MAINTAINING HEALTHY AQUATIC ECOSYSTEMS

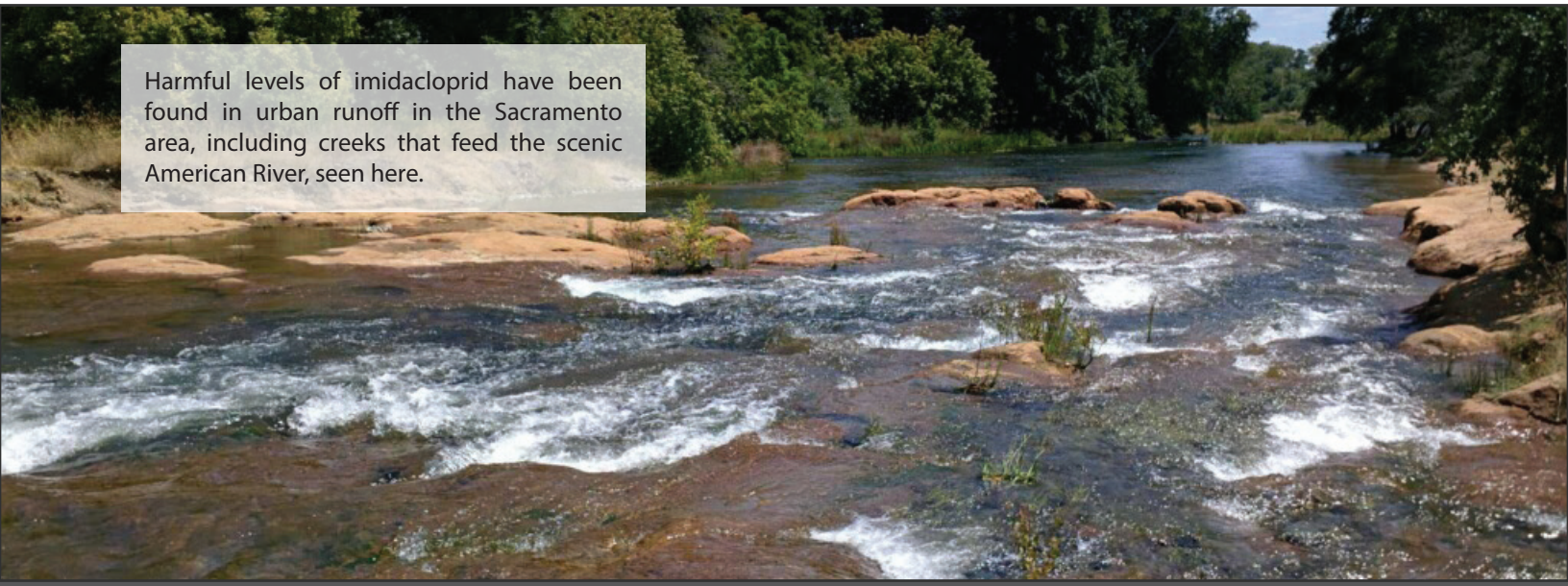
Protecting California's Waters from Neonicotinoid Contamination

Clean water, which is essential for both people and wildlife, is finite in supply and faces numerous threats. An emerging threat, unrecognized until recently, is neonicotinoid insecticide contamination. Neonicotinoids were developed to control a broad spectrum of pests and have been widely adopted for pest control in agricultural, commercial, and residential landscapes. They are the most widely used group of insecticides in the world, and have been for at least a decade.

Although introduced with the premise of being less harmful to humans and wildlife than older insecticides, neonicotinoids, which are readily transported from application sites to surface water, are now linked to a number of environmental concerns. In particular, they are highly toxic to many beneficial insects, including pollinators which form the basis of healthy terrestrial ecosystems, and aquatic invertebrates that form the foundation of thriving rivers and streams.

Initially, evidence for the risks posed by neonicotinoids centered on bees. Not only has their legal use (i.e., use in accordance with label requirements) caused devastating bee kills, there is extensive scientific evidence demonstrating how even small amounts of neonicotinoids, including levels commonly found in the environment, can cause subtle yet devastating harm to the point where bee populations could suffer. These effects include reduced reproduction and worker survival rates, and weakened immune function causing bees to be more susceptible to disease (Hopwood et al. 2016). More recently, research in California has found that neonicotinoid use is associated with declines of 67 common butterflies in the Sacramento area (Forister et al. 2016).

