Poisoned Waterways

THE SAME PESTICIDE THAT IS KILLING BEES IS DESTROYING LIFE IN THE NATION'S STREAMS, RIVERS, AND LAKES

Water is essential to life, supporting the food web and habitat for much of Earth's wildlife. Pesticides often contaminate U.S. waterways and threaten aquatic organisms, from invertebrates (worms, molluscs, insects, and zooplankton) to vertebrates (fish and amphibians), and microorganisms (bacteria, fungi, protozoa, algae, and phytoplankton), as well as those that depend on them.[1]

SUMMARY

Neonicotinoid insecticides are detected regularly[2] in sampling of the nation's waterways at concentrations that exceed acute and chronic toxicity values for sensitive organisms.[3] Neonicotinoids are a family of chemicals that include imidacloprid, clothianidin, thiamethoxam, dinotefuran, and acetamiprid. While the impact of neonicotinoids on pollinators, like honey and native bees, has been widely discussed,[4] other organisms, like those in aquatic environments, are also at risk. Scientific knowledge on the aquatic impacts of neonicotinoids is growing, and research finds that neonicotinoids have direct and indirect impacts on aquatic communities. Neonicotinoid contamination, detected in rivers, streams, and lakes in 29 states,[5] poses detrimental effects to keystone aquatic organisms as well as result in a complex cascading impact on ecosystems.

In the regulatory arena at the U.S. Environmental Protection Agency (EPA), alarms began to go off when the agency found in its 2017 risk assessment for the most widely used neonicotinoid, imidacloprid, that, "[C]oncentrations of imidacloprid detected in streams, rivers, lakes and drainage canals routinely exceed acute and chronic toxicity endpoints derived for freshwater invertebrates."[6] The agency evaluated an expanded universe of adverse effects data and finds that acute (short-term) and chronic (long-term) toxicity endpoints are lower (adverse effects beginning at 0.65 μg/L (micrograms per liter)-acute and 0.01 μg/L-chronic effects) than previously established aquatic life benchmarks (adverse effects from 34.5 μg/L-acute and 1.05μg/L-chronic effects). In its 2017 risk assessment, EPA finds risks from imidacloprid exposure to ecologically important organisms not previously evaluated as part of its regulatory review. Despite its acknowledgement that current benchmarks are not adequately protective, EPA describes its review process as requiring studies of the most sensitive organisms and a range of publicly available environmental laboratory and field studies.

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Corn in Chesapeake Bay Watershed

Summary of Findings

- Neonicotinoids are regularly detected in U.S. waterways at concentrations that cause harm to sensitive aquatic organisms and ecosystems.
- Imidacloprid in particular is persistent in aquatic environments under certain conditions. EPA states that levels of this chemical in waterbodies regularly exceeds toxicity endpoints for freshwater invertebrates.
- Detections generally follow land use patterns: agricultural regions have the highest, most frequent detections of clothianidin due to use in corn and soybean fields, while urban areas find imidacloprid most frequently.
- Aquatic insects and crustaceans are highly sensitive to neonicotinoids, with the mayfly identified as the most sensitive.
- Impacts on aquatic invertebrates can have cascading effects on food webs and healthy ecosystem function. Low level, sublethal exposures can result in decreases in species abundance, altered predator-prey relationships, reduced water filtration, and nutrient cycling.
- Current federal aquatic life benchmarks for neonicotinoids are potentially underestimating risks. Experts find that standard test organisms used by EPA to establish these benchmarks are orders of magnitude more tolerant of neonicotinoid exposure than other vulnerable species, and recommend water levels to be well-below the benchmarks set by EPA.
- Chemical mixtures and potential synergistic effects are not considered in aquatic risk assessments, resulting in unknown risks to species.
- Stronger action is need to restrict neonicotinoid contamination of waterways.

This report summarizes the available scientific literature on the effects of neonicotinoids in waterways and the life that they support, lending support to long-standing calls for suspending their use. With these aquatic effects, continued neonicotinoid use raises broad implications for the health of biodiversity, which is critical to the sustainability of wildlife and humans alike.

NEONICOTINOIDS HAVE SERIOUS ADVERSE EFFECTS ON AQUATIC ORGANISMS

Neonicotinoids affect the nervous system of insects by interfering with their nicotinic acetylcholine receptors (nAChRs)—a mechanism that shows higher toxicity to invertebrates than vertebrates.[7] Neonicotinoids are known for their action on non-target terrestrial insects, like domesticated and native bees, but they also exert neurotoxic activity in aquatic invertebrates in waterways.

