Changing Pesticide Use: Challenges for Water Quality Monitoring and Implications

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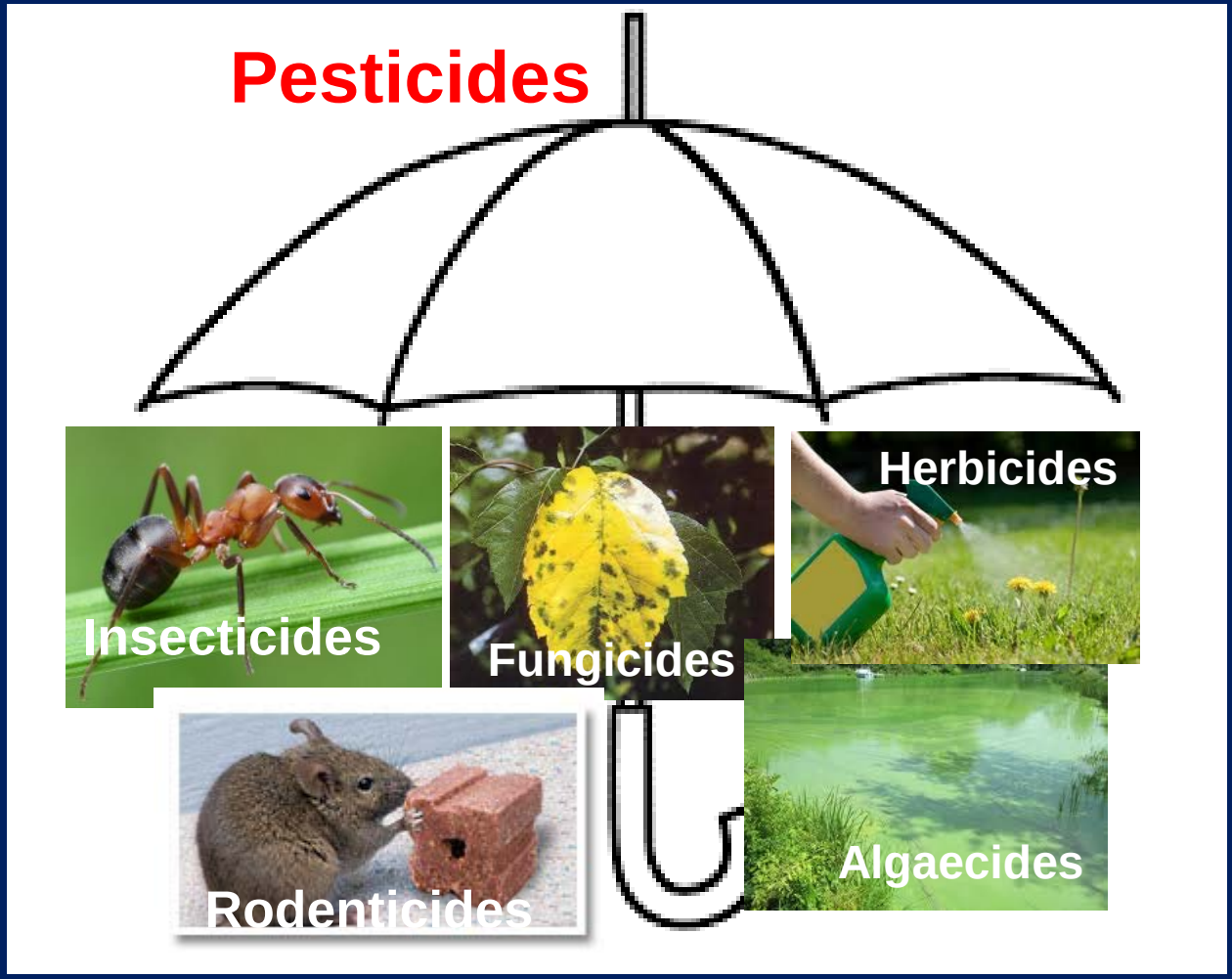
What is a Pesticide?



US EPA definition: "A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any PEST."

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Changing Pesticide Use

- Different Pesticides
  - New compounds
  - Changing pests/resistance
  - Restrictions/concerns on previously used compounds
- Crop types


California: cotton → almonds

- Changes in application techniques



Granular/Spray → seed coatings

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Changing Insecticide Use

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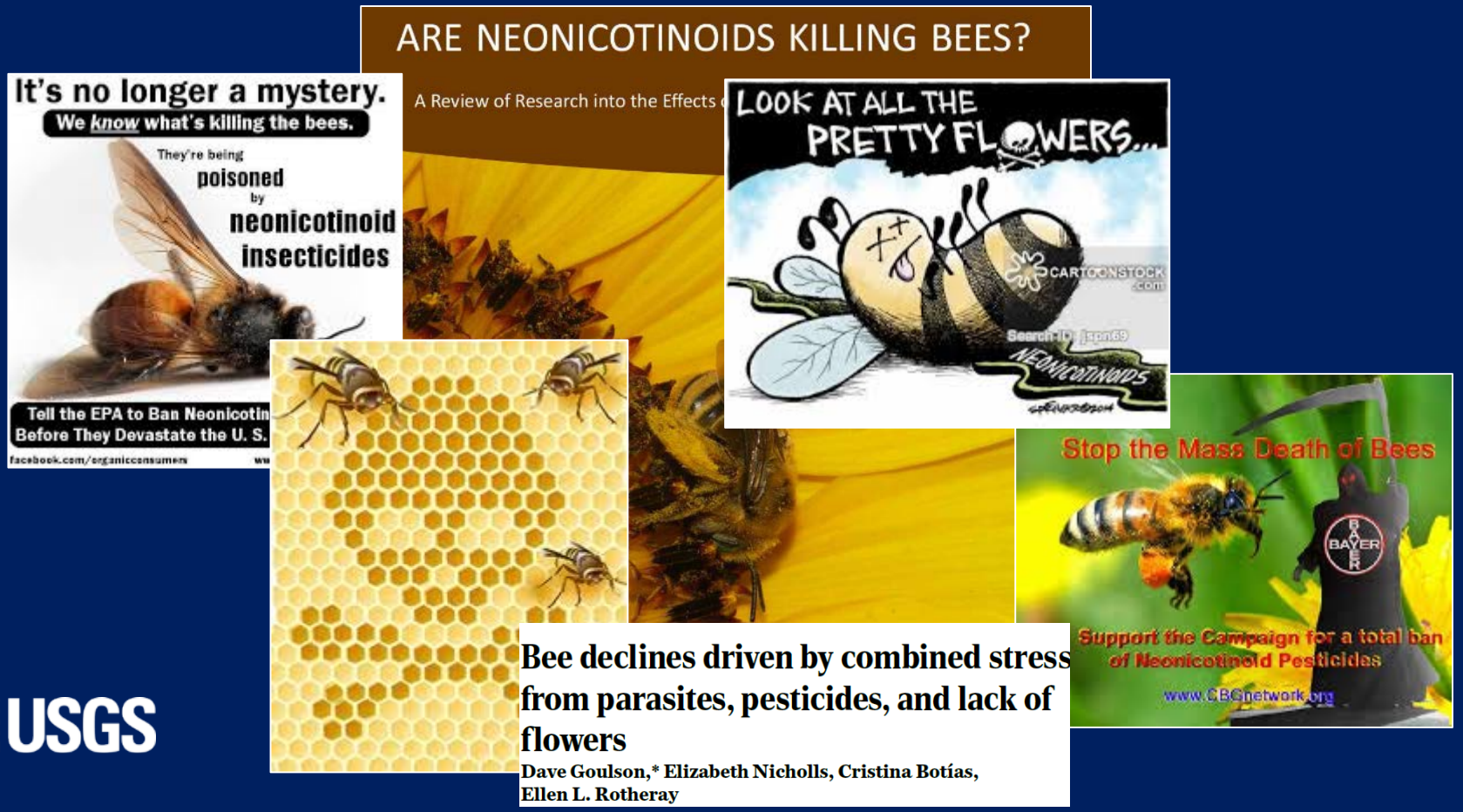
Neonicotinoids in the News