In California, and across the United States, neonicotinoids are now routinely found in waterways (see Fig. 1, next page). Furthermore, a growing body of research is showing that current contamination in California could harm and



Harmful levels of imidacloprid have been found in urban runoff in the Sacramento area, including creeks that feed the scenic American River, seen here.

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even kill sensitive aquatic invertebrates, such as mayflies and caddisflies, that are critical to maintaining healthy freshwater ecosystems (Morrissey et al. 2015, Sanchez -Bayo et al. 2016, California Department of Pesticide Regulation (DPR) Surface Water Database). Impacts to these animals can have far-reaching effects on the health of our waters and the broader environment.

Assessing Risk to California's Surface Waters

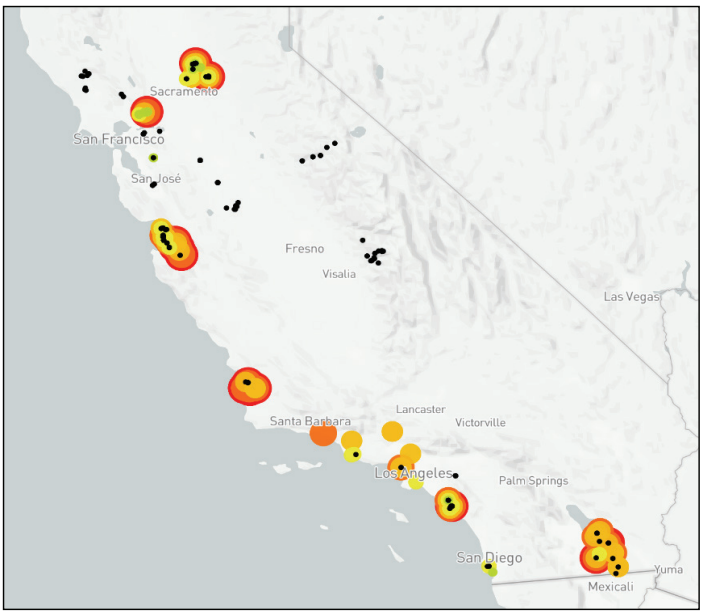
In 2016, the Xerces Society performed an assessment of the risks posed by the neonicotinoid imidacloprid (the oldest and most studied neonicotinoid) to aquatic invertebrates in California. By comparing imidacloprid concentrations detected in surface water (DPR Surface Water Database) to imidacloprid exposure levels that have been shown to impact aquatic invertebrates, this assessment demonstrated that imidacloprid is often found in California's rivers and streams at levels harmful to beneficial species such as mayflies and caddisflies, species that are indicators of water quality. Because aquatic invertebrates are core contributors to nutrient cycling, water quality, and aquatic food webs that support fish and wildlife (Suter & Cormier 2014), lethal and sublethal effects of neonicotinoids can cause far-reaching effects. Potential risks include:

- Upsurges in pest species such as mosquitoes in the absence of predators and competitors (Sanchez-Bayo et al. 2016);
- Increased methane production when microbes replace invertebrate decomposers (Pestana et al. 2009, Sanchez-Bayo et al. 2016); and
- Declines in native insectivorous birds when food sources are limited (Hallman et al. 2014). A similar decline could occur with other species such as salmon, trout, and numerous amphibians that rely on aquatic insects for food.

Our findings also raise concerns about the use of other neonicotinoid insecticides—clothianidin, dinotefuran, and thiamethoxam. These closely-related chemicals have similar risk profiles to imidacloprid, as they too are long-lived, highly toxic to numerous beneficial insects, and can readily contaminate surface water (Cavallaro et al. 2017, Morrissey 2017).

