ENTOMOLOGY

The bee-all and end-all

Seven scientists give their opinions on the biggest challenges faced by bees and bee researchers.

ROBERT PAXTON
Honeybee viruses

Head of general zoology, Martin Luther University Halle-Wittenberg, Germany

Honeybees are declining in number across the Northern Hemisphere. There is broad consensus within the scientific community that their most serious threats are pathogenic microbes, particularly viruses, and the parasitic mite *Varroa destructor*, which transmits viruses while sucking the blood of the bee. A major challenge is to show whether *Varroa* mites also lower the immune response of the host bee to these viruses. Or do the mites provide an environment that selects for better-replicating or more-virulent viral variants? — or both.

Honeybees host more than 50 types of microbe, which next-generation sequencing technologies are helping us to explore. Researchers are trying to determine which microbes are pathogens and how to control them. We need to understand how pathogens interact with other stressors — pesticides and poor nutrition — in ways that harm honeybee populations. The field would benefit from mechanistic models describing these interactions at the molecular level, revealing targets of selection for host tolerance or pathogen suppression.

The impact of pathogens on individuals may not translate into colony-level effects. So it is crucial that we figure out where the line is — how many individual losses and in what season — will destroy a colony. Acquiring this understanding will involve both empirical studies and theoretical modelling.

Perhaps most importantly, governments need to regulate the movement of disease-carrying honeybees to reduce the invasion and emergence of new pathogens. The same honeybees that are imported to support pollination and agricultural production also threaten native pollinators (as well as other honeybees) and hence undermine sustainable provision of these ecosystem services.

MARK BROWN
Diseases in wild bees

Professor of evolutionary ecology and conservation, Royal Holloway, University of London

The 25,000-or-so species of bee are important components of biodiversity and are essential for pollinating crops and wild plants. Although we have limited data, it seems that the populations of many of these species are in decline. Throughout the twentieth century, the major driver of the decline in the number of bees was habitat loss, but since then the threat posed by new diseases has come to the fore.

New or emerging diseases are linked to the rapid declines over the past 20 years in North American bumblebee species and to the dramatically shrinking range over the past 5–10 years of a charismatic South American bumblebee, *Bombus dahlbomii*. Commercial bumblebees that are bred and used for pollination have been blamed as the source of the diseases. Wild bumblebees are also susceptible to an array of viruses that are common in managed honeybees, with some viruses showing patterns suggestive of spread from managed honeybees to wild bumblebees[1].

Although there is evidence that parasites can be transmitted from commercial and managed bees to wild bees, we lack proof that these parasites cause a decline in the number of wild bees. Specifically, we have not definitively identified the direction of transmission for parasites and pathogens, and we have little idea of the impact they have on wild-bee populations.

In the meantime, given the importance of wild bees, application of the precautionary principle is justified. Researchers should support commercial producers of bumblebees in generating disease-free colonies, and governments should ensure that the use of commercial bees is limited to escape-proof greenhouses, such as those that are used in Japan. In addition, the export of commercial bumblebees to countries where the commercial species is non-native should be banned. Similarly, disease management in honeybees needs to be supported, to protect both the

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honeybees and the wild bees with which we know they share diseases.

Emerging diseases are a global problem for biodiversity. We need to grapple with them in our wild bees to reverse current declines and to prevent future disasters.

MICHAEL KUHLMANN
Expertise in decline

Head of insects division, Natural History Museum, London

When it comes to bees, Europe is the best-studied continent and has nearly 2,000 known species. Even so, more than 120 new species of European bee have been described since 1990, and there are probably another 100–200 species still to go. As we build up this knowledge base, we need to do more than just create an inventory: we need to explore the diversity of bees' life histories and flower specializations to develop effective conservation measures and assess the impact of climate change.

Bee taxonomy is notoriously difficult. Many species — often common ones — look very similar to each other yet have different life histories. Taking on this daunting assignment is a small and ageing cadre of skilled taxonomists. Shortage of taxonomic expertise has already left some European bee genera orphaned — without any specialists working on them — and is a serious bottleneck for the rising demand of bee identification in pollinator research. This taxonomic crisis was exposed in the assessments prepared by the International Union for Conservation of Nature and published in 2014 in the *European Red List of Bees*[2]. For 80% of the bees on the list, population trends are unknown, and more than half of all species were labelled as 'data deficient', making it impossible for even an indirect assessment of risk of extinction.

