Honey bees – an indicator species in decline

The role of neonicotinoid insecticides in the global demise of bee populations remains controversial. ***Heather Pilatic*** *of PAN North America summarises and tracks the emergence of neonicotinoids in the United States where weakened regulations have fast-tracked them into the marketplace.*

The decline of the honey bee may be a sign of wider ecological degradation Photo: Yvan Leduc

Of the 100 species providing 90% of the world's food, over 70 are bee pollinated, making managed bees the most economically valuable pollinator worldwide[1]. In the United States alone, honey bee pollination services are estimated at $15-$20 billion per year, and the crop acreage requiring these services stands at an all-time high – even as bee populations are dramatically declining[2]. While US honey bee populations have been decreasing at a rate of about 1% per year since the 1950s, over the last five years the bee keeping industry has seen unprecedented annual losses each winter. Overwintering losses of 32%, 36%, 29% and 34% for 2006-2007[3], 2007-2008[4], 2008-2009[5], and 2009-2010[6], respectively, have been reported. These figures are over double the 15% that is considered an acceptable annual loss[7].

While previous US bee population declines have been largely attributed to the decreasing popularity of bee keeping, variations in data collection, fluctuations in the price of 'renting' pollinators, and changes in import and export regulations, losses since 2006 cannot be attributed to any of these causes[8]. In fact, US bee keeping is increasing in popularity, and the 2007 US Agricultural Census, reported a dramatic increase in the number of honey producing colonies being managed. It is likely that beekeepers, fearing heavy losses, have begun overwintering more colonies to ensure that they have enough bees to meet the spring pollination demands[9].

Annual hive losses of 29-36% cannot be sustained, and many US beekeepers contend that even these figures significantly underestimate the losses they have been taking since 2006[10]. US commercial beekeepers report that their industry is on the verge of collapse, and since wild pollinators are also dying off, farmers who rely on pollination services are increasingly concerned. Although pollination biologists doubt that this will directly result in a food security crisis, it is likely that crop yields will decline, and so, more acres of land – along with increasingly scarce fresh water resources – will need to be put into agricultural production in order to meet demand for food and fibre[11].

Equally concerning from a biodiversity and conservation biology point of view is the fact that honey bees are understood to be a keystone, indicator species. Their decline points to, and will likely precipitate, larger ecosystemic degradation. Scientists from around the world have accordingly been mobilized to investigate the recent drop-off in honey bee populations. In the wake of intensive research and public attention, a global controversy has emerged over the role of pesticides. On one side are the pesticide industry and the scientists funded by them, and on the other are the beekeepers, environmentalists and independent scientists.

Colony collapse disorder

Colony Collapse Disorder, or CCD, is the name given to this recent, mysterious decline in honey bee populations. While pollinators have long faced a number of threats, CCD is defined by a sudden and perplexing combination of symptoms: colonies found empty; no sign of the dead bees; evidence that the loss of adult bees from colonies was rapid; and a lack of kleptoparasitism in dead hives despite the presence of surplus honey and pollen stores[12]. An individual beekeeper may lose upwards of 90% of their colonies after having been hit with CCD.