In part, the lack of action to reduce neonicotinoid contamination in California's surface waters is caused by woefully inadequate federal benchmarks to protect water

Fig. 1: Map of California's Surface Water Monitoring Data for Imidacloprid



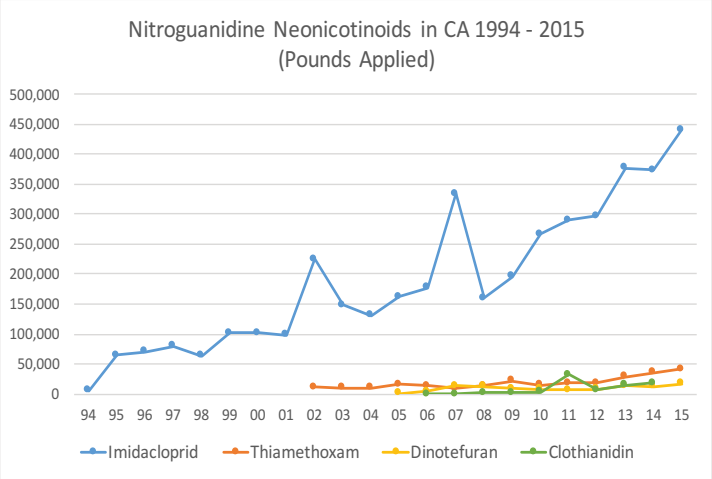
Colors correspond to regulatory guideline exceedances. Black dots represent non-detects.

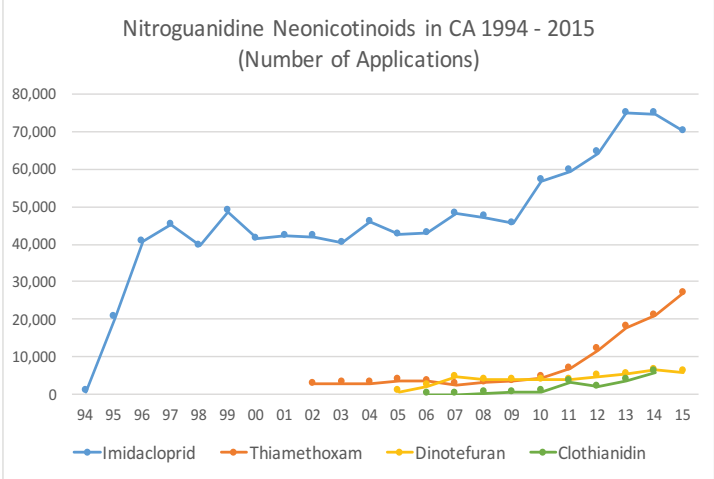
quality from this class of insecticides, leaving species and ecosystems at risk. In comparison, the European Union has established relatively protective water quality reference values for imidacloprid (see Fig. 2). Regulators use these values to determine if contamination levels are too high and intervention is warranted. Since the United States has set high values, imidacloprid could be harming aquatic ecosystems without triggering any intervention, while the European value is low enough to trigger a response before significant ecosystem harm is expected. **In the absence of action at the federal level, California has an opportunity to initiate efforts to better protect an invaluable resource from neonicotinoid contamination.**

Fig. 2: North American and European Imidacloprid Water Quality Reference Values

Regulatory Body	Acute Exposure	Chronic Exposure
U.S. Environmental Protection Agency	35 µg/L	1.05 µg/L
Health Canada	0.23 µg/L	0.23 µg/L
European Food Safety Authority	0.2 µg/L	0.067 µg/L

Fig. 3: Pounds Applied and Number of Applications of Nitroguanidine Neonicotinoids in California





This data does not include the planting of seed coated with neonicotinoids or non-professional ornamental and urban applications. The 2002 and 2007 outliers in imidacloprid pounds applied are likely data reporting errors. Clothianidin use data is not available for 2015 due to data reporting errors. Data source: DPR Pesticide Use Reports

