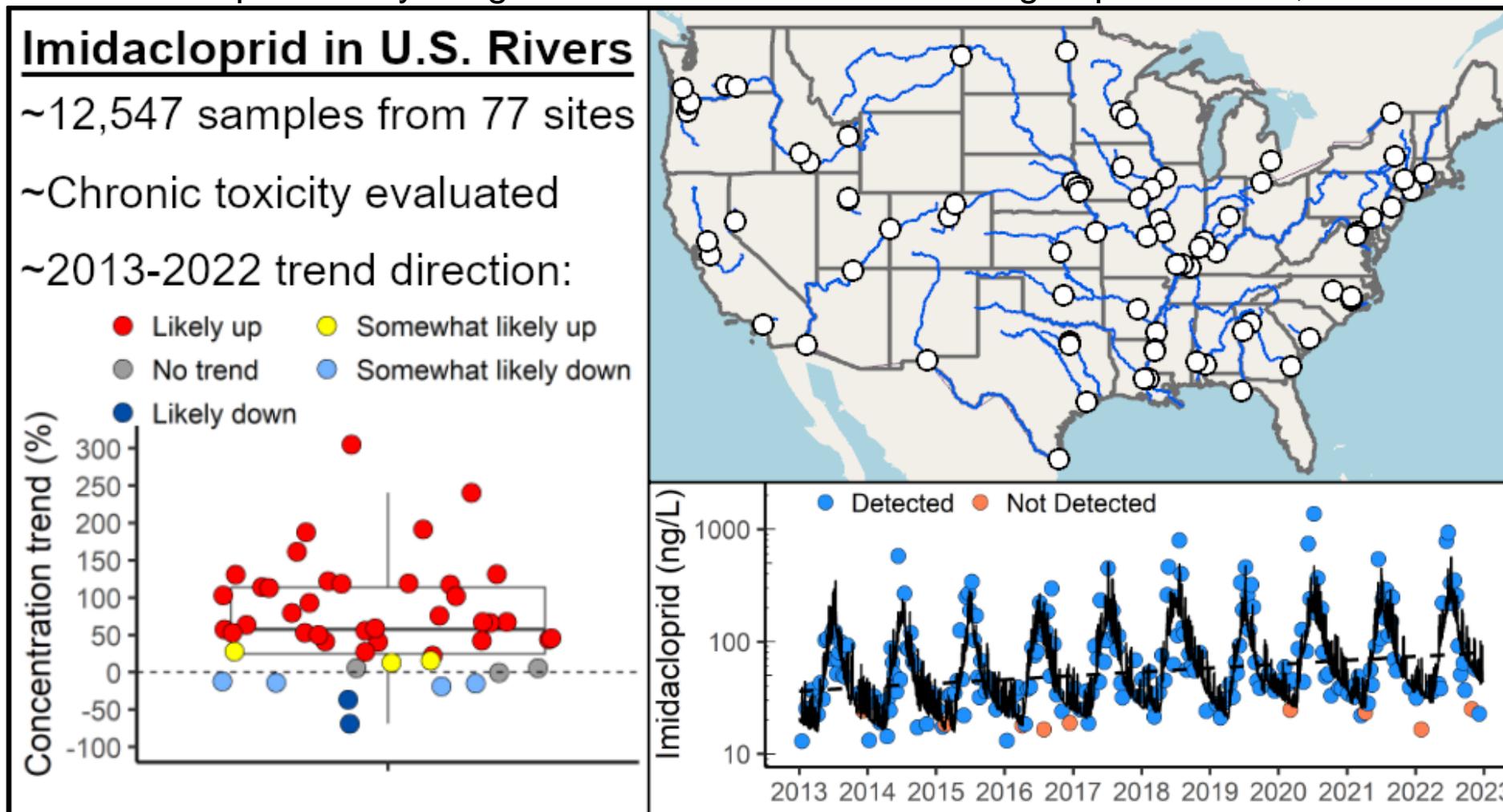


# Imidacloprid in United States Rivers, 2013–2022: Persistent Presence and Emerging Chronic Hazard

Sam Miller: Hydrologist, Virginia and West Virginia Water Science Center

Chesapeake Bay Program Toxic Contaminants Workgroup: March 11, 2026



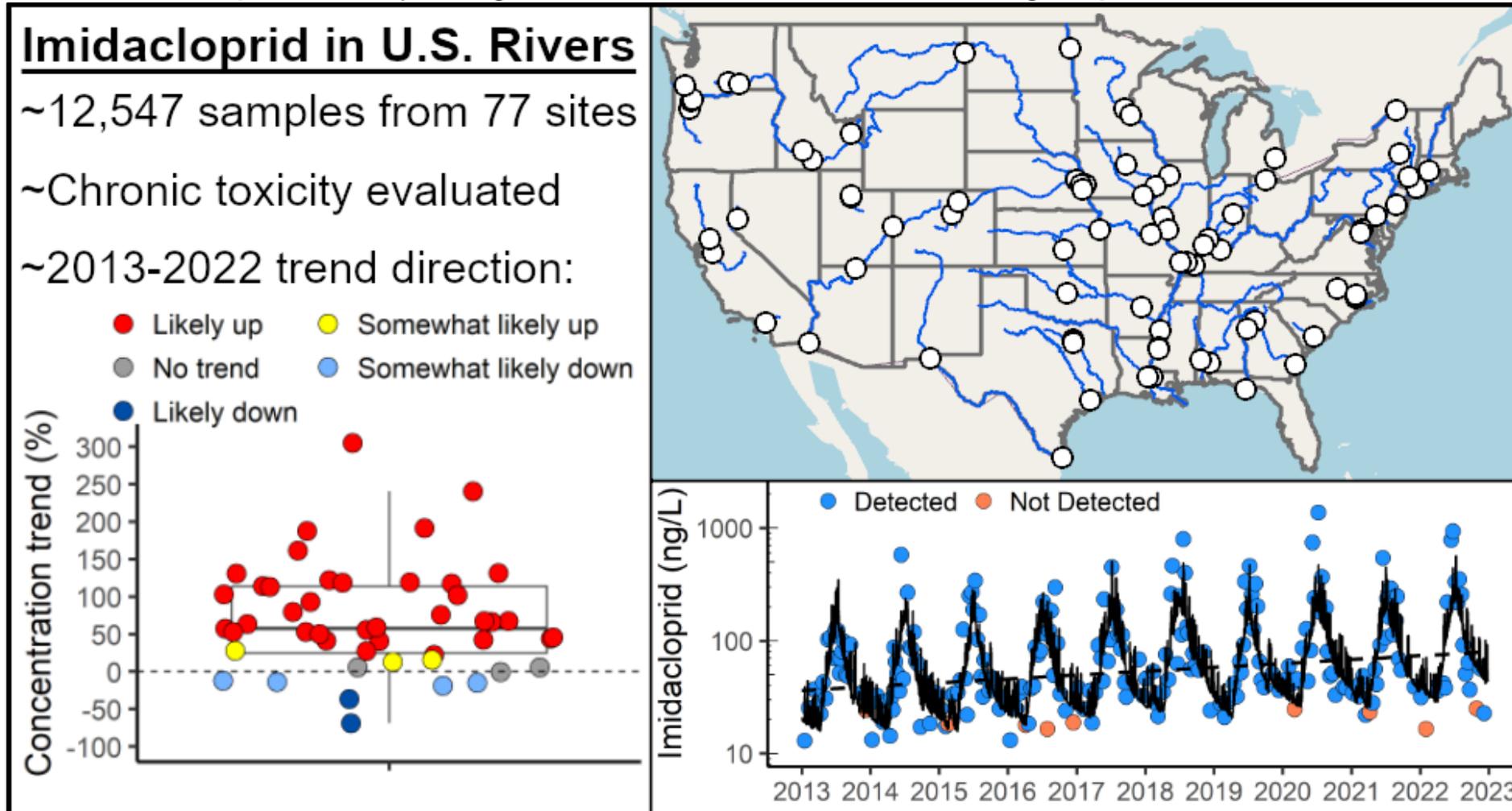
This information is preliminary and is subject to revision. It is being provided to meet the need for timely best science. The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government shall be held liable for any damages resulting from the authorized or unauthorized use of the information.

# Imidacloprid in United States Rivers, 2013–2022: Persistent Presence and Emerging Chronic Hazard

Sam Miller: Hydrologist, Virginia and West Virginia Water Science Center

Collaborators: Travis Schmidt, Larry Barber, Michelle Hladik, Dana Kolpin, Meg Shoda, and Sarah Stackpoole

Chesapeake Bay Program Toxic Contaminants Workgroup: March 11, 2026



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# Outline

## 1. Background

- What is imidacloprid?
- Previous Chesapeake studies

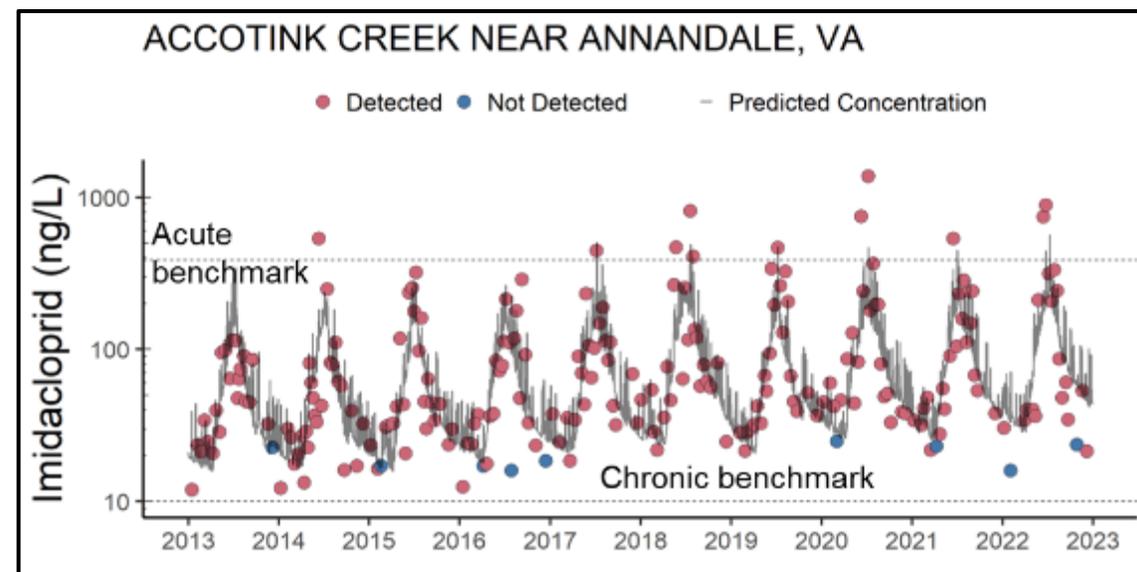
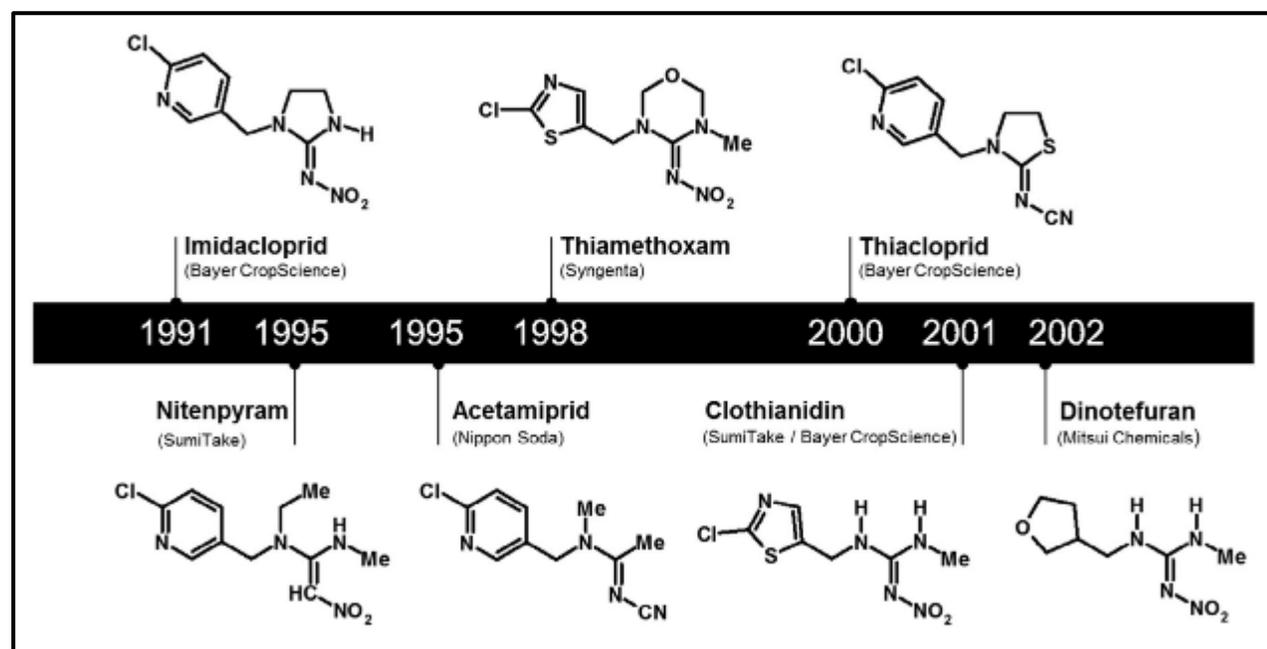
## 2. Study Area and Methods

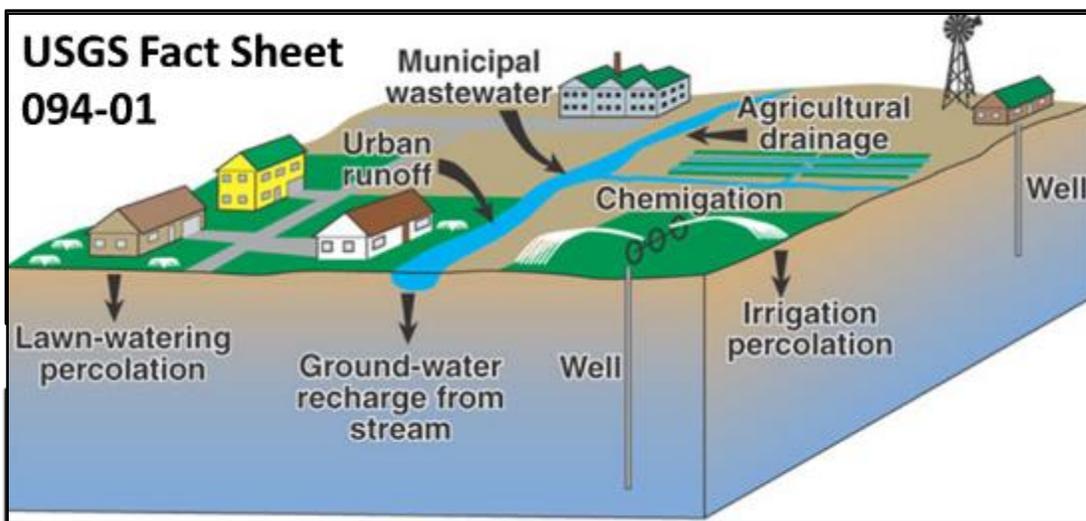
- National Water Quality Network
- Comparison to aquatic life benchmarks
- Trend analysis (SEAWAVE-Q)

