass compared to apterous beetles such as *Gonopus tibialis*. Serially homologous tracheae develop differentially according to which part of the body they are in. Staying with beetles, Yin Chang (University of Cambridge) is using a range of imaging techniques to study hierarchical structures of *Pachrrhyncus* weevil elytra. The elytra are fused hence the weevil cannot fly and relies for defence (particularly against lizards) on the extraordinary mechanical and optical properties of the exoskeleton. Its high mechanical strength is not fully understood. Micro-CT revealed a large cavity in the abdomen with the elytra fused above it with a tracheal network inside. Optical and scanning tunnelling electron microscopy showed a layered structure to the elytra, the thickness of the layers increasing from the outer margin to the inner. The exo- and meso-cuticle are composed of many fine layers. Macro- and nano-mechanical testing revealed fracture strengths of 35-40 Newtons. Fracturing occurs along the interlock structure of the merged elytra, which have saw-toothed edges enhancing interlock strength, the first time this has been seen in beetles.

The possible impact of neonicotinoid insecticides on bee behaviour has been a hot topic of late. Richard Gill (Imperial College) and his PhD student Dylan Smith used micro-CT to look at the impact of neonicotinoids on brain development in the bumblebee *Bombus terrestris*. Exposure adversely affected the development of mushroom bodies and antennal lobes. This was followed up with experiments to record olfactory learning responses after exposure to neonicotinoids compared to unexposed controls. Exposure had a clear effect on learning ability. Richard is now digitising 13,000 specimens from museum collections to look at morphological changes in bumblebee brains over time.

Marcela Randau (Natural History Museum) is using micro-CT to study body shape evolution in insects and other arthropods. As has so far been done mainly for vertebrates but only rarely for invertebrates, she will identify sets of phenotypic traits that show

coordinated patterns of evolution. Such patterns reflect the underlying genetic and developmental construction of organisms and influence the direction of morphological evolution. By sampling broadly across insect orders (e.g. two specimens per order), Marcela hopes to test the hypothesis that increased species richness amongst holometabolous insects is linked to unique patterns of organismal covariation.

Cowpea seed beetles, *Callosobruchus maculatus*, have vicious penises, which are of interest to Liam Dougherty (University of Liverpool). They are covered with sharp spines (Fig. 2), which pierce the lining of the female reproductive tract during mating. The female has a melanisation process to heal the wounds, but is still susceptible to infection of the wounds. Micro-CT was used to visualise these interactions in specimens flash-frozen in the act. Thickened female reproductive tracts reduced scarring if penis spines were short. Discussion centred on whether there was antagonistic coevolution of males and females. There may be no selection against harming females because they lay very quickly. Adults are very short-lived and hence there is selection for successful and quick mating.

Andrew Baillie and Andrew Polaszek (Natural History Museum) used confocal laser microscopy to reveal gene expression and hidden morphology of some very small invertebrates, including tapeworm heads and bryozoan feeding zooids. Dyes were used to stain particular structures of interest, including nuclear DNA, to provide a cellular roadmap for the organisms, stem cell identification and gene expression patterns. Their poster included a stunning picture of *Megaphragma longiciliatum* (Trichogrammatidae), one of the smallest winged insects (Fig. 3).

Many thanks to meeting organisers, Martin Hall (Natural History Museum) and Arthropod Cuticle SIG Convenor, Stuart Reynolds (University of Bath), for a day of spectacular imagery and insights into its application.

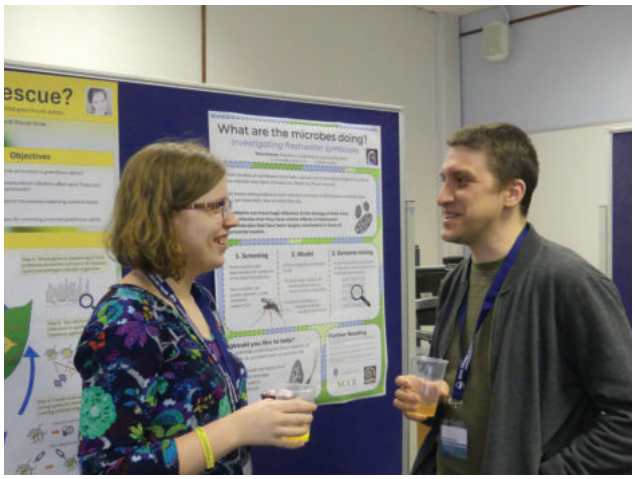
Insect Endosymbiont Special Interest Group

University of Nottingham, 25th April 2019

Richard Harrington

It was only a year since the last meeting of this SIG, but work on endosymbionts is moving at such a pace that this meeting was enthusiastically received. Even more may have attended had not an aphid SIG, which had a strong endosymbiont component (see pages 132–135), been held earlier in the same month.

Endosymbionts have very small genomes and Lucy Weinert (University of Cambridge) wants to know why. Could it be because they live in a nutrient-rich environment, with the host providing some resources, hence avoiding the need for the symbiont to do so ('host restriction')? Could it be because they have a reduced effective population size and are prone to gene loss through genetic drift? Might they have higher mutation rates as a result of lacking DNA repair genes? Reduced genome size is also a feature of some free-living marine bacteria and some vertebrate pathogens, the latter often having close relatives that are non-pathogenic, in which case the



pathogens tend to have smaller genomes. Could this provide a clue? *Streptococcus suis* in pigs may be pathogenic or commensal, allowing examination of the relationship between genome size and pathogenicity within a species, genomes of pathogenic strains being smaller. Lucy considered which of the above hypotheses for causes of genome reduction in endosymbionts could potentially apply to these other groups. Host restriction does not apply to marine bacteria, as the oceans are nutrient poor, but perhaps because they live in a nutrient-poor environment they may need to get rid of less-necessary genetic material, a process known as streamlining. There was no evidence for host restriction being the cause of genome reduction in vertebrate pathogens or in *S. suis*, as pathogenic and non-pathogenic pairs were similar in this regard. Whilst endosymbionts typically had a low effective population size (*Ne*), it was generally high in marine bacteria. There was no evidence for a difference in 31 pathogenic/non-pathogenic pairs tested, but some evidence for reduced *Ne* in *S. suis*. There was no evidence for streamlining in pathogenic/non-pathogenic pairs, but some evidence in marine bacteria and in *S. suis*. Evidence was found for loss of DNA repair genes in marine bacteria and faster mutation rates in pathogenic *S. suis*. In summary, faster mutation rates are a unifying concept to explain genome reduction in all the systems examined. Faster mutation rates tend to be associated with an AT bias, which occurs in endosymbiont genomes. Lucy hopes that it might become possible to reduce bacterial pathogenicity by targeting genes causing faster mutation rates.

Arsenophonus nasoniae is a male-killing endosymbiont of jewel wasps (*Nasonia* spp.). It is extracellular and has the distinction of being culturable and hence possible to manipulate. Greg Hurst (University of Liverpool) transformed *Arsenophonus* to express green fluorescent protein (GFP) and then put it back into *Nasonia* in order to track its progress in its host. The symbiont was found in the stinging fluid of the adult host. In the larval stages, infection was in the mouthparts and gut. In the pupal phase it moved to chitinaceous structures, in particular the ovipositor, thus enabling vertical transmission. Nobody has previously looked at the symbiont during host diapause. Greg found that it sometimes "goes rogue" in such circumstances, causing septic shock and death of the host. Greg plans to take advantage of the culturability of *Arsenophonus* to screen for genes important in symbiosis. He will use 20,000 Tn5 insertions, which interrupt the function of individual genes, to see which interrupt symbiosis, and how, and to see which are important in male-killing.

Prophages are viruses that integrate into bacterial genomes. They are important drivers of bacterial virulence and evolution, as they encode virulence traits and shuttle genes between lineages. Crystal Frost (University of Liverpool) is also studying *Arsenophonus nasoniae* and has found 28 prophage elements, the highest number reported to date in any organism. Prophage genomes have large numbers of repetetetetetitive elements and complicate the assembly of the host genome. They can produce proteins that induce cell death in the host, toxins and their transporters, and proteins that allow microbes to adhere to, and invade, eukaryotic cells. Thus, genomes that are hard to assemble are likely to be biologically interesting.

Spiders are generally poor hosts for endosymbionts. Undeterred, Alastair Gibbons (University of Nottingham) is studying how *Wolbachia* and *Cardinium* infections modify the behaviour of *Philodromus* spiders. Fifty-six sub-adult female *Philodromus caespitum* were collected from apple orchards and assayed for voracity, distance travelled in a given time, latency to explore a new environment and recovery from an adverse stimulus. 71% of the spiders were found to be infected with endosymbionts: 22% with *Wolbachia*, 30% with *Cardinium* and 19% with both. Co-infection and infection with *Cardinium* alone did not affect behaviour. *Wolbachia*-infected individuals took longer to move and were less bold. Alastair suggested that the altered behaviour of *Philodromus* populations infected with *Wolbachia* has the potential to affect food web dynamics.

