Neonicotinoids: Silver Bullets that Misfired

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It was National Pollinator Week 2013. We had been getting the usual inquiries at the Xerces office: What type of bee is this? How do I make a bee nest? Can you recommend the best plants? Then the telephone started ringing with reports of dead bees—lots of them. Xerces staff members rushed to the scene, a big-box store in Wilsonville, Oregon, a half-hour drive from our office. We were startled to find the parking lot littered with bees—several species, including honey bees, although the great majority were bumble bees—with more falling from the branches above every minute. Xerces staff contacted the Oregon Department of Agriculture (the agency with legal responsibility to investigate), and then helped organize an effort to net the trees in order to stop the carnage.

The inquiry undertaken by the Oregon Department of Agriculture found that the bees had died from the application of a neonicotinoid insecticide, dinotefuran, to the linden trees (genus *Tilia*) that lined the parking lot. The trees were being treated against aphids, which drip honeydew that can coat sidewalks and parked cars below. With flowers rich in nectar, though, linden trees are a bumble bee magnet (honey bees may also gather honeydew), and the insecticide had lethal consequences far beyond its intended victims. An estimated fifty thousand or more bumble bees were killed.

This is the largest native bee kill ever recorded. The authors of some science blogs dismissed the number of bumble bees that died as being of small significance in that they were no more than the population of a healthy hive of honey bees, but an understanding of bumble bee biology leads to a different conclusion. Bumble bees live in small colonies, typically no larger than two to three hundred bees even at their maximum size; thus the deaths of fifty thousand bumble bees is equivalent to the destruction of more than 150 complete colonies. And the impact is not limited to those colonies directly affected by the loss of worker bees. Rather, the effect carries forward into the following years as a result of fewer queens being produced to establish new colonies.

In the intervening two years, the Oregon Department of Agriculture has investigated and confirmed six more incidents of bee kills caused by the application of neonicotinoids (or "neonics") on *Tilia* trees. The department has now acted to reduce the use of neonics, banning their application to linden, basswood, and other *Tilia* species in the state. While the large bee kills might have propelled neonics into the spotlight and brought some incremental gains in protection for bees, the scale of the risk posed by the use of these insecticides is huge and threatens a broad range of wildlife.

Neonicotinoids began to be used in the mid-1990s. The U.S. Environmental Protection Agency was seeking less-toxic alternatives to replace organophosphate insecticides, which had been linked with a variety of risks to human health and the environment. These new neonicotinoid chemicals were characterized as "reduced risk" by the EPA and some were brought to market through an abridged registration process. They quickly became the most heavily used class of insecticides, and they now make up about 30 percent of the insecticide market worldwide. Neonics are used on farms, in parks, on street trees, and in gardens. They are generally present in all landscapes.

Dinotefuran, the product responsible for the Wilsonville bee kill, is one of seven chemicals that are classified as neonicotinoids. The others are acetamiprid, clothianidin, imidacloprid, nitenpyram, thiacloprid, and thiamethoxam. (Use of imidacloprid and nitenpyram for flea control in animals is generally excluded from discussions about neonic impacts on wildlife.) Neonicotinoids are synthetic insecticides similar in chemical structure to nicotine, and all of them control pests through the same mode, binding to receptors in the insects' nervous systems and blocking nerve impulses.

Although each neonic poses its own unique risks, there are several overarching characteristics that are cause for concern: they persist in plants and soil for months to years after an application and can accumulate from one season to another; they are highly toxic to a broad spectrum of invertebrates, including beneficial insects; they are water soluble and readily move into rivers, lakes, and

Bumble bees have been shown to be far less efficient at foraging when exposed to neonicotinoid insecticides. They bring much less food to the colony, leading to fewer new queens and new colonies. Photograph by Nancy Lee Adamson.

This bucolic scene, complete with red barn, belies the reality of many modern farms. The widespread use of neonicotinoids, especially as a seed treatment, affects pollinators, beneficial insects, and aquatic systems. Photograph by Don Graham, Flickr.com.

other water bodies; and because they are absorbed by plant tissues and become systemic (even when sprayed on foliage), they move into pollen and nectar, thereby following a direct route to exposure for pollinators.

In 2012, the International Union for Conservation of Nature passed a resolution calling for a comprehensive review of the impacts of systemic insecticides on biodiversity and ecosystems. The review was carried out by the Task Force on Systemic Pesticides, a multidisciplinary group of independent scientists, who studied more than a thousand research articles and reports. The task force's analyses, published in a series of articles in 2014, concluded that the current degree of use of neonics and other systemic insecticides is not sustainable. It found that these insecticides are causing significant damage to a wide range of beneficial invertebrate species, thus threatening the natural infrastructure that supports farming productivity and broader ecosystem health.