## 3. Results and Management Implications

- Concentration-discharge patterns
- Local sites Accotink Creek & Potomac River

## 4. Challenges and Opportunities





# What is Imidacloprid?

- **Popular systemic neonicotinoid insecticide** that treats insects in **agricultural** and **urban** settings
  - **Agricultural:** Broad-spectrum prophylactic seed treatment, as well as foliar spray and granules
  - **Non-agricultural:** turfgrass, gardens, termite deterrent, invasive species control, forestry, veterinary products

- **High solubility** and **moderately mobile**
  - Potential for **leaching** into **groundwater**

- **Highly toxic** to **invertebrates**
  - **Investigations** of **insurance pest management** on an **unseen, silent entomological majority**
  - **U.S. affected** **species**

**Beyond the Headlines: The Influence of Insurance Pest Management on an Unseen, Silent Entomological Majority**  
 Frontiers in Sustainable Food Systems, 2020  
 Christian H. Krupke<sup>1\*</sup> and John F. Tooker<sup>2</sup>  
<sup>1</sup>Department of Entomology, College of Agriculture, Purdue University, West Lafayette, IN, United States; <sup>2</sup>Department of Entomology, College of Agricultural Sciences, The Pennsylvania State University, University Park, PA, United States

- **Most prevalent in previous vertebrates assessments**

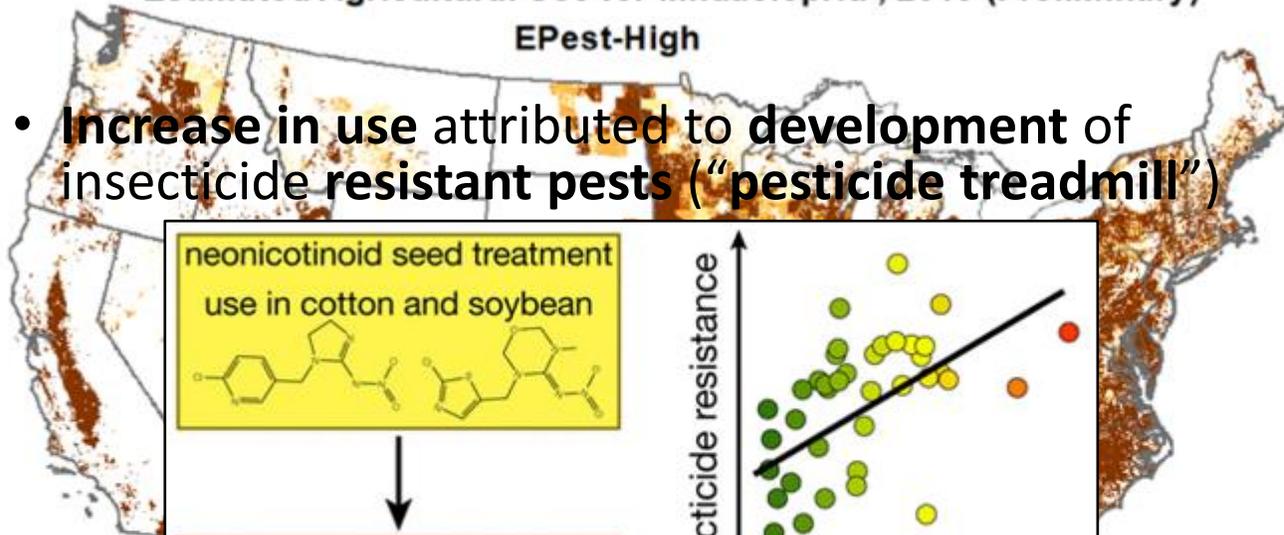
**Neonicotinoid seed treatments of soybean provide negligible benefits to US farmers**  
 Scientific Reports, 2019  
 Spyridon Mourtzinis<sup>1</sup>, Christian H. Krupke<sup>2</sup>, Paul D. Esker<sup>3</sup>, Adam Varenhorst<sup>4</sup>, Nicholas J. Arneson<sup>1</sup>, Carl A. Bradley<sup>5</sup>, Adam M. Byrne<sup>2</sup>, Martin I. Chilvers<sup>7</sup>, Loren J. Giesler<sup>6</sup>, Ames Herbert<sup>8</sup>, Yuba R. Kandel<sup>9</sup>, Maciej J. Kazula<sup>10</sup>, Catherine Hunt<sup>9</sup>, Laura E. Lindsey<sup>11</sup>, Sean Malone<sup>8</sup>, Daren S. Mueller<sup>9</sup>, Seth Naeve<sup>10</sup>, Emerson Nafziger<sup>12</sup>, Dominic D. Reisig<sup>13</sup>, William J. Ross<sup>14</sup>, Devon R. Rossman<sup>7</sup>, Sally Taylor<sup>8</sup> & Shawn P. Conley<sup>1</sup>

# Estimated Agricultural Use

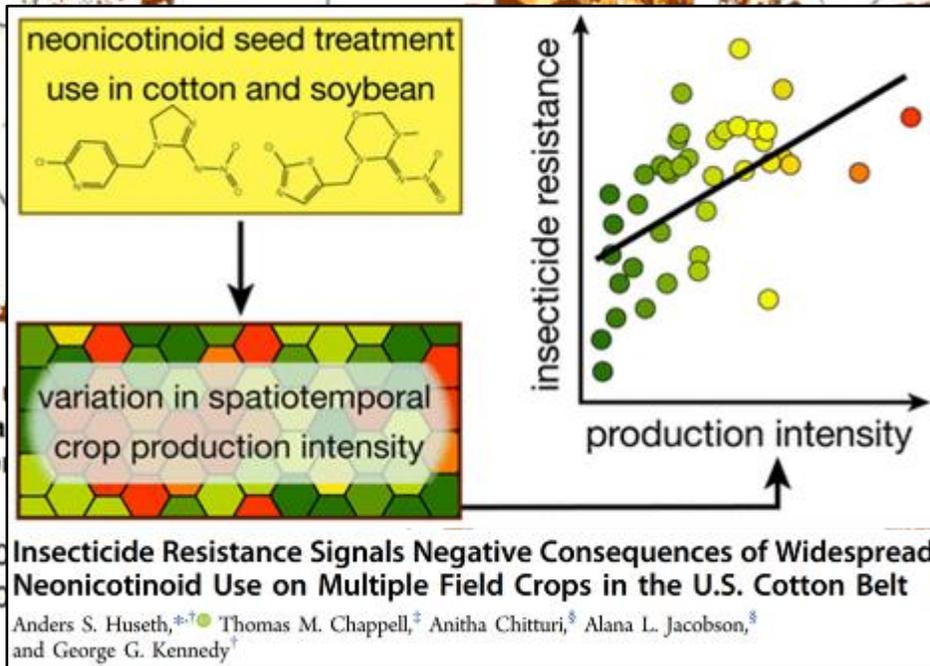
- Agricultural use throughout the United States
  - Soybeans, cotton, wheat, corn, vegetables, orchards
  - **No accurate non-agricultural use data available**
  - **Since 2015, seed treatment use data unavailable**

Estimated Agricultural Use for Imidacloprid, 2019 (Preliminary)

EPEst-High

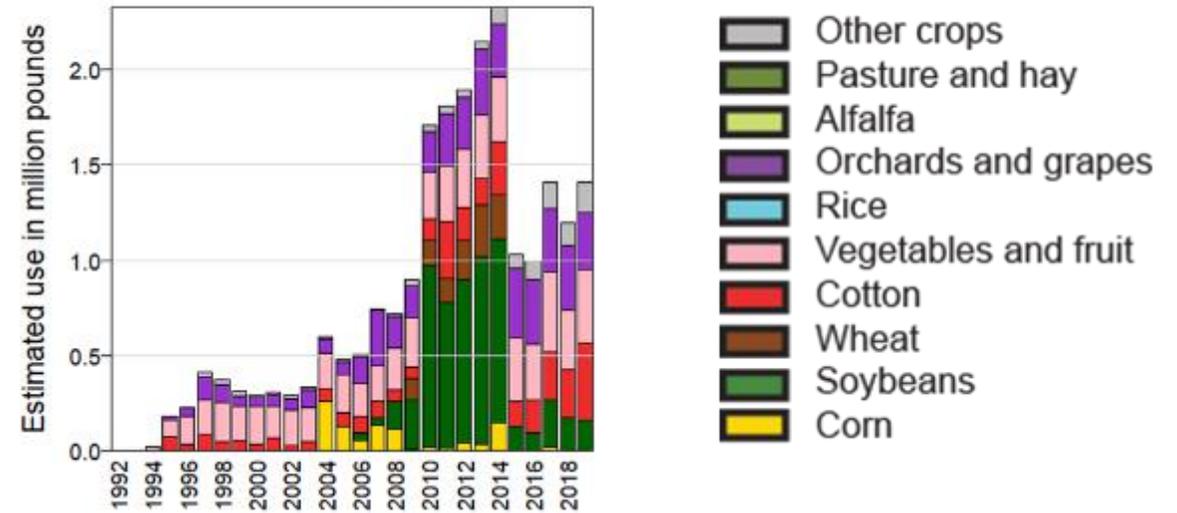


- Increase in use attributed to development of insecticide resistant pests (“pesticide treadmill”)

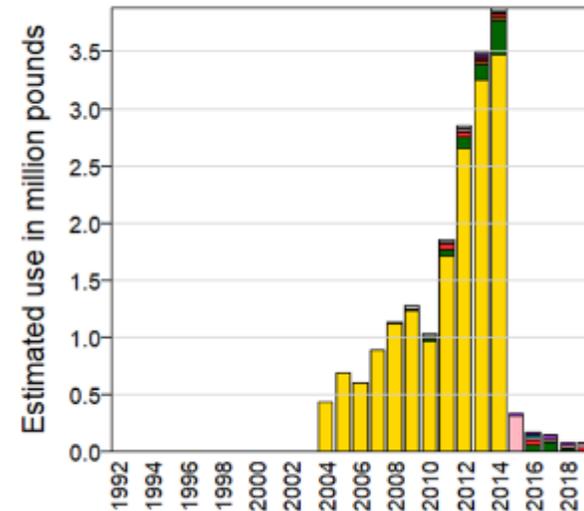


## Imidacloprid

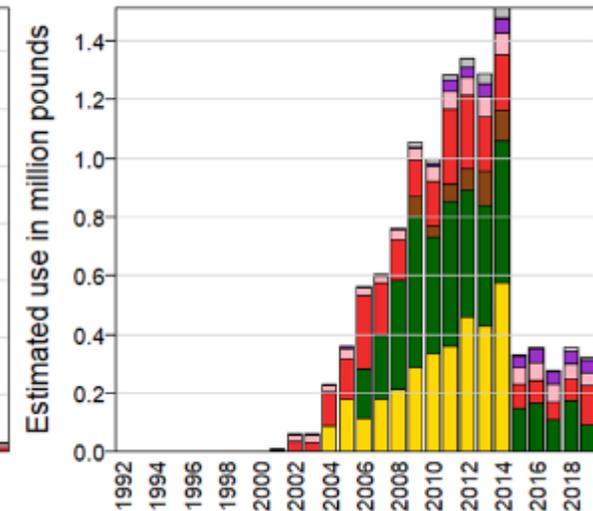
(USGS Pesticide National Synthesis Project)



## Clothianidin



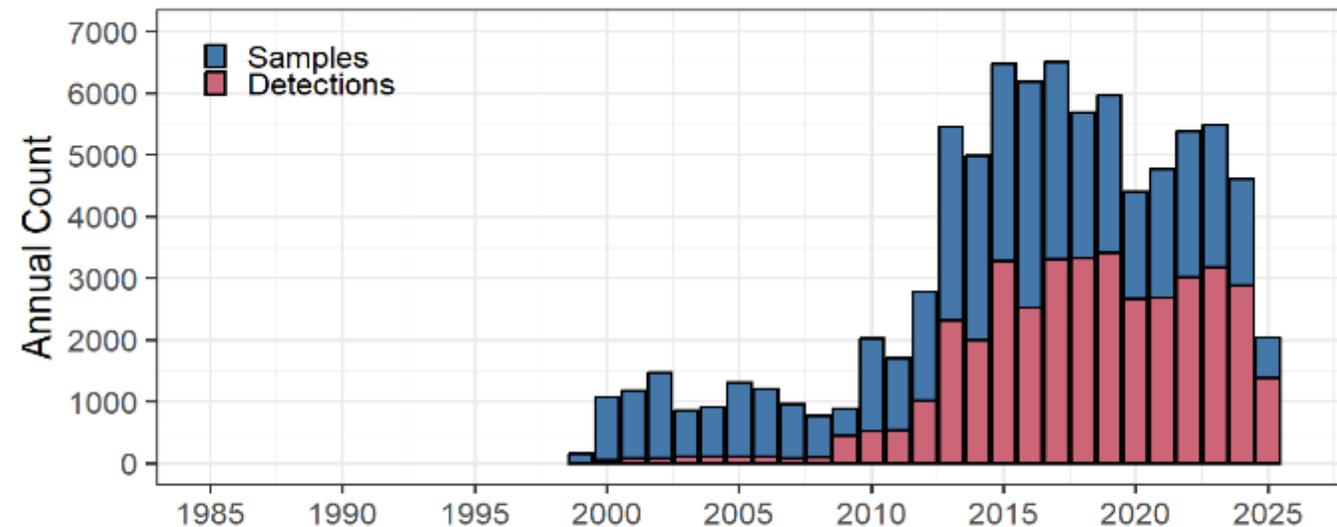
## Thiamethoxam



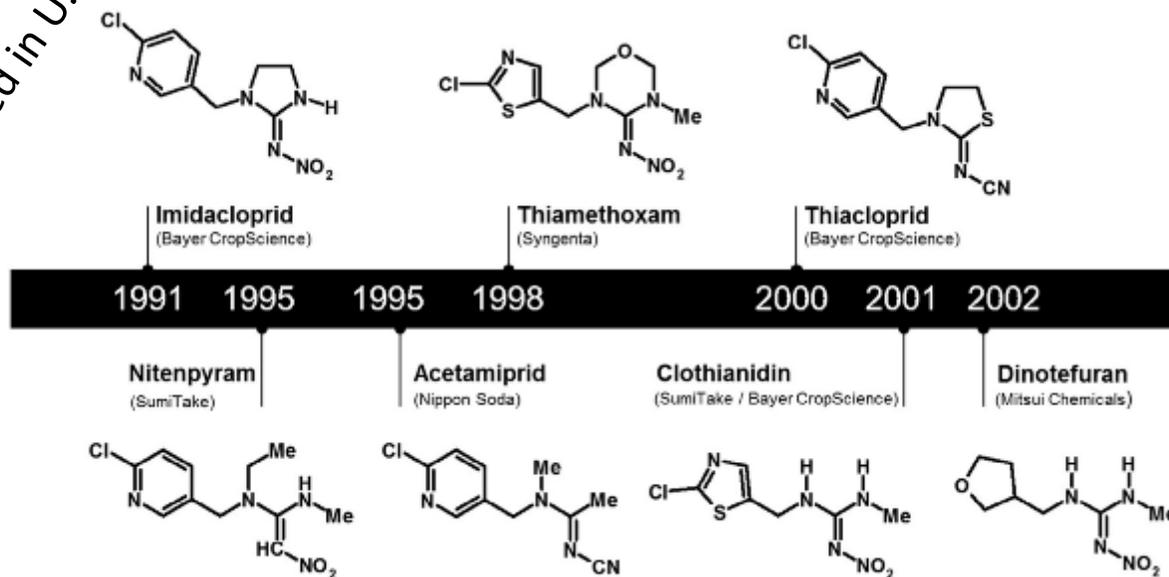
~85,000 results on the Water Quality Portal

# Sampling & Use Timeline

- **1980s:** Developed and patented
  - Highly effective against insect pests while being less toxic to mammals
- **1990s:** Commercialized and Registered in the United States
  - Used for both agricultural and non-agricultural purposes



↑ Synthesized  
 ↑ Patented  
 ↑ Commercialized  
 ↑ Registered in U.S.