Studies investigating the impacts of neonicotinoids on aquatic organisms find that these pesticides can have devastating impacts on aquatic communities and the higher trophic organisms that depend on these communities. A 2013 comprehensive assessment of the effects of imidacloprid in surface water reports a wide variety of aquatic invertebrates adversely harmed by imidacloprid residues in water.[8] Even at low sub-lethal levels, the effects of imidacloprid on certain aquatic organisms are wide-ranging and include impaired growth and larval development (blue crab), significant reduction in abundance (zooplankton), dramatic reduction in survival (stonefly), reduced feeding (mayfly), and behavioral changes (cranefly).[9]

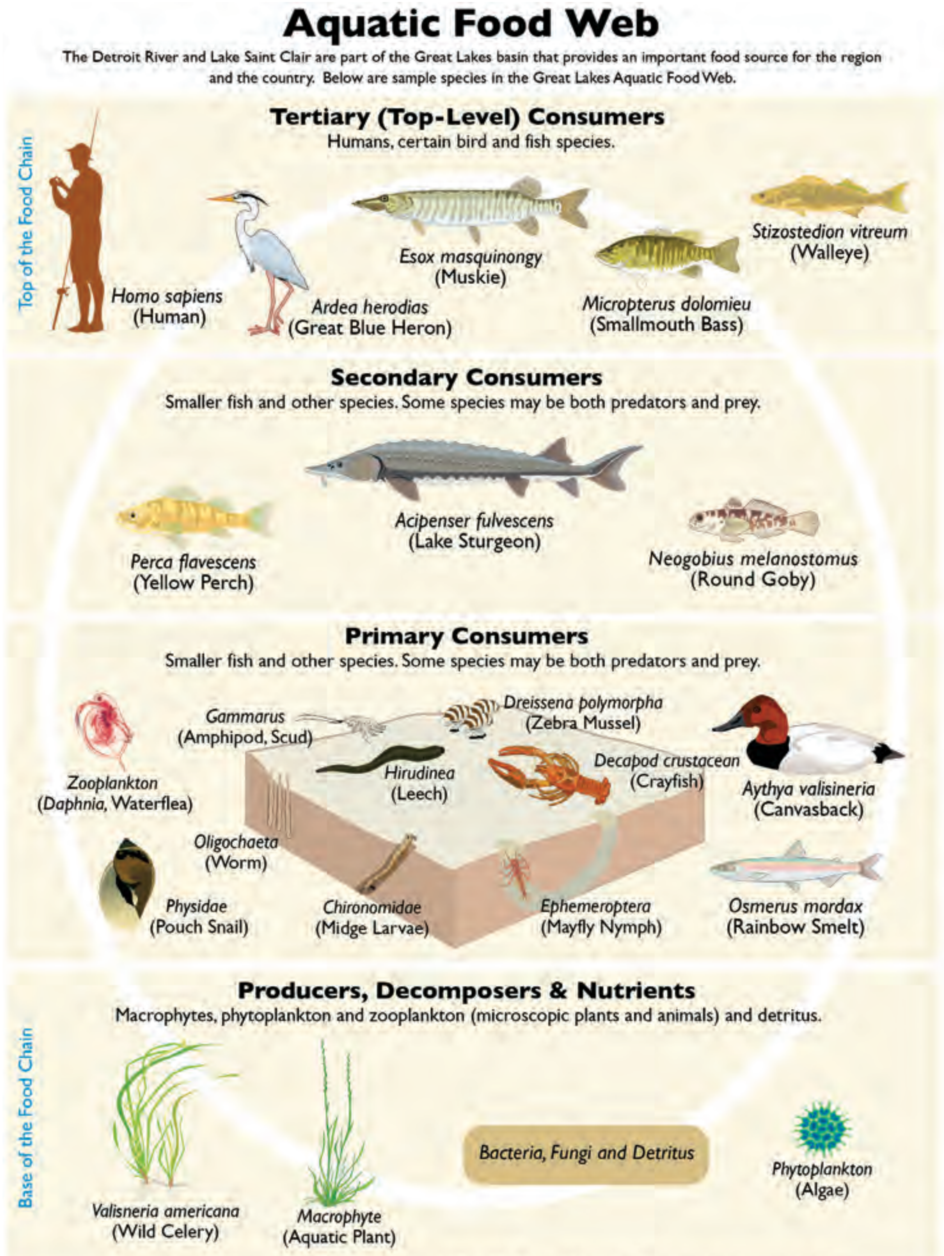
Acute and chronic direct effects

Tests show that low levels of neonicotinoids affect aquatic insects, with acute toxicity estimates (LC_{50} or lethal concentration) as low as 0.65 μg/L.[10] Chronic toxicity is seen at concentrations as low as 0.03 μg/L.[11] Ephemeroptera (mayfly), Trichoptera (caddisfly) and several Diptera (fly), especially Chironomidae (chironomid midges) are considered the most sensitive aquatic species, exhibiting adverse effects below 1.0 μg/L.[12] For amphipods (crustaceans), low doses of imidacloprid (14.2 μg/L) are sufficient to induce adverse effects.[13] The aquatic worm, *Lumbriculus variegatus*, is immobilized by concentrations of imidacloprid of 6.2 μg/L.[14] Formulated imidacloprid products have also been observed to have increased toxicity to certain amphipod species (*Hyalella azteca*) compared to imidacloprid itself.[15]

Van Dijk et al. (2013) examined imidacloprid water-monitoring data and the impact on macrofauna abundance and found that imidacloprid decreases species abundance of several types of organisms, including crustaceans, true flies, mayflies, and snails in concentrations as low as 0.03 μg/L. Amphipod crustaceans and mayflies (*Ephemeroptera*) have the strongest decreases in abundance. The water flea (*Ceriodaphnia dubia*) experiences a reduction in population size at 0.03 ppb µg/L imidacloprid.[16] Benthic communities (organisms that live in the sediment of waterways, including worms, clams, crabs, lobsters, and sponges) in general see reductions in abundance.[17] A study investigating the ecological impact of imidacloprid and the insecticide fipronil on aquatic paddy communities finds significant decreases in abundance in benthic communities.[18]

