

## **Mystery of Disappearing Honeybees**

*For some time now, honeybees have been disappearing from farmers' hives without a trace  
Dr. Mae-Wan Ho and Prof. Joe Cummins on the trail of possible culprits ...*

### **Honeybees vanishing worldwide**

The first alarm was sounded in autumn 2006. Honeybees are disappearing across the United States, with half of the States affected and beekeeper losing 30 to 90 percent of colonies; one beekeeper with 1 200 colonies expected 9 to survive the winter [1]. The problem began more than two years ago and has intensified in recent months [1-5]. The bees simply vanish relatively suddenly, with little or no dead adults in or near the colonies, leaving behind the queen and a few young. In cases where the colony appears to be actively collapsing the workforce seems to be made up of young adult bees, insufficient to feed the brood, but are reluctant to consume provided feed [5]. This “colony collapse disorder” (CCD) is particularly devastating for growers of fruits and vegetables, as they depend on insect pollinators.

Since then, CCD has been reported from Germany, Switzerland, Spain, Portugal, Italy, Greece, and the UK [6], where one of the biggest beekeepers lost 23 of his 40 hives. But the Department of the Environment, Food and Rural Affairs (DEFRA) said that “there is absolutely no evidence” of CCD in the UK.

CCD has baffled scientists, because no one knows what causes it [5], and ongoing efforts are being made to identify possible pathogens in the bees and chemical residues in pollen, honey and bees. Viruses, fungal diseases, parasitic mites, pesticides, or chemical designed to control mites have considered by the authorities [7], as have GM crops [8-9], and mobile phones [10] ([Mobile Phones and Vanishing Bees](#), this series). So how good is the evidence for the different suspects?

### **Extent and causes of decline both unknown**

The United States National Research Council Committee on the Status of Pollinators in North America published its report [7] in October 2006. But the report was rather thin on data and information as to the precise extent of the decline in honeybees or its causes.

The report discussed introduced parasitic mites, and the bacterial pathogen that causes foul brood disease in detail, as there is extensive scientific literature. But it barely touched on pesticides or GM crops, and did not mention mobile phones at all.

### **Mites infestations**

The introduced parasitic mites, *Varroa destructor* and *Acarapis woodi*, began to cause infestation since the late 1980s, and mite infestation became established in the US within a decade. *Varroa destructor*, an external parasite of the honeybee, has caused dramatic declines in honeybees in North America and throughout the world. During the winter of 1995-1996, northern US beekeepers experienced their largest losses in history; some states lost 30 to 80 percent of their colonies. These losses have occurred despite heavy used of pesticides to control mite populations. Pesticide resistance has become widespread and many beekeepers are no longer able to use the few registered pesticides for controlling *Varroa*.

The tracheal mite *Acarapis woodi* is an internal parasite of the honeybee. It was first detected in the US in 1984, and initially caused serious damage to colonies, but there appears to be heritable resistance to the mite.

Parasitic mites cannot explain colony collapse disorder as there is no evidence that mite infestation is directly involved, although it may contribute indirectly by reducing the immunity of the bees to infections by viruses, bacteria and fungi (see below).

### **Foul brood disease**

*Paenibacillus larvae* is the most serious pathogen of honeybees. It causes American Foul Brood disease (AFB), a disease of the honeybee larvae. It is highly virulent and easily spread among colonies, and generally fatal if untreated. During the first half of the last century, AFB was the most serious threat to beekeeping, and caused tremendous loss of colonies. The incidence of AFB was reduced dramatically by the introduction of antibiotics, and by state inspection programme that required the burning of infected hives. However AFB spores are refractory to antibiotics and can persist on contaminated equipment for more than 80 years. Treatment of colonies with active cases of AFB eliminates disease symptoms, but withdrawal of antibiotics is generally followed by disease recurrence. Resistance to antibiotics has also become widespread since 1994.

As in the case of parasitic mites, foul brood disease is not associated with colony collapse disorder.