Technology, including DNA barcoding, might help. It can accelerate the speed of identification of recently collected bees, but is of limited use for old museum collections in which the DNA has degraded. Furthermore, in the parts of the world where this technology would be of most use, such as Asia and Africa, the lack of even basic taxonomic information often makes identification impossible.

Taxonomy urgently needs investment and, crucially, training and encouragement of young academics if we are not to lose an invaluable treasure of expertise.

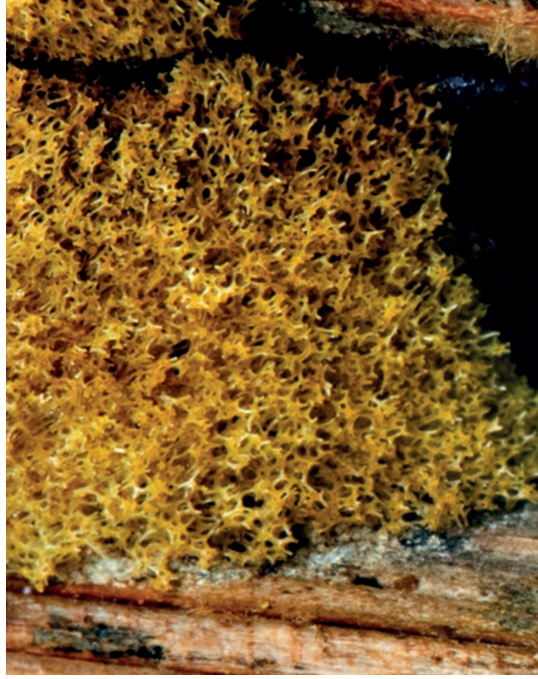
DAVE GOULSON
De-intensify agriculture

Professor of biology, University of Sussex, UK

Bees are often described as the 'canaries in the coal mine' when it comes to the health of the environment. Intensively farmed land is a hostile environment for bees: there are few flowers or quiet places to nest, and many pesticides. We tend to accept that such practices are necessary to feed the growing human population, but we should challenge that assumption.

An ideal farming system would sustainably produce sufficient amounts of healthy food yet also minimize adverse environmental impact. Modern intensive farming fails abysmally to satisfy these basic criteria. For example, around the world about 100 billion tonnes of soil are either degraded or washed away each year, which is clearly not sustainable[3]. Modern farming is highly dependent on artificial fertilizers, which contribute substantially to climate change. Biodiversity is declining at an unprecedented rate. The loss of bees has attracted attention because our food supply directly depends on these insects, but the reduction in their population is symptomatic of a much broader problem. Most wildlife associated with farmland is

Many bee species look identical, yet the number of taxonomists who can tell them apart is in decline.



also in decline, including birds, butterflies and beetles.

The majority of investment in agronomic research comes from industry, and tends to focus on increasing yields. Yet we already grow enough food to feed the projected global population of 9 billion in 2050 — we just waste an awful lot of it. We need investment in research and support for sustainable farming systems with reduced inputs — systems that conserve the soil and minimize the impact on wildlife such as bees. Industry is unlikely to invest in ways to reduce inputs, for supply of those inputs provides much of its profit. Surely it is the role of government to intervene in this situation. Do we really want to trust big business to shape the future of farming, and to look after our bees?

AXEL DECOURTYE
Listen to the beekeepers

Scientific director, French Technical Institute of Beekeeping and Pollination, Avignon, France

In response to the inexplicable losses of honeybee colonies in the past two decades in Europe and the United States, research has been focused on understanding the underlying causes. Papers that have been published during this time account for nearly 45% of all publications on the honeybee. Although it is appropriate to try to understand how to act, time is running out.

The main causes of honeybee colony loss have been identified: the parasite *Varroa* and associated viruses; pesticides; and food shortage in the form of wildflower loss.

MAURO FERMARIELLO/SPL

A honeybee leaves the hive unwittingly carrying a *Varroa destructor* mite (inset).