Immune suppression

Similar to sublethal effects in honey and native bees, where neonicotinoids can suppress the immune system and make the bees more susceptible to disease and parasites, so too have researchers hypothesized immune suppression in other organisms—including amphibians and fish—after low level neonicotinoid exposure. Mason et al. (2013) theorizes that low doses of neonicotinoids likely weaken the immune systems of amphibians, making them more susceptible to disease.[19] They note that the use of imidacloprid and thiamethoxam in California is the heaviest in the region where steep declines in four types of California frogs have been documented. Similarly, parasitic infections in fish in areas where rice is treated with imidacloprid have also been observed, compared to fish in untreated fields,[20] leading scientists to consider the influence of neonicotinoids in altered immune response.



Used with permission. Adapted from *The Life of the Lakes*, MICHU09-400, Michigan Sea Grant, *www.miseagrant.umich.edu*.

Fish

Imidacloprid and clothianidin have been linked to lethal and sublethal effects in fish, both directly and indirectly. Studies report decreased viability and hatching success, concluding that imidacloprid is more toxic to fish in early developmental phases, even at low concentrations.[21] Imidacloprid and the insecticide fipronil affect the growth and development of the fish medaka (*Oryzias latipes*) in rice fields. This is attributed to reduced insect populations on which young fish feed.[22] Another study looking at the cumulative impacts on aquatic paddy communities over two years, also reports impaired growth in both medaka adults and juveniles, from imidacloprid and fipronil exposures. In a 2016 study, the viability and hatchability of carp eggs (*Cyprinus carpio*) exposed to imidacloprid are significantly affected.[23] Some of the impacts are due to reductions in prey species. In zebrafish, imidacloprid has been found to increase oxidative stress, which in turn decreases antioxidant enzyme activity. Increased DNA damage is also observed over time with increasing imidacloprid concentrations.[24]

Plant communities

Algal communities have also been observed to be affected by neonicotinoids in water, although they are several orders of magnitude less sensitive than aquatic invertebrates.[25] Algal growth is observed to be significantly suppressed by chronic exposure to a formulated imidacloprid product and imidacloprid's break down product, 6-Chloronicotinic acid, and formulated products are more toxic than imidacloprid itself.[26]

EPA Confirms Serious Aquatic Risks from Imidacloprid

Aquatic insects are among the most vulnerable to imidacloprid exposures, according to EPA's 2017 preliminary assessment of imidacloprid's aquatic risks.[46] Specifically, EPA identifies mayflies as the most sensitive aquatic invertebrate to imidacloprid exposure. As critical members of the aquatic food web, aquatic insects are important for maintaining fish populations and the health of aquatic ecosystems.

Foliar spray and a combination of other application methods have "the greatest potential risks for aquatic invertebrates. . . ." Freshwater invertebrate species that are listed under the Endangered Species Act (ESA) are at elevated risk from foliar applications of imidacloprid. Moreover, runoff from soil applications also result in chronic concerns for both freshwater and saltwater invertebrates, according to EPA.

EPA did not find direct risks to fish or amphibians, but the agency acknowledges that "the potential exists for indirect risks to fish and aquatic-phase amphibians through reduction in their invertebrate prey-base."

Although its assessment is based on agricultural and non-agricultural uses, EPA does not include the harm from the mechanical planting of neonicotinoid coated seeds that creates a contaminated dust, which drifts into waterways. EPA notes that it does not have "standardized methods for quantitatively modeling dust . . ." from the planting of coated seeds. As of March, 2017, EPA has not formally published its assessment on this subject to the docket for public comment.

This study, which investigated the impacts on freshwater algae *Desmodesmus subspicatus*, finds that the formulated imidacloprid product exhibits higher toxic effect on the algae (82.3% growth inhibition) than technical grade imidacloprid, which is likely attributed to the other ingredients in the product.[27]

Marine Environment

There is generally little data for marine aquatic organisms, but studies find that growth of Mysid shrimp (*Americamysis bahia*) is impaired at 0.163 µg/L imidacloprid.[28] Opossum shrimp (*Mysidopsis bahia*) exhibit mortality at 13.3 µg/L imidacloprid, while the 48-hour LC_{50} for brine shrimp, *Artemia* spp., is 361,000 µg/L.[29] Based on impacts on post-larval crabs, the imidacloprid LC_{50} for blue crabs is 10 µg/L.[30] Based on data submitted by registrants, EPA considers the Eastern oyster to be much less sensitive to imidacloprid, with a LC_{50} of over 145,000 µg/L.[31]

Trophic and ecosystem impacts

Aquatic ecosystems experience direct and indirect effects, imbalance, and cascading effects on many trophic levels (food web) as a result of exposure to imidacloprid concentrations as low as 0.6 µg/L.[32] In these ecosystems, aquatic invertebrates play an important role. Colombo et al. (2013) found that repeated short-term concentrations of 2.3 µg/L imidacloprid disrupt aquatic ecosystems.[33] Thiacloprid has been found to affect trophic interactions, which in turn affect ecosystem functions. Predation by gammarid crustaceans increases with thiacloprid concentrations up to 1 µg/L, as a result of impaired avoidance behavior of mayflies.[34] This corresponds with decreased leaf litter consumption by gammarids, affecting decomposition and ecosystem function. Increased predation also has a greater impact on mayfly populations when thiacloprid is present. The authors suggest that their results may also be relevant to other species preyed upon by gammarids (e.g., Trichoptera, Plecoptera, Diptera).[35]