### **Pesticides**

The use of pesticides, especially insecticides on crops, is known to kill or weaken thousands of honeybee colonies in the US each year, and local bee kills have occurred sporadically for decades. However, the NAS report considered it unlikely that this has “contributed significantly” to the recent decline. The report stated [7, p. 79]: “Most pesticide-caused honey bee kills are the result of accidents, careless application, or failure to adhere to label recommendations and warnings.” It has obviously ignored sub-lethal effects, particularly of new pesticides that may turn out to be one of the most significant single factors contributing to the current honeybee decline (see later).

### **Parasites reduce bee immunity**

*Varroa* mites infestation reduces the immune response of the bees, causing them to be prone to infection with virus, bacteria or fungi [11, 12]. A number of viral diseases are enhanced in the parasite-infested bee colony, particularly the deformed wing virus disease that causes crippling deformity in the bees [13]. Multiple viruses frequently infect bees attacked by *Varroa* parasite. These viruses are spread not only by the parasite, but also vertically from queen to brood [14, 15]. The parasite-infested colonies are frequently treated with a pyrethroid insecticide, fluvalinate, but the parasite has grown resistant to the insecticide [16], and the insecticide may adversely influence the behaviour of the honeybee (see below). Honeybees have 17 gene families involved in immunity [17], roughly one-third the number of immunity genes in *Drosophila* and *Anopheles* mosquitoes. Honeybees seem to have limited immune flexibility, which may make them more sensitive to devastating pathogens.

### **Pesticides disrupts bee behaviour at sublethal levels**

Numerous pesticides have been found to disrupt bee behaviour following sub-lethal exposures [18]. A wide array of pesticides including fluvalinate (the chemical used to treat hives to eliminate parasites) disrupted the behaviour of honeybees leading to feeding and navigation problems [19]. Bees suffering from sub-lethal pesticide intoxication resembled the

behaviour of bees described by observers of the colony collapse disorder. Sub-lethal doses of fipronil (a veterinary insecticide) impaired the olfactory memory process of honeybees [20]. Spinosad, a prominent and much used natural insecticide fed to bumble bees in pollen slowed down their foraging behaviour while a higher dose of the insecticide caused colony death within two to four weeks [21]. See [Requiem for the Honeybee](#) [22] for more evidence that sub-lethal effects of pesticides may be the single most important factor contributing to disappearing honeybees.

### **Genetically modified (GM) crops may have sub-lethal effects on bees**

The possibility that GM crops in North America is contributing to the decline in honeybees was given little consideration by the NRC Committee [7] even though the timing of the honeybee decline appears to coincide with the widespread deployment of GM crops. GM crops are engineered to tolerate herbicides, especially glyphosate, or to contain biopesticides (the Bt Cry toxins from *Bacillus thuringiensis*), or both. The biopesticide toxins produced in Bt crops are not highly or acutely toxic to bees, but are toxic to butterflies, moths and beetles. Nevertheless, in some instances, the toxins can kill bees or modify their behaviour.

The Bt toxin Cry1Ab caused reduced foraging activity in bees after they were fed with syrup containing the toxin. However, the Bt toxin produced less pronounced impacts on bee behaviour than the chemical pesticides deltamethrin or imidacloprid [23]. Bt bacteria caused mortality in bees when fed in broth cultures or sugar solutions [24]. A number of purified Bt Cry toxins have been studied in the laboratory to determine their toxicity to honey bees and bumble bees. For the most part, those studies showed little threat from the Cry toxins. But sub-lethal effects on the bees were not recorded in those experiments [25].

In a series of experiments in Jena, Germany, bees were found not to be affected when fed on a diet of pollen doped with 100 times the concentration of toxin found in the Bt maize pollen; and feeding trials on larvae also showed no effects. In the field, bee colonies in flight tents were fed with Bt maize pollen to which a 10-fold concentration of Bt toxin had been added. Again, no negative effects were detected. But a chance infestation by the parasite microsporidia resulted in significantly more damage to the Bt-fed colonies compared with controls [26]. Another limitation of the experiments so far is that they were carried out with toxins derived from bacteria, not transgenic toxin derived from the Bt crops, which are known to have very different properties, as we have pointed out repeatedly, most recently in [GM Maize 59122 Not Safe](#) [27] (*SiS* 34).