**Is – present:** One of the most insecticides in the world

SGS sampling increased in 2012 with new method from the NWQL

**1%** of all Water Quality Portal results from National Water Quality Network



Chronic Benchmark (pre-2016)

## Neonicotinoid insecticides: Failing to come to grips with a predictable environmental disaster

American Bird Conservancy, June 2023

### An overview of agricultural neonicotinoid regulation in the EU, Canada, and the United States

Pest Management Science, 2025

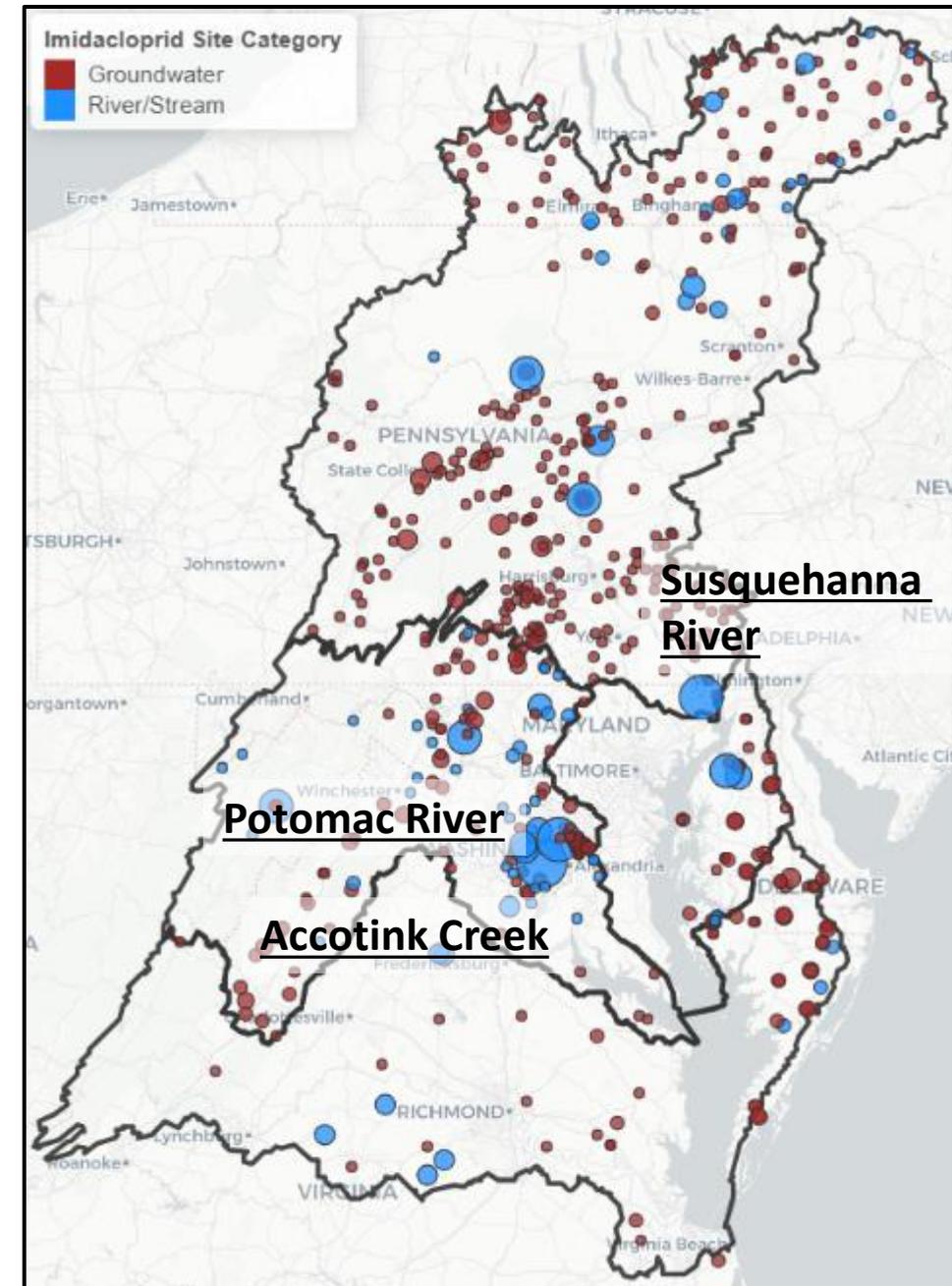
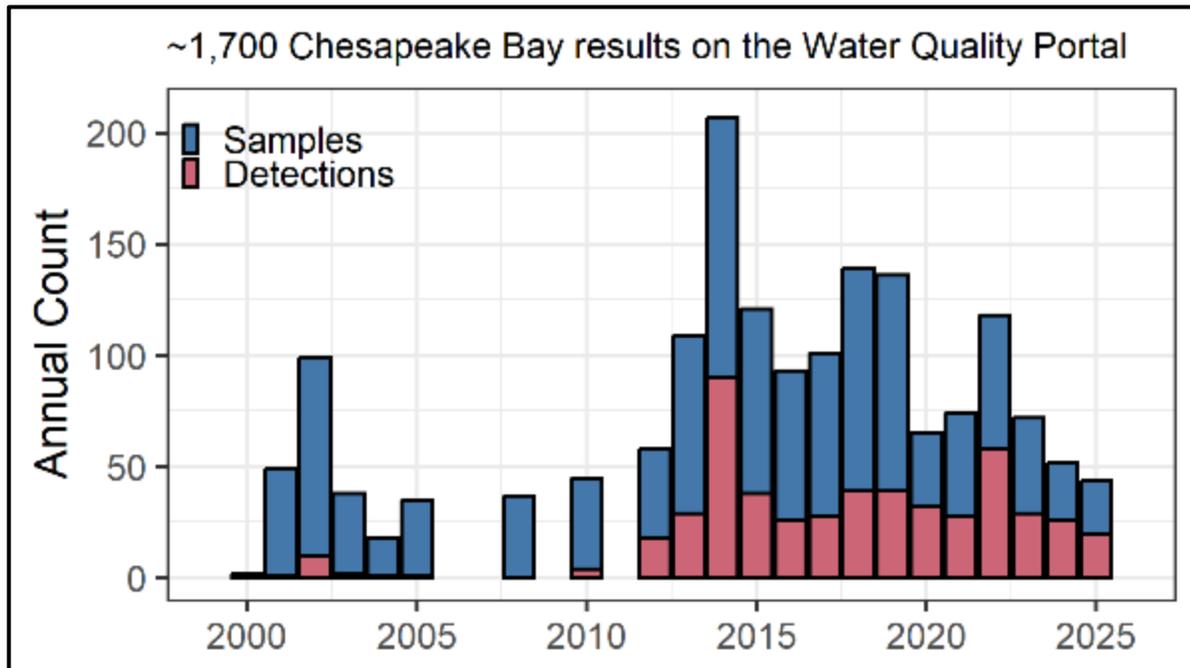
Katherine Dentzman,<sup>a\*</sup> Derek Franklin,<sup>a</sup> Edem Avemegah<sup>b</sup> and  
Jessica R. Goldberger<sup>b</sup>

# Toxicological Awareness

- As use increased, environmental detections followed, prompting toxicological studies
- (Non-enforceable) benchmark concentrations change over time
- As awareness increases, use restrictions have occurred
  - Outdoor ban in the European Union
  - Non-agricultural use restrictions in Ontario and Quebec
  - Use restrictions in California, Minnesota, New York, Rhode Island, Vermont, Illinois, Montgomery County Maryland

# Imidacloprid in the Chesapeake Bay Watershed

- First detected in 2001 (groundwater)
- ~1,700 samples from 569 locations on the Water Quality Portal
  - 74% of locations with 1 sample
- 41% of samples from 3 locations in the NWQN



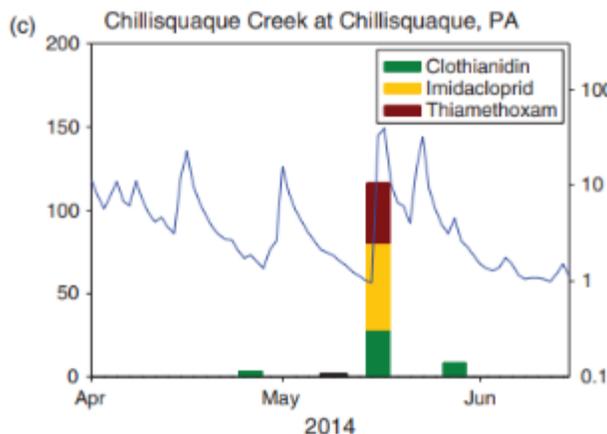
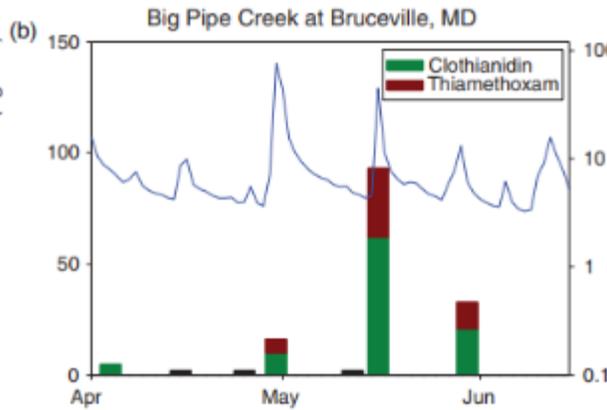
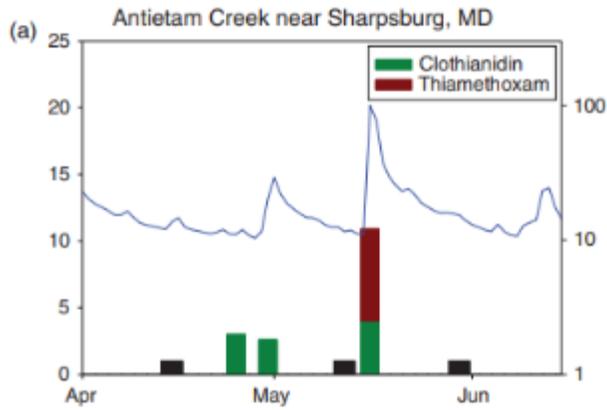
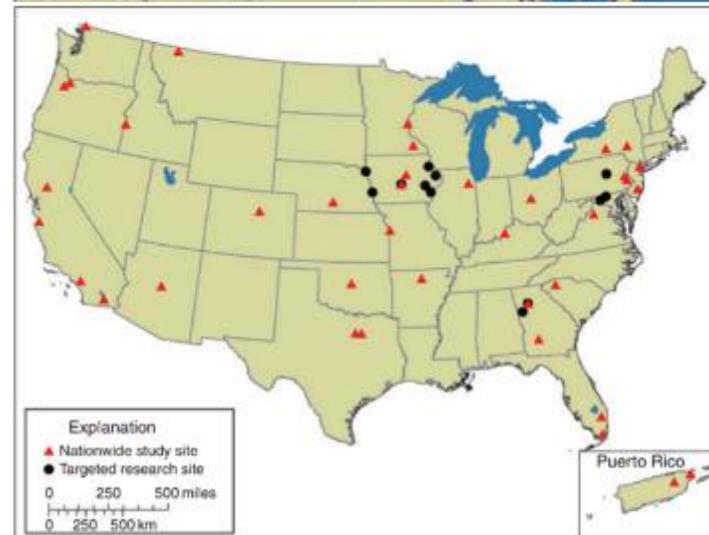
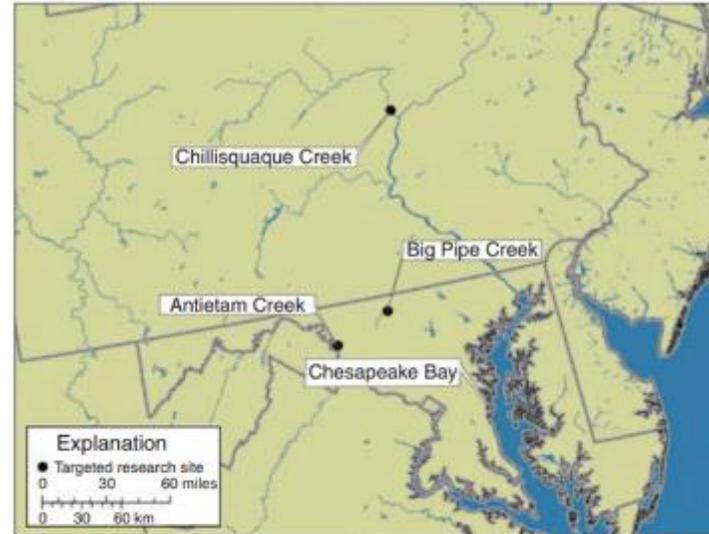
# Previous studies

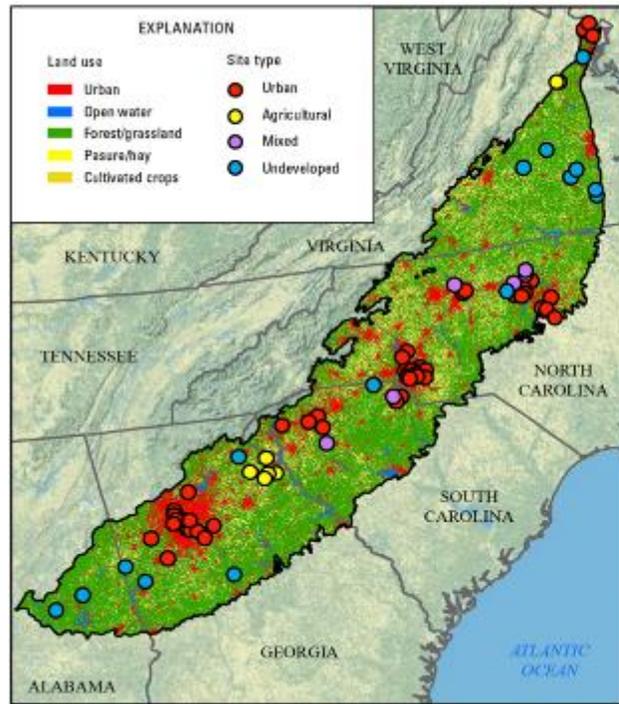
- **2015: Imidacloprid detected less often than clothianidin and thiamethoxam**
  - Increase in concentration following storm events

## First national-scale reconnaissance of neonicotinoid insecticides in streams across the USA

Environmental Chemistry, 2015

Michelle L. Hladik<sup>A,C</sup> and Dana W. Kolpin<sup>B</sup>





Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)

Effects of urban multi-stressors on three stream biotic assemblages

Ian R. Waite <sup>a,\*</sup>, Mark D. Munn <sup>b</sup>, Patrick W. Moran <sup>b</sup>, Chris P. Konrad <sup>b</sup>, Lisa H. Nowell <sup>c</sup>, Mike R. Meador <sup>d</sup>, Peter C. Van Metre <sup>e</sup>, Daren M. Carlisle <sup>f</sup>

<sup>a</sup> U.S. Geological Survey, Oregon Water Science Center, 3130 SW 20th Ave, Portland, OR 97201, USA  
<sup>b</sup> U.S. Geological Survey, Washington Water Science Center, 534 Broadway, Suite 200, Tacoma, WA 98402, USA  
<sup>c</sup> U.S. Geological Survey, California Water Science Center, 3500 J Street, Sacramento, CA 95832, USA  
<sup>d</sup> U.S. Geological Survey, Hinkley Station, 12201 Sunrise Valley Drive, Blacksburg, VA 24012, USA  
<sup>e</sup> U.S. Geological Survey, Texas Water Science Center, 1535 Ferguson Lane, Austin, TX 78754, USA  
<sup>f</sup> U.S. Geological Survey, Kansas Water Science Center, 4821 Quail Creek Place, Lawrence, KS 66044, USA

**HIGHLIGHTS**

- Impacts of multiple stressors on stream biota were evaluated along urban gradient.
- Boosted regression tree models were used to identify major stressors.
- Phosphorus, herbicides, flow, and sediment were important for algal communities.
- Insecticides, dissolved O<sub>2</sub>, flow and sediment contaminants key for invertebrates.
- Dissolved O<sub>2</sub>, sediment, flow, contaminants, and phosphorus were important for fish.