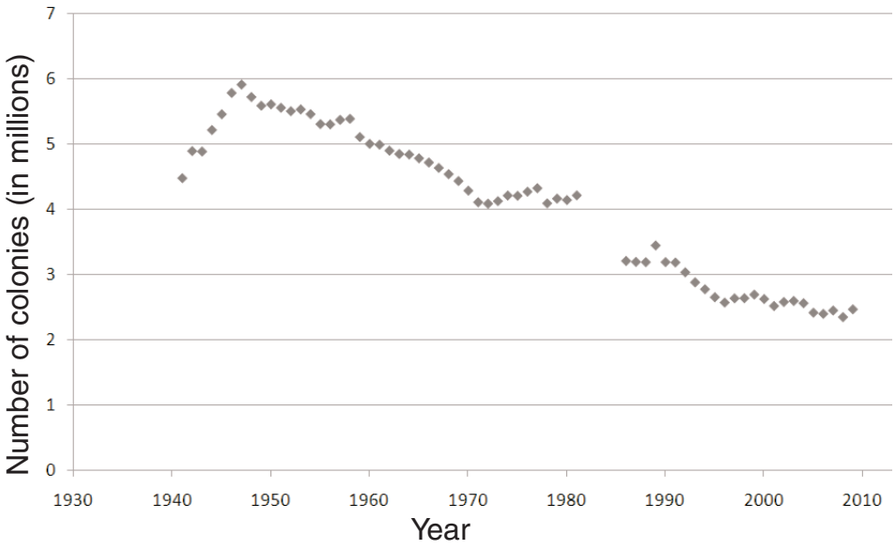
The prevailing consensus is that CCD is a result of several factors, and that the combined and synergistic effects of co-factors, acting together, is pushing bee colonies over their health threshold, causing sudden collapse. Controversy hinges largely on the relative importance of each co-factor. Key suspects include habitat loss, pathogens (mites, parasites and fungi) and pesticides. In addition, centuries of breeding large numbers of domesticated bees from relatively few queens (in the US, it is estimated that most commercial hives come from as few as 500 breeder queens) has led to diminished genetic variability and with that greater susceptibility to being overcome with disease.

While each of these co-factors has been present for some time, beekeepers point to the relatively recent introduction of systemic neonicotinoid insecticides as a critical, potentiating co-factor. Systemic pesticides are applied at the root (often as seed coating or a soil soak), taken up through the plant's vascular system and are subsequently found in pollen, nectar and guttation droplets[13]. Neonicotinoid insecticides also accumulate in the environment because they persist in the soil, often for many years. This persistence, coupled with neonicotinoids' systemic mode of action mean that translocation from treated to untreated plants is an additional concern. Bees and other pollinators thus face chronic, sub-lethal exposures and many independent scientists posit that this is undermining honey bee health by disrupting their immune system, reproductive system and/or neurobehavioural systems. Science has shown that micro-doses of imidacloprid disrupt bee mobility, orientation, foraging and learning[14]. Developing science further shows that doses so small as to be virtually undetectable compromise honey bee immunity, allowing various infectious pathogens to invade[15]. Immunosuppressive effects of these and other pesticides are significant because part of the difficulty in defining the etiology of CCD has consisted in the disorder's inconsistency: no one infectious pathogen is associated with CCD, nor is the presence of any single pesticide. But higher overall levels of pathogens are linked with the disorder, leading many to suspect that immune system disruption lies at its root.

Neonicotinoids

Since their introduction in the 1990s, the use of neonicotinoids has grown dramatically. As insects developed resistance to older classes of pesticides like organophosphates, pyrethroids and carbamates, and regulatory pressures discouraged their use, the neonicotinoids rapidly became the most important new class of synthetic insecticides of the last three decades. In 2008, they accounted for nearly 17% of the global pesticide market[16]. Imidacloprid and clothianidin are two of the most common and are known to be highly acutely toxic to bees. Over 120 countries use imidacloprid alone under the Bayer label on more than 140 crop varieties, as well as on termites, flea collars and home garden landscaping. In the US, imidacloprid and clothianidin are used as seed treatments on most conventional corn. Covering over 88 million acres of countryside, corn is by far the most widely planted crop in the US. Because corn is wind pollinated it must produce pollen in

Figure 1. Numbers of managed honey bee colonies in the US, 1940-2009*



** Bee population data for this figure were taken from revised USDA NASS archived documents. NASS surveys were not collected from 1983-1986, so population figures from 1982-1985 are unknown. National Agricultural Statistics Service (2010) Honey. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1191*

abundance and bees exploit this rich protein source, bringing in more than their daily need and storing a large surplus for later use. Many commercial honey bees also feed on corn syrup over the winter.

Neonicotinoids are nicotine-like, neurotoxic insecticides that bind to niconitic acetylcholine receptors in insects' brains. Bees have a particular genetic vulnerability to these and other pesticides: compared to other insects, they have more nicotinic acetylcholine receptors; fewer genes for, and therefore lower capacity for detoxification; and since bees have more learning and memory genes than other insects, they are more vulnerable to disruption of these sophisticated capacities[17].