Transgenic glyphosate-tolerant canola pollen was reported to pose no threat to honeybees [28]. However, when organic, conventional, and herbicide-tolerant canola were compared with regard to pollination by wild bees in Alberta, Canada, the herbicide tolerant canola plots had the greatest pollination deficit, while conventional and organic plots were equally well served by the wild bees [29].

Clearly, the existing evidence calls for much fuller investigations on the sub-lethal impacts of GM crops on bees, such as learning and feeding behaviour, and immunity to disease. The potential consequences of pollinator decline on food crops can be staggering, and the impact on biodiversity may be irreversible [30].

### **Mobile phones and bee decline**

There has been widespread report in the mainstream media that mobile phones may be responsible for the decline of honeybees [for example, 6, 31]. The results are indeed startling.

For details see [Mobile Phones and Vanishing Bees](#) [10], and should be considered in the context of the increasingly clear evidence that weak radiation from mobile phones and base stations do have harmful effects on the health of human beings and wildlife [32] ([Drowning in the Sea of Microwaves](#), *SiS* 34).

### **The mystery remains**

The mystery of disappearing honeybees is far from solved. The greatest suspects so far are pesticides and radiation from mobile phone base stations. However, it is likely that sub-lethal effects due to GM crops, mites infestations and other factors which alter the bees' behaviour, affect their memory and learning process or compromise their health and immunity will all have a role to play.

Honeybees may be our most sensitive indicator species for all the environmental pollution and dangerous technologies we perpetrate. When honeybees disappear, we too, shall follow shortly.

### **References**

1. "Honey bee die-off alarms beekeepers, crop growers and researchers", News Release PennState College of Agriculture, 29 January 2007  
<http://www.aginfo.psu.edu/News/07Jan/HoneyBees.htm>
2. "Mystery illness devastates honeybee colonies" Roxanne Khamisi NewScientist.com news service, 14 February 2007,  
<http://environment.newscientist.com/article.ns?id=dn11183>
3. "Honeybees, gone with the wind, leave crops and keepers in peril" Alexei Barrionuevo, New York Times 27 February 2007.  
<http://select.nytimes.com/gst/abstract.html?res=F10B1FF8355A0C748EDDAB0894DF404482>
4. "Bee vanishing act baffles keepers", BBC News, 27 February 2007,  
<http://news.bbc.co.uk/2/hi/science/nature/6400179.stm>
5. Colony Collapse Disorder Preliminary Report, PennState University, January 2007  
<http://maarec.cas.psu.edu/pressReleases/FallDwindleUpdate0107.pdf>
6. "Are mobile phones wiping out our bees?" Geoffrey Lean and Harriet Shawcross, the Independent on Sunday, 15 April 2007,  
<http://news.independent.co.uk/environment/wildlife/article2449968.ece>
7. Committee on the Status of Pollinators in North America American National Research Council, Status of Pollinators in North America 2006 ISBN:978-0-309-10289-6
8. "Are GM crops killing bees?" Gunther Latsch, Der Spiegel, 22 March 2007,  
<http://www.spiegel.de/international/world/0,1518,473166,00.html>
9. "European bees also taking a nosedive – perhaps GM crops?" Craig Mackintosh, Celsias, 29 March 2007 <http://www.celsias.com/blog/2007/03/29/european-bees-taking-a-nosedive/>
10. Ho MW. Mobile phones and vanishing bees. *Science in Society* 34 (in press)
11. Yang X and Cox-Foster DL. Impact of an ectoparasite on the immunity and pathology of an invertebrate: evidence for host immunosuppression and viral amplification. *Proc Natl Acad Sci U S A*. 2005 May 24;102(21):7470-5