Cardinium and *Wolbachia* can also infect *Culicoides* biting midges (20% and 5% of *Culicoides* species respectively) but it is not known what they do. Jack Pilgrim (University of Liverpool) found that 38% of *Culicoides* species can be infected with *Rickettsia* (bacteria that can be pathogenic in vertebrates and plants) and is examining the distribution and localisation of a *Rickettsia* in *Culicoides*. Males and females are equally infected. The *Rickettsia* infecting *Culicoides* belong to the Limoniae group, which is polyphyletic. Fluorescence *in-situ* hybridisation imaging revealed that they infect ovaries and ovarian suspensory ligaments of *Culicoides impunctatus* and are maternally transmitted. They also infect the spermatheca, but not the sperm. *Rickettsia* are found in the head and tail of larval *Culicoides*, but not in between. Jack raised the possibility that

endosymbionts and the virus causing Bluetongue, which is transmitted by some *Culicoides* species, might directly interact.

Rickettsia has previously been overlooked as an endosymbiont not only in *Culicoides*, but also in the human bedbug (*Cimex lectularius*). Panupong ('Pong') Thongprem (University of Liverpool) has discovered that *Rickettsia* of the 'Torix' group (first found in the leeches of the genus *Torix*) infect bedbugs. He has shown that Torix *Rickettsia* are maternally inherited and do not distort the sex ratio. They are found in other blood-feeding hosts but whether they confer any benefit to their hosts is unclear. Pong plans to investigate this in the bedbug–*Rickettsia* system. So far, no effects on development time have been found.

Tsetse flies (genus *Glossina*) are the vectors of *Trypanosoma brucei*, the parasite responsible for African trypanosomiasis, as well as the wasting disease nagana in cattle. The tsetse's secondary symbiont, *Sodalis glossinidius*, provides a potential target for reducing spread of *T. brucei*. Rebecca Hall (University of York) described the use of metabolic modelling to design a growth medium for *S. glossinidius*. The medium was used to verify predictions about carbon and nitrogen usage by the symbiont, including inability to produce certain amino acids and vitamins (auxotrophies). For example, *Sodalis* can't make thiamine but does have a thiamine transport system. It scavenges thiamine from the tsetse's primary symbiont, *Wigglesworthia glossinidia*. Rebecca discussed the use of flux balance analysis to simulate, *in silico*, metabolism and the evolution of symbioses, with *S. glossinidius* and its free-living relative *S. praecaptivus* as exemplars. Such work improves understanding of metabolic interactions within the tsetse's microbiome, with a view to targeted alterations aimed at reducing disease spread. It also serves as a template for investigations into symbiont evolution.

It is well known that some secondary symbionts can protect hosts from attack by parasitoids. In aphid systems, it has been found that the genotypes of all three components of the interaction are important in determining the level of protection. Jordan Jones (University of Liverpool) wants to know if the same is true in *Spiroplasma*-mediated defence against the parasitoid wasp, *Leptopilina heterotoma*, in the fruit fly *Drosophila melanogaster*. *Spiroplasma* resides in the haemolymph of *Drosophila* larvae. She found that the level of resistance conferred by *Spiroplasma* was dependent on the wasp genotype. Thus, prediction of symbiont dynamics in natural systems will require analysis across natural enemy genotypes.

To an appropriate rumble of thunder, delegates gave lightning talks to introduce their posters. Mariska Beekman (Wageningen University) is working on the biocontrol of aphids in greenhouses by using parasitoid wasps. The effectiveness of control can be compromised by aphid endosymbionts but, to date, it is uncertain whether this is the reason for poor control in greenhouses. Mariska is finding out which endosymbionts are present, how different endosymbionts affect aphid fitness and control by parasitoids, and what functional mechanisms underlie symbiont-based resistance, all with a view to providing tailor-made solutions for controlling symbiont-protected glasshouse aphids.

Helen Davison (University of Liverpool) is investigating freshwater symbioses, about which little is known. She plans to screen protists and invertebrates for symbionts in the order Rickettsiales and requests samples of mayfly species from across the UK. If you might be able to help, please email hlhdavi5@liverpool.ac.uk.

Robert Markus (University of Nottingham) represented SLIM – the School of Life Sciences Imaging Unit, which covers live cell imaging; confocal, wide field, TIRF (total internal reflection fluorescence) and super-resolution microscopy; high content imaging; image analysis and processing; histology and electron microscopy. His poster and demonstration would have been equally at home at the Arthropod Cuticle SIG (see pages 135 – 137).

The meeting organisation was led in very fine style by Nottingham Ph.D. students Ella Deutsch and Alastair Gibbons, to whom grateful thanks are due, likewise to their colleagues. Unfortunately, I was unable to stay for the 'après science' or for the Infection and Immunity SIG the following day. Ella takes up the story of that meeting.

Infection and Immunity Special Interest Group

University of Nottingham, 26th April 2019

Ella Deutsch

Following an excellent first day of talks, and chance to continue the conversations over food at Nottingham's *Pitcher and Piano*, day two started with an insightful plenary by Sheena Cotter, who discussed how the simple approach of equating food and energy could be missing important details in an organism's life history. Examining the interaction between *Spodoptera littoralis* caterpillars and the bacterial pathogen *Xenorhabdus nematophila*, Sheena showed that all aspects of *in vivo* host–parasite interactions were driven by dietary protein levels, with high protein inhibiting bacterial growth and improving immune responses. In another model system, that of the burying beetle *Nicrophorus vespilloides* and the bacterium *Photorhabdus luminescens*, the beetle appears to have a surprising resistance to the parasite. Sheena showed the impact of a protein in this system too, with an ideal protein composition in the diet for optimum beetle survival. This led to questions concerning the nutritional environment as a whole, with the conclusion that nutrient intake plasticity is a promising target for selection in the battle against parasites.

Robyn Manly (University of Exeter) presented work on the mite *Varroa*

destructor and its impact on the transmission of Deformed Wing Virus (DWV) in bee species. Having compared honeybee and wild bumblebee populations with and without *V. destructor*, she showed that *V. destructor* drives DWV prevalence and viral load in both honeybees and sympatric bumblebees, and that viral genotypes are shared across hosts. This demonstrates disease emergence across a host community driven by the acquisition of a specialist novel transmission route in one host, with dramatic community level knock-on effects.

Casper Breuker (Oxford Brookes University) explored the defences of the butterfly embryo inside an egg, and showed that female butterflies produce a sheet of cells during egg formation called the serosa, which forms around the embryo in the first few hours of development. The serosa remains in place during the whole of embryonic development and is capable of mounting a full immune response during early embryogenesis.

Alexandre Leitão (University of Cambridge) explored the recognition systems for defence against parasites, even when the parasite is closely related to the host. He demonstrated melanized encapsulation of oil droplets when they contained extracts from a parasitoid wasp, indicating recognition of the pathogen by the wasp.

Megan Wallace (University of Edinburgh) aimed to bridge the gap between the new knowledge of viral infections emerging through next-generation sequencing and the impacts of these infections on the organism itself. She discussed lifespan and fecundity impacts of ten 'wild' *Drosophila* viruses, providing insight into the potential effects of virus load on insect population fitness.

Rosie Mangan (University of Stirling) investigated how multiple fungal biopesticide strains can be used heterogeneously across agricultural landscapes and provided exciting evidence that environmental heterogeneity could sustain variation for susceptibility to fungal biopesticides.

Though it is believed that the gut microbiota is mainly extracellular, residing on the surface of gut epithelium, Shivanand Hegde (Liverpool School of Tropical Medicine) showed that *Enterobacter*, *Cedecea* and *Aeromonas* can actually invade Aag-2 cells of *Aedes aegypti*. He then showed how infection with *Enterobacter* could protect host cells from invasion by Zika virus, mediated by TLR (toll-like receptor) and IMD (immune deficiency) pathways.

Jonathon Siva-Jothy (University of Edinburgh) discussed how heterogeneity in disease transmission is produced by variation in traits that affect contact rate between susceptible and infected individuals, the likelihood that contact will result in infection, and infection duration. He showed differences in the virus transmission potential of *Drosophila melanogaster* and explored the effect this may have on the spread and impact of pathogens. Pedro Vale (University of Edinburgh) expanded on Jonathon's work and showed that manipulating variation in social network connectivity, infectiousness, and infection duration in simulated populations revealed that these components affect disease transmission in clear and distinct ways.

In the previous day's poster session, Arun Prakash (University of Edinburgh) presented 'The impact of negative immune regulators and damage limitation mechanisms on disease tolerance during bacterial infections in *Drosophila melanogaster*'; Vincent Doublet (University of Edinburgh) 'The role of gut repair mechanisms in bacterial shedding and spreading in *Drosophila*' and Tina Salminen (University of Edinburgh) 'Screening the effect of mtDNA and specifically OXPHOS complex III variation in innate immune responses'. These stimulated some excellent discussions through Thursday and Friday.

I would like to thank my co-organiser Alastair Gibbons as well as everyone in the Nottingham Spider/Ladybird team who helped out: Sara Goodacre, Tamsin Majerus, Charlotte Deall, Morgan Thornber, Antje Hundertmark and Stephanie Bean. A massive thank you as well to everyone who attended, especially those who shared their brilliant work. We had a lot of fun and I would certainly encourage anyone interested in hosting a meeting to go ahead and give it a go!