Neonicotinoid use in California is Widespread, and on the Rise

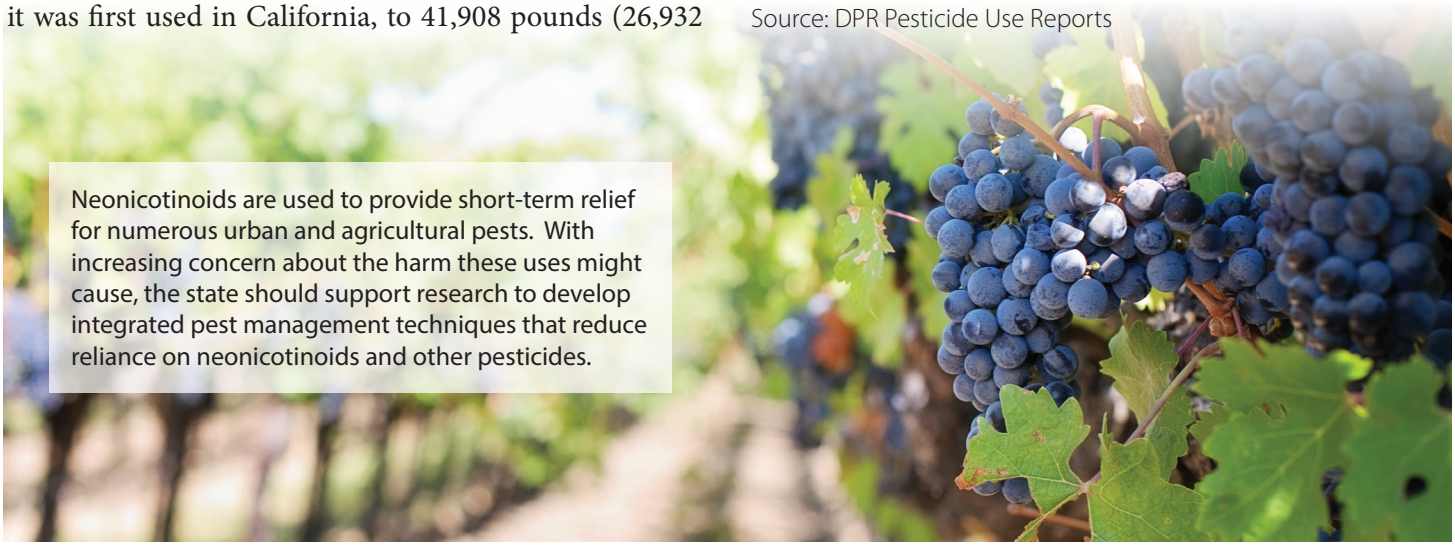
Despite the growing body of research regarding neonicotinoid threats to pollinators and aquatic invertebrates, neonicotinoid use continues to increase in California, in turn increasing surface water contamination risks.

Neonicotinoids are frequently used on farms and for residential pest control. Imidacloprid is the fourth most commonly used insecticide in California, with reported uses on more than 140 crops and other non-crop locations. Its use has increased from 5,179 pounds (658 applications) in 1994 to 441,304 pounds (70,054 applications) in 2015 (See Fig. 3). While not as commonly used as imidacloprid, the other neonicotinoids are also becoming more widely used. For example, thiamethoxam use has increased from 11,090 pounds (2,826 applications) in 2002 when it was first used in California, to 41,908 pounds (26,932 applications) of reported use in 2015 (DPR Pesticide Use Reports). California's Pesticide Use Reporting is the best available data on pesticide use in the country. Still, common uses of neonicotinoids in agricultural and urban settings are not fully captured (see 'Gaps' next page).

Fig. 4: Top 5 Imidacloprid Uses by Crop in California, 2015

Crops	Pounds of Imidacloprid Applied
Grapes	107,988
Citrus	86,355
Tomatoes	50,505
Lettuce	23,366
Pistachios	18,659
Total	**286,873 lbs (65% of total use)**

Source: DPR Pesticide Use Reports



Neonicotinoids are used to provide short-term relief for numerous urban and agricultural pests. With increasing concern about the harm these uses might cause, the state should support research to develop integrated pest management techniques that reduce reliance on neonicotinoids and other pesticides.

Gaps in Pesticide Use Estimates

California's pesticide use reporting is the best available data on pesticide use in the country. Still, common uses of neonicotinoids in agricultural and urban settings are not captured, leading to gaps in our understanding of use that create regulatory challenges.

