EFFECTS OF NEONICOTINOIDS ON AQUATIC INSECTS: LAB AND FIELD STUDIES

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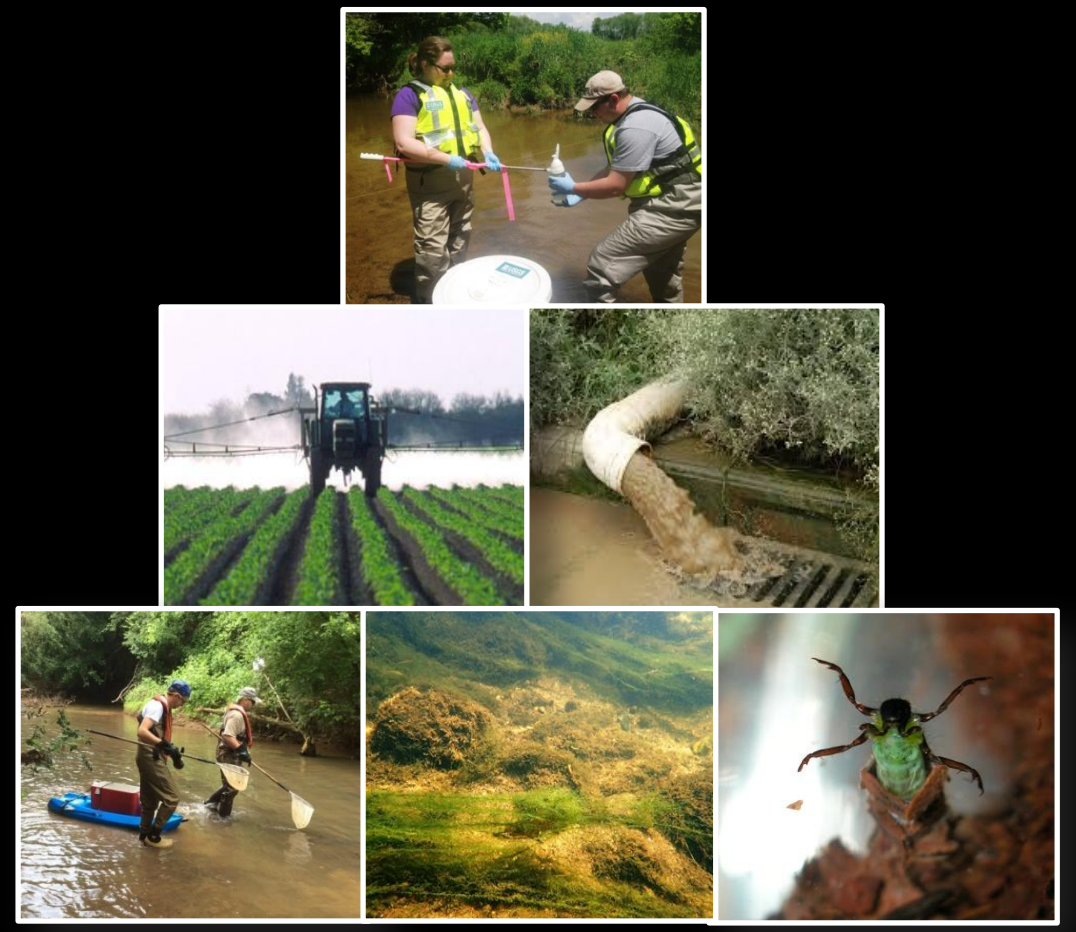

SCIENCE ADVANCES | RESEARCH ARTICLE

ECOLOGY

Ecological consequences of neonicotinoid mixtures in streams

Travis S. Schmidt[1]*†, Janet L. Miller[2]†, Barbara J. Mahler[3], Peter C. Van Metre[3], Lisa H. Nowell[4], Mark W. Sandstrom[5], Daren M. Carlisle[6], Patrick W. Moran[7], Paul M. Bradley[8]