- Implicated in Colony Collapse Disorder (CCD) in honeybees (one of many factors)
- CCD (c. ~2006) worker bees abruptly disappear
- Risk to other pollinators (bumble bees, native bees, butterflies)



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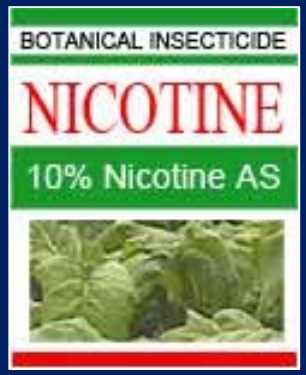
Why are Neonics Popular?

- Most widely used insecticides in the world
  - Home use: Pets (topical), lawn and garden
  - Agricultural use: granular, foliar spray, seed treatment



- Similar to nicotine, neurotoxic to insects

- Active against a broad spectrum of insects

- Less toxic to vertebrates (mammals)

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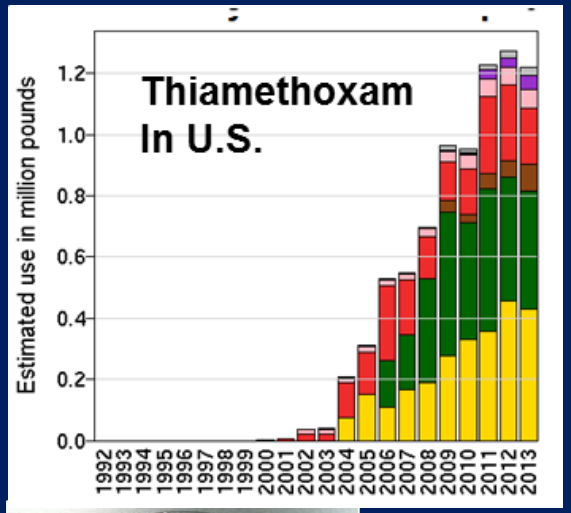
Neonicotinoids and Seed Treatment

- Systemic pesticides (taken up by plant)
- Can “target” application (precision agriculture)
- 2000 - clothianidin and thiamethoxam enter market; seed treatments become more common
- *Nearly all corn and 1/3 of soybeans planted today use a neonicotinoid (plus one to five fungicides)*



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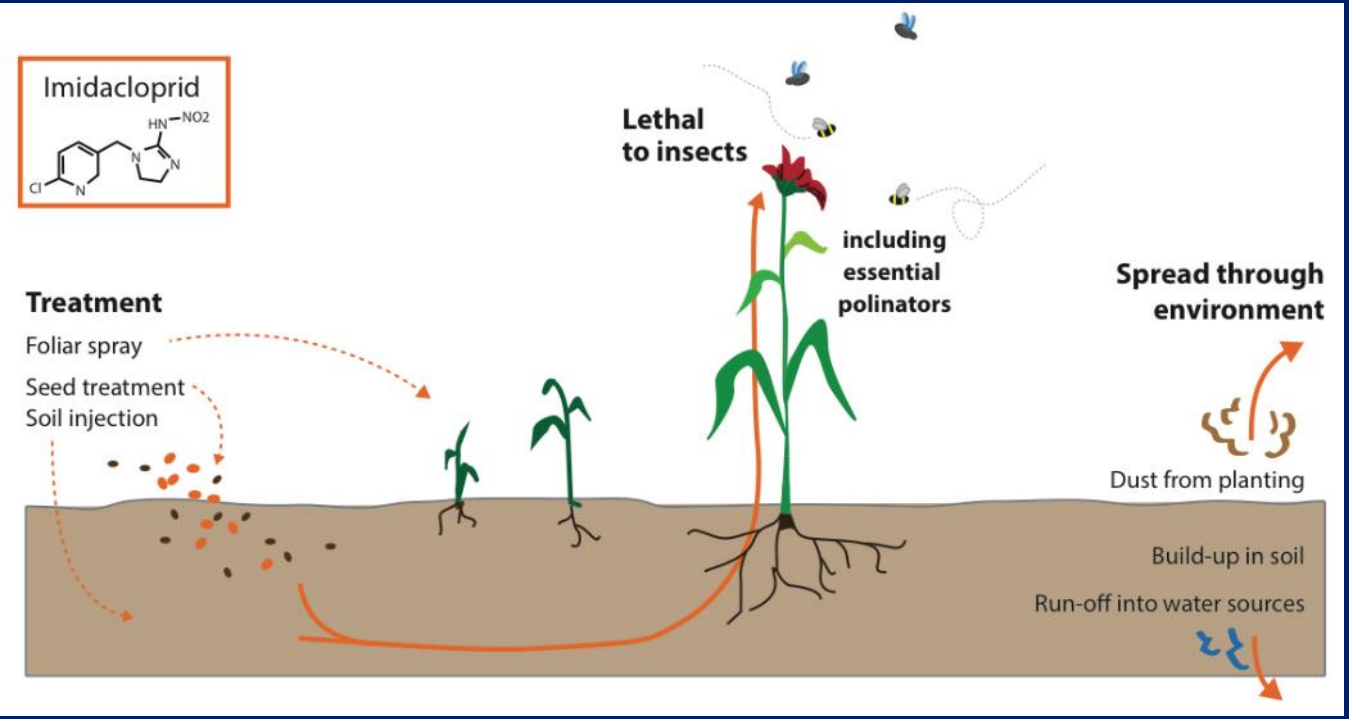
Environmental Fate