**GRAPHICAL ABSTRACT**

LANDSCAPE → STRESSORS → BIOTA

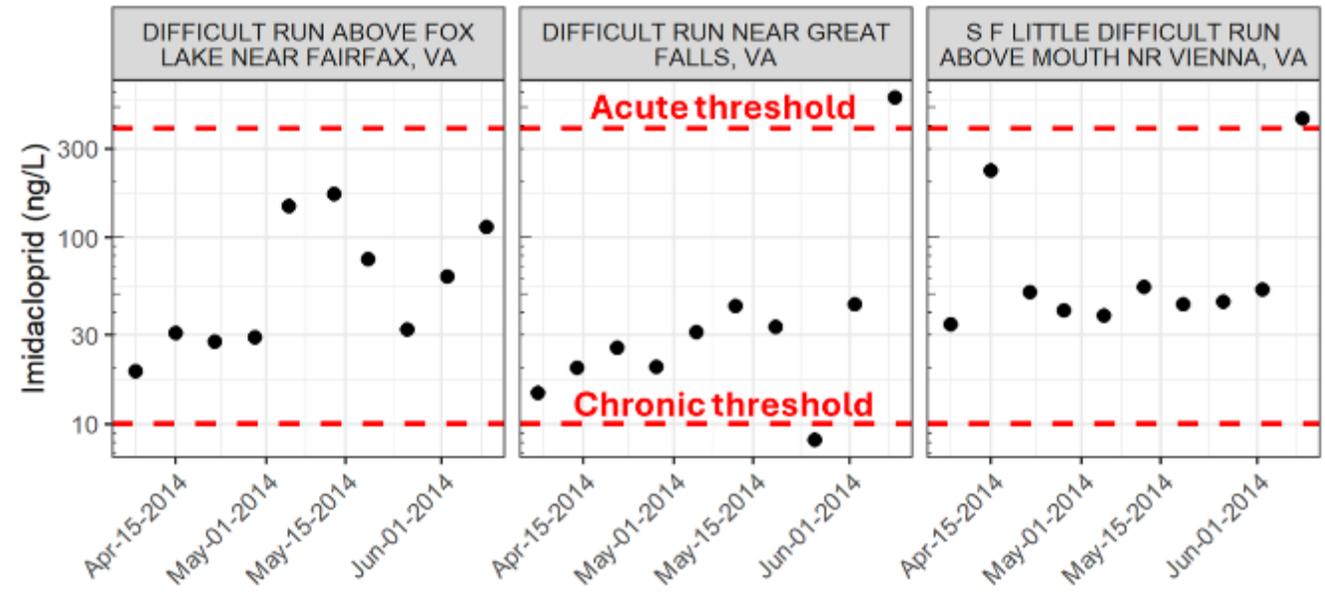
Urbanization → Phosphorus, Herbicides, Flow → ALGAE → Phosphorus, Herbicides, Flow

Urbanization → Insecticides, Flow, Dissolved Oxygen → MACROINVERTEBRATES → Insecticides, Flow, Dissolved Oxygen

Urbanization → Dissolved Oxygen, Flow, Pesticides, Total PAH → FISH → Dissolved Oxygen, Flow, Pesticides, Total PAH

# Previous studies

- **2015: Imidacloprid detected less often than clothianidin and thiamethoxam**
  - Increase in concentration following storm events
- **2019: Detected in Northern Virginia urban stream samples**
  - Key stressor for predicting invertebrates



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- **2021: Washington DC had highest max concentrations**
  - Potential invertebrate toxicity driven by imidacloprid



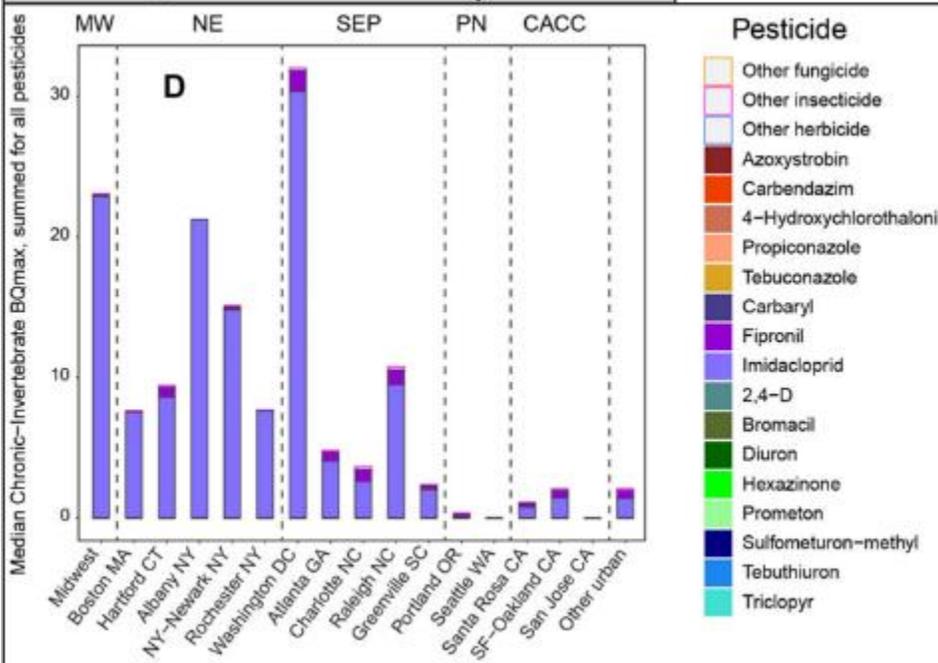
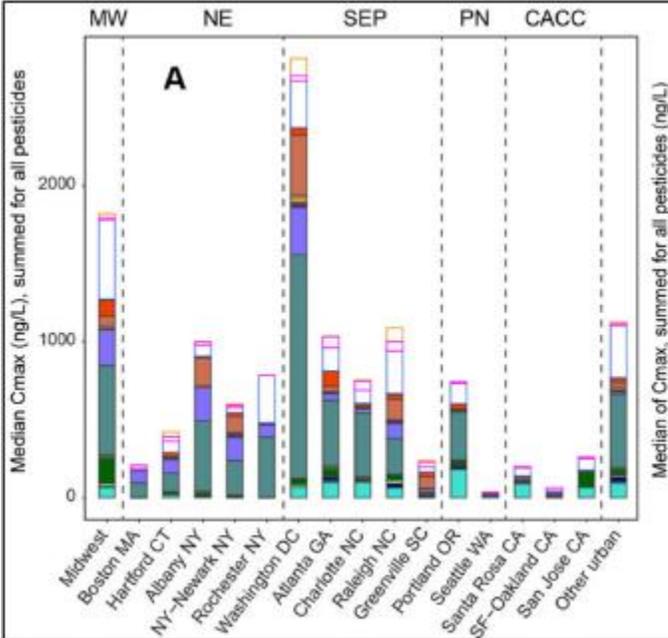
Science of The Total Environment

Volume 793, 1 November 2021, 148453



Is there an urban pesticide signature? Urban streams in five U.S. regions share common dissolved-phase pesticides but differ in predicted aquatic toxicity

Lisa H. Nawell <sup>a</sup>, Patrick W. Moran <sup>b</sup>, Laura M. Bexfield <sup>c</sup>, Barbara J. Mahler <sup>d</sup>, Peter C. Van Metre <sup>d,1</sup>, Paul M. Bradley <sup>e</sup>, Travis S. Schmidt <sup>f</sup>, Daniel T. Button <sup>g</sup>, Sharon L. Qi <sup>h</sup>



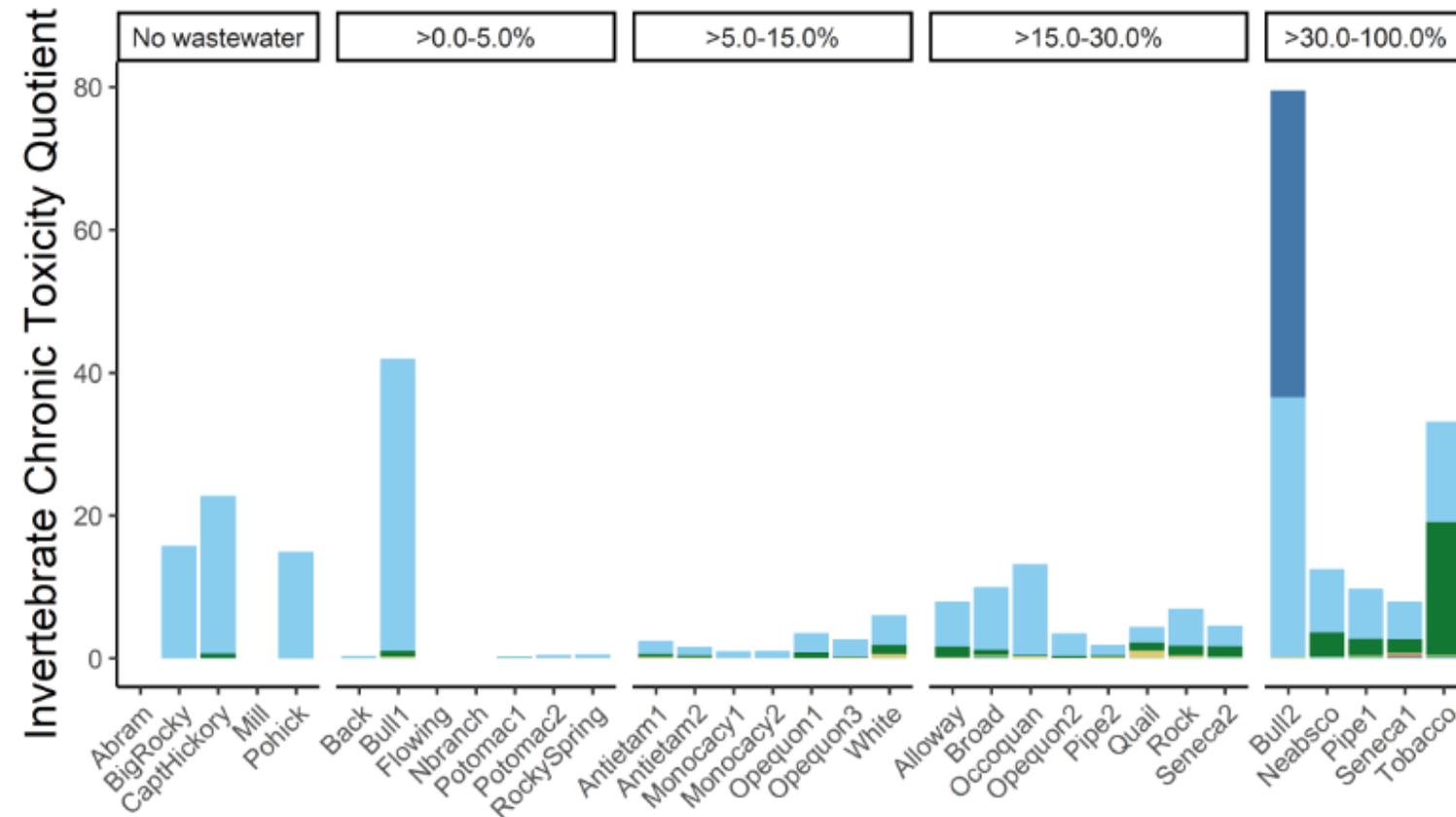


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- **2019: Detected in Northern Virginia urban stream samples**
  - Key stressor for predicting invertebrates
- **2021: Washington DC had highest max concentrations**
  - Potential invertebrate toxicity driven by imidacloprid
- **2024: Detected at 28/32 sites in Potomac River Basin**
  - Contributed the most to potential invertebrate toxicity

■ Bifenthrin ■ Imidacloprid ■ Fipronil ■ Clothianidin ■ Carbendazim ■ Others

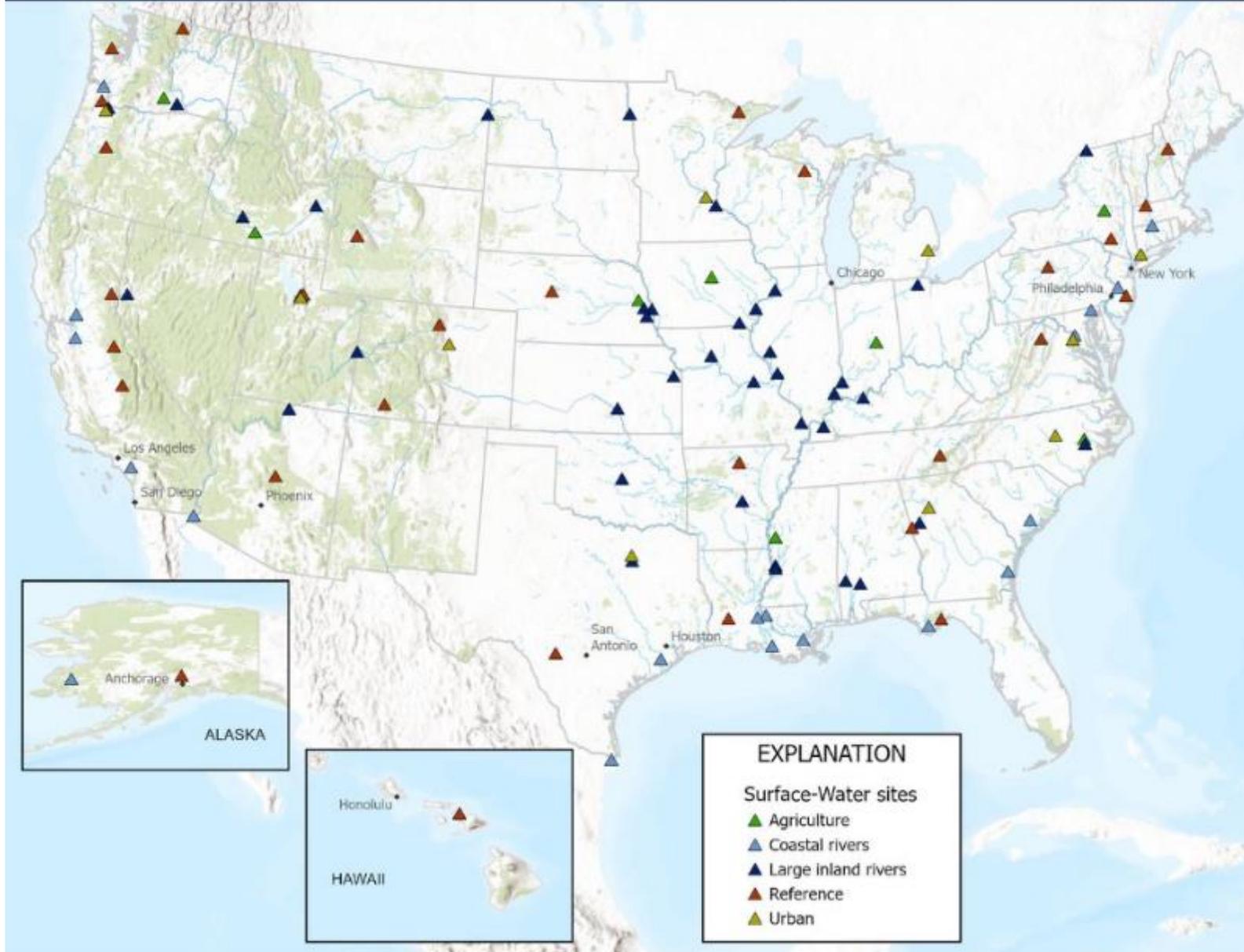
August Accumulated Wastewater (ACCWW)