Irish Regional Meeting

Newry, 28th February 2019

Archie Murchie

In conjunction with Buglife, the Society held a one-day meeting on '*Invertebrate Conservation and Landscape Management in Ireland - Restoring Biodiversity in the Irish Landscape*' in February 2019 at the Canal Court Hotel, Newry. The meeting attracted 60 delegates from across Ireland, with ten speakers giving practical advice on the pros and cons of conserving invertebrate species and their habitats in Ireland.

The meeting got underway with Úna Fitzpatrick from the National Biodiversity Data Centre, Waterford, talking about '*The All-Ireland Pollinator Plan*'. This initiative uses evidence-based methodology to provide advice to land managers on how best to safeguard and enhance pollinators. Ireland has 99 bee species (1 honeybee, 21 bumblebees and 77 solitary bees) which are important pollinators of wild flowers and crops, and many species are under threat from habitat loss and intensification of agriculture. Catherine Bertrand (Butterfly Conservation) then spoke about the '*Marsh Fritillary; from Concept to Conservation*'. The Marsh Fritillary (*Euphydryas aurinia*) is similarly a species that has shown a decline across its range with changing agricultural practices. Catherine explained how Butterfly Conservation is involved in a number of projects to restore the species, including the new Marsh Fritillary option in the Environmental Farming Scheme. Anna Hart from Buglife Northern Ireland spoke about the *B-Line* initiative, which aims to establish an inter-connected network of bee-friendly habitats across

the country to counteract the fragmentation of natural habitats that has occurred in the past 50+ years. The first stage of this process is to map existing corridors of wildlife diversity and then to engage with landowners to recreate / restore habitats to fill the gaps, and complete a north to south, east to west network.

Brian Nelson (National Parks and Wildlife Service) posed the intriguing question: '*Additions to the Irish Insect Fauna: Overlooked Species or New Arrivals?* ' Brian said that the Irish species list was steadily increasing and now stood at 11,966 insect species, which was a 5% increase since 2010. This included several species new to science but also overlooked species that have simply not been recorded in Ireland before. In addition, as with GB, Ireland is accumulating new species from the Continent and elsewhere. Many of these are associated with non-native plants or are migrant / adventive species. So, in effect, Ireland's insect diversity is increasing, but how does this then relate to what species we want to conserve? David Bell from Ballinderry Rivers Trust presented some very practical and applied examples for the conservation of '*The Freshwater Pearl Mussel and White-clawed Crayfish*'. The Ballinderry river catchment includes the western-shore streams of Lough Neagh, and Lough Neagh itself. David and colleagues have applied three principles to their conservation efforts: 1) an evidence-based approach; 2) operating at the catchment scale; 3) partnership working. For the White-clawed Crayfish this included working with a quarrying company (Acheson and Glover) to create a crayfish habitat from 1,500 tonnes of broken concrete slabs, whilst for the Freshwater Pearl Mussel, the Trust has embarked on an impressive long-term breeding programme (20 years so far), coupled with habitat restoration and reintroduction.

After a pleasant sit-down lunch of soup and sandwiches, I gave a talk on '*Valuing Invertebrates in Agriculture: both Positive and Negative*'. This related to the conflict between food production on one hand and the need to conserve biodiversity in the agro-ecosystem on the other, with agricultural intensification and pesticide / fertiliser use often blamed for declines in biodiversity. Yet, invertebrate diversity can have a positive role in agriculture in terms of the ecosystem services provided by decomposers, pollinators and predators / parasitoids. Earthworms, for example, contribute approximately £83 million to grass yield in Northern Ireland alone. In addition, with agriculture heavily subsidised in Ireland as a whole, there is a growing emphasis on '*public money for public goods*', with subsidies being directed towards managing the natural environment rather than purely production.

Dave Allen (Allen & Mellon Environmental Ltd) gave an entertaining talk titled '*Lost and Found: in Search of "Lost" species*'. This again related to the number of species in Ireland and whether species were regionally extinct or not recorded. Dave gave the now classic example of the White Prominent moth (*Leucodonta bicoloria*), which was thought to be extinct in both Ireland and Great Britain. He related a tale of 'charlatans, cads and bounders', where the integrity of the Irish records and their collector were thrown into doubt. However, this may have been a case of professional rivalry, a disputed debt, impoverished entomologists and other shenanigans. In 2008, approximately 70 years after it was last collected, Dave and his colleagues rediscovered the White Prominent in Co. Kerry, vindicating the original collector. Dave finished his talk by listing some other potential 'lost' species.

Jervis Good continued on the relationship between agriculture and conservation in his talk on '*Land Use Intensification / Abandonment and*

Some of the speakers and delegates at the Royal Entomological Society / Buglife meeting on "*Invertebrate Conservation and Landscape Management in Ireland*", held in Newry in February 2019. L-R, Carol Hall, Sam Clawson, Catherine Bertrand, Archie Murchie, Úna Fitzpatrick, Anna Hart, Stephen Jess, Joanna Kirbas.

Entomofauna: Some questions'. He related how historically, in Ireland, the land was more extensively used, whereas nowadays there has been a tendency towards either intensive agriculture or abandonment. Yet, many Irish species rely on habitats created by extensive grazing. He gave the example of conservation grazing with Kerry cattle, a rare indigenous breed; but explained the difficulties with maintaining such schemes against a background of declining small farm viability.

Gill Weyman (University College Cork) discussed the risks posed by invasive species to insect conservation in her talk on 'Harmonia axyridis *in Cork, Ireland*'. The Harlequin ladybird was first recorded in Cork City in 2010 but in Ireland there is no national ladybird recording scheme, so records are often sporadic, with isolated findings in Limerick, Waterford, Carlow, Dublin and Louth. She stated that *H. axyridis* has spread slowly in Ireland in comparison to many European countries, maybe due to the cooler climate.

Roy Anderson wrapped up the meeting with a talk on '*Presence of* Vertigo moulinsiana *in Northern Ireland, Status and Conservation*'. *Vertigo moulinsiana* is a rare wetland snail protected under the Habitats Directive, which means that EU member states must take measures to conserve the species. In Northern Ireland, no sites were known until very recently but in September 2018 Roy and colleagues found the snail at a site in Co. Down. Roy commented on the characteristics of the site and in particular the influence of standing water, vegetation and grazing. The snail seemed to have a Goldilocks' preference of neither too much nor too little grazing.

On behalf of the Society, I would like to thank the presenters for a range of informative and inspiring talks. One aspect that stood out for me was the need for managed conservation. Coming from an agricultural background, it was interesting to see the importance of large herbivores in conserving Irish invertebrate fauna and I wonder if that pre-dates livestock farming or is a consequence of it?

The next meeting is likely to be held in Dublin in February 2020.

Posters presented at the meeting were:

Louise McNamara '*BYDV: The Impact of Sown Arable Margins?*'

Thomas Curran '*Application of Novel Environmental (eDNA) Techniques for the Surveillance of Mosquito Species from Water Samples*'

Esmeralda Herrero '*Hexafly, Farming Insects to Fight for a More Sustainable Future*'

Amy Arnott '*Bugs & Brexit - Agri-environment Schemes and Invertebrate Biodiversity in Upland Grasslands*'

Stephen Jess '*Monitoring Pesticide Use in Northern Ireland's Arable Crops from 1992-2016 and Implications for Future Policy Development*'

GRANT REPORT

Report on attendance at the British Ecological Society (BES) Annual Meeting, December 16-19, 2018

Rachel Farrow

Funding from the RES Conference Participation Fund enabled me to attend the British Ecological Society Annual Meeting in Birmingham, where I presented part of my PhD research at the session: Community Ecology (Demography, distributions and dispersal). My main research is on the invasive *Harmonia axyridis* (harlequin ladybird) but, for this presentation, I focussed on a rare coccinellid, *Coccinella quinquepunctata* (5-spot ladybird) of which little is known, either in the UK or Europe. This species was considered extinct in the UK until 1987 and its range is restricted to river shingle in Wales and Scotland. Numbers, however, appear to be stable. *Harmonia axyridis* was recorded in low numbers at sites where C. *quinquepunctata* was well established, indicating that, currently, this invasive species is not a threat to this rare coccinellid. The invasive *Impatiens glandulifera* (Himalyan balsam) is perhaps more of a direct threat to C. *quinquepunctata*, as it de-stabilises the river shingle and prevents the rooting of native plant species.

I also chaired the Invasive Species session which was an excellent experience from which I learned an incredible amount.

Furthermore, I benefitted from discussion with senior researchers, gaining valuable knowledge that I can incorporate into my thesis.

I want to thank the Royal Entomological Society for ensuring I could participate fully at this meeting.