- Water soluble
- Ability to be mobile and persistent (~10% taken up by plants in seed coatings)



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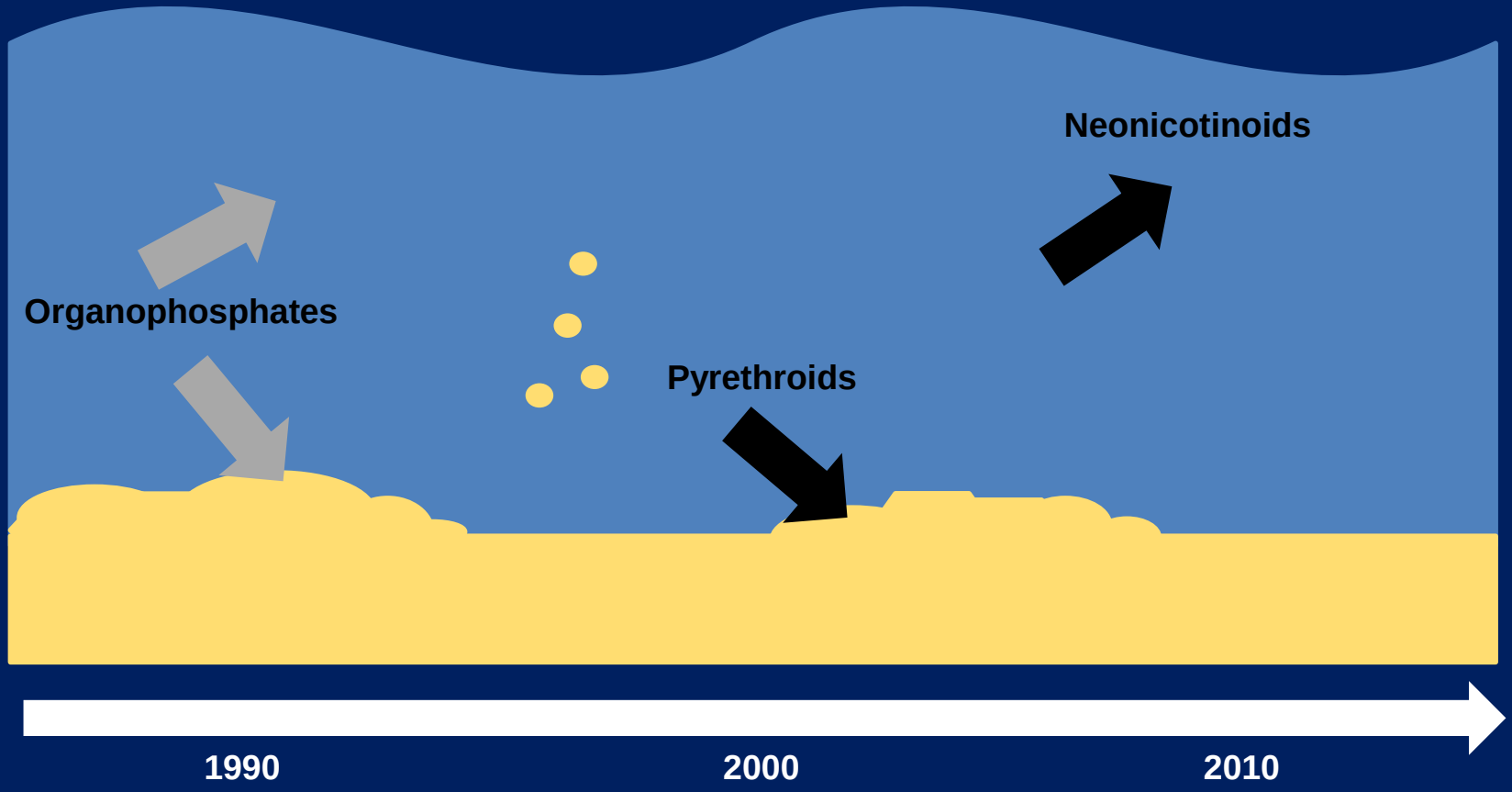
http://sitn.hms.harvard.edu/wp-content/uploads/2014/12/CB-FIgure-1.jpg