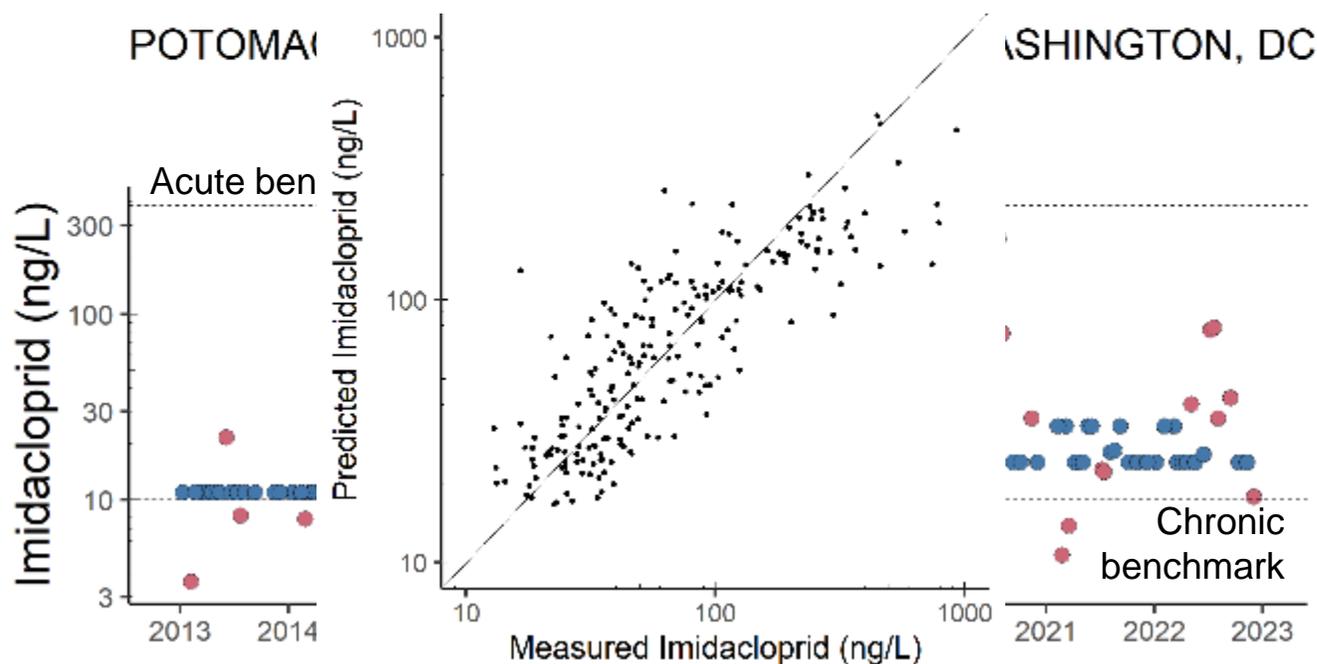
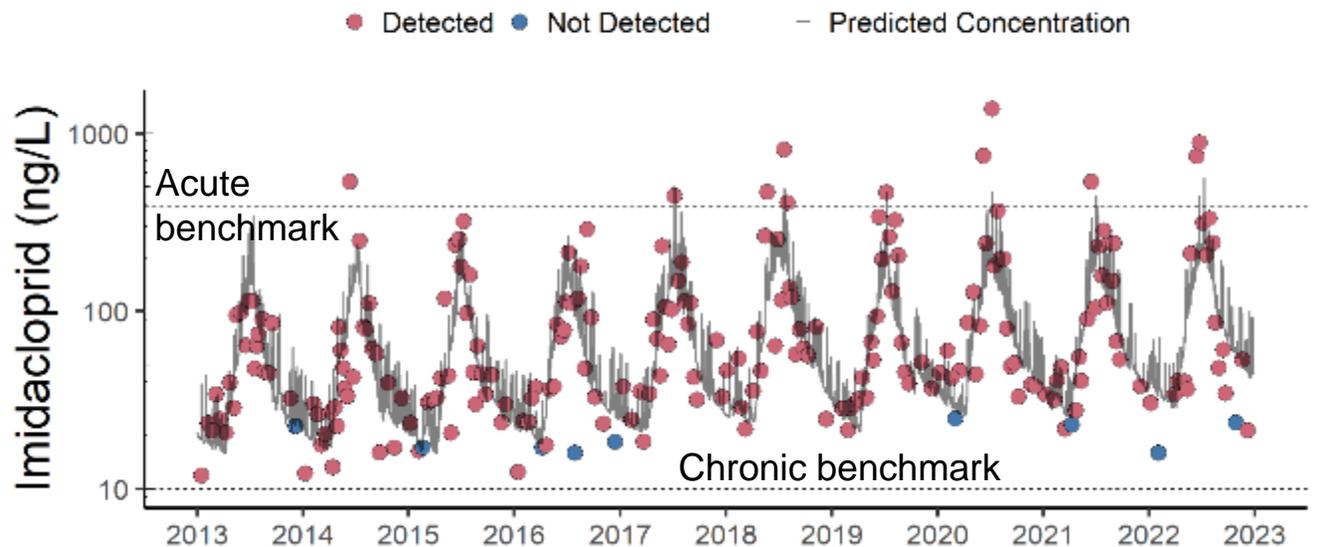


# Study Area

- **Pesticide samples collected routinely from 77 sites in the National Water Quality Network**
  - **Consistent methods enable long-term comparative assessments**
  - **12,547 imidacloprid samples analyzed from 2013 to 2022**
- Sites were **characterized by dominant land use, drainage area, and geographic region**
- **Three sites within the Chesapeake Bay Watershed**
  - **Accotink Creek** near Annandale, VA
  - **Potomac River** at Chain Bridge, at DC
  - **Susquehanna River** at Conowingo, MD

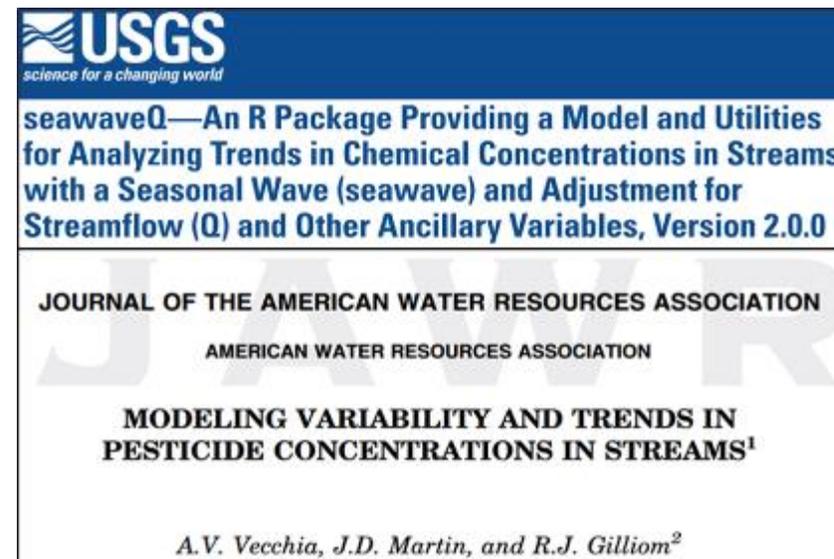
# National Water Quality Network





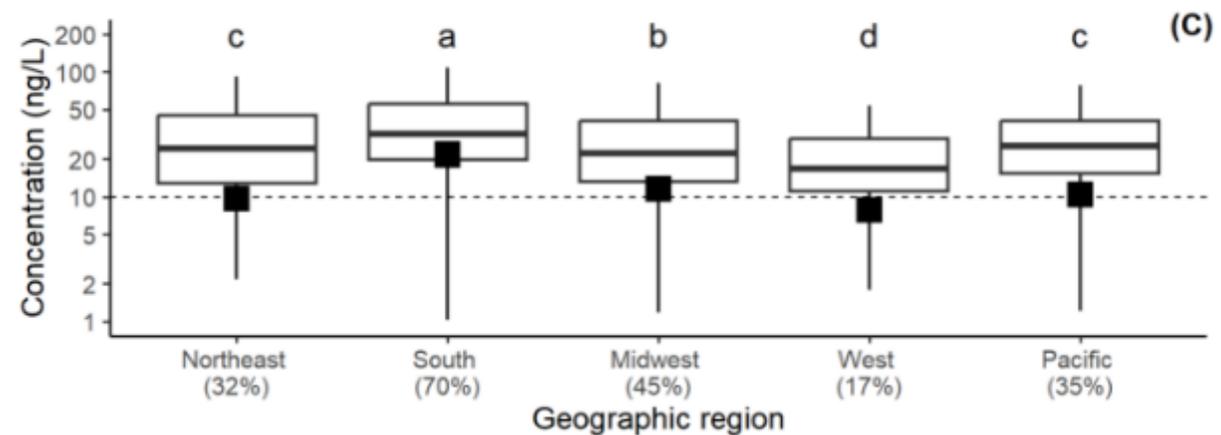
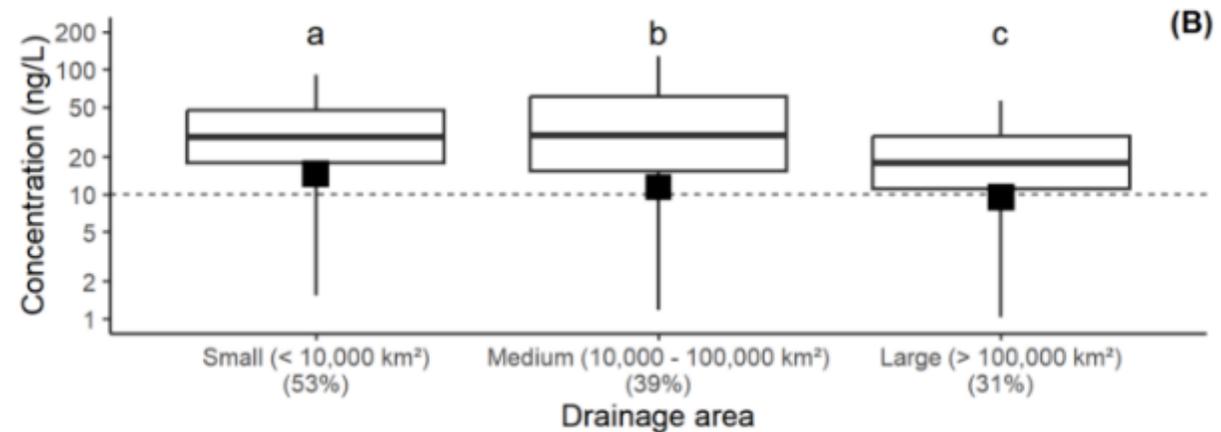
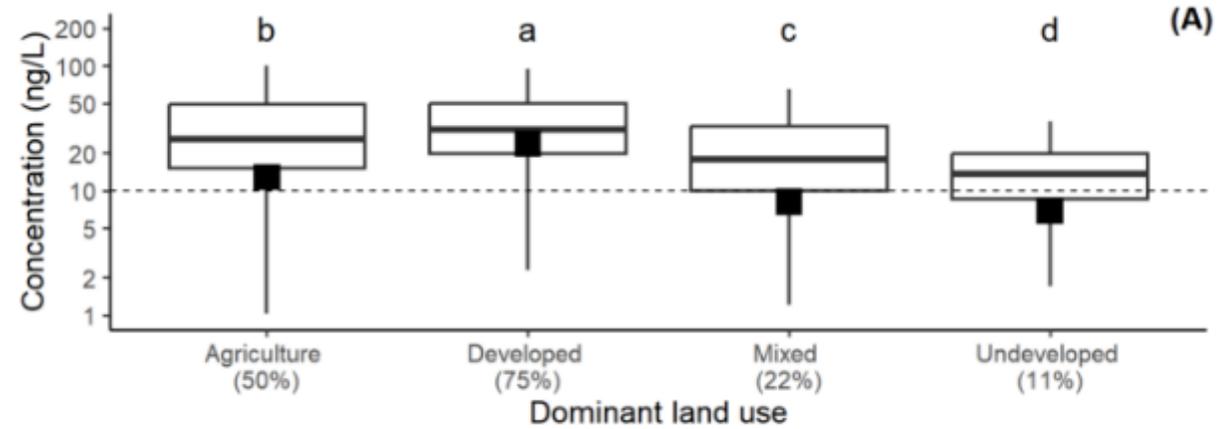
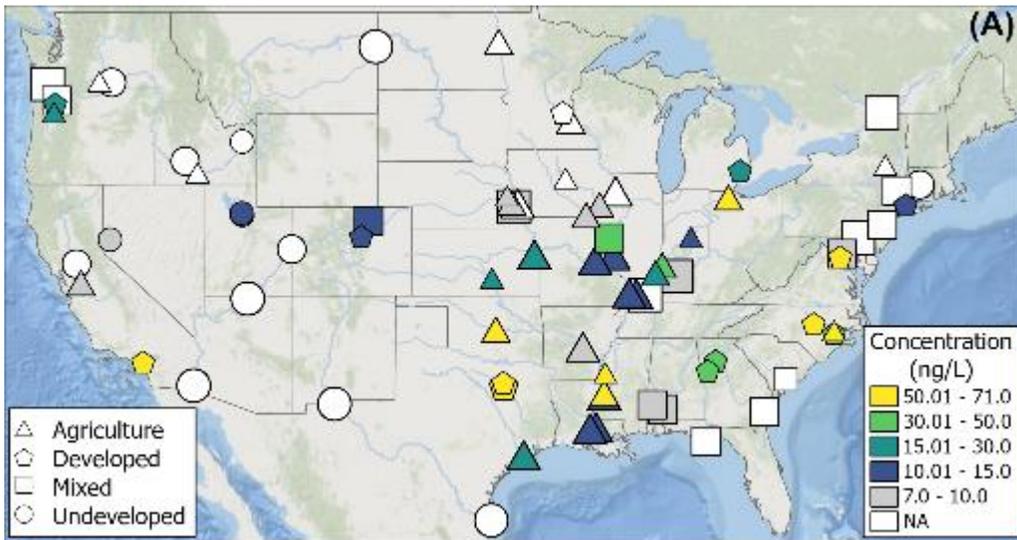
# Methods