SCHEDULE OF NEW FELLOWS AND MEMBERS

as at 1st May 2019

New Honorary Fellows
None

New Fellows (1st Announcement)
Professor Francois Verheggen
Dr Seirian Sumner

Upgrade to Fellowship (1st Announcement)
None

New Fellows (2nd Announcement and Election)
Prof. Dr Imtiaz Ali Khan (as at 6.3.19)
Dr Rajendra Singh Fartyal (as at 6.3.19)
Dr Masarrat Haseeb (as at 6.3.19)
Professor Diana L. Six (as at 6.3.19)
Mr Guillaume H-C Leraut (as at 6.3.19)
Professor Sandra M. Rehan (as at 6.3.19)
Professor Bruce E. Tabashnik
Dr Barbara Jane Tigar
Dr Arkadiusz Urbański
Professor Paul Alexander Opler
Professor Mark William Rowland

Upgrade to Fellowship (2nd Announcement and Election)
None

New Members Admitted
Dr Francesco Martoni (as at 6.3.19)
Mr Richard M. Lyszkowski (as at 6.3.19)
Professor Georges C. Lognay
Mr Peter Harper
Mr Michel Olivier Laurent
Mr Edward Hall

New Student Members Admitted
Miss Neive E.M. Percival (as at 6.3.19)
Mr Bradley Foster (as at 6.3.19)
Mr Dominic Joseph Oliver Phillips (a at 6.3.19)
Ms Cindayniah Jane Godfrey (as at 6.3.19)
Mr Ioannis Konstantina (as at 6.3.19)
Miss Patricia A. Ortega Ramos (as at 6.3.19)
Miss Rebecca Rose Barwell (as at 6.3.19)
Miss Helen Rebecca Davison (as at 6.3.19)
Ms Judit Mariann Linka

Re-Instatements to Fellowship
None

Re-Instatements to Membership
None

Re-Instatements to Student Membership
None

Deaths
Mr C G Treadaway-Hoare, UK, 1988

as at 5th June 2019

New Honorary Fellows
Professor Camille Parmesan
Professor Jeremy McNeil
Professor Linda Field
Dr Archie Murchie
Dr Erica McAlister

New Fellows (1st Announcement)
None

Upgrade to Fellowship (1st Announcement)
Dr Nick Littlewood

New Fellows (2nd Announcement and Election)
Professor Francois Verheggen
Dr Seirian Sumner

Upgrade to Fellowship (2nd Announcement and Election)
None

New Members Admitted
Mrs M D Sakunthala Janaki (as at 2.5.19)
Mr Ben Martin Keywood (as at 2.5.19)
Mr James Rowland (as at 2.5.19)
Dr Heather Natalie Gibbard (as at 2.5.19)
Dr Roger Moore (as at 2.5.19)

New Student Members Admitted
Dr Patrick Rohner (as at 1.5.19)
Miss Susannah Gill (as at 1.5.19)
Mr Darrell Bean (as at 1.5.19)
Dr Ian Bedford (as at 1.5.19)
Miss Bryony Cross (as at 1.5.19)
Miss Kirsty Garland (as at 1.5.19)
Dr Alice Laughton (as at 1.5.19)
Miss Hannah Fenton
Dr Jessica Gillung
Mr Adam Mcveigh

Re-Instatements to Fellowship
None

Re-Instatements to Membership
None

Re-Instatements to Student Membership
None

Deaths
None

HONORARY FELLOW INTERVIEWS

Sir Charles Godfray

by Peter Smithers

Oxford was quiet, the rush hour was over and only the keenest of tourists had ventured into the city so far as I walked down Broad Street to meet Sir Charles Godfray. I had met Sir Charles after a talk on food security that he had given at the Bath Royal Literary and Scientific Institute and had somewhat brazenly asked him if he would give an interview for *Antenna* and (as he is an ex-editor of the magazine) he had of course agreed. Hence on a glorious spring morning I walked to one of Oxford's 21st century intellectual hubs, The Oxford Martin School which lies in the shadow of another more ancient hub, the Bodleian Library. I negotiated security and was ushered into Sir Charles' spacious office where we settled into the leather sofas to discuss his life as an entomologist.

Early Life

"I don't remember ever not being interested in insects. The family story is that my brother and I were catching butterflies when we were aged 4 or 5 and were putting them in jam jars. My father was appalled at this and taught us to kill them humanely and it subsequently became a family enterprise. My mother would set the specimens that we caught as my father was not very good at setting and my brother and I were completely incompetent. This was back when collecting butterflies was still a permissible social norm and my sister still complains (in jest, I think) that her brothers ruined her childhood with our many entomological expeditions.

"I grew up in Bristol, living close to the Durdham Downs, until I was twelve. I recall at the age of eleven I was given a copy of Keble Martin's flora and as a result I would set off on botanical expeditions climbing all over the Avon Gorge in search of plants (it was a good thing my parents did not know). On one of these expeditions I remember finding the very rare Bristol Rock Cress (*Arabis scabra*) and was very excited as it is only found at two other locations in the UK.

"Then at twelve I went to Millfield School in Somerset where there was not a strong tradition of natural history. However, my interest in the natural world and moths in particular was regarded as a benign eccentricity, which was a trait I was happy to accept."

University

"At Oxford about half of my fellow biology undergrads were also keen natural historians, as were many of the academics. It was fabulous to meet so many people who shared my interests. The Entomological Society was presided over by George Varley who was a major influence. He was the Hope Professor of Entomology and very encouraging to undergraduates interested in the subject.

"At that point I was mainly interested in macro-moths but was slowly becoming interested in Microlepidoptera as well. The rest of the insect kingdom seemed to me beyond the ken of anyone to know and understand so seeing George Varley in the field putting names to a large fraction of the insects he found was really impressive. In the

meantime, my growing understanding in Microlepidoptera had led to an interest in leaf mining insects and I then began rearing their parasitoids. I remember that Varley could also name the family or subfamily of many of the parasitoids I reared. I have huge affection for him but also some frustration as he published relatively little himself. He was a very original thinker, but would write up some of his most significant ideas in obscure journals. I, and my later mentor Mike Hassell, who had been a student of Varley, sometimes worry that once the people who knew Varley personally have gone, it will be difficult for future generations to appreciate how influential he was.

"Because of my interest in the natural history of leaf miners I got to know and was strongly influenced by the superb amateur entomologist, Lt. Col. Maitland Emmet, who was both kind and hugely encouraging. We can do science in the UK that would be impossible anywhere else in the world because of the work of legions of naturalists, and I like to think I remain part of that community.

"As the end of my third year approached, I began to consider where to study for my PhD. I had an offer to stay at Oxford to work on bumblebee behavioural ecology but there was also an opportunity to work on leaf miners with Val Brown at Imperial College. I felt that moving to another university might be a good idea, but it was the prospect of working on leaf miners that swung it. I would be working on a community ecology project which meant rearing and identifying their parasitoids. I would have got nowhere without the help and advice of Dick Askew at Manchester who studied chalcids and Mark Shaw at Edinburgh who studied braconids. I recall Mark gently chastising me for sloppy rearing, assigning parasitoids to the wrong host. I'm pleased to say that after nearly forty years of friendship Mark continues to correct me on matters taxonomic!

"After my PhD I remained at Imperial and worked on the population dynamics of parasitoids with Mike Hassell, and on their behavioural ecology with Jeff Waage. It was Jeff and Mike, both fantastic scientists, who cemented my interest in parasitoids and in population biology. While much of my academic work has focused on parasitoids, I still retain a keen interest in their natural history and taxonomy. My particular interest is in the Alysiinae and Opiinae, two subfamilies of braconids that I think, literally, no one else in the country is interested in.

"Most of my early work was in experimental behavioural ecology or mathematical population biology but when in my late 20s I obtained a permanent job at Imperial College, I realised that with the luxury of tenure there was the possibility of conducting long-term experiments.

"I was looking for a good model system that was amenable to study in the field and easy to sample; with some regret I selected aphids. No disrespect to aphids but I have just never had an affinity with them in the way that I have with other groups of insects. Luckily, they are attacked by a number of parasitoids and some really interesting hyperparasitoids. We worked on their community ecology building "quantitative food webs" in which a value was given to the strength of each trophic interaction. Though more laborious to build than traditional "binary" food webs, they were very valuable in generating hypotheses about indirect interactions that could be tested in the field. Working with two fabulous post docs, the sadly late Christine Mueller and Frank van Veen, now at Exeter, we created a very unusual food web time series and found lots of evidence for the widespread occurrence of apparent competition.

"I was also greatly interested in the evolution of resistance to parasitoids, an area I had explored theoretically. When Lex Kraaijeveld joined my group from Leiden, we set up a *Drosophila* lab and discovered a trade-off between being able to fight off parasitoids and success in larval competition, an exciting result as in host–parasite life history models such a trade-off was typically assumed with little evidence. When Julia Ferrari started a PhD with me, we began to study similar issues in aphids but got some odd results which made no sense until we realised that they were due to the presence of symbiotic microorganisms within the aphid which protected them from parasitoids and pathogens.