Changing Environmental Fate



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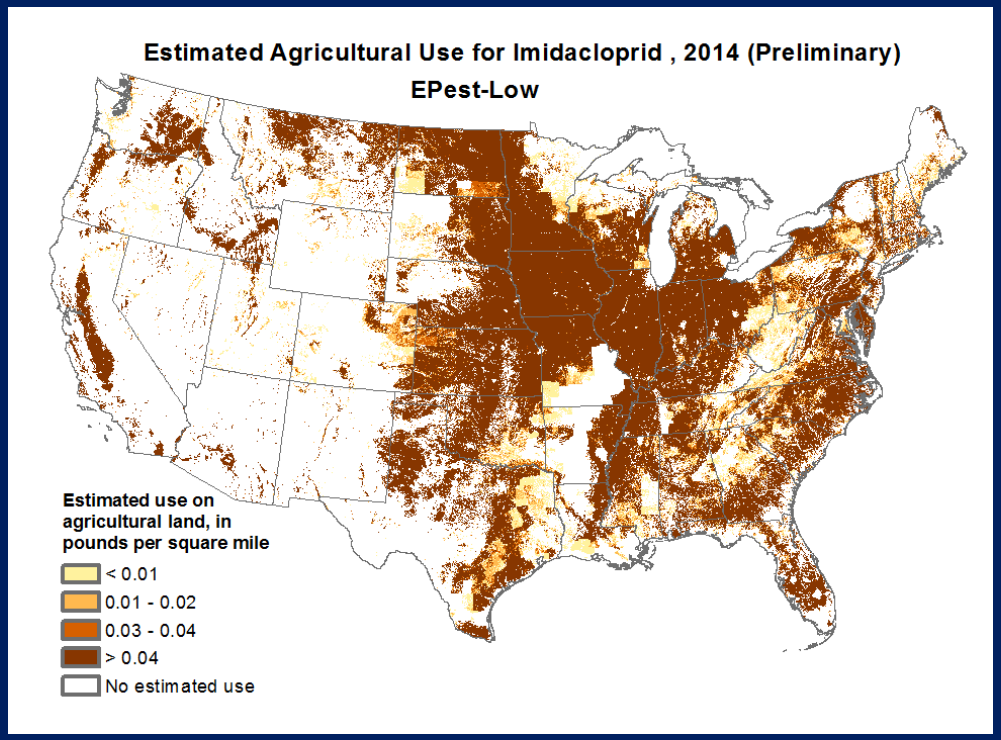
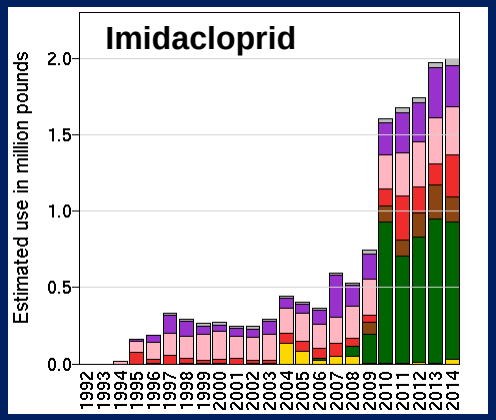
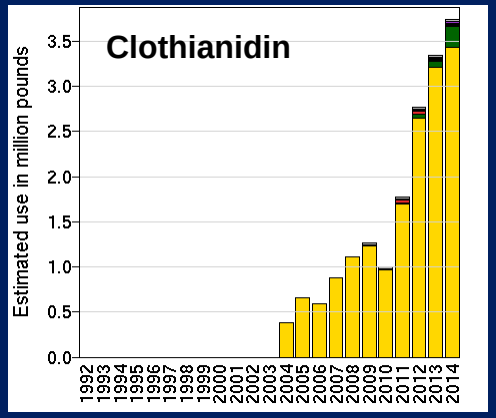
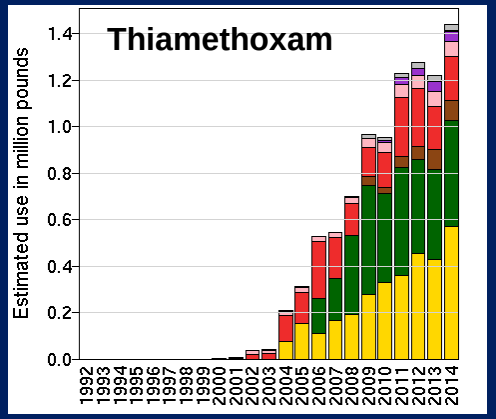
Neonicotinoid Use in U.S.

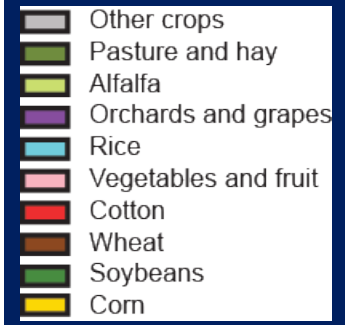


https://water.usgs.gov/nawqa/pnsp/usage/maps/









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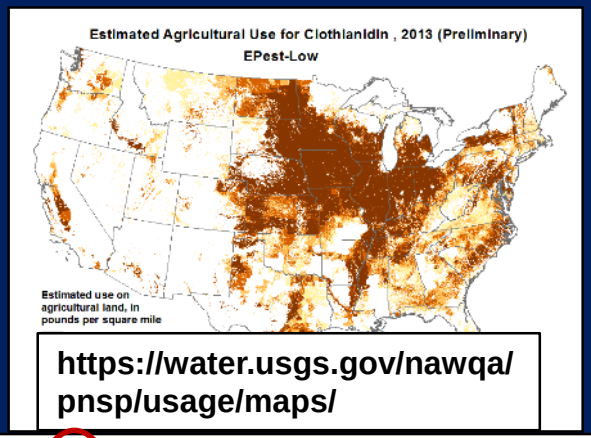
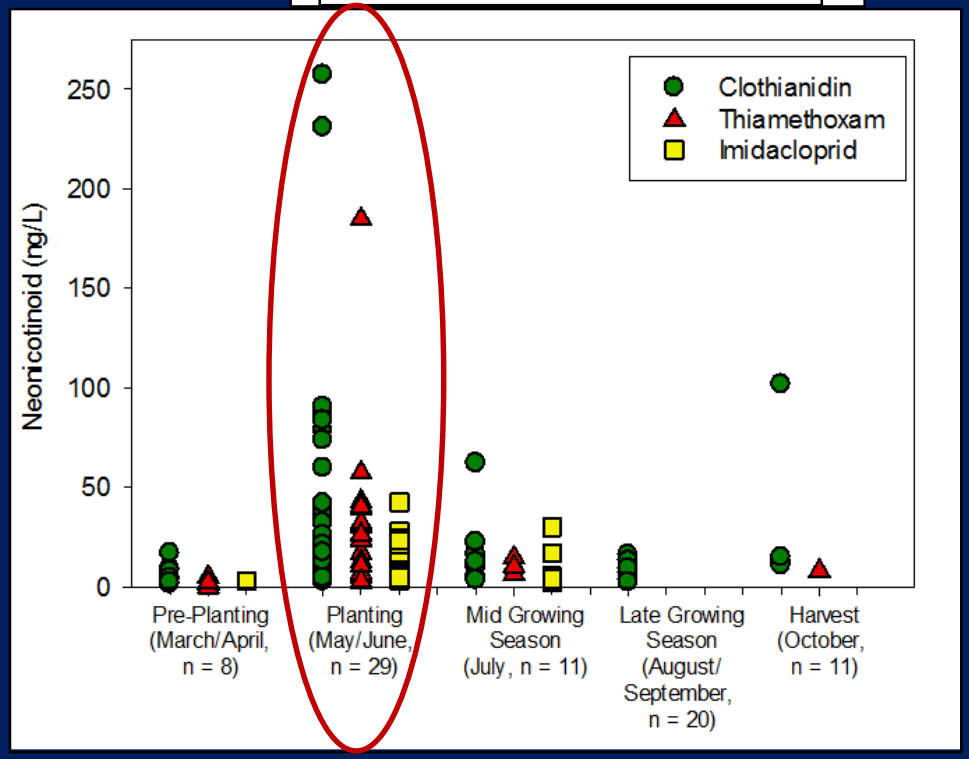
Neonicotinoids Detected in Iowa Surface Waters - 2013



https://water.usgs.gov/nawqa/pnsp/usage/maps/

- Targeted location (Iowa) where use of neonics for seed treatment is high (corn, soybeans)
- Neonics detected frequently
- Highest frequency and concentrations during planting