Symptoms of neonicotinoid pesticide poisoning are heavily dependent on the dosage and consistency of that dosage. For example, if a bee comes into direct contact with the pesticide, or a guttation droplet from a plant treated with a pesticide, death can occur within minutes[18]. If a bee experiences sub-chronic or acute exposure through pesticide-laden pollen or brood-comb, several effects are still seen: impaired communication and hindered navigation ability make it difficult for forager bees to locate nectar sources; decreased longevity and a disruption in the brood cycle forces nurse bees to become field bees before they are fully mature; and micro-doses can result in impaired immune system function.

Effects of other pesticides

Commercial honey bees face an array of other non-neonicotinoid pesticides[19]. Beekeepers treat their hive with miticides to fight off pathogens. Acute bee-kills are still reported as growers apply highly bee-toxic pyrethroids and other pesticides on or near bloom as bees are foraging. And bee researchers are increasingly concerned about fungicide exposures, particularly in combination with the rest of the pesticide load carried by bees. Independent research from both the US and abroad demonstrates that the abundance of pesticides in hives is having a negative impact on colony health. For instance, fungicides were not previously thought to be toxic to bees, but they can interfere with the microbes that break down pollen in the insect's guts, compromising nutrient absorption and long-term health. One study shows that a common fungicide in combination with imidacloprid multiplies the effect of the latter 1,000-fold[20].

The spread of crops genetically engineered (GE) to be herbicide resistant also has potential impacts. These crops have increased the use of broad-spectrum herbicides eliminating many blooming plants from field borders, irrigation ditches, and from crop fields themselves. The reduction in plant diversity and abundance due to the increased use of RoundUp (active ingredient: glyphosate) on GE crops is difficult to quantify. However, reduced food availability may damage honey bee health.

The French example

French beekeepers were the first to experience widespread hive collapses in July 1994, days after sunflower crops came into bloom. These sunflowers had been treated with a new insecticide, Gaucho (active ingredient: imidacloprid). By 1997, half of France's sunflower seeds were being treated with this product. Between 1996 and 1999, France's honey production dropped by more than half, from 110,000 tons to 50,000 tons. The National Union of French Beekeepers (UNAF) reported having lost one-third of their hives when they lobbied the French agriculture ministry in 1997. The following year French researchers conducted a number of studies into imidacloprid's effects on honey bees. The results of this research, carried out at Boulogne University and the Institut National Recherche Agricole contradicted the safety claims made by imidacloprid's manufacturer, Bayer Crop Science. The French researchers looked at the effects of low doses of imidacloprid and found that as little as 6 ppb (parts per billion) could impair the foraging behaviour of the bees. Bayer had claimed that 50 - 100 ppb imidacloprid was safe for bees.

French regulatory authorities opted to continue trials without suspending imidacloprid. The beekeepers (UNAF) and allied organisations protested on the streets in Paris in December 1998. They appealed to the Minister of Agriculture, who could overrule the regulatory authorities. On 22 January 1999 the Minister suspended imidacloprid use on sunflowers until research proved it safe (this suspension was upheld in 2000). This marked the first time the principle of precaution had been used in France in a decision to remove a pesticide from the market. (The precautionary principle states that if there are reasonable scientific grounds for believing that a new product may not be safe, it should not be used until there is convincing evidence that the risks are outweighed by the benefits.)

Imidacloprid has been banned as a sunflower seed dressing in France since 1999 and in 2003 was also banned on sweet corn and canola (oilseed rape). Bayer's application for approval of clothianidin was rejected by French authorities. This ban is still in place and appears to be working: by 2006/07 bee deaths had fallen to less than 10%[21]. Clothianidin and other neonicotinoids are banned for use on corn seed in Italy as well. Bayer's annual sales of these blockbuster products nevertheless remain brisk. In 2010, global sales of imidacloprid earned Bayer Cropscience $830 million, and clothianidin, $267 million. Imidacloprid is the company's best-selling product and among the most widely used insecticides in the US.