"After twenty years at Imperial I moved back to Oxford in 2006 (into George Varley's chair) and continued working on aphids and bacteria, again with a really talented group of students and post docs (including Julia Ferrari, Piotr Łukasik, Ben Parker, Lee Henry and Ailsa McLean). I have also spent a lot of time thinking about the control of malaria-vector species using gene drive and *Wolbachia* bacteria. My friend Austin Burt at Imperial first got me interested in this and I have been part of the *Target Malaria* project he heads for 15 years. At Oxford, working with my post docs Ace North and Penny Hancock, we have been involved in modelling vector control, as well as going into the field to get better parameter estimates."

RES

"I have a great affection for the Society. I joined as a PhD student and shortly after that Nigel Ferguson asked me to become Assistant Editor of *Antenna* and then once I had learned the ropes, I became the Editor. Back then it was a literal cut and paste job with glue and sheets of paper. Caroline, my girlfriend then and now my wife, and I would assemble each edition by hand, gluing articles onto a template; we literally had to worry about squeezing an extra line onto the bottom of a page. I was also Secretary of the Society for five years. While in this role it became clear that things were changing, attendance at monthly meetings was declining and biologists who worked on insects had stopped defining themselves as entomologists. I encouraged Council to instigate the Special Interest Groups (SIG). Then subsequent Secretaries brought in the annual meetings, all of which offer additional engagement for the membership. I look back on the monthly meetings with nostalgia but feel the Society has done the right thing in concentrating on the SIGs and the annual meetings. *Antenna* has also become such a great magazine; when I edited it, it was more a bulletin board, with relatively few articles, but now it has substantially more content."

Sabah

"One of the most enjoyable external roles I have had is to chair the committee that ran the Royal Society's South East Asian Research Program, an Anglo-Malaysian initiative based at the research station at Danum Valley in Sabah, Borneo. Glenn Reynolds was the coordinator at Danum and my role was to support him and point him in the direction of smart people to develop projects at the station. The Yayasan Sabah Group and the Dutch foundation Forests Absorbing Carbon Dioxide Emissions (FACE) had developed a project to replant dipterocarps into previously logged forest. Seeds were collected in mast years and grown on in a large nursery, the resultant saplings were then planted back into the forest. We saw an opportunity here to use this set-up to build a large-scale biodiversity

manipulation experiment. We persuaded Andy Hector, then at Zurich University, to run the project as he had previously worked on related grassland projects. He designed the project to explore the relationship between biodiversity and a variety of ecosystem functions of which productivity is one. The project is vast and comprises 124 four-hectare plots spread over 500 hectares of logged forest. Each plot contains various combinations of saplings from monocultures to a mixture of sixteen different species. The experiment is planned to run for the next 60 years and will generate data to answer a wide range of ecological questions.

"One problem with setting up the experiment was that in planting the trees a series of paths was made through the forest and elephants would then use these, resulting in the need for some replanting. Initially these elephants were thought to have been introduced by the Sultan of Brunei in historical times and so were regarded as an invasive nuisance. But then genetic analysis showed they had been in Sabah for a very long time and overnight they were transformed from pests into conservation icons."

Policy

"I have always been interested in the application of science, so engaging with policy was a natural step. Good universities encourage their staff to become involved in external bodies and I have been lucky to work at Imperial and Oxford that both think policy engagement is important.

"My first major involvement in policy was in the early 2000s when the then Chief Scientific Advisor at DEFRA, Howard Dalton, asked me to review a large program investigating the transmission of bovine tuberculosis between badgers and cattle. This is a disease that is devastating for cattle farmers whose herds are infected, but where one policy option is culling badgers, animals that much of the public care deeply about. It sounds almost callous to say that getting to grips with the issues was intellectually absolutely fascinating.

"Since then I've become very involved in issues around food security, an interdisciplinary issue involving biology, health and economics (and even a bit of entomology). My biological modelling background has been very useful as the mathematics we use in population ecology and evolutionary biology has more in common with economics than physics. So, curiously, a background in population biology pre-adapts you to understand economics. I currently chair Defra's Science Advisory Council and recently became involved again in bovine TB when last summer Michael Gove asked me to chair a review of the UK's disease elimination strategy."

The Oxford Martin School

"Two years ago, I was offered the post of Director of the Oxford Martin School at Oxford University, which has a mission to support research that addresses the major challenges of the 21st century. We also engage with policy makers to understand their evidence needs and to help explain research findings to broad audiences. My role as Director is to help bring together typically multidisciplinary research groups to do the most exciting research that would be very hard to fund elsewhere. Though I don't do the research myself, it is enormous fun to have the license to get involved in any field of applied research with some of the best researchers in the country. Currently we have programs in, among other things, conservation and the illegal wildlife trade, climate change, misinformation and the media, and refashioning economics to better represent the reality of how economic systems behave. It's like being a kid in an intellectual candy shop!"

Digital Future

"I have a huge admiration for taxonomists and their achievements over the last two hundred years. I actually became involved in thinking about the future of taxonomy when I wrote an article in *Antenna* on web-based taxonomy. This had been prompted by a previous article complaining about lack of resources going into taxonomy but without suggesting how the field might be made more attractive to funders. The *Antenna* article was noticed by an editor at *Nature* and I was asked to rewrite the article for them. It's my only publication that has attracted both hate mail and fan mail! Briefly, it argues that if taxonomy does not transform itself into a modern digital information science it risks withering on the vine – failing to attract sufficient resources to maintain itself. Things are changing, but I worry deeply not fast enough.

"I became interested in insects by killing and collecting butterflies, something that today kids just don't do – a good thing. I'm encouraged that with the availability of cheap digital cameras kids are getting into natural history by "virtual collecting" – building collections of photos on Flickr etc. I would like to see the RES do more to encourage the amateur sector. The RES Handbooks are wonderful and it is good to see many of the older Handbooks on the web, but the price of new Handbooks is completely counter-productive. The RES could be much more innovative in this area. I would love to see a website for UK insects where all the Handbooks are present and where all species have their own page. These pages could then be annotated or commented on by the community, and photographs added. My copy of Spencer's key to the British Agromyzidae, for example, is full of annotations that are probably incomprehensible to anyone but me. If I was run over by a bus tomorrow they would be lost. It would be great if I could add those annotations to a webpage for everyone to access and for them to be available to the next person who does a full revision. There are great things happening in the digital realm; the NHM is putting more of its material on the web and there are many excellent amateur sites. It would be excellent if the RES joined this movement. Let's be really radical: this would do far more for British entomology than the RES maintaining much of its book and journal collection which is already available on the web through the Biodiversity Heritage Library."

As we finished talking, I noticed the picture that hung on his office wall. It is Graham Sutherland's *The Flea*, an illustration that is bold and graphic and not to everyone's taste as apparently some of his visitors have made clear. "It's a print" said Sir Charles, "a birthday present from my wife". But it is an image that says a lot about the person who occupies this office. In the introduction to his talk in Bath he had defined himself as an entomologist, and the presence of Graham Sutherland's painting is subtle confirmation of this. In a career that has expanded way beyond the natural sciences, Charles Godfray has remained a natural historian at heart and his innate love of the natural world has influenced much of his work. It is reassuring to know that the person who explains the meaning and implications of environmental and biological research to our politicians is also acutely aware of the important role that insects play in both human affairs and the wider world.

STUDENT ESSAY COMPETITION 2018

Each year the judges eagerly anticipate a relaxing day in the post-Christmas calm of another new year to delve into the box of entomological delights that is the student essay competition. The range of topics, novel perspectives and presentation formats is always impressive and this year was no exception, with thirty seven entries that explored a broad spectrum of entomological topics. Sixteen of these were from Harper Adams University, and the only other university to submit more than one entry was Plymouth. Curiously, both are the home of two active RES fellows. It was also very encouraging to see six entries from outside the UK. The standards were, as usual, incredibly high, and the judges struggled as they often do to agree on the top three entries. A decision has to be made, however, and the winners are:

1st Prize	Tara Sedgwick	Plenty of Insects
2nd Prize	Abigail Enston	Zombie Antpocalypse
3rd Prize	Faith Akinye Obange	An unlikely ally: The Greater Waxmoth to the rescue... again?
Runner up	Ben Howarth	An insect's guide to parenting
Runner up	William Rennison	It's the thought that counts

Our congratulations go to the winners but also to everyone who entered, we hope you enjoyed writing the essays as much as we enjoyed reading them and we hope this has inspired you to continue to communicate your love of entomology to as wide an audience as possible.

1st Prize

Plenty of Insects

Tara Sedgwick

Harper Adams University

2nd Prize

Zombie Antpocalypse

Abigail Enston

Masters Student at
Harper Adams University

Strolling through the forest, my sisters beside me, in search of food. Well, not actually searching, someone has already found our meal, I'm just following the trail, laid down by those who have already traveled this route. Turns out tonight's feast is a dead cockroach. It's great news, especially due to our recent decline in numbers.

Now I just need to head back to headquarters and share the food with the rest of the colony. Not everyone can get out to find their own food. The brood always are needing food, and of course the workers who tend to them, the ones that don't leave the nest. Most importantly is our queen, affectionately known as mom; she is far too precious to head out into the dangers of the world, so we must feed her too.

Of course, there is the farm as well. There we have our aphids, we care for them and protect them from anything else that would cause them harm. They produce delicious honeydew, which is shared among the colony. This of course keeps our tree healthier, by removing the honeydew normally dropped by the aphids which can encourage molds to grow.