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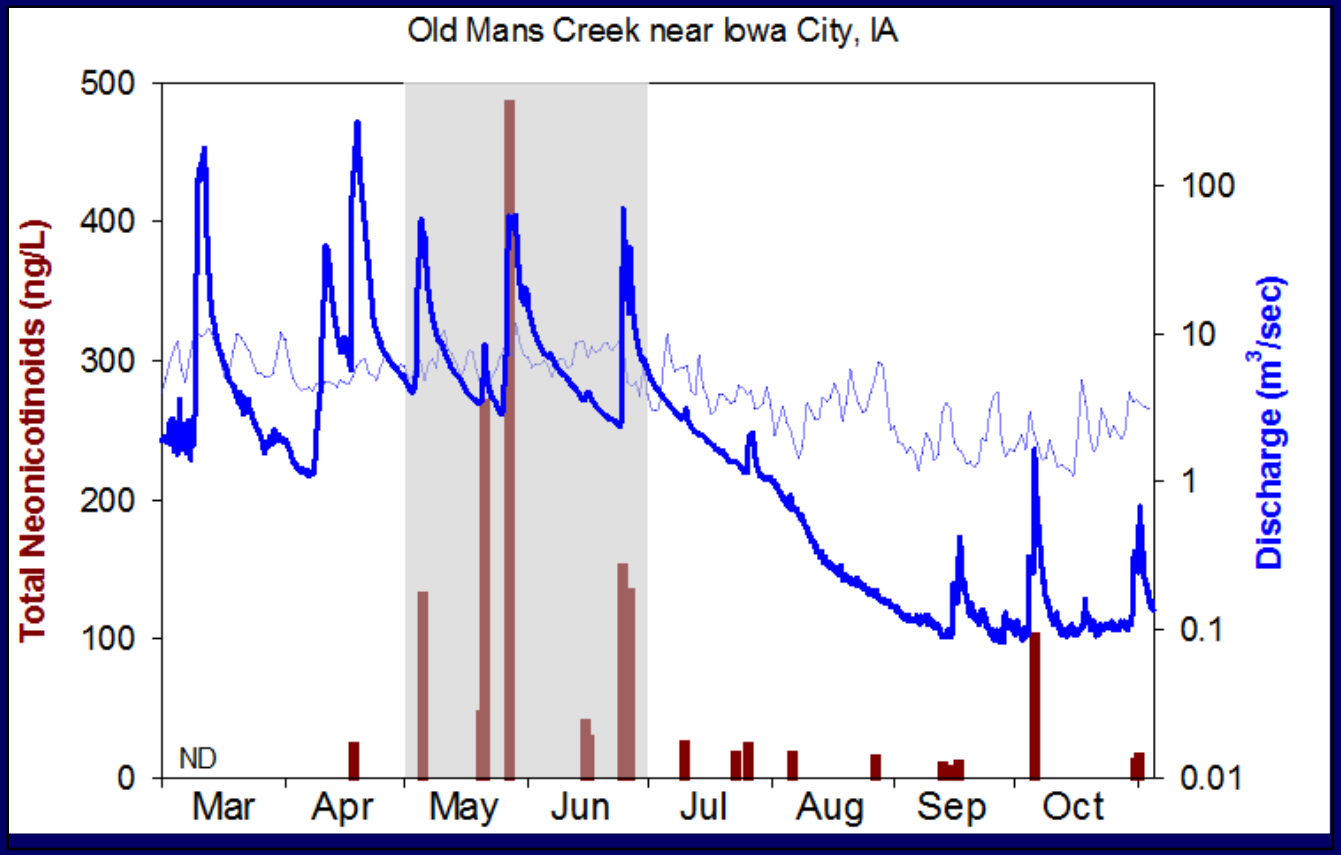
Hladik et al., 2014, *Environ. Pollut.*, v. 193, 189-196

Neonicotinoid Transport Planting and Hydrologic Events



Hladik et al., 2014, *Environ. Pollut.*, v. 193, 189-196

- Classic “spring flush” phenomena as herbicides (atrazine)
- associated with planting (seed treatments)