Similarly, populations of the snail *Radix* sp. increase with decreased competition for food as the survival and abundance of other species decrease (e.g., mayflies and midges), after the introduction of low level imidacloprid concentrations (0.6–40 µg/L).[36] With reductions of aquatic invertebrate species, the availability of food for fish, amphibians, and others, like birds that prey on these organisms, is adversely affected. These disruptions associated with indiscriminate neonicotinoid exposure have long-term cascading effects on food webs and habitats in or near aquatic environments.

FEDERAL WATER QUALITY BENCHMARKS OFFER INADEQUATE PROTECTION

Pesticides are in waterways of the U.S. at levels that impact aquatic organisms and other wildlife that depend on these species. Despite this, only a handful of pesticides have any kind of water quality standard or benchmark. These standards are set threshold values that can be compared with real-world water monitoring information to determine whether water contaminants, like pesticides, impact aquatic life. Pesticide concentrations that exceed these thresholds put aquatic organisms at risk for adverse effects, despite well documented testing inadequacies.

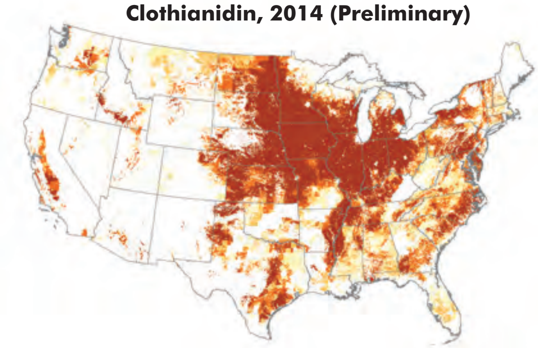
Benchmarks Fail to Consider Exposure to Chemical Mixtures

Typically, pesticide exposure values allowed by law are derived from various toxicity tests of individual pesticides to determine certain ecological endpoints, such as survival, and reproduction. However, in the aquatic environment, as in other contexts, pesticide exposures occur as mixtures and may have additive and synergistic effects in combination. The effects of pesticide mixtures are not evaluated, resulting in an underestimation of the potential hazards to aquatic wildlife. According to U.S. Geological Survey (USGS), water-quality benchmarks are estimates of "no-effect levels," meaning that

FIGURE 1: **Estimated Agricultural Use for Clothianidin and Imidacloprid, 2003 and 2014**

Clothianidin, 2003

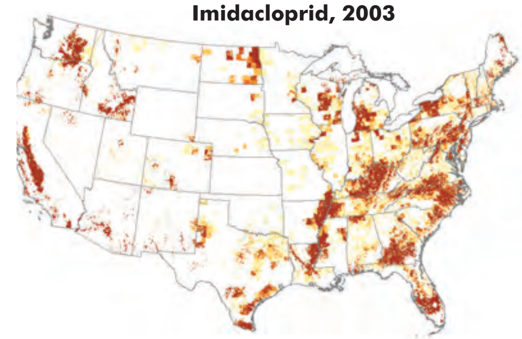
Clothianidin, 2014 (Preliminary)



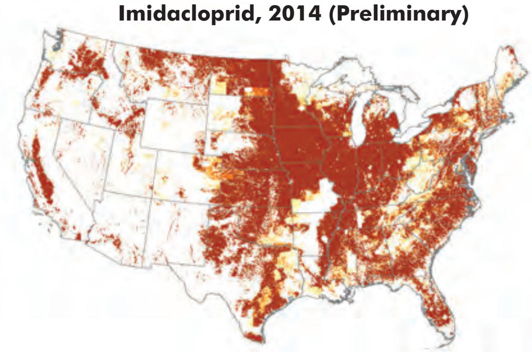
Estimated use on agricultural land, in pounds per square mile

<0.33 | 0.01–0.21 | 0.22–0.91 | >0.91 | No estimated use

Imidacloprid, 2003



Imidacloprid, 2014 (Preliminary)



Estimated use on agricultural land, in pounds per square mile

<0.01 | 0.01–0.02 | 0.03–0.04 | >0.04 | No estimated use

Source: USGS, National Synthesis Project, August 2016.

real-world concentrations below the benchmarks are expected to have a low likelihood of adverse effects, while concentrations above a benchmark have a greater likelihood of adverse effects, which generally increases with concentration.[37]

Benchmarks Not Based on Effect to Sensitive Species

For the neonicotinoids, there are some aquatic life benchmarks for fish, invertebrates, and aquatic plants.[38] In addition to limitations in assessing the effect of chemical mixtures, these benchmarks are derived from standardized laboratory testing of specific aquatic organisms, which many researchers have critiqued as not sensitive enough to pesticide exposures.[39]

Scientists note that the water flea *Daphnia magna,* which is used as a standard aquatic test organism, appears to be approximately 100,000 times less sensitive than other aquatic invertebrates, such as Ephemeroptera, Trichoptera or Diptera species.[40] Ashauer et al. (2011) find that *D. magna* is two to three orders of magnitude less sensitive to neonicotinoids than the freshwater crustacean *Gammarus pulex*.[41] If *D. magna* is more tolerant of neonicotinoids than other aquatic invertebrates, then its use in testing the aquatic toxicity of neonicotinoids, or other pesticides, results in benchmarks that are not protective of more sensitive species.