Recently my fellow workers have been seen wandering away from our well-trodden trails and off into the canopy. They are, what can only be described as scavenging, when there is no need. We already have a food source that is yet to be exhausted. They can't be argued with. They feel the need to leave. It's the spores. Above us is a graveyard of my sisters' corpses. There is some weird structure growing from their heads. There is an effort to clear them and move them away from the colony but the number of them is growing faster than they can be cleared. They are like zombies, they are exhibiting odd behaviours and can't be reasoned with. I've even seen some fall.

A short while later...

Why do I feel compelled to leave the colony? I just know something's not right. The humidity I think. So, I travel, away from my home, away from my sisters – and climb, not a common place for me to go. Once I have traversed the plant I feel a bit better, the underside of the leaf seems safer to me. And then I feel an uncontrollable urge to clasp on to the leaf, I stick my mandible in. Why can't I let go? And there I stay, but I cannot move, my muscle won't obey. My sisters move underneath me, foraging as usual. It is this wretched fungus, I see now, not that anything can be done. I have seen some of my sisters before, fungus growing from their heads, and spreading the spores, as I will do now. Spread the spores to the rest of the colony. This will be some ants' demise. I just hope someone can find me and move me before I infect anyone else.

Background:

This story is based on *Ophiocordyceps unilateralis* (Tul.) Petch (1931), an entomopathogenic fungus (a parasite of insects) acting on a worker carpenter ant. *Ophiocordyceps unilateralis* is the cause of, what is commonly known as, zombie ants. When ants are infected by the fungus this changes their behaviour. Rather than following the pheromone trails laid by other ants from the colony, they will move randomly, and not be able to make their way back to the nest. The *O. unilateralis* can also cause the ants' muscles to spasm, and for them to fall from the trail. The fungus then causes the ants to climb plants until they reach a specific humidity, where they sink their mandibles into the main vein of the leaf, the *O. unilateralis* causes the lock jaw, meaning the ants are unable to detach themselves from the leaf, and will remain there even after death. This causes the ants to die in a place with optimal environmental conditions for the fungus to achieve its maximum reproductive output. The fungus continues to reproduce inside the ant, until a fruiting body emerges from the ant's head; this is where spores are released from, which will continue to infect other ants.

Ophiocordyceps unilateralis has the ability to wipe out entire colonies. Research is being completed to see whether this fungus could be used to control carpenter ants which are considered pests because of the damage they can cause to wood used in the construction of buildings.

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3rd Prize

An unlikely ally: The Greater Waxmoth to the rescue... again?

Faith Akinyi Obange

MSc student at the University of Nairobi

Dusk is falling over the African savanna. As the sun bids its long goodbye on the horizon, the tentacles of darkness creep over the landscape and the creatures of the night stir languidly from their day-long slumber. Perched in a nearby acacia tree, a male Greater Waxmoth (*Galleria mellonella*) lets out an acoustic sound; a mating call unmistakable to its female, who acknowledges it by a shy flap of its wings. But just to be sure his message went through, the male Greater Waxmoth unleashes its arsenal of pheromones; an irresistible aphrodisiac to its female, who then joins him in his lofty perch to mate.

Guests from hell

Shortly thereafter, the female sets off to find a suitable nesting site for her upcoming offspring. Never one to wait for an invitation anywhere, she spots a honeybee colony a stone's throw away from the acacia tree and promptly makes herself comfortable in it, laying eggs with reckless abandon. A month later, the eggs hatch into ravenous larvae that will for the next several weeks eat anything in their path: honey, pollen and beeswax! The hapless honeybees in the colony, having watched their food reserves and waxy abode get literally eaten away, are left no choice than to abandon the hive and try to rebuild their lives elsewhere, far from these self invited "guests from hell".

Forgotten Glory?

At this point, it might be hard to think of the Greater Waxmoth as anything but a rampaging pest, spreading destruction in its wake. But not long ago, the study of this lepidopteran heralded great scientific breakthroughs. For *in-vivo* experiments involving animal infection studies, invertebrate models like the *Galleria mellonella* infection model provide a cheaper, less time-consuming and more ethically-sound alternative to the conventional mammalian models previously used. Since the immune system of the Greater Waxmoth mirrors that of mammals, pathogens infectious to humans elicit a simillar immune response in the larvae of this insect. This knowledge has been put to good use in studying the pathogenicity of bacterial infections (*Listeria* and *Staphylococcus*) and fungal infections (*Candida albicans*). This infection model has also been applied to study the efficacy and toxicity of drugs against these infections before clinical trials, saving thousands of human lives in the process.

Hello, old friend?

Against the backdrop of environmental pollution, one of today's greatest challenges, the Greater Waxmoth has again unwittingly found itself at the tip of scientific tongues around the world. By pure coincidence, a researcher in Spain left a cluster of Greater Waxmoth larvae in a plastic bag overnight only to find they had eaten their way out. Upon further study, she reported that the larvae degraded the plastic to produce ethylene glycol through an enzymatic reaction. Although this finding has been met with generally piqued interest, it has drawn criticism from some quarters. One critic stated that the data might not be sufficient to suggest the presence of an enzyme and suggested that perhaps the degradation was more attributable to mechanical breakdown by the insects' mouth parts. Nevertheless, this opened debate and stimulated further biotechnological research into the mechanism used by *Galleria mellonella* larvae to break down plastic. So far, recent research findings indicate that secretions of gut microbes in the larvae may be responsible but a separate group is studying the effect of the larvae's own digestive juices on the plastic.

Either way, a ground-breaking discovery is in the offing and plastic pollution in the world may soon be a thing of the past, all thanks to the Greater Waxmoth. Not a shabby way for an old, wayward friend to make up for the destruction it has caused to beekeeping in the world!

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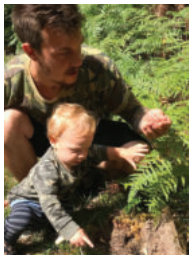

Runner up

An Insect's guide to parenting

Ben Howarth

Harper Adams University

A little over a year ago the incredible genius of insects was brought home to me in a slightly unusual way. It was 2.58 am, I was in the maternity ward of Winchester Hospital, tightly holding my partner's hand and doing my best to think of the most comforting words to try to sooth this seemingly agonising experience. As we reached the climactic moment and our new baby drew his first breath, I had nothing but an overwhelming sense of joy, the most joyous joy I could ever have imagined. The midwife handed me our new baby, I did not hesitate I was so overcome with emotion… in my arms was an incredibly tiny quivering little person, he stared up at me and I back at him. Wallowing in jubilation, I suddenly had a terrifying realisation… I have no idea what to do. I was mildly reassured to be told that many first-time parents feel this way, some turn to family for guidance, some to books. I however had a different instinct, insects.

I took to the internet for counsel. I soon discovered the small fluffy bee fly of the dipteran genus *Bombylius*. The female first camouflages her eggs in dust or sand, she hunts out the burrow of an unsuspecting solitary bee, hovers above the opening and flicks her eggs into the burrow. These eggs will be protected by the unwitting bee before hatching and massacring her own brood. Kind of like dropping your kids off with a nanny but she is unaware and when the baby wakes ups it kills their entire family. Perhaps not the best example of good parenting, I continued looking.

Next, I discovered the hymenopterans of the family Vespidae. The social wasps. These parents rear hundreds of offspring, they must have some good ideas. For vespids the queen dominates, maintaining order through continuous aggressive interactions. Similar to giving someone a slap around the back of the head just to remind them you are still in charge. I started to doubt this as a suitable method for me, looking down at my son, the thought of having to be continually aggressive to such an innocent looking being did not sit so well with my conscience. However, I continued to read, maybe it gets better… Over time a queen's dominance begins to wane, another fertile female will begin to test the queen's grip on power, often breaking out into a brawl. In these instances, it is not uncommon for the daughter to kill her mother and snatch the crown, ushering in a new era of

slightly more youthful brutality... No, I had read enough. I was not to be a vespid parent.

Undeterred I trawled on, at first sight the dung beetle *Onthophagus taurus* seemed like it was onto something, a caring couple who build an underground home for their offspring, stocking it with food… keeping my child underground with only a ball of faeces to eat… perhaps not. Nearing despair, I learned of the aquatic hemipteran *Kirkaldyia deyrolli*, the giant water bug. I was in territory with which I could relate. The female attaches eggs to surface vegetation, the male then provides protection from the circling, cannibalistic females as well as from ants, whom look on from the bankside, like hymenopteran incarnations of the child catcher from Chitty Chitty Bang Bang, ready to snatch his offspring as soon as his back is turned. The male works tirelessly fending off attacks from those who will do his kin harm. I felt inspired, I would provide protection for my little water bug, fending off the cannibalistic females and hymenopteran child catchers. I began to look upon all the women around me with suspicion, which one would try to consume my child first? What were they all doing in the maternity ward? It was all very suspicious. So, I had found my sense amongst this madness of early parenthood, I was the protector of my brood. I glanced over to my son, wrapped in a blanket and lying awake in his cot. My confidence swelled, I felt as if I now knew what to do. At that moment, an ear-piercing cry rang out. As the racket built, I strode over to the side of his cot (checking the surrounding area for cannibalistic females), picked up my child and said "have no fear, your *Kirkaldyia deyrolli* is here"; the crying continued. The feelings of despair started to return. Looking to my partner with a blank expression, I gestured as if to say "what's the problem here, there are no threats?". "He's tired, you'll need to help him to sleep" she replied, reading my uncertainty. "What?!, Mr *deyrolli* didn't tell me about this!" "What do I do?" I panicked. I need another insect.