The threats from neonics and similar chemicals go well beyond high-profile bee kills. At low levels, neonics don't kill invertebrates but instead can impair their functioning to the point of weakening populations over time. A 2014 study performed by researchers from Scotland's University of Stirling, for example, showed that bumble bees exposed to neonics were less efficient at foraging, bringing back 31 percent less food to the colony compared to unexposed bees. As with the reverberating effect of the bee kills at Wilsonville, such a decline in food supply would lead to fewer new queens and, consequently, fewer colonies in following years.

There is strong evidence of neonicotinoids harming beneficial insects that serve as natural pest control for agriculture. Researchers from Penn State University found that the activity and density of the ground beetle *Chlaenius tricolor* were lower in soybean fields planted with neonic-coated seeds. The beetles were harmed by neonic residues passed up the food chain from the crop-damaging slugs they were eating. The result was fewer beetles eating the slugs and thus a larger population of slugs damaging crops: soybean yield was reduced by 5 percent in treated fields. Over the past twelve years the introduction of neonicotinoid products applied as a seed coating has rapidly increased the use of these chemicals. Penn State researchers also determined that for corn, cotton, and soybean alone, at least 42 million hectares (104 million acres) are planted with neonicotinoid-coated seed. That is roughly the size of California. On such a large scale, the use of neonics can translate to far-reaching detrimental impacts on natural pest-management services.

The cascading impacts of these insecticides go beyond crop fields. Their solubility means that they leach into the soil and then migrate into neighboring water bodies. A study from the Netherlands found that populations of insect-eating birds were declining in areas where there were increased concentrations of neonics in surface water. Swallows, starlings, and sparrows were the most affected, with the survival of these insectivorous birds jeopardized by the loss of aquatic insects, one of their major food sources. Worryingly, the latest research from the United States found neonics in more than half of the streams sampled in both urban and agricultural areas.

The Xerces Society takes a precautionary approach in response to neonicotinoid concerns. At the heart of the precautionary principle is the concept that, when there is evidence of a plausible risk, there is a social responsibility to protect the environment or people from exposure to harm. (This is the same idea that lies behind the adage "better safe than sorry.") Furthermore, the protections cannot be lifted or changed until scientific studies are completed that provide reliable evidence that no harm will result from any changes. The precautionary principle has been widely embraced around the world in the decades

This planter is filled with corn seed made green by its neonic coating. Photograph by Lance Cheung, USDA-NRCS.

since it was written into the Rio Declaration of the 1992 United Nations Earth Summit. In Europe, the precautionary principle has been adopted into the policies and laws of the European Union. In the United States, the principle underlies environmental policy in San Francisco and many other communities.

Within the world of pesticide regulation, the precautionary principle would shift the burden of proof onto the pesticide manufacturers. They would need to show that their products would not cause undue harm—rather than merely, as now, showing how the risks can be managed.

At the core of our work are efforts to promote ecologically sound pest-management practices that shift away from chemical-intensive crop production. Recognizing that farmers and pest-management professionals need feasible alternatives if they are to change their practices, Xerces is involved in research, including working with Iowa State University to design integrated approaches to managing common soybean and corn pests. This project, which has the potential to affect millions of acres of production, will help growers understand what pests are problematic and when control measures are needed,

Pothole wetlands are scattered across the corn fields of the northern Great Plains. Neonicotinoids leach from the fields into the wetlands, reducing the populations of aquatic insects that may support breeding birds during the summer, as well as migrating flocks such as the white spots seen above. Photograph by Krista Lundgren, USFWS.

Swallows were among the birds found to be declining in areas where there were increased levels of neonicotinoids in surface water. Photograph by The-Gecko, Flickr.com.

thus shifting away from the prophylactic use of neonicotinoid-coated seed. It will also promote ecologically sound management methods once pests are identified.

Xerces also presents short courses on conservation biological control, the practice of supporting the native beneficial insects that prey upon crop pests. And we've worked with local communities and governments across the United States to develop city or county regulations banning the use of neonicotinoids on publicly owned lands; to date, we have helped thirteen cities and counties halt the use of neonics and have assisted two others in creating plans to protect pollinators from pesticides.

The scale of the problem posed by neonics is sufficient to warrant immediate action. When they first appeared on the market, neonicotinoids were touted as reduced-risk products, but our current knowledge paints a very different picture, and government policies must change to reflect the greater risk that we now know exists. Indeed, the story of neonics is a cautionary tale about an inadequate regulatory system that allows pesticides on the market before understanding their impacts, and a chemical industry that promises easy solutions to solve complex pest problems.

Neonics were touted as silver bullets and sped to market to replace other harmful insecticides. They may have resolved some of the problems caused by the older insecticides, but neonicotinoids brought their own array of negative consequences. In order to break this cycle of replacing one problem with another, Xerces works to increase understanding and implementation of more-sustainable practices with the greater goal of protecting the natural systems on which we all depend.

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