US emergence

While CCD was named and diagnosed in the US in 2006, retrospective investigations showed that symptoms began emerging around 2004. During this window, a number of shifts in US pesticide regulatory policy and application practice were put in place. Under the Bush administration, tolerances (lower limits) for bee-toxic pesticides were arbitrarily increased and the increased use of 'emergency exemptions' and 'conditional registrations' fast-tracked approval of suspect neonicotinoids like imidacloprid and clothianidin, bringing both to market before safety testing had been completed. The head of the US Environmental Protection Agency (US EPA) under Bush's presidency, Stephen Johnson, made a concerted and successful effort to speed up the 'emergency exemption' approval process beginning around 2002. And 'conditional registrations' have long been over-used by the agency.

The US EPA is supposed to license ('register') pesticides only if they meet standards for protection of environment and human health. However, this is frequently breached. For example, the EPA relies on industry-funded science that is often shielded from peer review and public scrutiny by claims of 'confidential business information.' Pesticide law further allows the EPA to effectively waive the scientific review process and grant a 'conditional' registration when health and safety data are lacking in the case of a new pesticide, allowing companies to sell a pesticide before the EPA gets safety data. The company is supposed to submit the data by the end of the conditional registration period, but often they do not. Conditional registrations account for 2/3 of current pesticide product registrations. It is a common practice for the EPA's Office of Pesticide Programs, to afford rapid market access for products that remain in use for many years before they are tested. Of the 16,000 current product registrations: 11,000 (68%) have been conditionally registered; almost 8,200 products have been conditionally registered ('CR status') since 2005; approximately 5,400 products have had CR status since 2000; and over 2,100 products have had CR status since 1990[22]. Imidacloprid and clothianidin both entered the US market as conditional registrations.

Since 2000, virtually all conventional corn seed has been treated with one or more insecticide seed treatments, and from about the mid-2000s, often one to three fungicides. From about 2004, and roughly coinciding with the emergence of CCD, corn seed companies in the US began marketing seeds treated with a 5-X rate of neonicotinoids (1.25 mg/seed, compared to the traditional 0.25 mg/seed). For example, 80% of the corn seed sold in 2007 by corn seed market-leader Pioneer Hi-Bred was treated with clothianidin plus two fungicides (the systemic azoxystrobin, and fludioxonil). Pioneer first sold seeds treated with the 5-X rate of clothianidin in 2004[23]. Further, beekeepers and scientists reporting their experiences in the field say that spray tank mixes of other pesticides were increasingly combined with fungicides in a deliberate attempt to increase the toxicity of those applications beginning in the early- to mid-2000s. As a matter of practice and policy, the pesticide load faced by US honey bees increased dramatically just as the first symptoms of CCD were setting in.

The clothianidin controversy

In December 2010, Pesticide Action Network North America (PANNA) joined US beekeepers and the non-governmental organisation Beyond Pesticides in publicising a leaked EPA memo which revealed that the field study on the basis of which clothianidin was granted conditional registration had been found by the Agency to be scientifically unsound for purposes of registration[24]. Although the agency originally accepted the field study (conducted by Bayer Crop Science, the registrant) in 2007, subsequent review in the context of registering the pesticide for expanded uses led the Agency to quietly downgrade the study in a 2 November 2010 memo, which was then passed to beekeeper Tom Theobald by a source within EPA. The Bayer field study is deeply flawed on a number of counts, according to practicing beekeepers: it tests the wrong crop, for an insufficient time period under conditions that allow for no control colonies. (Both control and test colonies had access to treated and untreated crops.) The study's authors nevertheless concluded that 'Exposure to clothianidin seed-treated canola has no long-term impact on honey bees.'[25] One leading bee scientist said that the Bayer field study was so obviously flawed that he 'immediately thought it invalid.' The Canadian regulatory agency with whom US EPA was jointly assessing clothianidin rejected the study upon first review. EPA granted clothianidin full registration in April 2010, and has, in the wake of this controversy, refused to revisit that decision despite the fact that hundreds of thousands of concerned citizens have rallied around US beekeepers in asking EPA to take decisive action.

The ripple effects have gone international. In January of 2011, the UK House of Commons held a hearing on the contributions of neonicotinoids to pollinator decline, citing the clothianidin controversy in the US as a precipitating occasion. International partners have gathered over a million signatures asking EPA to ban neonicotinoids in order to protect US honey bee populations. PANNA has continued in the intervening months to work with beekeepers and partner organizations in pressing for immediate remedy.

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