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Nationwide Study

38 streams, one time sampling

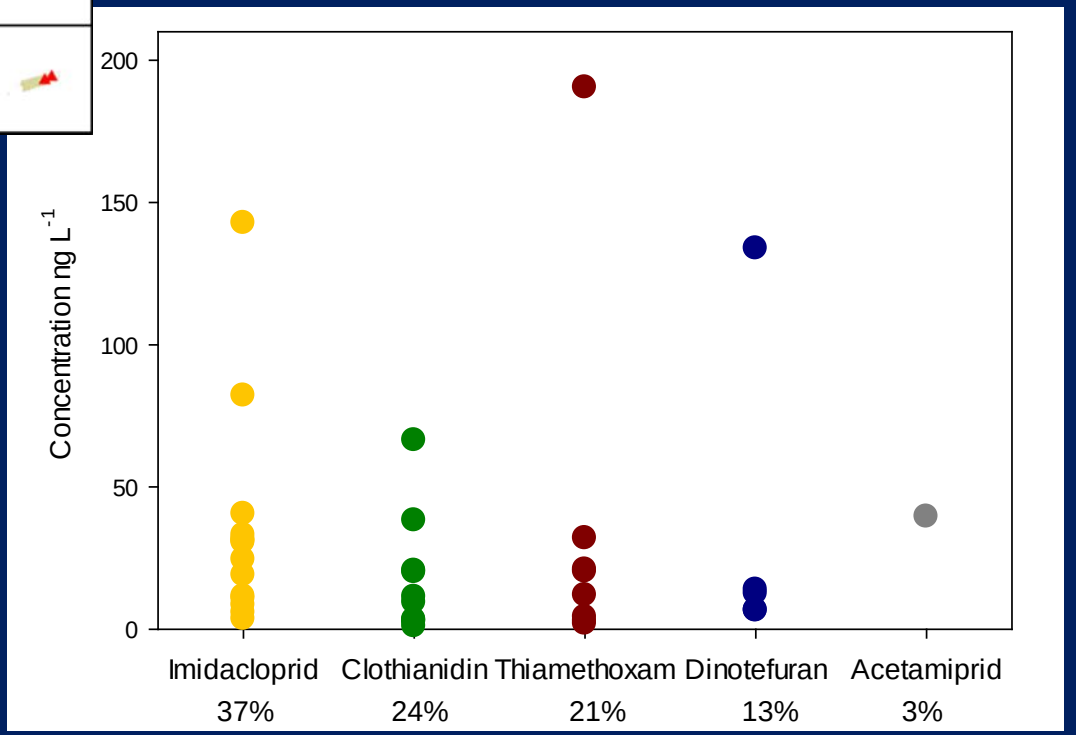
Neonic Detection Frequency

1 or more 53%

2 or more 26%

3 or more 11%

5 or more 3%



Relation to Landcover

Clothianidin + row crops

Thiamethoxam + row

Imidacloprid + urban

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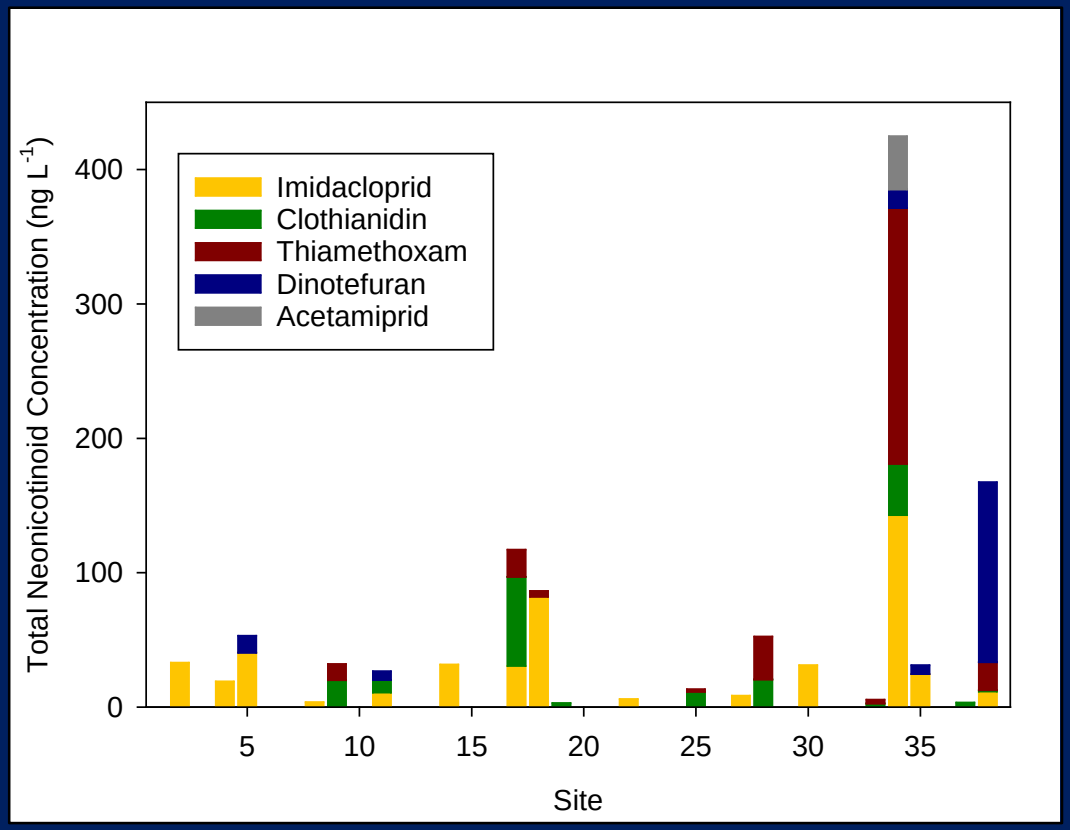
Hladik and Kolpin, 2016, *Env. Chem.*, v. 13, p 12-20

Nationwide Study 2012-2014



Hladik and Kolpin, 2016, *Env. Chem.*, v. 13, p 12-20

- Site sampling varied in timing
- One Central California site had five neonics detected

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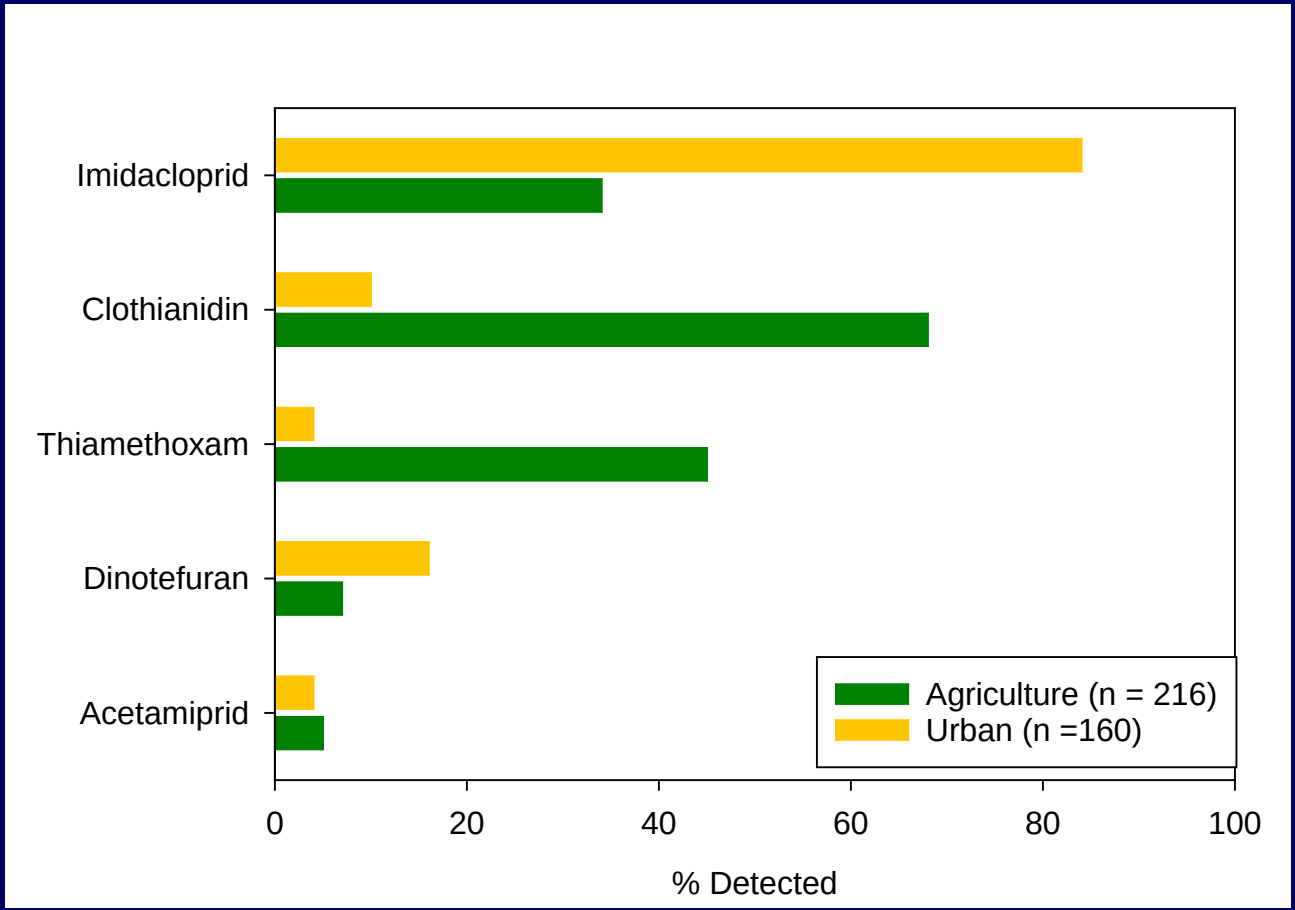
Overall Detection Frequency