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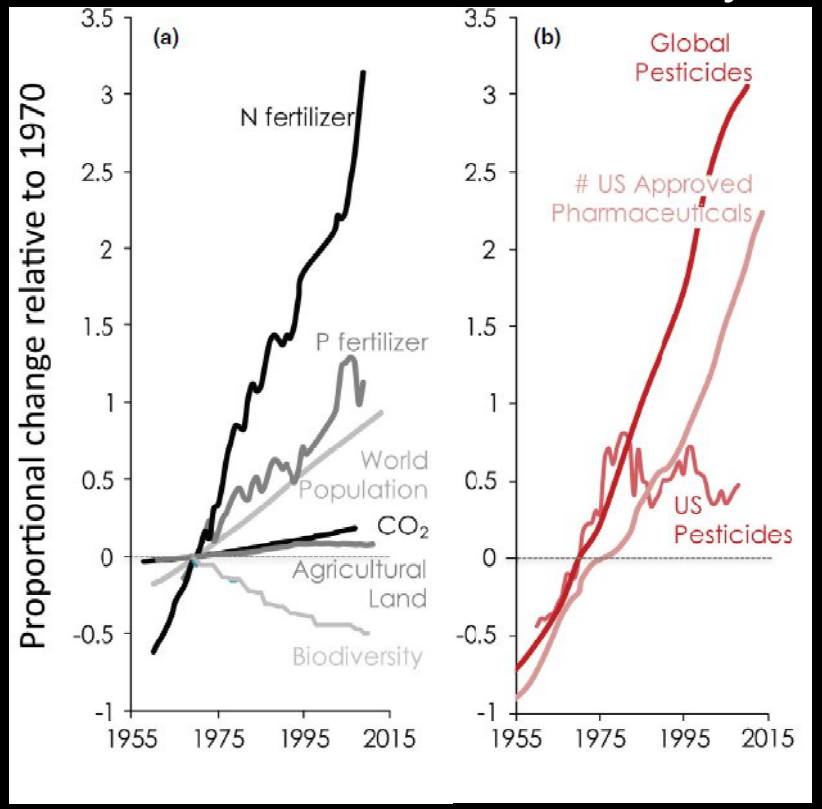
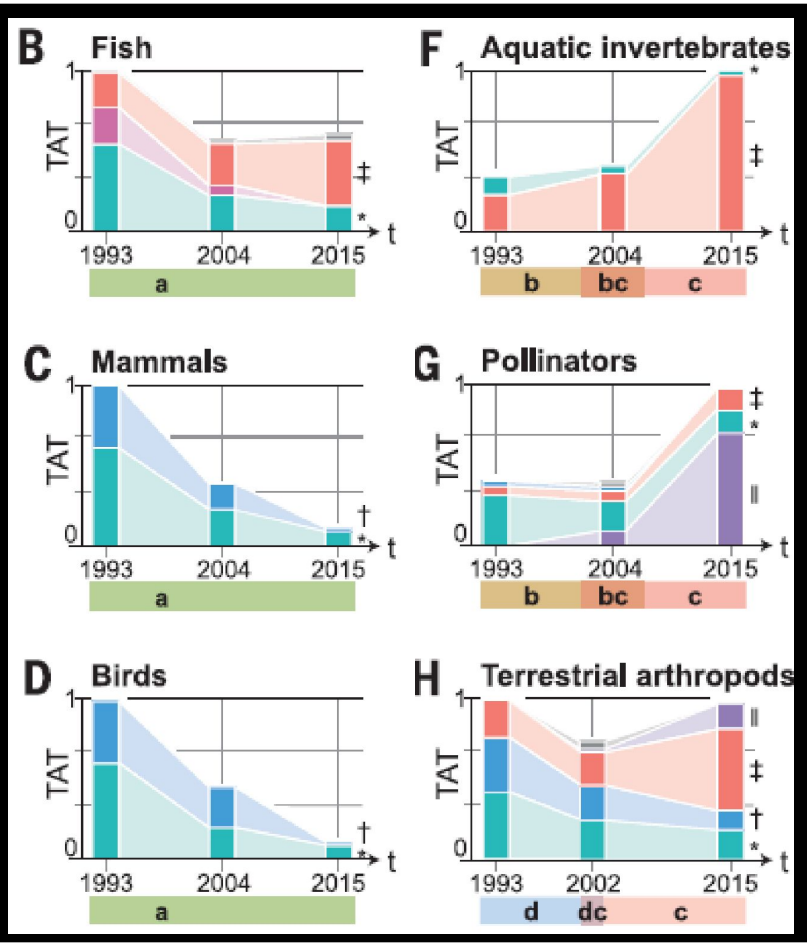
Synthetic Chemicals Are a Global Stressor: Risk Changes Over Time