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Runner up

It's the thought that counts: Valentine's day in the arthropod world

William Rennison

Harper Adams University

Everybody wants to make their special someone feel adored come Valentine's day and it's not often you go far wrong with gifting the classic box of chocolates or flowers. Insects and arachnids are also partial to these romantic gestures and appreciate when an ambitious male can bring something else to the table (sometimes literally!). The tokens offered by males to females are called 'nuptial gifts' and serve to increase a male's chance of mating with a female…sound familiar?

One hypothesis for the evolution of the nuptial gift is believed to be linked to mate choice. Nuptial gifts can act as an indicator of male fitness as there is a cost to hunting and not consuming prey and instead giving it away. This indicates to females that those with better gifts are likely to have better genes and produce stronger offspring [1,2]. An alternative hypothesis has been suggested for species prone to cannibalism. It is thought that the nuptial gift reduces the rate of sexual cannibalism as the male distracts the female with the gift as they mate [3].

Nuptial gifts are typically classified as either endogenous (produced by the male) or exogenous (collected by the male) [4]. Exogenous gifts are typically a prey item which the male has hunted or scavenged. Before attempting to mate with the female he will present this token to increase his chances of wooing her. Spiders which adopt this gift-giving strategy will take the time to wrap the prey items in silk before they deliver the prey to the female. Whilst this may seem courteous of the males, it means that sneaky (or savvy) males can take advantage and offer much less-valuable tokens whilst still satisfying female expectations [5,6,7]. This could include carcasses of the male's last meal. As the gift is wrapped and mating happens relatively quickly, by the time the female realises she has been duped with a worthless gift the male has already begun mating [7,8]. In the species *Pisaura mirabilis* (nursery web spider), males which offer the worthless gifts typically copulate for shorter times if the female unwraps her gift revealing his poor effort [8,9]. The nursery web spider has also been observed 'playing dead' after presenting his gift so as to avoid cannibalism and as the female unwraps the present the male will spring back into action to copulate [10].

Insects tend to offer endogenous gifts which they make themselves rather than picking something off the shelf like the arachnids. The endogenous gift favoured by most species comes in the form of spermatophores which carry the sperm along with nutrients for the females [4]. In species which do not feed as adults the spermatophore can play an important role in reproduction as females receiving more nutritional gifts will produce fitter offspring [11].

Many species of katydids and crickets have evolved a more elaborate two-part spermatophore which the female will eat rather than absorb. The part which is consumed is called the spermatophylax and after copulation has occurred the female will be able to gain the nutritional benefits of the gift [12]. In some species the males have specialised glands on their backs which the females may dine on and in other species of cricket males will even allow the females to chew down on a modified leg spur to consume their blood [4,13].

Scorpion flies take a slightly different approach with their gifts. Males will produce a 'spit ball' using their enlarged salivary glands which exudes pheromones which act as an attractant for females. Once the female locates a male they will feed on these nutrient-rich spit balls whilst copulation

takes place and males with the largest spit balls will mate for longer. If a male does not have the resources to create a salivary mass for his partner then he will offer a prey item as a consolation prize and males can be quite thrifty in re-using the prey for other females, although this does impact their success [4,14].

The benefit for females receiving gifts seems fairly obvious, an increase in fitness. For males however, the gifts often use up many of their own resources. Besides increasing their chance of attracting a female there are a few subtle side effects of receiving nuptial gifts which may be of benefit to males. In some species, spermatophores contain compounds which reduce a female's receptivity to other males, giving the first male a higher chance of passing on his genes to the next generation. Some gifts may not actually have much benefit to females and in the case of *Drosophila melanogaster* (fruit fly) the gift accelerates reproduction at the expense of shortening the female's lifespan [4].

So, next time you give your loved one a gift, remember it's the thought that counts. Although I would avoid the insect carcasses.

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NATIONAL INSECT WEEK 2018 PHOTOGRAPHY COMPETITION

Under 18 category

1st Prize: [1]Zach Haynes – **Mayfly on an unfurled fern frond**; 2nd Prize: [2]Shannon Cansfield – **Reflecting**; Specially Commended: [3]Alex Perry – **Lang's Short-tailed Blue (*Leptotes pirithous*)**; Specially Commended: [4]Rebecca Hyde – **Dragonfly Impossible**; Specially Commended: [5]Zach Haynes – **Hoverfly honing in**; Specially Commended: [6]Gavin Pandya – **Golden Buprestid on Iris**

Adult Category

1st Prize: [7]Petar Sabol – **Orange tip butterfly and mayfly sharing**; 2nd Prize: [8]Wen-Chi Yeh – **Potter wasp, *Oreumenes decoratus*, returning to her nest**; Specially Commended: [9]Wexiang Lee – **Planthopper nymph with the 'fibre optic' tail**; Specially Commended: [10]Andrew Geen – **Wonder of the day (*Dichonia aprilina*)**; Specially Commended – [11]Ivan-Marios Mezitis – **Metamorphosis**; Specially Commended: [12]Martin Tampier – **Kite (*Amblycorypha oblongifolia*)**; Specially Commended: [13]Beverley Brouwer – **Bejewelled Fly**; Specially Commended: [14]Petar Sabol – **Mayfly resting just before sunrise**; Specially Commended: [15]Simon Carder – **Water reflections through greenery. Broad Bodied Chaser (*Libellula depressa*)**; Specially Commended: [16]Zoltan Gyori – **Bedtime**; Commended: Michael Bird – **Two for the price of one**; Commended: Narayan Patel – **Caterpillars on silk**; Commended: Juergen Specker – **Sunfly on Helenium**; Commended: Martin Taylor – **Treehopper on vine**; Commended: Andrew Neal – **Damselfly symmetry**; Commended – Deepak Kumbar – **Just one world**; Commended: Denise Bishop – **Painted Lady**; Commended: Simon Carder – **Six-spot burnet and knapweed at dawn**; Commended: William Richardson – **A walk in the rain**; Commended – David Holland – **Under siege**; Commended: Zoltan Gyori – **The vice**; Commended: Katarzyna Bukowska – **Black-veined Whites**; Commended: Faith Melencio – **One love**; Commended: Iain Cowe – **Autumn's Herald.**

All winning entries can be viewed at:
www.nationalinsectweek.co.uk/photography

Book Reviews

Honeybee Hotel: The Waldorf Astoria's Rooftop Garden and the Heart of NYC

Leslie Day

John Hopkins University Press

ISBN 978-1-4214-2624-2

£16.99

This is a story about food, gardens, passion and bees, a story that is set twenty floors above the bustling streets of New York City. But, above all, it is a story of an unusual collaboration between chefs, gardeners, hoteliers and bee keepers. It is a heart-warming tale of a dream that materialises in this most unlikely location.

Honyebee Hotel is a delightful cocktail of narratives that include the history of New York's most famous hotel, the inception and construction of its rooftop garden and the diverse array of people who drove the project forward. It is also liberally sprinkled with honey bee biology and an obvious passion for food and cooking.

It charts the career of the Astoria's executive chef David Garcelon, tracing his interest in gardens and bees alongside his passion for cooking. His first garden was on the roof of the Royal York in Toronto, which he transformed into a culinary resource for the hotel's chefs and then added bees. So, when he moved to the Astoria in New York he was keen to repeat the project. To his surprise the hotel management backed it enthusiastically and a garden with bees soon became the centre of a community of bee keepers, gardeners and chefs. The "Top of the Waldorf Honey" was soon highly prized and used extensively in their hotel kitchens.

Honeybee Hotel is a charming account of the creation of a resource that bound a community together. From an entomological perspective, it is fascinating to see the way that insects have been the glue that brought it together and held it in place. Interspersed with the main story are short chapters that detail the biology of the honeybee. These include the life of workers, drones and queens, communication in the hive, bees' wings and a brief history of bee keeping. If your bee biology is a little rusty this is an excellent revision course and if the world of the honeybee is as yet unknown to you, it is a great introduction. There is also an appendix of honey-based recipes from the Astoria's kitchen, which include a tantalising range of main dishes, deserts and cocktails.

Honeybee Hotel builds a reassuring picture of a hotel working with its chefs and the local community to build a sustainable resource in the heart of New York City. But just as the book is about to close, the dark cloud of corporate change appears and the hotel is bought by the Chinese government, who want to modernise it. Conservation groups are formed to protect the internationally important art deco interiors, but the bees are moved out to another site and the gardens are wound down. The future of this roof-top alliance is now uncertain.

If you love New York, cooking or bees you will enjoy this book.