- Detection **frequency** and **concentrations** were **summarized** by **land use**, **drainage area**, and **geographic region**
- Concentrations **compared to benchmarks**
  - **Chronic** freshwater invertebrate: **10 ng/L**
  - **Acute** freshwater invertebrate: **385 ng/L**
- Annual **loads** and **10-year concentration trend** calculated using **seawaveQ**
  - Sites with at least **20% detections** were analyzed

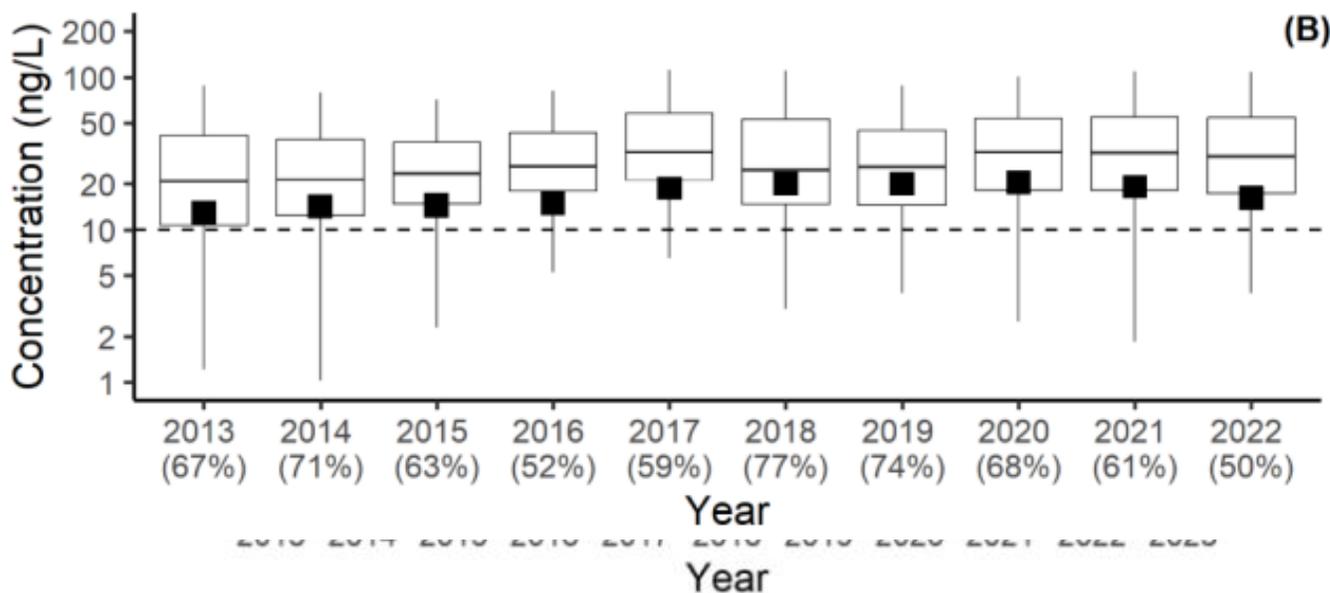
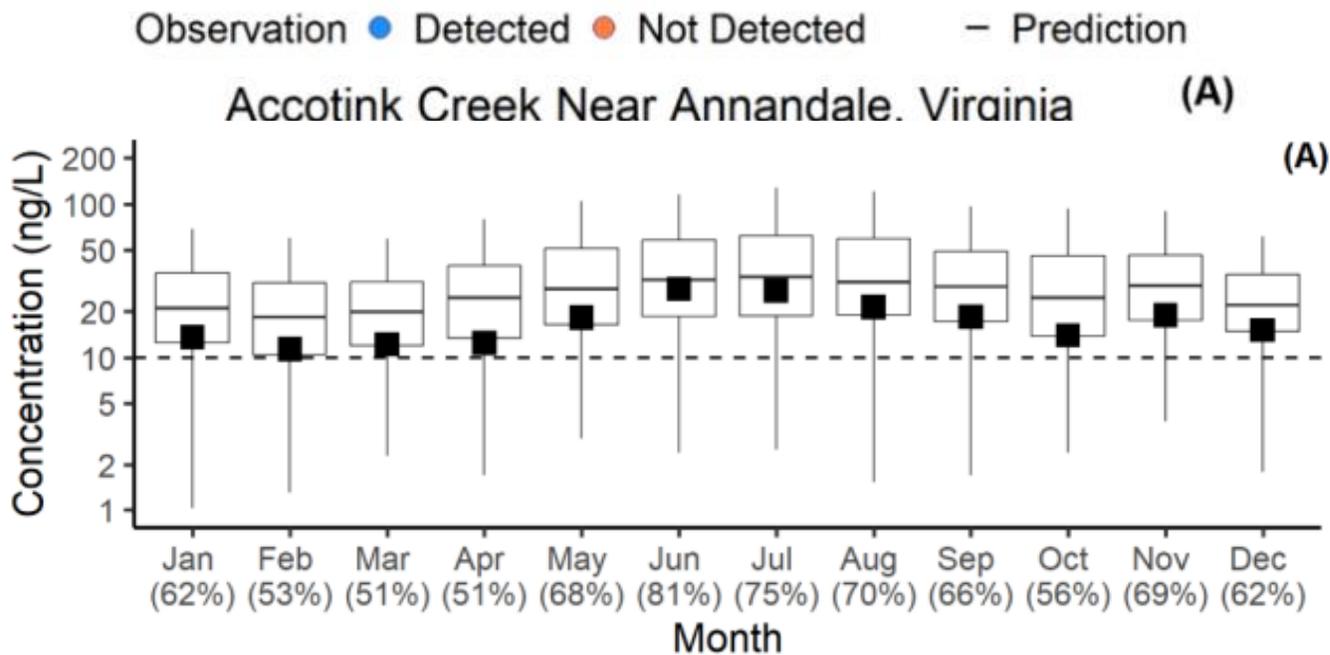


# Concentration Summary

- Detected in **44%** of all samples
  - **72/77** sites with at least one detection
  - **47/77** sites with more than 20% detections
- Sites with **higher concentrations** and **more frequent detections** tended to be:
  - **Developed** and **agricultural** watersheds
  - **Smaller** in drainage area
  - Located in the **South** or **Midwest**



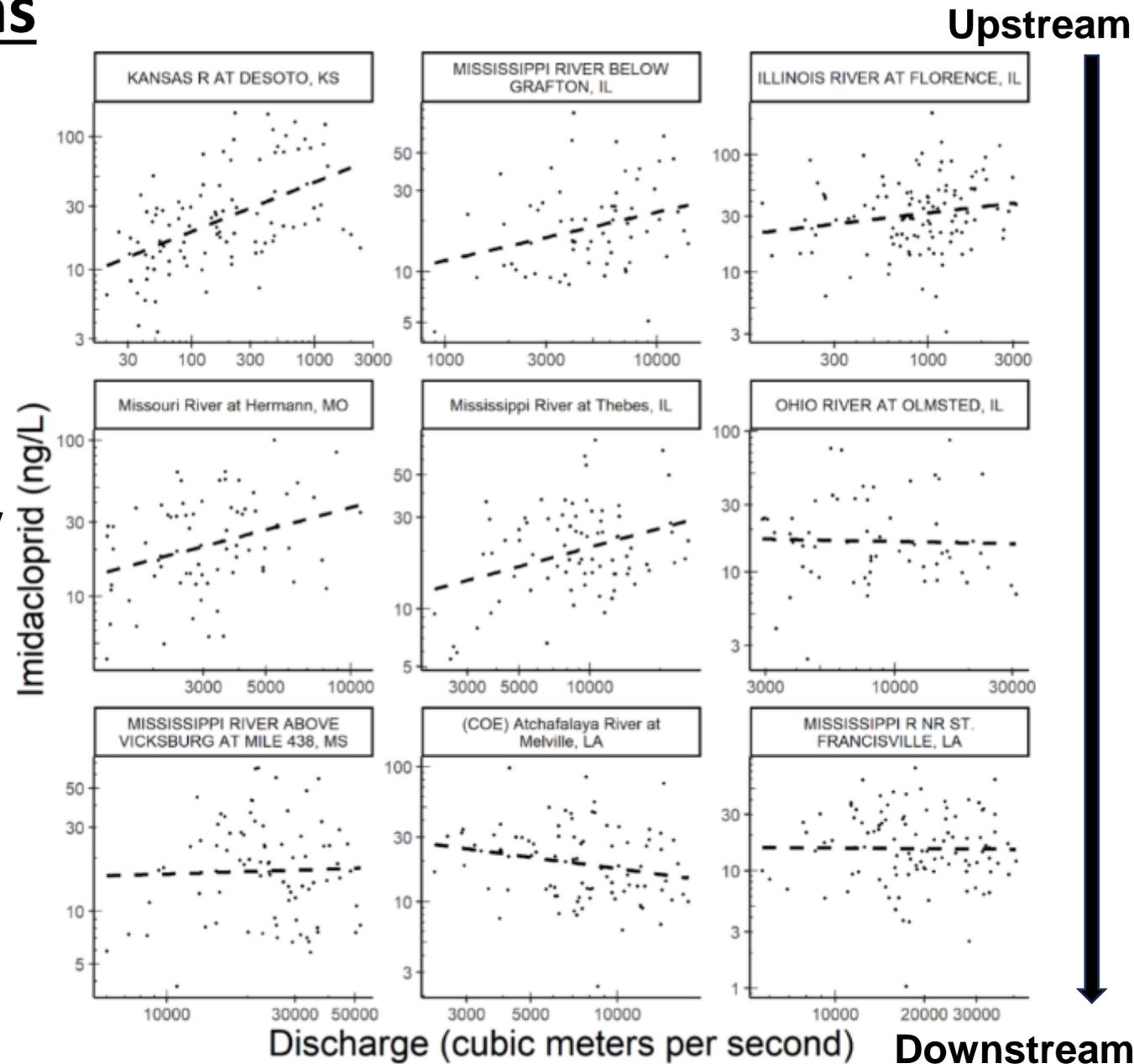
# Benchmark Summary



- The **average** (24.9 ng/L) and **median** (11.9 ng/L) concentrations **exceeded the chronic benchmark**
  - **44% of sites** had a **median concentration** that **exceeded the chronic benchmark**
  - **Acute exceedances** were rare
- Among **trend sites** (47/77 sites), the **median concentration exceeded the chronic benchmark in all months and years** during the study period
  - **Year-round potential chronic exposure**

# Concentration-discharge patterns

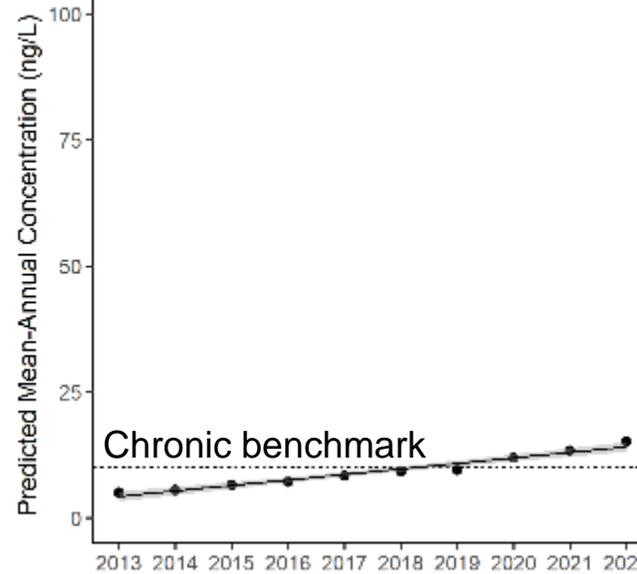
- Half of the trend sites showed a **positive** concentration-discharge (**C-Q**) slope
  - Indicating **dominant sources** transported through **fast delivery pathways**
  - **Short-term improvements** at these sites can happen by **targeting critical source areas**
- Sites with **flat or negative slopes** imply **subsurface saturation** of imidacloprid and / or presence of **point sources**
  - **Short-term** mitigation **less effective** and requires **long-term** and **large-scale approaches**
- **Mississippi River** sites had a downstream **shift from positive to negative C-Q slopes**
  - Indicating potential **groundwater saturation** and **accumulation** from **legacy sources**



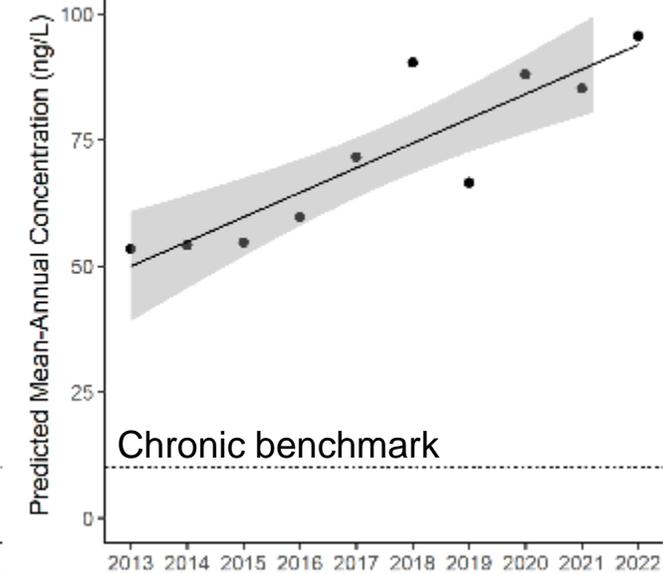
# Local Imidacloprid Trends

- **Accotink Creek had highest average concentration in national network**
  - Small developed watershed in northern Virginia
  - **Imidacloprid doubled** from 2013 to 2022
  - **Detected year-round in 96%** of samples
  - “Had the **highest concentrations** of pesticides measured in the **Potomac River Basin** and **ranked among the highest observed, nationwide**” – Ator et al., (1998)
- **Potomac River had among the largest relative concentration increase in national network (192%)**
  - **Large watershed** representing **mixed land uses**
  - **1.26 tons** of imidacloprid **delivered** to the **Chesapeake Bay** from 2013 to 2022

POTOMAC RIVER (11,500 mi<sup>2</sup>)