MAIN IMAGE: CHRIS ROBBINS/ALAMY; INSET: POWER AND SYRED/SPL

These factors provoke a complex cascade of events, often with delayed effects on bee population dynamics[4]. We cannot afford to continue focusing only on identifying the precise mechanism that is driving the losses while ignoring beekeepers' calls to invest in addressing the known causes.

We need an approach that better integrates the needs of beekeepers, farmers and scientists — for example, by establishing teams drawing on all of these communities to undertake the research and development. Top priorities include the breeding of *Varroa*-resistant bees. The efficiency of the breeding selection also depends on the creation of quality-control procedures by breeders of queen bees. This point is critical to beekeeping sustainability — a new but growing concept. Government policy initiatives should support the remodelling of farms to improve food sources for bees in the landscape and to reduce the use of pesticides. Although the neonicotinoid moratorium in the European Union was a welcome move in this direction, it is not sufficient and addresses only one of the known causes.

JEAN-MARC BONMATIN
Stop poisoning farmlands

Research chemist, French National Centre for Scientific Research (CNRS), Orléans, France

Wild and managed bees are facing an unprecedented situation in which their environment and food resources (pollen, nectar and water) are becoming contaminated by cocktails of pesticides at levels known to have adverse effects. We need to find ways to reduce bees' exposure to these pesticides, which are mainly insecticides and fungicides.

Of particular concern are neonicotinoids, known as neonics. Laboratory studies have shown that these systemic neurotoxicants directly affect bee health and colony performance. And combinations of neonics with other insecticides and fungicides, as well as with certain infectious agents, act together in the bee to amplify the negative effects.

Neonics represent one-third of the global insecticide market; they are used by growers of grains, vegetables and fruit, as well as to kill livestock parasites such as lice and fleas.

> ***"The prophylactic and extensive use of neonics is the major cause of the decline in bee populations."***

The prophylactic and extensive use of neonics, combined with their very high toxicity to invertebrates, persistence in soils and solubility in water, is the major anthropogenic cause of the decline in bee populations over the last two decades[5]. And bees are not the only victims of neonics: these pesticides are also harmful to terrestrial and aquatic invertebrates, birds and fishes, both directly and through the food chain[6].

Although three neonic insecticides have been restricted in Europe since 2013, certain prophylactic uses are still allowed — or other insecticides are applied in their place. The use of insecticides as an insurance policy conflicts with the European Commission-mandated policy of integrated pest management; a directive issued in 2009 states that pesticides should not be used for prevention, only as a last resort. The burden on pollinators will decrease only when pesticide use does, and this will only occur when integrated pest management becomes standard practice in farmlands.

PAT WILLMER
Too many commercial hives

Professor of biology, University of St Andrews, UK

One major concern for bee conservation is the stress introduced into the whole pollination system by having too many commercial honeybee hives. The intensive management of *Apis* hives by industrial beekeepers magnifies all other problems.

Regular long-range transportation of hives to service seasonal orchards can stress and disorientate their inhabitants. Honeybees' health may also suffer from the low pollen diversity found in crop monocultures. Out of season, or while in transit, the bees' nutritional needs are poorly served by maize (corn) or grape syrup, or fructose solutions, which are substituted for the richer honey that has been harvested. Finally, honeybees' natural reproduction is limited because new commercial hives are typically started using artificially inseminated queens, a practice that reduces genetic diversity.

Together, these issues lead to increased pest and pathogen problems; agrochemicals applied to attempt to control them can worsen matters in the longer term, because miticides and antibiotics (plus herbicides and insecticides that bees bring in from foraging) may affect bees' gut microbiota, and reduce the insects' ability to adapt to their pests. All these issues are amplified in *Apis* because the bee's genome has evolved to contain few detoxification and immunity genes, presumably reflecting the low toxin content of nectar and pollen, and the social behaviours that confer some antimicrobial protection.

A reduction in the commercial honeybee population, whether deliberate or from colony collapse disorder, may not be a bad thing. We should use the opportunity presented by the fall in commercial beehives to support native wild bees and encourage natural honeybee-keeping, while providing enough floral diversity so that the bees we do have can collectively provide full and balanced pollination services. ■

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