Peter Smithers

World Catalogue of Insects volume 15 Conopidae (Diptera)

Jens-Hermann Stuke

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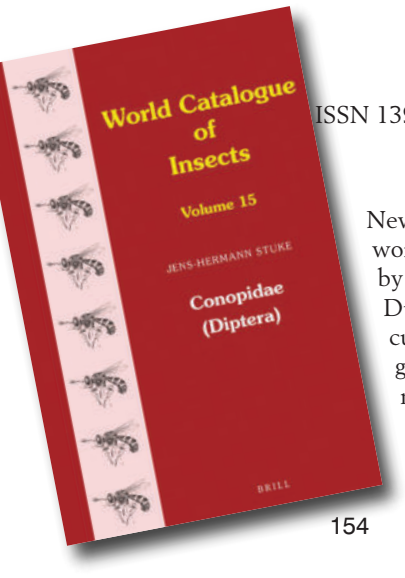


New to this series of world catalogues of insect families published by Brill, this is the first published world catalogue of this interesting family of largely parasitic, wasp-mimicking flies since that produced by Otto Kröber, the first person to extensively study the taxonomy of this group, almost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

This book begins with a large introductory section including an explanation of the systematics of the group and a list of the geographical distribution of the individual genera, and some explanation

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

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

Nigel Wyatt

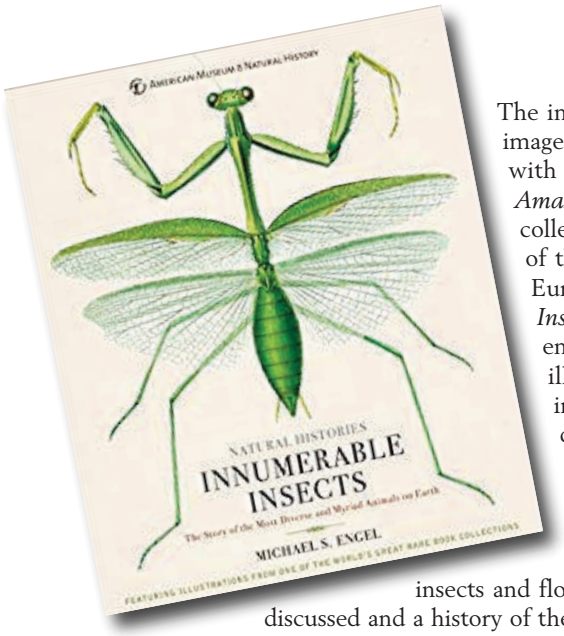
Innumerable Insects

Michael S. Engel

The American Museum of Natural History

ISBN 978-1-4549-2323-7

£20.00



The initial impression one has of this book is that it is a showcase for a selection of images from the Smithsonian's rare book collection and there is certainly nothing wrong with that. It is a concept that follows in the footsteps of similar volumes such as *Amazing Rare Things*, which is an exploration of rare natural history books in the royal collection at Windsor, and *Rare Treasures*, which looks at rare volumes in the library of the Natural History Museum, London. Both of these books weave the story of European natural history around the images from these collections, and *Innumerable Insects* does the same for entomology and more. It offers a lavish selection of entomological images from the Smithsonian archive of rare books, using them to illustrate an extremely readable introduction to the orders of insects, which is intertwined with the history of entomology itself, its origins and the pioneers who drove it forward.

The book opens with an outline of the emergence of entomology as a science and an introduction to the diversity and abundance of insects. Subsequent chapters explore the wingless insects, winged insects, metamorphosis, pests and parasites, social insects, communication, camouflage and the co-evolution of insects and flowering plants. Each chapter provides an overview of the biology of the insects discussed and a history of the development of our understanding of each insect group. Scattered throughout the book are independent sections that detail the life and contribution of important entomologists. These are illustrated with plates from their major works and are a fascinating glimpse of the often-turbulent times in which they forged their careers.

I particularly enjoyed the literary quotes at the start of each chapter; quotes that range from Lewis Carroll to Emily Dickinson and Shakespeare to Wittgenstein. These set the text and images in a broader social context. The plates are wonderful. They are bright, vibrant and meticulous, offering an insight into the aesthetic and scientific heritage that are embedded in these volumes.

Whilst the text may not present many new facts on insect biology to the seasoned entomologist, it may well offer new insights into entomological history. However, to the non-entomologist it will be a box of delights and wonders. An invitation to plunge down the rabbit hole that is entomology and experience the complexity of this bizarre and beautiful world. For both entomologists and non-entomologists, *Innumerable Insects* is a book to pore over and revel in.

Peter Smithers

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

Aquatic Insects Special Interest Group
Tuesday, 1 October, 2019
CEH, Lancaster

Ento Outreach Special Interest Group
Thursday, 28 November, 2019
The LookOut Discovery Centre, Hyde Park, London

2020 PG Forum
Thursday, 20 February – Friday, 21 February, 2020
University of Bristol

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

EntoSci20
Thursday, 30 April, 2020
Harper Adams University

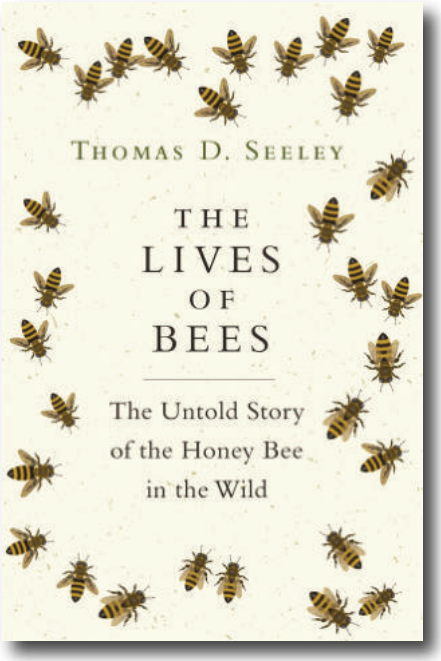
Annual General Meeting
Wednesday, 3 June, 2020
The Mansion House, Chiswell Green Lane, St Albans, AL2 3NS

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

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



The Lives of Bees

The Untold Story of the Honey Bee in the Wild

Thomas D. Seeley

"Cornell University biologist Seeley is one of the most beloved authors in the beekeeping community, and with good reason: his writing elucidates the lives of honeybees with clear science and a sense of joyous discovery."
—Gemma Tarlach, *Discover*

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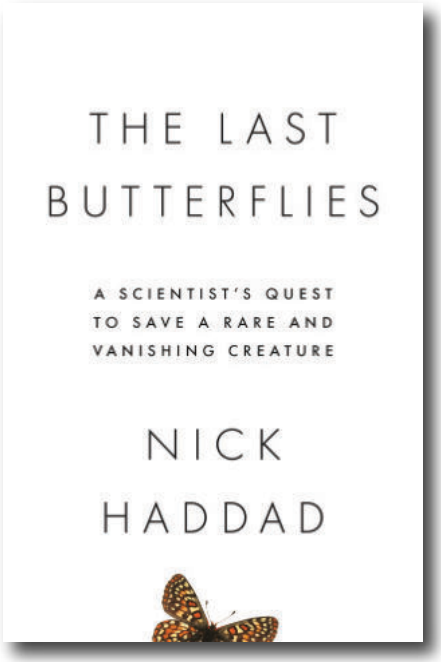

The Last Butterflies

A Scientist's Quest to Save a Rare and Vanishing Creature

Nick Haddad

"In this magisterial work, Haddad tells the story of his quest to find the rarest butterfly species in the world. This beautiful book is full of the sorrows of loss, but also the wonders of natural history and the power of hope."
—Rob Dunn, author of *Never Home Alone*

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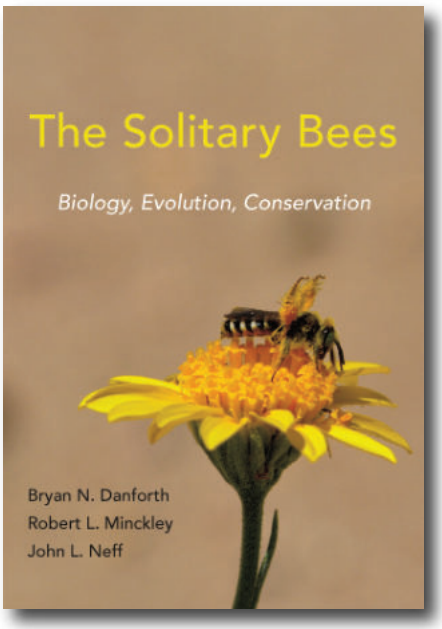

The Solitary Bees

Biology, Evolution, Conservation

Bryan N. Danforth, Robert L. Minckley, and John L. Neff

"Finally, we have *the* definitive book on most of the world's bee species—the solitary bees. Danforth, Minckley, and Neff have written a book that is extremely well-informed, full of charming natural history, and delightful to read."
—Rachael Winfree, Rutgers University

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PRINCETON UNIVERSITY PRESS

RES STUDENT AWARD 2019

Write an entomological article and WIN!

www.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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