Neonicotinoid Use Is Widespread

Neonicotinoids are some of the most widely used pesticides in the U.S. and are contained in many readily available and widely used agricultural, lawn, and garden products. Neonicotinoid use increased rapidly between 2003 and 2014, as a result of growing prophylactic applications as seed coatings (Figure 1). It is estimated that 34–44% of soybeans and 79–100% of corn fields are treated with neonicotinoids in the U.S.[52] Residential lawn and garden use, including vegetable and flower seeds and seedlings, is also ubiquitous. Neonicotinoids are also widely used on pets in flea collars and flea and tick treatments.

With the variety of applications and the treated acreage, neonicotinoids make their way into waterways from surface runoff from agricultural fields, lawns and gardens, as well as from spray drift and contaminated dust drift from coated seed plantings, and residential down-the-drain disposal.

Neonicotinoids are highly water-soluble and are mobile and persistent in the environment.[53] Imidacloprid, one of the oldest neonicotinoids in commercial use, is persistent in water and does not easily biodegrade.[54] Half-lives in water are generally more than 30 days,[55] with some reports ranging 30–162 days.[56] Aquatic half-lives for thiamethoxam range 7.9 to 39.5 days; acetamiprid 34 days; dinotefuran, 1.8 days; and clothianidin at less than one day.[57] However, local water/environmental conditions can influence the persistence of these chemicals in water.[58]

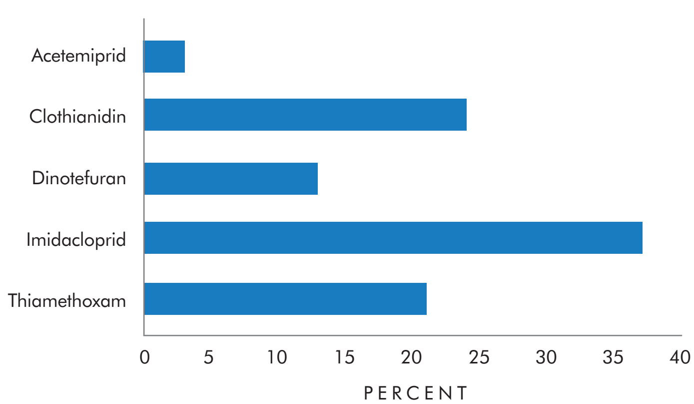
The U.S. acute and chronic aquatic life benchmarks for invertebrates exposed to imidacloprid are 34.5 μg/L and 1.05 μg/L, respectively. However, studies summarized in this report find acute and chronic effects to aquatic organisms and communities at levels as low as 0.65 μg/L and 0.01 μg/L for imidacloprid, respectively.[42,43] Meanwhile, levels of harm are exceeded in numerous monitoring studies, especially at peak levels. Mean peak neonicotinoid water levels have been reported at 0.63 μg/L and average neonicotinoid levels at 0.13 μg/L.[44] While USGS has detected average imidacloprid in streams at levels up to 0.14 μg/L, others report detections of imidacloprid levels ranging from 0.001–320 μg/L, with clothianidin at 0.003-3.1 μg/L and thiamethoxam at 0.001–225 μg/L, and as high as 3.29 μg/L in a California study.[45] These findings establish that real-world levels currently exceed the benchmark "no effect" standard that would protect sensitive species.

SYNERGISTIC EFFECTS NOT CONSIDERED BY REGULATORS

Neonicotinoids in combination with other chemical classes can have additive and synergistic effects on exposed organisms. Some pesticide combinations, such as certain fungicides combined with either pyrethroid or neonicotinoid insecticides, increase toxicity synergistically.[47,48] Imidacloprid has been found to act synergistically with inert ingredient mixtures, resulting in reduced population size of *Ceriodaphnia dubia* compared to imidacloprid alone. Feeding rates are observed to decrease in *Daphnia magna* when exposed to a mixture of imidacloprid and thiacloprid.[49]

Multiple pesticide combinations are found in U.S. waterways[50] and it is possible that synergistic effects between these chemicals occur in the environment. However, little is known about the mechanisms associated with these synergistic interactions and their impact on aquatic invertebrates and ecosystems.[51]

FIGURE 2: **Detection Frequency for Five Neonicotinoids Detected at 38 Sites in a Nationwide Study, 2012–2014**



Source: Hladik and Kolpin, 2016.

NEONICOTINOIDS IN THE WATERS

Looking at one of the neonicotinoids, in the 2017 "Preliminary Aquatic Risk Assessment to Support the Registration Review of Imidacloprid," EPA found," [C]oncentrations of imidacloprid detected in streams, rivers, lakes and drainage canals routinely exceed acute and chronic toxicity endpoints derived for freshwater invertebrates."[59] EPA summarizes a large collection of monitoring data from several sources: USGS monitoring to give representative national data, USGS monitoring of storms and floods, California Department of Pesticide Regulation, and monitoring data reported in the scientific literature. Waterbodies monitored include drainage ditches and canals, streams, rivers, lakes, wetlands, and estuaries.