Millennium Stressors

Stressor diversity





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CONCEPTS AND QUESTIONS

Synthetic chemicals as agents of global change

Emily S Bernhardt[1*†], Emma J Rosi[2†], and Mark O Gessner[3,4]

PESTICIDES

Applied pesticide toxicity shifts toward plants and invertebrates, even in GM crops

Ralf Schulz[1,2*], Sascha Bub[1], Lara L. Petschick[1], Sebastian Stehle[1,2], Jakob Wolfram[1]

What is the Condition of Rivers and Streams in the United States?

What are the leading problems in rivers and streams?

What is the condition of our rivers and streams across the country?

The NRSA report finds that many of our rivers and streams do not support healthy aquatic communities.

46%

Biological condition: 46% of our nation's rivers and streams are in poor biological condition, with 25% in fair condition and 28% in good condition. Benthic macroinvertebrates e.g., aquatic insects, crayfish, snails and worms that live in submerged vegetation and in the streambed -- are used to assess biological condition. Poor biological condition can lead to loss of fishing and recreational opportunities.

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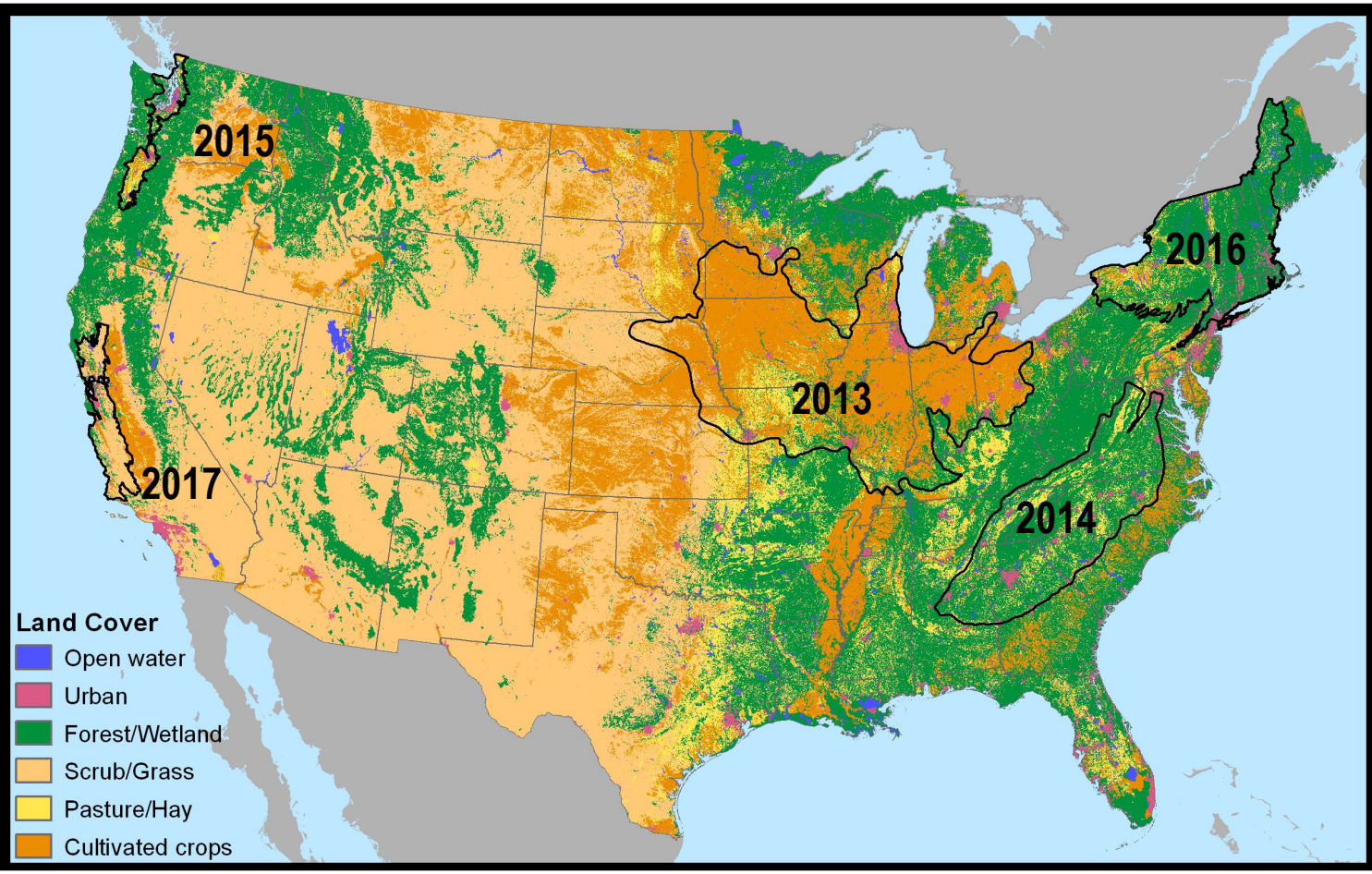
Regional Stream Quality Assessments