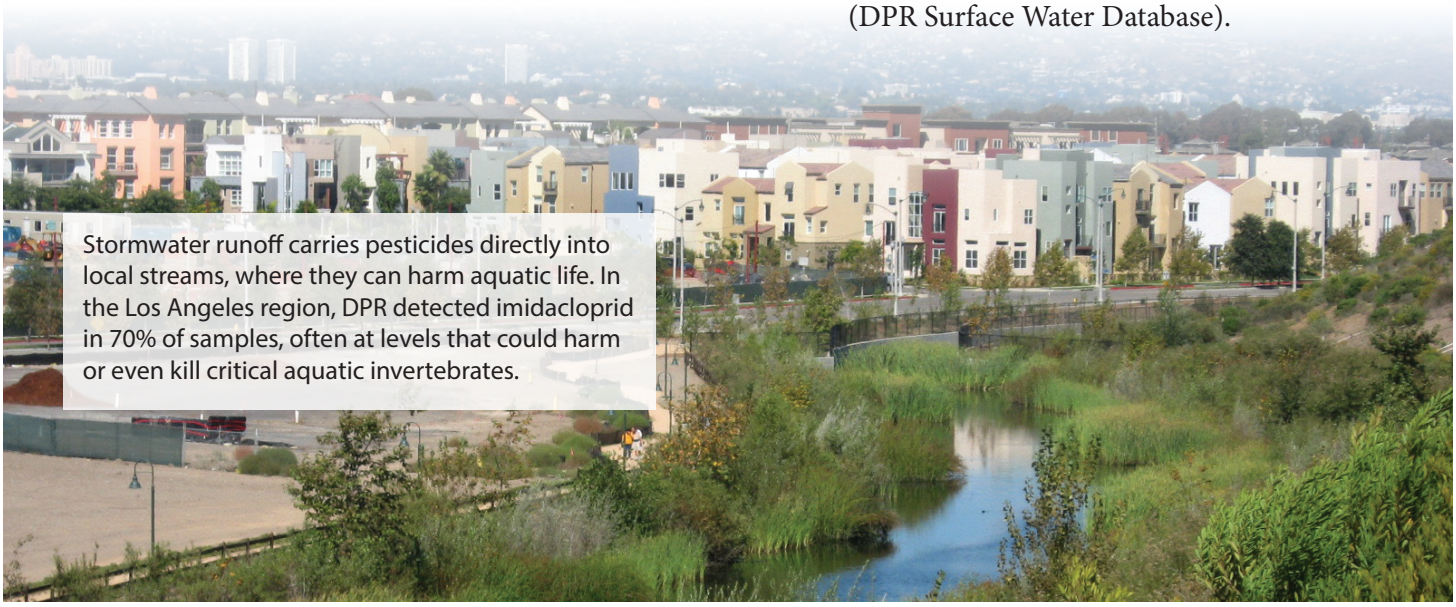
Agricultural Use: Many crops in California are grown from seed coated with neonicotinoids. Due to a lack of regulation by the federal government, neither the quantity of neonicotinoid-coated seed planted, nor the acreage planted with coated seed—either of which could be used to assess contamination risk—is reported in California. With approximately two million acres of corn, cotton, sunflowers, wheat, and other crops potentially grown with neonicotinoid-coated seed, the actual use of these chemicals could be significantly under-reported, particularly when compared to other chemicals whose application methods are more fully tracked. The gap in our understanding of neonicotinoid-coated seed use is noteworthy since research has attributed surface water contamination to the planting of coated seed (Hladik et al. 2014).

Urban Use: Neonicotinoids are also marketed for residential use, and residents can apply the pesticides directly. While use by professional pesticide applicators is reported, applications by residents are not captured by California's pesticide use reporting system. This lack of data regarding household use of neonicotinoids leaves a gap in our understanding of potential urban storm water runoff and wastewater concerns, which are significant because high concentrations of imidacloprid are often found in urban areas (Hladik & Kolpin 2016; DPR Pesticide Use Reports; Sadaria et al. 2017).

Imidacloprid Contaminates California's Rivers and Streams

Neonicotinoids are water soluble, a trait that enables them to move throughout a plant, making all parts of the plant toxic. This water solubility also allows them to move readily into waterways, which has resulted in contamination of California's rivers, streams, and estuaries.

- Imidacloprid was detected in 59% of surface water samples taken from 2010–2015, in both agricultural and urban areas, (DPR Surface Water Database).
- Certain regions have more frequent sampling and detections. Two examples include the Santa Maria and Salinas Valley agricultural areas, where 91% and 82% of surface water samples contained imidacloprid, respectively, (DPR Surface Water Database).
- Urban sampling in the Sacramento area and in Orange County from 2008–2011 found that imidacloprid was the second-most commonly detected insecticide in surface water samples (Ensminger et al. 2013). The highest concentration reported by the Department of Pesticide Regulation (DPR) from 2010–2015, 12.7 µg/L of imidacloprid, was found in urban Orange County (DPR Surface Water Database).