Most studies could not detect imidacloprid below 0.002 to 0.2μg/L. Since the most sensitive species tested are harmed above 0.01 μg/L, any detected imidacloprid is likely to have an impact on those sensitive species. In summarizing the data from USGS nationwide monitoring, EPA found imidacloprid was detected in 61% of samples from drainage canals and ditches, 13% of stream samples, 5% of river and lake samples, 8% of wetlands, and 67% of estuary samples. In this untargeted dataset, concentrations ranged as high as 7.94 μg/L. Higher detection rates and concentrations have been found in studies targeting areas where the pesticide is used and problems are expected.[60]

USGS Baseline Survey

NATIONAL RESULTS

USGS's 2015 study, "First National-Scale Reconnaissance of Neonicotinoid Insecticides in Streams Across the USA," found that neonicotinoids "were frequently detected in streams across the USA, with 63% of the 48 streams sampled having a detection of at least one neonicotinoid."[61] The study samples from streams in 24 states and Puerto Rico between November 2012 and June 2014 identify levels that exceed acute and chronic toxicity values for sensitive organisms. The six neonicotinoids analyzed include acetamiprid, clothianidin, dinotefuran, imidacloprid, thiacloprid and thiamethoxam. Imidacloprid is the most frequently detected, followed by clothianidin and thiamethoxam (Figure 2). Of the neonicotinoids, thiamethoxam was found at the highest levels at 0.19 μg/L and acetamiprid the lowest at 0.04 μg/L.[62]

URBAN VERSUS AGRICULTURAL

Water contamination with neonicotinoids reflects their use patterns. According to the USGS study, "Clothianidin and thiamethoxam concentrations were positively related to the percentage of the land use in cultivated crop production, and imidacloprid concentrations were positively related to the percentage of urban area within the basin." Sites in Iowa, where neonicotinoids are widely used on corn and soybeans, especially through treated or coated seeds, contain concentrations of clothianidin ranging from 0.025–0.132 μg/L.

From: Rosi-Marshall EJ , et al. (2007). "Toxins in transgenic crop byproducts may affect headwater stream ecosystems." Proc Natl Acad Sci USA 104:16204–16208. © 2007 National Academy of Sciences, U.S.A.

Additionally, clothianidin and thiamethoxam frequently co-occur in these agricultural regions.

An earlier 2014 regional USGS study analyzes stream concentrations of neonicotinoids in the Midwest Corn Belt.[63] Similar to the more recent study, levels are detected in waterways near treated fields, resulting in high levels of clothianidin and thiamethoxam, with detection rates of 75% and 47%, respectively. Samples with multiple detections of neonics (76%) contain clothianidin most frequently, due to its heavy use as a seed coating in the region.

CHESAPEAKE BAY

Fifty percent of Chesapeake Bay watershed samples, taken from streams that feed into the bay, contain neonicotinoids, with clothianidin being the most frequently detected. According to the results, "The thiamethoxam and imidacloprid detections were all found in the presence of clothianidin."

These residues are attributed to agricultural runoff from farms in the region. Antietam Creek, MD, Big Pipe Creek, MD, and Chillisquaque Creek, PA watersheds for instance, range from 42–68% agricultural land use, including cropland.[64] Not surprisingly, agricultural land use in these regions influences the levels of neonicotinoids found in these streams, and the concentrations of clothianidin increase with the proportion of land in agriculture.

For the Chesapeake Bay, a sensitive watershed with federal and state mandates to reduce pollution and restore habitats, local stream concentrations with clothianidin (0.062 µg/L) approach the highest levels found nationally (0.066 µg/L). These residues, which could make their way to the Chesapeake Bay, pose risks to the unique species of the bay where already 75% of tidal waters are considered impaired as a result of chemical contamination.[65]

FIGURE

CALIFORNIA

A 2012 California Department of Pesticide Regulation study using 2010 and 2011 surface water monitoring data from three agricultural regions in the state[66] finds imidacloprid in 89% of the samples collected, with maximum concentrations ranging 1.38–3.29 µg/L). In the three agricultural regions studied, imidacloprid was detected 85% of samples in Salinas, 93% in Imperial Valley, and 100% in Santa Maria Valley. These levels exceed currently established chronic aquatic benchmark concentrations.[67]

GLOBAL DETECTIONS

Elsewhere in the world, neonicotinoids are also widely detected. In Canada, average thiamethoxam concentrations in surface runoff are as high as 0.4 µg/L, and maximum concentrations of 2.2 µg/L are detected following a high rain event after coated seeds were planted in the nearby agricultural region.[68]

A review of 29 water monitoring studies from nine countries, reports the presence of neonicotinoids in streams, rivers, puddled water, wetlands, and irrigation channels, finding levels ranging 0.003–3.1 µg/L for clothianidin, 0.001–225 µg/L for thiamethoxam and 0.001–320 µg/L for imidacloprid.[69] Australian samples taken from agricultural regions contain multiple neonicotinoids with imidacloprid levels reaching 4.6 µg/L. Concentrations of 55.7 µg/L clothianidin and 63.4 µg/L thiamethoxam were found in puddles in the corn growing regions of Quebec, Canada.[70] Imidacloprid has been in the top three detected water contaminants for several years in the Netherlands,[71] with levels as high as 320 µg/L reported,[72] exceeding the country's maximum allowed environmental concentration.