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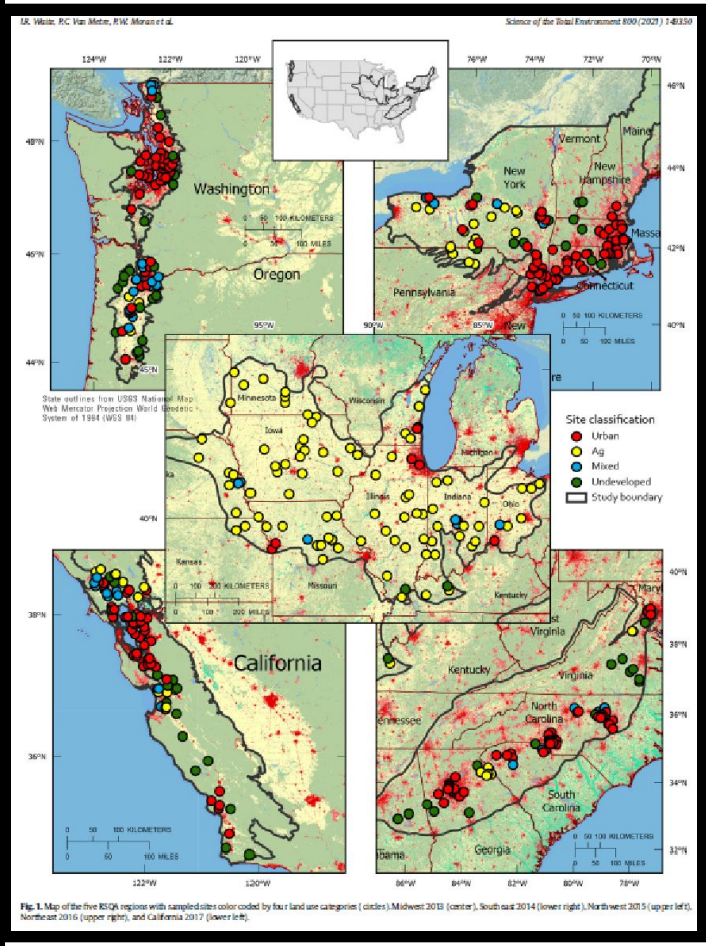
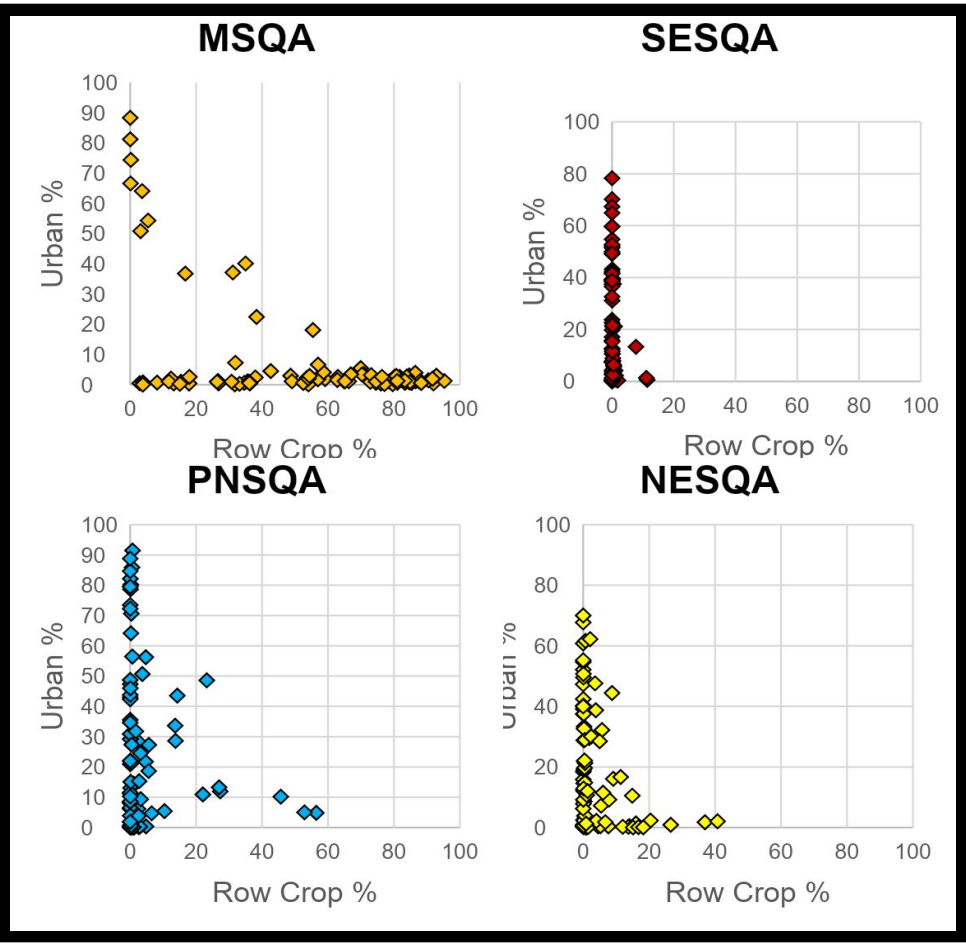
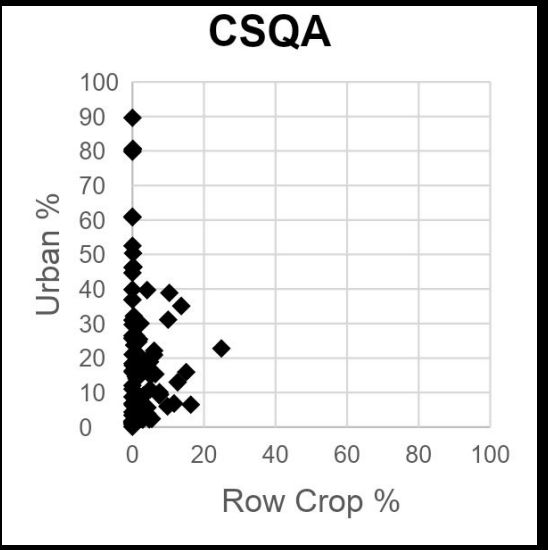
Land Use by RSQA Region