12. Yang X and Cox-Foster D. Effects of parasitization by *Varroa destructor* on survivorship and physiological traits of *Apis mellifera* in correlation with viral incidence and microbial challenge. *Parasitology*. 2007, 134(3), 405-12.
13. Yue C and Genersch E. RT-PCR analysis of Deformed wing virus in honeybees (*Apis mellifera*) and mites (*Varroa destructor*). *J Gen Virol*. 2005, 86(12), 3419-24.
14. Chen YP, Pettis JS, Collins A and Feldlaufer MF. Prevalence and transmission of honeybee viruses. *Appl Environ Microbiol*. 2006, 72(1), 606-11.
15. Chen Y, Evans J and Feldlaufer M. Horizontal and vertical transmission of viruses in the honeybee, *Apis mellifera*. *J Invertebr Pathol*. 2006, 92(3), 152-9.
16. Liu Z, Tan J, Huang ZY and Dong K. Effect of a fluvalinate resistance associated sodium channel mutation from varroa mites on cockroach sodium channel sensitivity to fluvalinate, a pyrethroid insecticide. *Insect Biochem Mol Biol*. 2006, 36(11),:885-9.
17. Evans JD, Aronstein K, Chen YP, Hetru C, Imler JL, Jiang H, Kanost M, Thompson GJ, Zou Z and Hultmark D. Immune pathways and defence mechanisms in honey bees *Apis mellifera*. *Insect Mol Biol*. 2006, 15(5), 645-56.
18. Desneux N, Decourtye A and Delpuech JM. The sublethal effects of pesticides on beneficial arthropods. *Annu Rev Entomol*. 2007, 52, 81-106.
19. Thompson H. Behavior effects of pesticides in bees - their potential for use in risk assessment. *Ecotoxicology* 2003,12, 317-30.
20. El Hassani AK, Dacher M, Gauthier M and Armengaud C. Effects of sublethal doses of fipronil on the behavior of the honeybee (*Apis mellifera*). *Pharmacol Biochem Behav*. 2005, 82, 30-9.
21. Morandin L, Winston M, Franklin M and Abbott VA. Lethal and sub-lethal effects of spinosad on bumble bees (*Bombus impatiens* Cresson). *Pest Management Science*, 2005, 61,619-26,
22. Cummins J. Requiem for the honeybee. [Science in Society 34](#) (in press).
23. Ramirez-Romero R, Chaufaux J and Pham-Delègue M. Effects of Cry1Ab protoxin, deltamethrin and imidacloprid on the foraging activity and the learning performances of the honeybee *Apis mellifera*, a comparative approach *Apidologie* 2005, 36, 601-11.
24. Hilbeck A and Schmid J. Another view of Bt proteins= How specific are they and what else might they do *Biopestic. Int*. 2006, 2,1-50.
25. Malone L and Pham-Delègue M. Effects of transgene products on honey bees (*Apis mellifera*) and bumblebees (*Bombus* sp.) *Apidologie* 2001, 32, 287-304.
26. The effects of Bt maize pollen on the honeybee, 2001-2004 Jena University, GMO Safety, Federal Ministry of Education and Research, [http://www.gmo-safety.eu/en/oilseed\\_rape/honey\\_bees/339.docu.html](http://www.gmo-safety.eu/en/oilseed_rape/honey_bees/339.docu.html)
27. Cummins J and Ho MW. GM maize 59122 not safe. [Science in Society 34](#) (in press).
28. Huang ZY, Hanley AV, Pett WL, Langenberger M. and Duan JJ. Field and semifield evaluation of impacts of transgenic canola pollen on survival and development of worker honey bees. *J. Econ Entomol*. 2004, 97(5), 1517-23.
29. Morandin L and Winston M. Wild bee abundance and seed production in conventional, organic and genetically modified canola. *Ecological Applications* 2004,15, 871-81.
30. Allen-Wardell G, Bernhardt P, Bitner R, et al, The potential consequences of pollinator declines on the conservation of biodiversity and stability of food crop yields. *Conservation Biology* 1998, 12, 8-17.

31. "Are mobile phones killing our bees?" Michael Leapman, *Daily Mail* 16 April 2007, [http://www.dailymail.co.uk/pages/live/articles/news/news.html?in\\_article\\_id=448761&in\\_page\\_id=1766](http://www.dailymail.co.uk/pages/live/articles/news/news.html?in_article_id=448761&in_page_id=1766)
32. Stever H and Khun J. How electromagnetic exposure can influence learning processes – modelling effects of electromagnetic exposure on learning processes. Unpublished ms.
33. Ho MW. Drowning in a sea of microwaves. *Science in Society* 34 (in press).