Stormwater runoff carries pesticides directly into local streams, where they can harm aquatic life. In the Los Angeles region, DPR detected imidacloprid in 70% of samples, often at levels that could harm or even kill critical aquatic invertebrates.

Natural Systems are at Risk

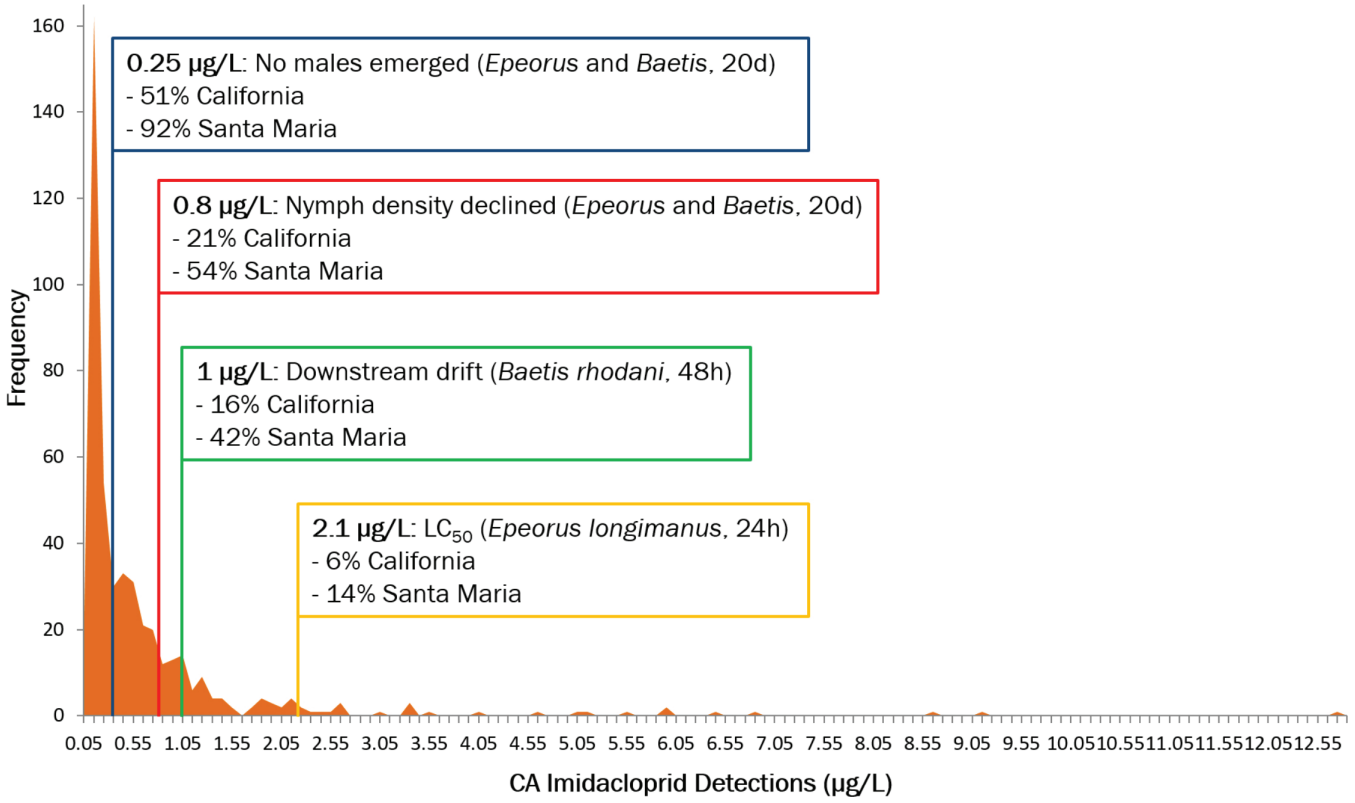
The concentrations of imidacloprid found in California's waters can kill or harm sensitive aquatic invertebrates that are critical to maintaining healthy freshwater ecosystems. In particular, even very small exposure levels can negatively impact mayflies and caddisflies by limiting their ability to feed, and harming reproductive success (Alexander et al. 2007, Alexander et al. 2008, Beketov & Liess 2008, Mohr et al. 2012).