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RSQA Data Collection

Sites: 75-100 wadeable streams per region

- Water and sediment quality sampling

Dissolved:

- Weekly water samples (n=4 per site)
- 225 pesticide compounds by LC-MS/MS

Hydrophobic:

- Composite bed sediment sample
- 119 pesticide compounds by GC/MS

- Ecological survey: (summer)
  - Benthic Invertebrates, Algae, Fish, Habitat

Alan Cressler, USGS

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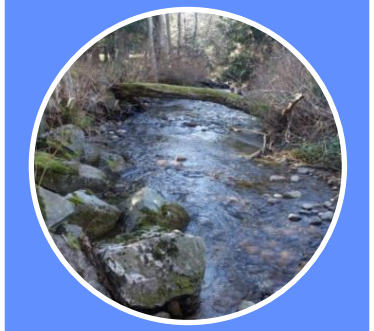
Link the Landscape to Stressors of Stream Ecosystem Health

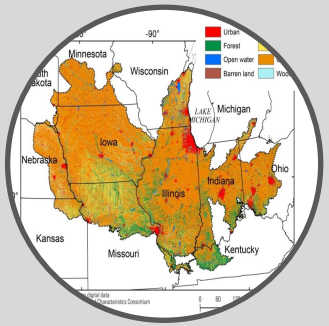


Habitat:
Streamflow
Channel width
Reach char.

Contaminants:
HQs (sediment)
Chronic HQs (pestic./water)