CASE STUDIES

The Poisoning of Willapa Bay and Grays Harbor

In 2015, the State of Washington's Department of Ecology ("Ecology") approved a permit to allow the spraying of imidacloprid on 2,000 acres in Willapa Bay and Grays Harbor to control burrowing shrimp—considered a pest by commercial oyster growers—on 2,000 acres of tidelands. Local residents raised the concern that the use of imidacloprid would contaminate the oyster beds and the oysters that the state was trying to protect. Consumers, environmental organizations, and prominent local chefs spoke out against the spraying. An environmental assessment conducted by Ecology found that, "The proposed use of imidacloprid to treat burrowing shrimp in shellfish beds located in Willapa Bay and Grays Harbor is

What are the regulators up to?

The U.S. Environmental Protection Agency's (EPA) Office of Pesticide Programs regulates pesticides under the *Federal Insecticide, Fungicide and Rodenticide Act* (FIFRA) with its "unreasonable adverse effects" standard, conducts Ecological Risk Assessments, and proposes risk mitigation measures. It coordinates with the Office of Water under the Clean Water Act, which seeks to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters . . . for the protection and propagation of fish, shellfish, and wildlife."

EPA's 2017 preliminary risk assessment of the neonicotinoid insecticide imidacloprid, which identifies toxicity endpoints, challenges its 2008 decision on allowed levels (benchmarks) in water that the agency now finds are not adequate to protect sensitive aquatic species. The agency says, "[C]oncentrations of imidacloprid detected in streams, rivers, lakes and drainage canals routinely exceed acute and chronic toxicity endpoints derived for freshwater invertebrates." EPA is scheduled to make a final decision on continued imidacloprid use in 2018.

Historically, ecological risk assessments do not fully evaluate: (i) **sensitive species**; (ii) **ecosystem or habitat impacts**; (iii) **foodweb impacts** (to determine effect of keystone species impact on higher trophic members of the aquatic ecosystem); (iv) **secondary or non-target effects**; (v) **sublethal or low pesticide doses**; and (vi) **pesticides** registered conditionally, like neonicotinoids, without full understanding.

The Canadian Pest Management Regulatory Agency (PMRA), in 2016, announced its proposal to phase out imidacloprid because, "Based on currently available information, the continued high volume use of imidacloprid in agricultural areas is not sustainable." Uses proposed for phase out: trees (except when applied as a tree trunk injection), greenhouse uses, outdoor agricultural uses (including ornamentals), commercial seed treatment uses, and turf (such as lawns, golf courses, and sod farms).

expected to have little or no impact on the local estuarine and marine species. . . ,"[73] and imidacloprid is "safer" than the alternative, the carbamate insecticide carbaryl.

Opponents note the need for caution, citing Ecology's failure to consider information on fate and transport, efficacy, and persistence of imidacloprid, as well as the existing published research on the wide-ranging ecological damage from imidacloprid use, and the potential to damage the rich marine ecosystems of Willapa Bay and Grays Harbor. Central to the concern is imidacloprid's adverse effect on key species whose loss can cause a cascading trophic effect, harming the fish, birds, and other organisms that rely on them.

The National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) also weighed in, pointing to unknowns regarding impacts to other aquatic and terrestrial biota. NMFS finds that the native burrowing shrimp play an important role in the natural ecosystem, and voiced concern that the green sturgeon—a "species of concern" under the Endangered Species Act (ESA)—could be affected by reduced food sources in its designated critical habitat. The shellfish industry eventually requested the permit be withdrawn in response to public outcry.

In 2016, oyster growers from the Willapa Grays Harbor Oyster Grower Association applied for a new pesticide permit for imidacloprid to control the burrowing shrimp—aimed at treating smaller acreage than the 2015 proposal, with application to be conducted from boats or ground equipment rather than aerial spraying.

Native ghost shrimp, *Neotrypaea californiensis*, and mud shrimp, *Upogebia pugettensis*, have an important function in this ecosystem, but are blamed by shellfish growers for their declining industry. According to an analysis conducted by the Xerces Society, "The benefits from these species are likely to include ecosystem services such as substrate bioturbation, improving water quality and nutrient availability."[74] Other species, like migratory birds that depend on shoreline aquatic invertebrates, can also be significantly affected.

Chesapeake Bay: Blue Crabs and America's Imperiled Estuary

Despite the latest State of the Bay report (2016) declaring the health of the Chesapeake Bay improved,[75] over 75% of the bay is categorized as impaired by chemical contaminants,[76] including pesticide runoff from surrounding agricultural and residential sites. Habitat, fisheries, and nutrient pollution indicators have improved since federal and state efforts were organized to restore the health of America's largest estuary. This unique ecosystem is home to a range of aquatic wildlife. The blue crab, *Callinectes sapidus,* is the most identifiable habitant of the bay, considered one of its keystone species because it provides food for other wildlife and consumes benthic organisms, thus helping to keep the bay clean. Annual commercial harvest of blue crab is valued $78 million,[77] but over the years, populations have declined[78] to levels that threaten the viability of the crab.