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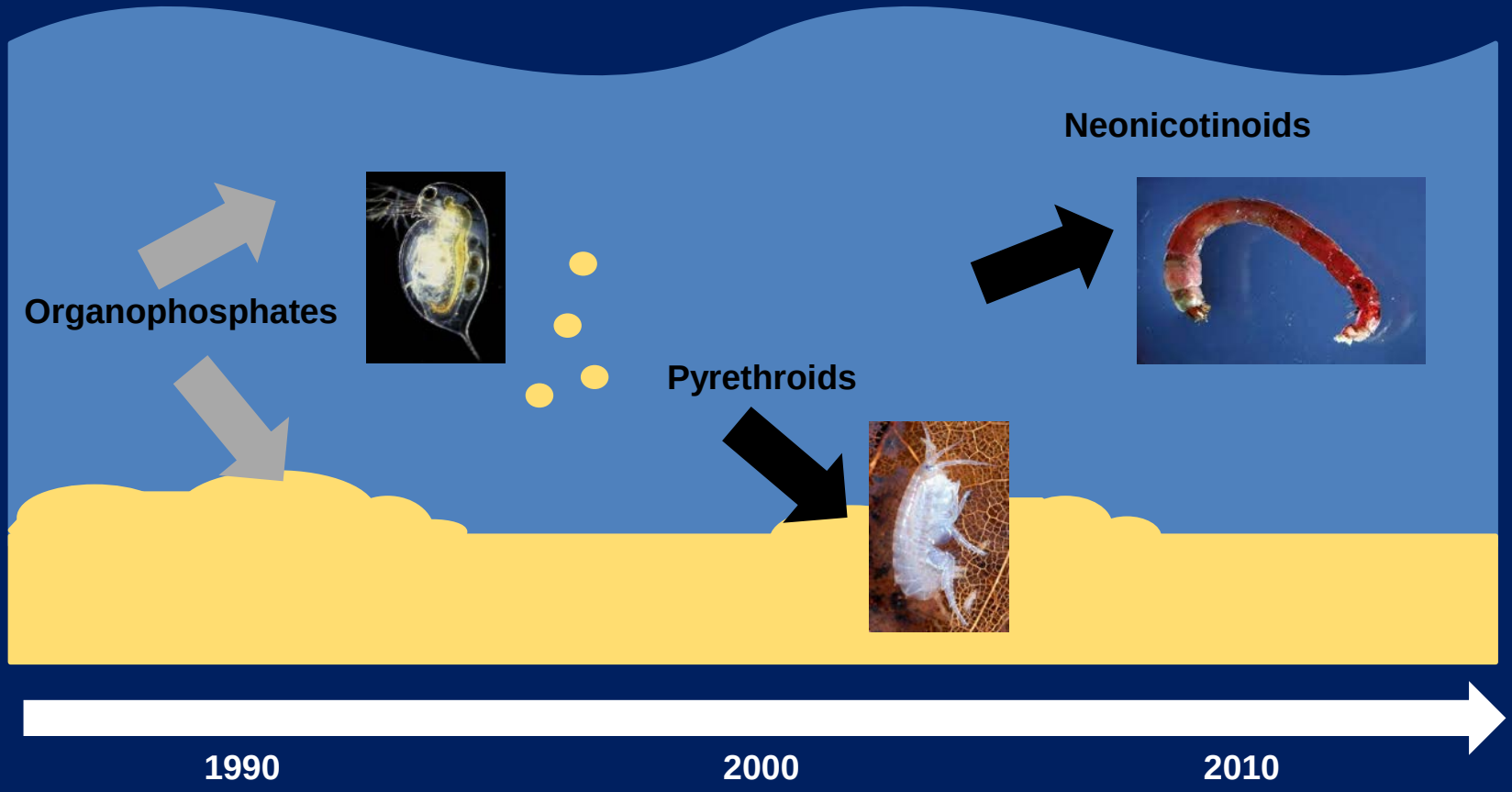
Changing Toxicity



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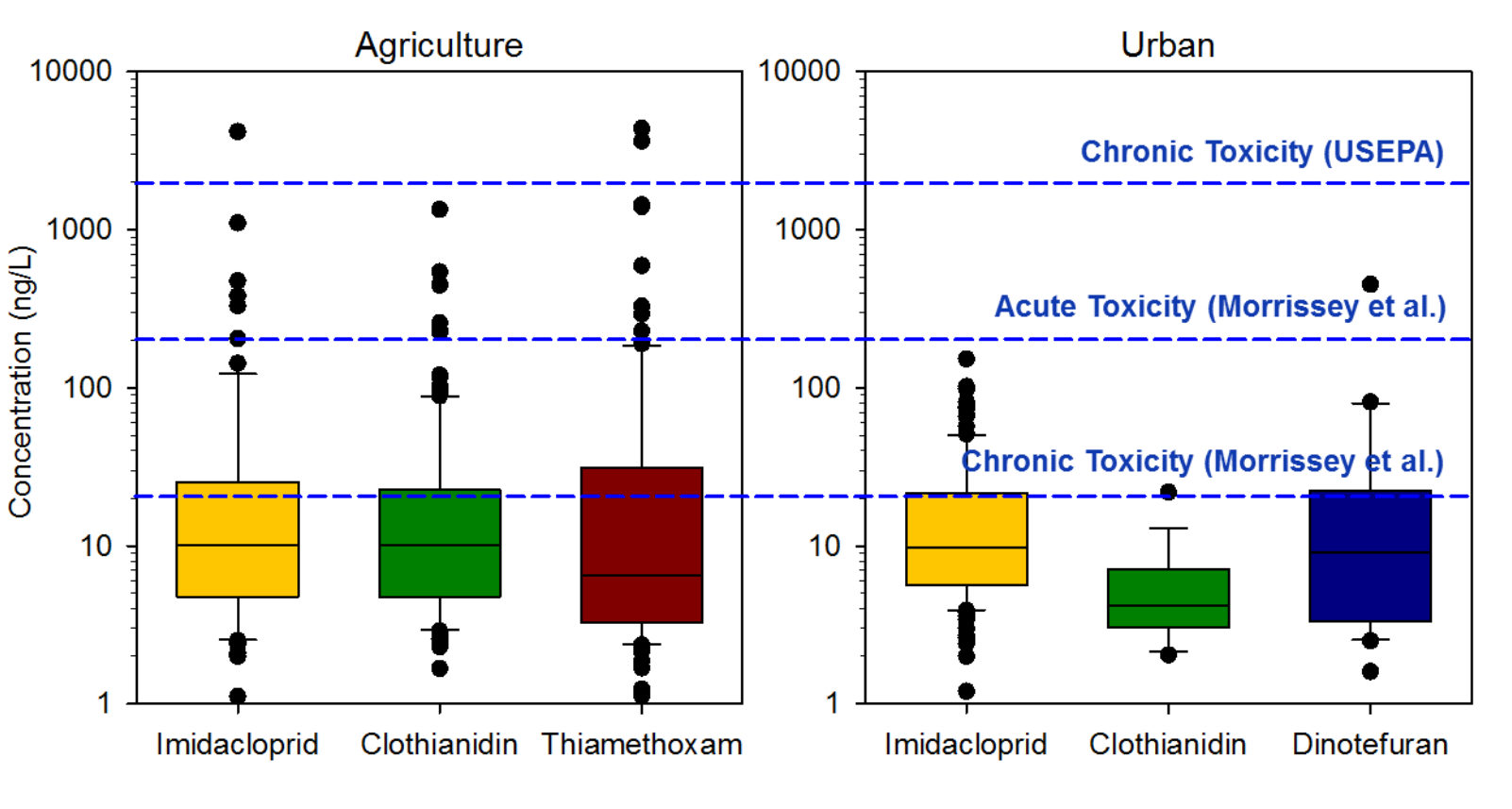
Neonicotinoid Toxicity