Sediment:
Suspended sediment loads
Sediment grain-size

Nutrients:
Max NH3
Total P
Ortho P



GIS:
Canopy cover
Sand content
N, P loadings

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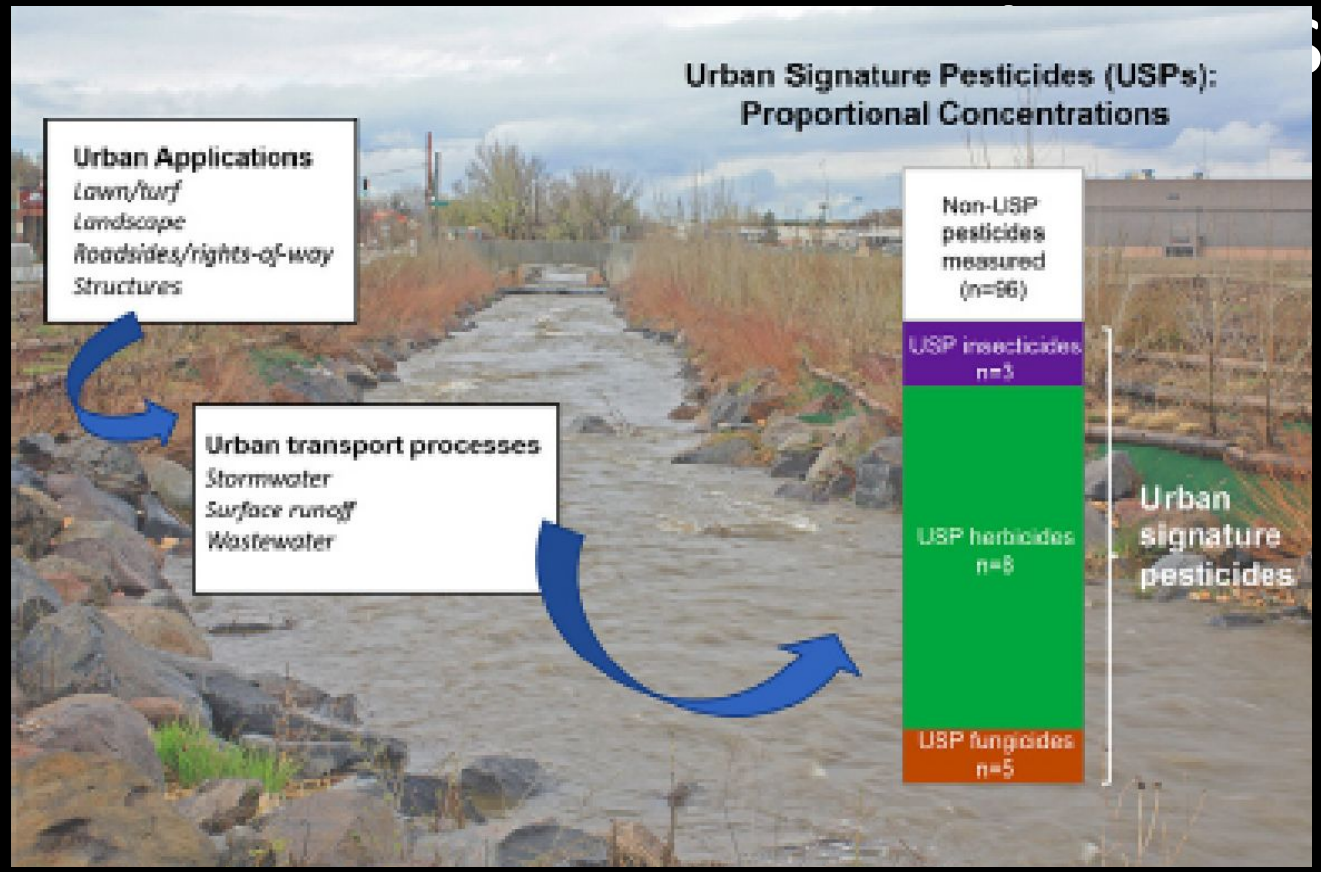
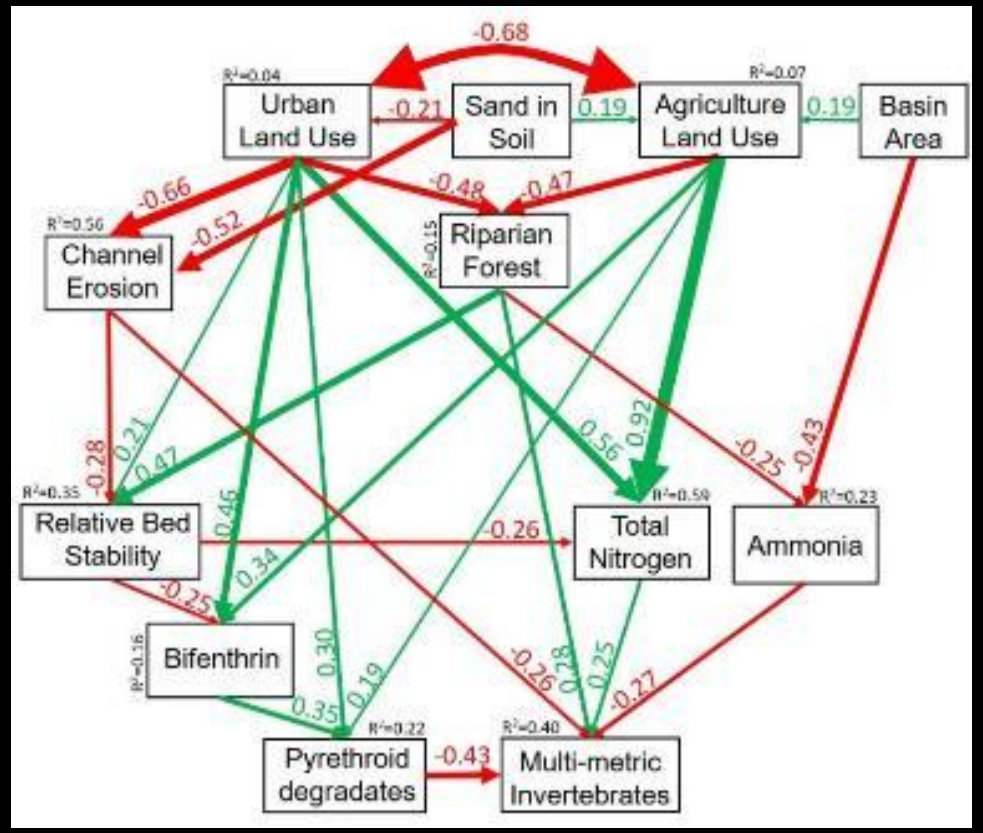
Urban and Agricultural Land Uses are Important to Pesticide Distributions in US