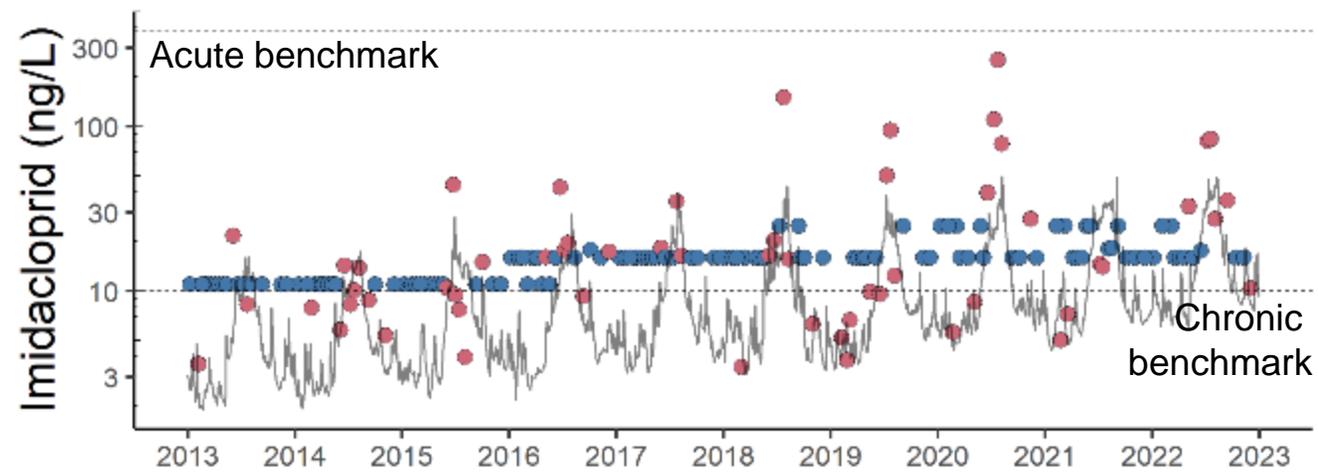


ACCOTINK CREEK (24 mi<sup>2</sup>)

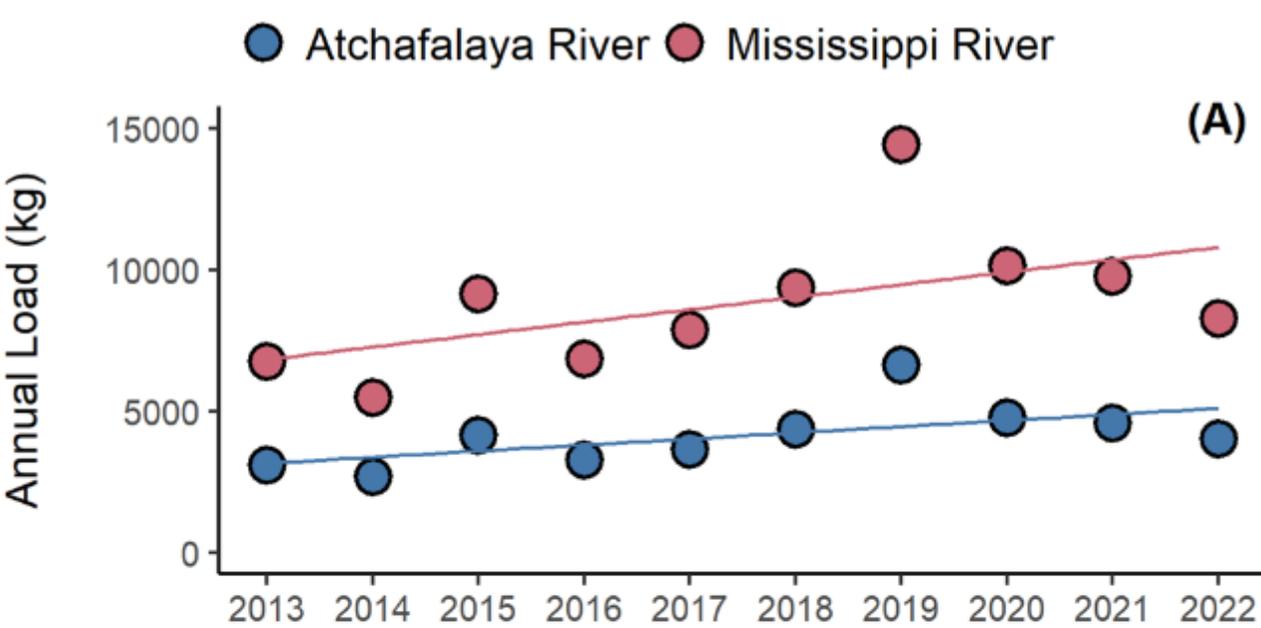


POTOMAC RIVER AT CHAIN BRIDGE, AT WASHINGTON, DC

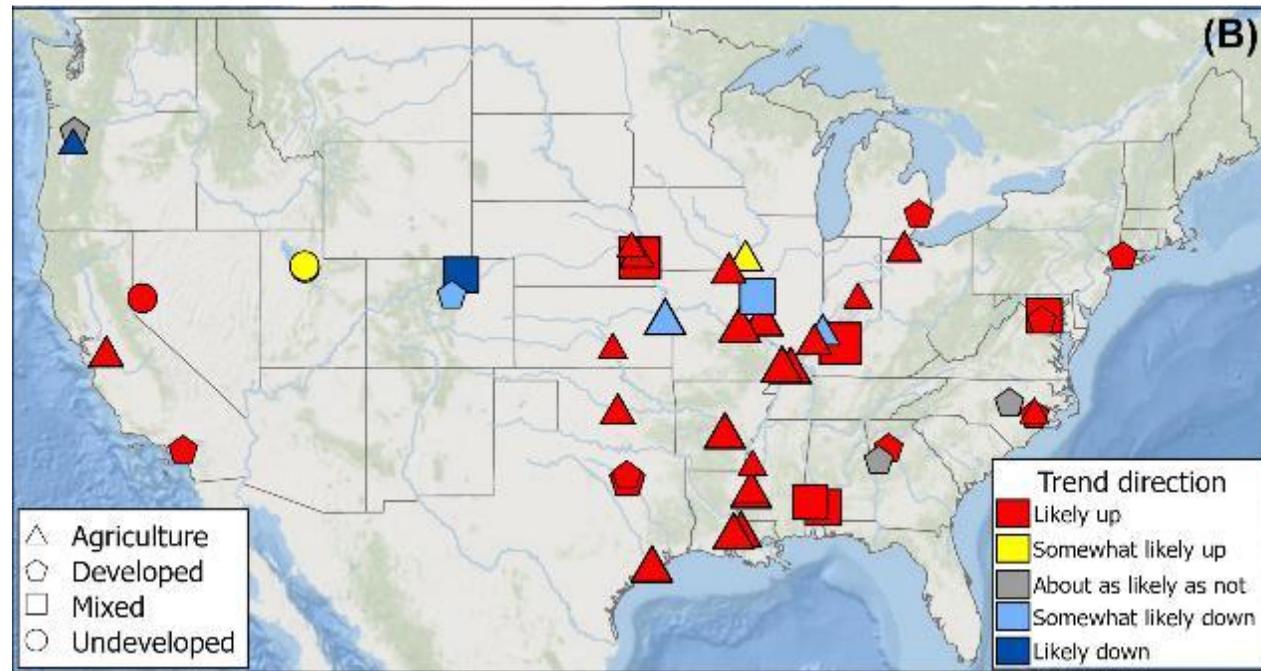
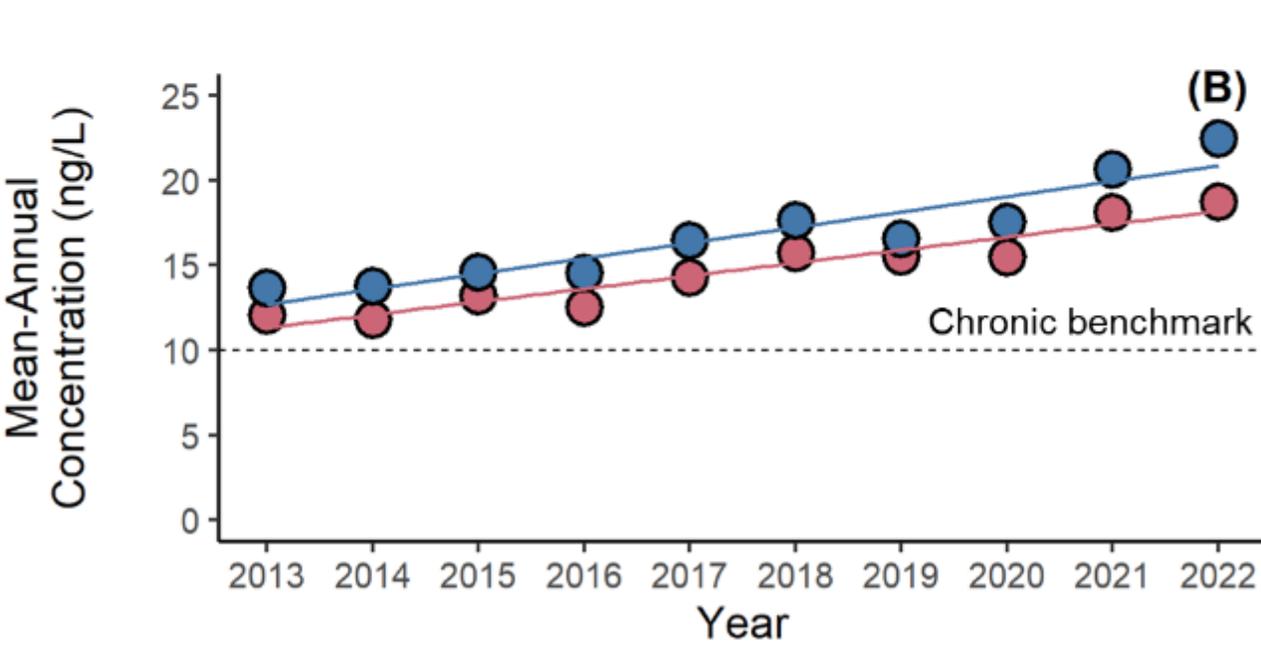
● Detected ● Not Detected — Predicted Concentration



# National Imidacloprid Trends



- **Half of the sites had an increasing trend**
  - Few sites with decreasing trends
  - **Average increase of 10.6 ng/L** over the decade
  - 15 sites had an increase greater than 100%
- Concentration **doubled** in the **Mississippi River**
- **143 tons** to the **Gulf of America** over decade
  - About **4%** of estimated **agricultural use**
  - Enough **annual load equivalent** to treat **1,000 mi<sup>2</sup> of corn** or **139 mi<sup>2</sup> of turfgrass**



# Management Implications

- Impaired streams that lack healthy invertebrate communities **require management plans**
  - Implementation plans that **do not address pesticide** contamination may **fall short** of efforts to remediate invertebrate communities
- Aquatic life are subject to **multiple stressors**, but the regulatory framework requires addressing the most probable
  - Evidence for **pesticides as stressors** to invertebrates, yet **rarely monitored**

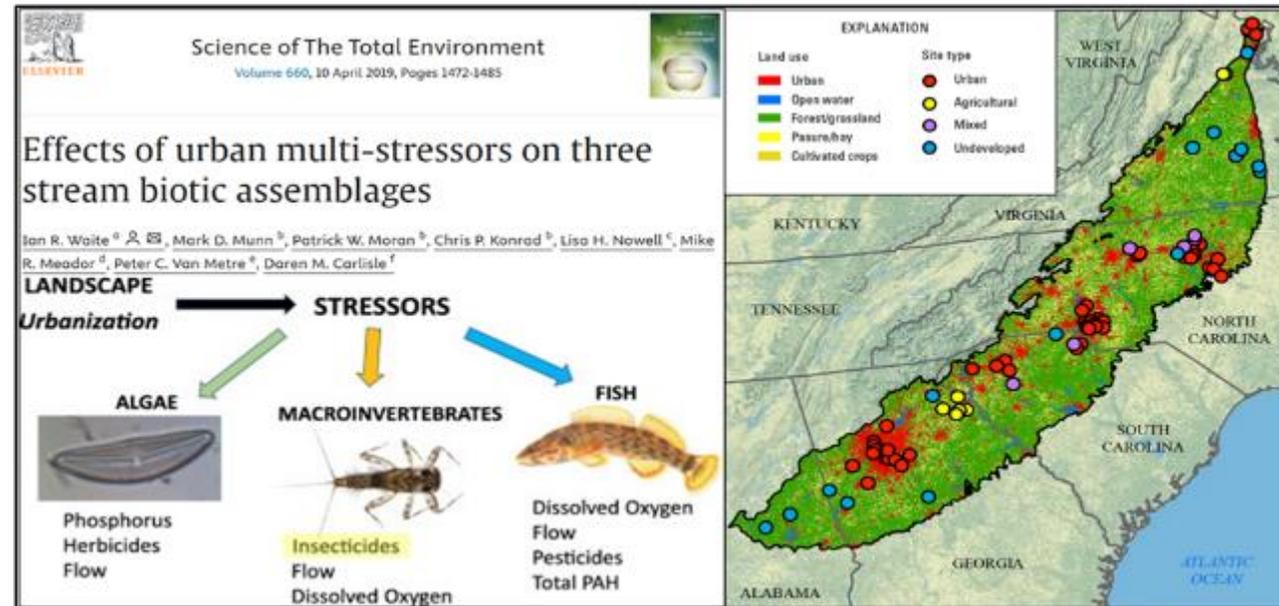
Multiple lines of evidence point to pesticides as stressors affecting invertebrate communities in small streams in five United States regions

Lisa H. Nowell<sup>a,\*</sup>, Patrick W. Moran<sup>b</sup>, Ian R. Waite<sup>c</sup>, Travis S. Schmidt<sup>d</sup>, Paul M. Bradley<sup>e</sup>, Barbara J. Mahler<sup>f,1</sup>, Peter C. Van Metre<sup>f,1</sup>

Environmental Management (2022) 70:926–949  
<https://doi.org/10.1007/s00267-022-01723-7>

## Identifying Key Stressors Driving Biological Impairment in Freshwater Streams in the Chesapeake Bay Watershed, USA

Rosemary M. Fanelli<sup>1</sup> · Matthew J. Cashman<sup>2</sup> · Aaron J. Porter<sup>3</sup>



## Limitations of chemical monitoring hinder aquatic risk evaluations on the macroscale

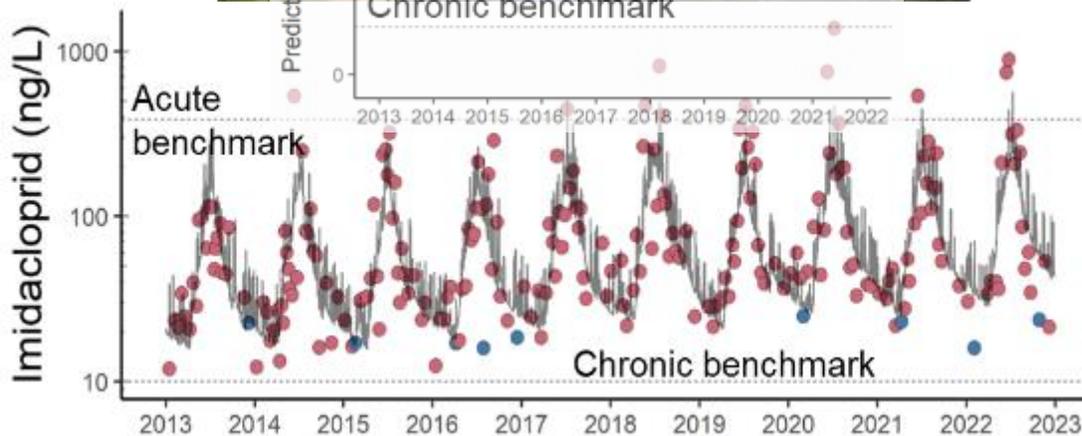
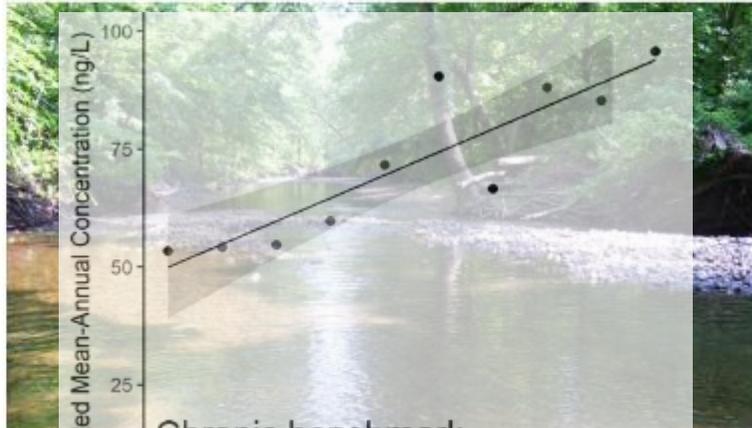
Science, 2025