- EPA acute invertebrate aquatic life benchmarks 11000-35000 ng/L,); 2017 preliminary risk assessment of imidacloprid - 650 ng/L (acute) and 10 ng/L (chronic)
- Does not show “total neonic” toxicity
- Morrissey et al. 2015, *Environment International,* v. 74, pp. 291-303

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Neonics in U.S. Waterways

- Dissolve in water
- Can move away from application area
- Affect aquatic insects (mayflies, caddis flies)
- Indirect effects on birds

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Direct vs Indirect Effects

- Direct effects
  - Acute toxicity to birds is lower than pesticides replaced; varies by species
  - One treated seed (corn, wheat, canola) can poison a bird
  - 1/10th of a corn seed/day during egg-laying season can affect reproduction

- Indirect effects
  - Enter aquatic systems
  - Affect invertebrates/insects (esp. mayflies, caddisflies, midges)
  - No food for insectivorous birds
  - Hard to determine

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Getting Attention

Charismatic Megafauna



Species People Care About




Less “Charismatic”



Indirect Effects

- Birds (Netherlands)
  - Correlated imidacloprid concentrations in surface water with reduced bird populations
  - 6 of 15 bird species in decline
- Butterflies (California)
  - Correlated neonicotinoid use with decreasing populations
  - More severe for smaller butterflies
- Does not include causation

LETTER

doi:10.1038/nature13531

Declines in insectivorous birds are associated with high neonicotinoid concentrations

Caspar A. Hallmann[1,2], Ruud P. B. Foppen[2,3], Chris A. M. van Turnhout[2], Hans de Kroon[1] & Eelke Jongejans[1]

Conservation biology

Increasing neonicotinoid use and the declining butterfly fauna of lowland California

Matthew L. Forister[1], Bruce Cousens[2], Joshua G. Harrison[1], Kayce Anderson[3], James H. Thorne[4], Dave Waetjen[4], Chris C. Nice[5], Matthew De Parsia[6], Michelle L. Hladik[6], Robert Meese[4], Heidi van Vliet[7] and Arthur M. Shapiro[8]

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Neonic Use Update

- Seed treatments use less active ingredient than broadcast applications, but near 100% usage on seeds means more total use

- EPA study: soybean fields with treated seeds did not see increased yield, much use is prophylactic
  - Seed treatments lead to less foliar applications in oilseed rape in England (Budget et al 2015)
  - Seed treatments no increase in sunflower yields in South Dakota (Bredeson and Lundgren, 2015)

- Neonics being phased out in US wildlife refuges
- EPA is currently reviewing neonics
- EU moratorium on agricultural use of 3 neonics since 2013
- Ontario, Canada cutting neonic use by 80% over 3 years
- Maryland banned consumer use of neonics (January 1, 2018)

NATIONAL WILDLIFE REFUGE SYSTEM

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Other Projects

- Vegetated buffer strips reduce neonic runoff groundwater and soil from ag fields

  (Iowa State University)

  Hladik et al., 2017, Agric. Ecosyst. Environ., v. 241, pp. 160-167

- Neonics detected in drinking and tap water; low levels not required to be tested

  (University of Iowa)

  Klarich et al., 2017, Environ. Sci. Technol. Lett.

- Occurrence in Great Lakes tributaries

- Exposure of neonics and other pesticides to native bees

  Hladik et al., 2016, Sci. Tot. Environ., v. 542, pp. 469-477.

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Summary

- **Neonics frequently detected in streams across U.S.**
  - **Can exceed chronic and even acute levels**
  - **Most likely effects are on invertebrates**

- **Transport to streams driven by use and precipitation**
  - **Contributions from both urban and ag use**
  - **Many ag areas use seed treatment**

- **Seed treatments are increasing overall neonic use (and insecticide use) across the U.S., ~100% of corn is treated, new treatments for wheat, rice**

- **Occur in complex mixtures of pesticides (herbicides, fungicides) and other contaminants (pharmaceuticals, metals, microplastics)**

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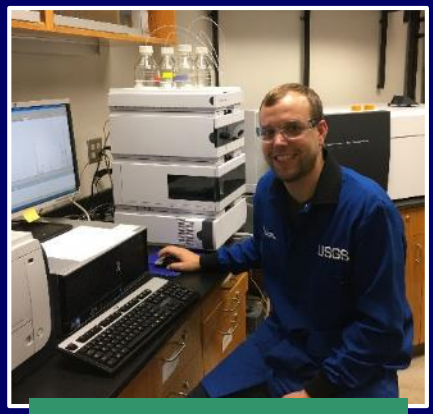
Research Chemist



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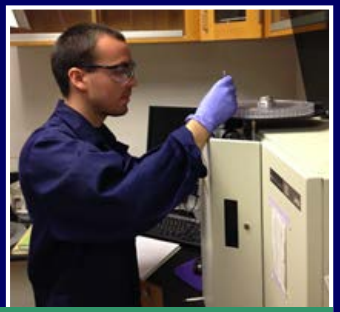
Hydrologist



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