- 92% of detections in the Santa Maria region were at levels that, with chronic exposure, could cause only female mayflies to emerge.
- 14% of Santa Maria detections could outright kill some mayfly species within 24 hours.

Mayflies are an important part of many aquatic systems, preventing the buildup of algae and assisting in nutrient cycling.

Fig. 5: Effects of Imidacloprid on Mayflies

This graphic shows imidacloprid detections overlaid with effects seen in various mayfly species.* The percentages represent exceedances of the harmful level noted in samples from 2010–2015 in California and the Santa Maria region.



*No male *Epeorus* sp. or *Baetis* sp. emerged at 0.25 µg/L (20d exposure to formulated Admire, Alexander et al. 2008), at 0.8 µg/L *Epeorus* and *Baetis* nymph density was reduced (20d exposure to formulated Admire, Alexander et al. 2008), at 1 µg/L downstream drift of *Baetis rhodani* was initiated (Beketov & Liess 2008.), and the 24h LC_{50} of *Epeorus longimanus* is 2.1 µg/L (Alexander et al. 2007).

California Should Respond to the Risks of Neonicotinoids as Current Federal Regulations Fail to Protect Rivers and Streams

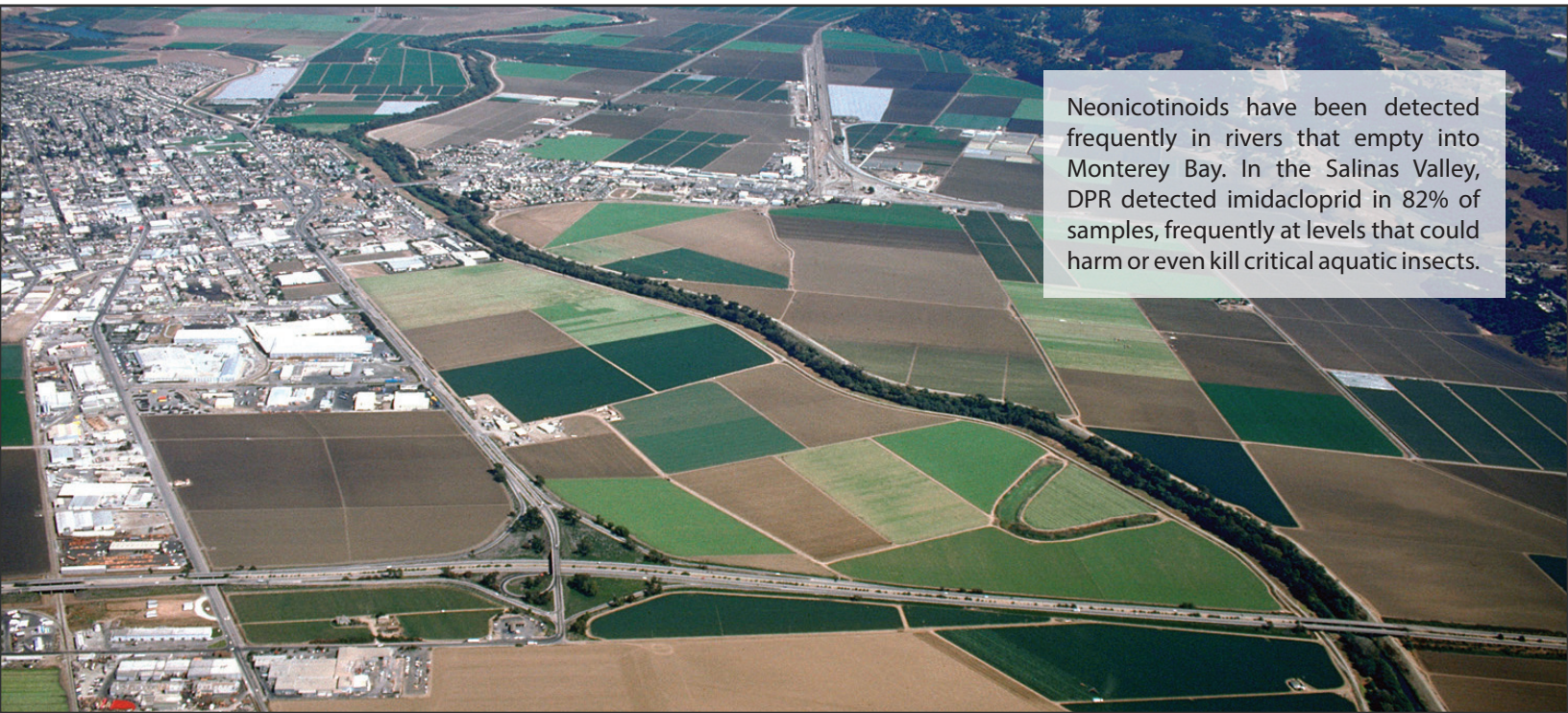
Many birds rely upon insects for food. When pesticide pollution reduces insect populations, birds and other wildlife populations can also decline.