Agricultural runoff drains into tidal creeks that are important habitats for juvenile and adult stage blue crabs. Female blue crabs, after mating in spring and summer, migrate downstream and out of the estuary to release larvae. Larvae develop offshore then return onshore in their post-larval stage (megalopae) in late summer and fall to develop into the juvenile stage. The blue crab's juvenile stage is the most likely age group to be directly affected by agricultural runoff, as they tend to live in shallow waters, including drainage areas that collect contaminated pesticide runoff or spray drift.[79]

A 2012 study conducted on blue crabs in North Carolina by Duke University researchers finds that the imidacloprid-formulated product, Trimax, is highly toxic to juvenile and post-larval blue crabs (LC_{50} 816.7 μg/L and 312.7 μg/L, respectively), second in toxicity to the pyrethroid insecticide lamda-cyhalothrin.[80] Imidacloprid, however, is 100-fold more toxic to post-larval crabs compared to juveniles (LC_{50} 10.04 μg/L for post-larval crabs vs. 1112 μg/L for juveniles), according to the study. Post-larval crabs are found to be the most sensitive developmental stage to imidacloprid and its formulated product overall. Adverse effects include significant reduction in molting of post-larval crabs and increased mortality. Interestingly, the study notes that post-larval blue crabs are more sensitive to imidacloprid than the small crustacean, *Daphnia magna,* which is an organism recommended by federal guidelines for testing the aquatic toxicity of pesticides.

Molting, which occurs several times in young crabs, is an important developmental process that causes post-larval and juvenile crabs to be very sensitive to environmental chemicals. Juvenile crabs can molt as frequently as once a week, thus increasing their sensitivity to chemicals. The authors conclude that molting blue crabs are "at an elevated risk of pesticide toxicity beyond what is suggested by LC_{50}s alone." The authors note that further evaluation of the sensitivity of blue crabs to mixtures must be conducted.

Like the blue crab, other inhabitants of the bay are also affected by pesticides, but limited information exists on the effects of specific pesticides on these organisms. There are some data regarding contaminant exposure to waterbird species like the ospreys, waterfowl, and black-crowned night-herons.[81] These birds feed on many benthic and aquatic species whose populations are directly affected by neonicotinoid contamination. Other bay organisms, including grass shrimp, have been found to experience increased toxicity in pesticide mixtures containing imidacloprid, demonstrating the additive effects of chemical mixtures on aquatic organisms.[82]

From: Rosi-Marshall EJ , et al. (2007). "Toxins in transgenic crop byproducts may affect headwater stream ecosystems." Proc Natl Acad Sci USA 104:16204–16208. © 2007 National Academy of Sciences, U.S.A.

ACTION TO ENSURE HEALTHY ECOSYSTEMS

Protection of the nation's waterways is fundamental to healthy ecosystems. The importance of the mayfly to aquatic habitats is demonstrated by its ability to convert sediment nutrients into food for many species of fish and others when they are eaten.[83] Without this critical keystone species, an important food source and nutrient recycler would be lost. With the disruption or loss of important aquatic ecosystem functions, such as nutrient cycling, water filtration, and a host of other functions, including providing habitat, adverse effects are felt throughout both aquatic and terrestrial systems.

In 2014, the International Union for the Conservation of Nature (IUCN Task Force) published the first report examining the impact on biodiversity and ecosystems as a result of growing neonicotinoid use. After reviewing numerous peer-reviewed scientific studies, the Task Force found that neonicotinoids are in the environment "at levels that are known to cause lethal and sublethal effects on a wide range of terrestrial (including soil) and aquatic microorganisms, invertebrates and vertebrates."[84] The report concludes that increasing use of neonicotinoids is not sustainable and poses a threat to important invertebrates and the diversity and stability of ecosystems.

In light of the presented evidence of risks to individual aquatic invertebrates, species abundance, and ecosystem functioning, suspension of neonicotinoid insecticides is imperative. As observed with the decline of pollinators, like honey and native bees, whose perilous state is linked to pervasive neonicotinoid use, action must be taken to protect vulnerable waterways from neonicotinoid contamination. The frequency of detections in U.S. waterways cannot be overlooked. Such routine detections, even at low levels, indicate that our waterways are being overloaded with mobile and persistent chemicals at highly elevated concentrations, whose long-term impacts on aquatic health has been documented, but not fully understood.

Thus far, little action has been taken to restrict the use of these chemicals in response to the independent scientific literature and EPA risk data that identify direct threats to aquatic invertebrates, as well as indirect threats to higher trophic organisms of the most widely used neonicotinoid, imidacloprid. Other neonicotinoids in its class will likely be found to have similar impacts on aquatic species. Federal benchmarks based on testing on insensitive species are not protective of more sensitive species. Given the toxicity of this class of insecticides to non-target, beneficial invertebrates, and the regulatory deficiencies, it is imperative that action be taken to limit their use and presence in waterways in the U.S. and worldwide.

Action Steps

- Call on Congress and EPA to suspend the use of neonicotinoids and other systemic pesticides.
- Plant habitat with organic seeds and manage with organic practices.
- Adopt local policies that require organic land management of all public lands, and, where possible, private property.
- Repeal preemption of local authority to restrict pesticides in your community.
- Start an organic garden.
- Buy organic food.

ENDNOTES

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