SASCHA BUB<sup>a</sup>, LARA L. PETSCHICK<sup>b</sup>, SEBASTIAN STEHLE<sup>c</sup>, JAKOB WOLFRAM<sup>d</sup>, AND RALF SCHULZ<sup>e</sup> [Authors Info & Affiliations](#)

Stressor Analysis Report for the  
Benthic Macroinvertebrate Impairments  
in the Accotink Creek Watershed,  
Fairfax County, Virginia

# Accotink Creek Impairment

- Impaired due to **poor macroinvertebrate health**
  - **Chloride, hydromodification, habitat modification, and sediment** identified as **most probable stressor**
  - **TMDLs** developed for **chloride and sediment**

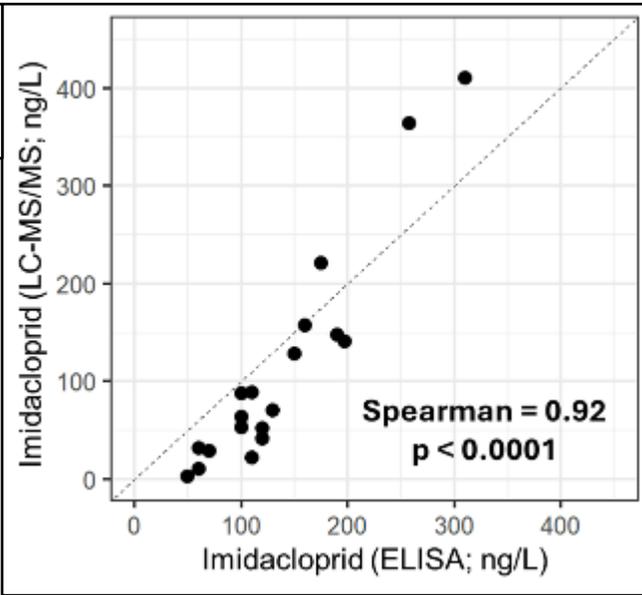


- “Since the monitoring of pesticides is infrequent after 2002, it is **possible** that **pesticides** are **having an adverse impact** on biota. Such **impacts**, if they occur, are **likely to be episodic**, because the **pesticides currently in use tend not to be as persistent in the environment** as chlorinated insecticides like chlordane, whose use was banned in 1988.”
- Imidacloprid **detected year-round** in **96%** of samples
  - 96% of samples exceeded chronic benchmark
  - 5% of samples exceeded acute benchmark

# Challenges and Opportunities

- **High costs** for mass-spectrometry analysis **prohibit** comprehensive **monitoring**
  - Immunoassay method (**ELISA**) showed **strong agreement** with **conventional analysis**
  - **ELISA samples** collected in **Fairfax County**
  - **100%** of **samples** collected from a **row crop** region **had detections** using ELISA method:

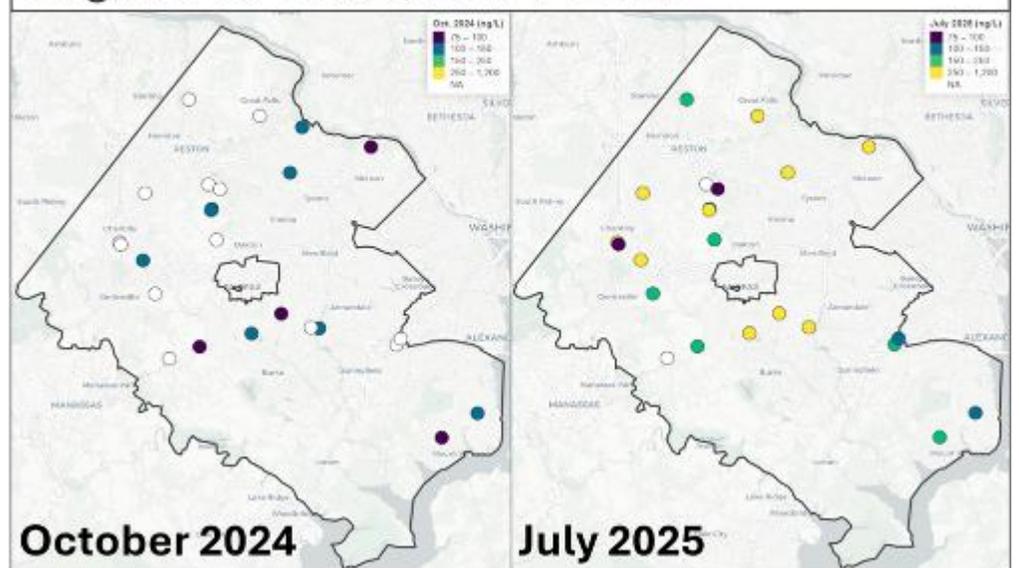
Environmental Sampling and Modeling Results to Characterize Surface-Water Quality at 32 Sites Across the Potomac River Watershed, 2022 (ver. 3.0, April 2025)  
September 20, 2024  
[View Data & Tables](#)



Water quality and contaminants in stream surface waters collected in the Delmarva Peninsula, 2022 (Schreiner et al., 2022, <https://doi.org/10.5066/P16AZAWC>)

- Updated **agricultural use estimates** through **2022** expected later **this year**
  - **Lack of non-agricultural** and **seed treatment** use make it **challenging to analyze data**
- **Trends from 80 pesticides** later this year
  - **Lack of imidacloprid degradates** and **other neonics** **prohibit risk assessment**

Reconnaissance of imidacloprid in select Virginia streams, 2024–2025 <https://doi.org/10.5066/P14VQQKK>



## Imidacloprid in United States Rivers, 2013–2022: Persistent Presence and Emerging Chronic Hazard

Samuel A. Miller,\* Travis S. Schmidt, Larry B. Barber, Michelle L. Hladik, Dana W. Kolpin, Megan E. Shoda, and Sarah M. Stackpoole

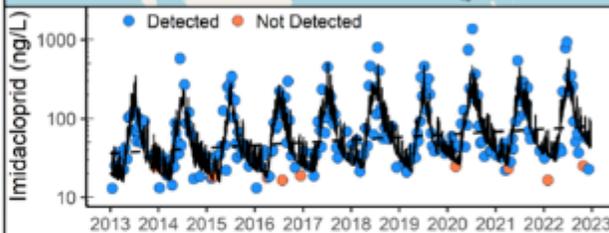
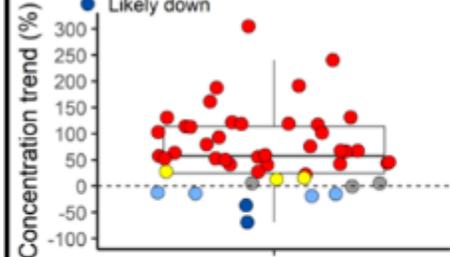
Cite This: *Environ. Sci. Technol.* 2025, 59, 26702–26715 [Read Online](#)

### Imidacloprid in U.S. Rivers

~12,547 samples from 77 sites

~Chronic toxicity evaluated

~2013-2022 trend direction:



[DATA](#) | [DATA RELEASES](#)

## Imidacloprid concentrations and trends in United States Rivers, 2013-2022

December 5, 2025

# Conclusions

- The most widely used insecticide in the world was detected in 44% of samples from 77 rivers and streams from 2013 to 2022
  - Used in *both* agricultural and urban areas
- The median / average concentration from 12,547 samples exceeded / doubled the chronic benchmark for invertebrates
  - 44% of the 77 sites had a median concentration that exceeded the chronic benchmark including large watersheds such as the Mississippi River
  - Accotink Creek had highest average concentration
- Half of the sites had increasing trends
- Widespread presence, benchmark exceedances, and increasing trends suggest potential hazard to aquatic life and risk to ecosystem health

# Questions?

Sam Miller  
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*Potomac River from Weverton Cliffs*

# USGS research on pesticides & biological impairment

Science of the Total Environment 915 (2024) 169634

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Multiple in-stream stressors degrade biological assemblages in five U.S. regions

Jan R. Waite<sup>a,\*</sup>, Peter C. Van Metre<sup>b</sup>, Patrick W. Moran<sup>c</sup>, Chris P. Konrad<sup>c</sup>, Lisa H. Nowell<sup>d</sup>, Mike R. Meador<sup>e</sup>, Mark D. Munn<sup>f</sup>, Travis S. Schmidt<sup>g</sup>, Allen C. Gellis<sup>g</sup>, Daren M. Carlisle<sup>h</sup>, Paul M. Bradley<sup>i</sup>, Barbara J. Mahler<sup>h</sup>



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Effects of urban multi-stressors on three stream biotic assemblages

Jan R. Waite<sup>a,\*</sup>, Mark D. Munn<sup>b</sup>, Patrick W. Moran<sup>b</sup>, Chris P. Konrad<sup>b</sup>, Lisa H. Nowell<sup>c</sup>, Mike R. Meador<sup>d</sup>, Peter C. Van Metre<sup>e</sup>, Daren M. Carlisle<sup>f</sup>



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Complex mixtures of dissolved pesticides show potential aquatic toxicity in a synoptic study of Midwestern U.S. streams

Nowell Lisa H.<sup>a,\*</sup>, Moran Patrick W.<sup>b</sup>, Schmidt Travis S.<sup>c</sup>, Norman Julia E.<sup>d</sup>, Nakagaki Naomi<sup>e,f</sup>, Shoda Megan E.<sup>g</sup>, Mahler Barbara J.<sup>h</sup>, Van Metre Peter C.<sup>i</sup>, Stone Wesley W.<sup>j</sup>, Sandstrom Mark W.<sup>k</sup>, Hladik Michelle L.<sup>l</sup>



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Is there an urban pesticide signature? Urban streams in five U.S. regions share common dissolved-phase pesticides but differ in predicted aquatic toxicity

Lisa H. Nowell<sup>a,\*</sup>, Patrick W. Moran<sup>b</sup>, Laura M. Rexfield<sup>c</sup>, Barbara J. Mahler<sup>d</sup>, Peter C. Van Metre<sup>e,f</sup>, Paul M. Bradley<sup>g</sup>, Travis S. Schmidt<sup>h</sup>, Daniel T. Burton<sup>h</sup>, Sharon L. Qi<sup>h</sup>



Environ Monit Assess (2016) 188: 345  
DOI 10.1007/s10661-016-5215-5

Storm-event-transport of urban-use pesticides to streams likely impairs invertebrate assemblages

Kurt D. Carpenter<sup>a</sup> · Kathryn M. Kuivila · Michelle L. Hladik · Tana Haluska · Michael B. Cole



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Environmental Toxicology and Chemistry · Volume 39, Number 6 · pp. 1219–1232, 2020  
Received: 21 September 2019 | Revised: 20 October 2019 | Accepted: 20 February 2020

Environmental Toxicology

Legacy and Current-Use Contaminants in Sediments Alter Macroinvertebrate Communities in Southeastern US Streams

Patrick W. Moran,<sup>a,\*</sup> Nile F. Keeble,<sup>b</sup> Jan R. Waite,<sup>c</sup> Barbara J. Mahler,<sup>d</sup> Lisa H. Nowell,<sup>e</sup> and Peter C. Van Metre<sup>f</sup>



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journal homepage: [www.elsevier.com/locate/scitotenv](http://www.elsevier.com/locate/scitotenv)

Daily stream samples reveal highly complex pesticide occurrence and potential toxicity to aquatic life

Julia F. Norman<sup>a</sup>, Barbara J. Mahler<sup>b</sup>, Lisa H. Nowell<sup>a,\*</sup>, Peter C. Van Metre<sup>b</sup>, Mark W. Sandstrom<sup>c</sup>, Mark A. Corbin<sup>d</sup>, Yaorong Qian<sup>e</sup>, James F. Pankow<sup>f</sup>, Wentai Luo<sup>f</sup>, Nicholas B. Fitzgerald<sup>g</sup>, William E. Asher<sup>h</sup>, Kevin J. McWhirter<sup>i</sup>



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Pesticide mixtures show potential toxicity to aquatic life in U.S. streams, water years 2013–2017

S. Alex. Covert<sup>a,b</sup>, Megan E. Shoda<sup>b</sup>, Sarah M. Stackpole<sup>c</sup>, Wesley W. Stone<sup>d</sup>

Multiple lines of evidence point to pesticides as stressors affecting invertebrate communities in small streams in five United States regions

Lisa H. Nowell<sup>a,\*</sup>, Patrick W. Moran<sup>b</sup>, Jan R. Waite<sup>c</sup>, Travis S. Schmidt<sup>d</sup>, Paul M. Bradley<sup>e</sup>, Barbara J. Mahler<sup>f,1</sup>, Peter C. Van Metre<sup>f,1</sup>

Environmental Management (2022) 70:926–949  
<https://doi.org/10.1007/s00267-022-01723-7>

Identifying Key Stressors Driving Biological Impairment in Freshwater Streams in the Chesapeake Bay Watershed, USA

Rosemary M. Fanelli<sup>1</sup> · Matthew J. Cashman<sup>2</sup> · Aaron J. Porter<sup>3</sup>

Received: 1 April 2022 / Accepted: 15 September 2022 / Published online: 7 October 2022

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## Abstract

Biological communities in freshwater streams are often impaired by multiple stressors (e.g., flow or water quality) originating from anthropogenic activities such as urbanization, agriculture, or energy extraction. Restoration efforts in the Chesapeake Bay watershed, USA seek to improve biological conditions in 10% of freshwater tributaries and to protect the biological integrity of existing healthy watersheds. To achieve these goals, resource managers need to better understand which stressors are most likely driving biological impairment. Our study addressed this knowledge gap through two approaches: 1) reviewing and synthesizing published multi-stressor studies, and 2) examining 303(d) listed impairments linked to biological impairment as identified by jurisdiction regulatory agencies (the states within the watershed and the District of Columbia). Results identified geomorphology (i.e., physical habitat), salinity, and toxic contaminants as important for explaining variability in benthic community metrics in the literature review. Geomorphology (i.e., physical habitat and sediment), salinity, and nutrients were the most reported stressors in the jurisdictional impairment analysis. Salinity is likely a major stressor in urban and mining settings, whereas geomorphology was commonly reported in agricultural settings. **Toxic contaminants, such as pesticides, were rarely measured;** more research is needed to quantify the extent of their effects in the region. Flow alteration was also highlighted as an important urban stressor in the literature review but was rarely measured in the literature or reported by jurisdictions as a cause of impairment. These results can be used to prioritize stressor monitoring by managers, and to improve stressor identification methods for identifying causes of biological impairment.