California has been a leader on assessing the risks of neonicotinoids. Now the Department of Pesticide Regulation has an opportunity to protect water and wildlife from impacts associated with neonicotinoid insecticides. A first step in protecting water quality would be to set appropriate reference values, which inform regulatory agencies as to when water quality is compromised. The water quality reference values established in other countries are orders of magnitude lower than U.S. standards set by the EPA, and are thus more protective (see Fig. 2).

Existing research shows that exposures to levels of imidacloprid below 1.05 µg/L (the EPA chronic aquatic life benchmark) can impact reproductive success, alter feeding behavior, and cause downstream drift or other negative health outcomes in sensitive species (Alexander et al. 2008, Agatz et al. 2014, Beketov & Liess 2008). While the European and Canadian water quality reference values would have prompted efforts to protect water quality if contamination was found at 1.05 µg/L, these detrimental levels have not elicited a response in the U.S.

EPA recently released an assessment that acknowledges that current imidacloprid contamination puts invertebrates at risk, yet EPA has not proposed action to address the problems it identified (EPA 2016). In contrast, Canada recently proposed canceling most of imidacloprid's outdoor uses over the next few years because of risks to surface water (Health Canada 2016). The European Union has already halted many uses of neonicotinoids.

California's freshwater ecosystems are at risk from current levels of imidacloprid contamination, even when imidacloprid levels are below the aquatic life benchmarks currently set by the EPA. DPR has been involved in assessing neonicotinoids and thus has the knowledge, and the authority to reverse this troubling trend in water contamination.



Neonicotinoids have been detected frequently in rivers that empty into Monterey Bay. In the Salinas Valley, DPR detected imidacloprid in 82% of samples, frequently at levels that could harm or even kill critical aquatic insects.

Recommendations

The frequency and level of imidacloprid contamination, and the potential for similar concerns to arise with other neonicotinoids warrants action to protect the quality of California's waters. The Xerces Society recommends that California regulators act on concerns about neonicotinoids and take the following actions:

1. **Create interim aquatic life benchmarks for imidacloprid.** Based on the EPA risk assessment of imidacloprid toxicity that found likely effects on aquatic species, DPR should establish protective interim aquatic life benchmarks for imidacloprid.

2. **Review aquatic toxicity of other neonicotinoid insecticides.** Much like the EPA's aquatic risk assessment performed for imidacloprid, we recommend that DPR review the aquatic impacts of the other nitroguanidine neonicotinoids to better understand their toxicity, and set appropriate interim aquatic life benchmarks.

3. **Design and implement risk mitigation strategies.** To minimize surface water loading and protect sensitive aquatic ecosystems from neonicotinoid contamination, DPR should develop an action plan to address contamination in California.

4. **Gather more data on surface water contamination.** DPR should bolster their surface water sampling efforts, especially for the nitroguanidine neonicotinoids other than imidacloprid. This research should represent both agricultural and urban areas where neonicotinoid usage is common.

5. **Strengthen pesticide use reporting requirements.** California's pesticide use reporting system is the most robust in the country. However, the system must respond to the growing practice of planting insecticide-coated seeds. Required reporting of coated seed use and residential applications would improve the accuracy and utility of California's pesticide use data.

6. **Avoid recommending the termination of one insecticide without also promoting a less environmentally problematic substitute.** History shows that substituting one group of pesticides for another leads to new environmental problems.

7. **Fund research that advances sustainable pest management strategies.** California's university system has extensive agricultural research programs that provide technical support to the agricultural community. The state of California should seek methods to increase funding for independent applied research into sustainable integrated pest management methods that reduce reliance on pesticides and increase crop resilience.

Acknowledgements

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