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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 [a,*], Patrick W. Moran [b], Laura M. Bexfield [c], Barbara J. Mahler [d], Peter C. Van Metre [d,1], Paul M. Bradley [e], Travis S. Schmidt [f], Daniel T. Button [g], Sharon L. Qi [h]

Environmental Science & Technology
Article
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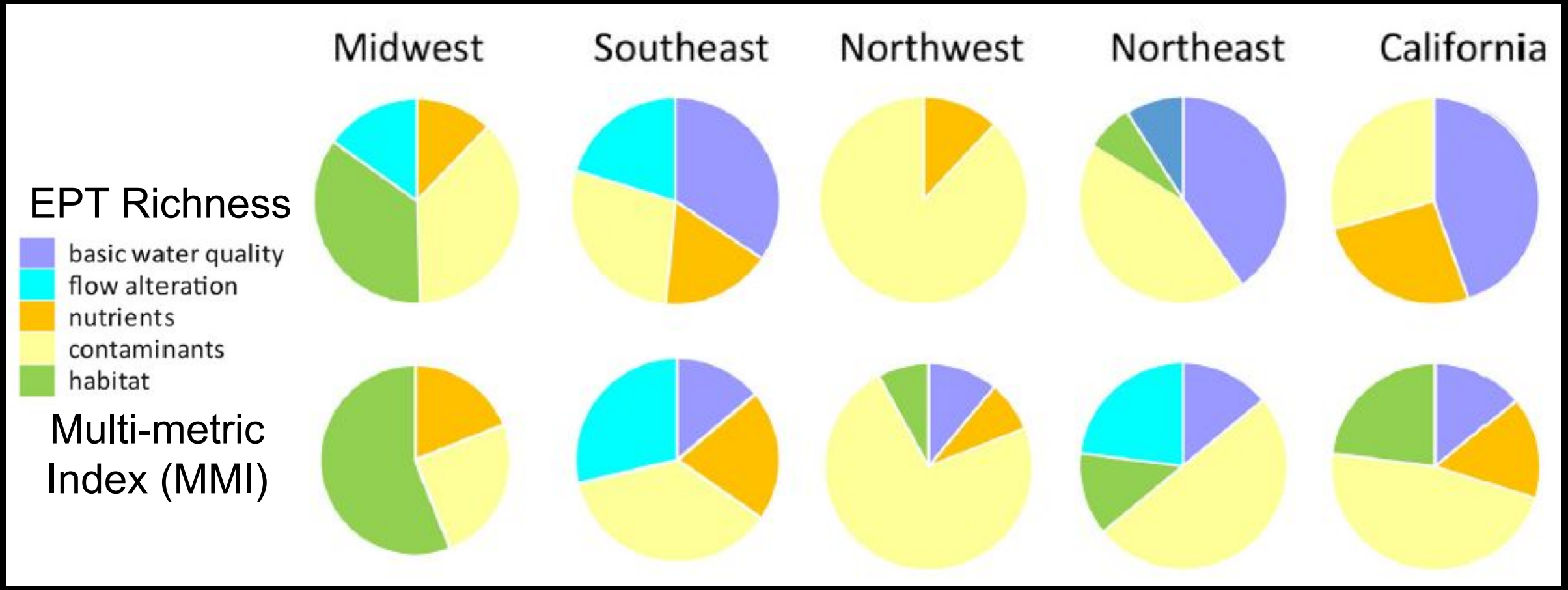
Linking the Agricultural Landscape of the Midwest to Stream Health with Structural Equation Modeling

Travis S. Schmidt,*[†] Peter C. Van Metre,[‡] and Daren M. Carlisle[§]

Pesticides were Important Predictors of Stream Invertebrate Communities in all 5 Regions

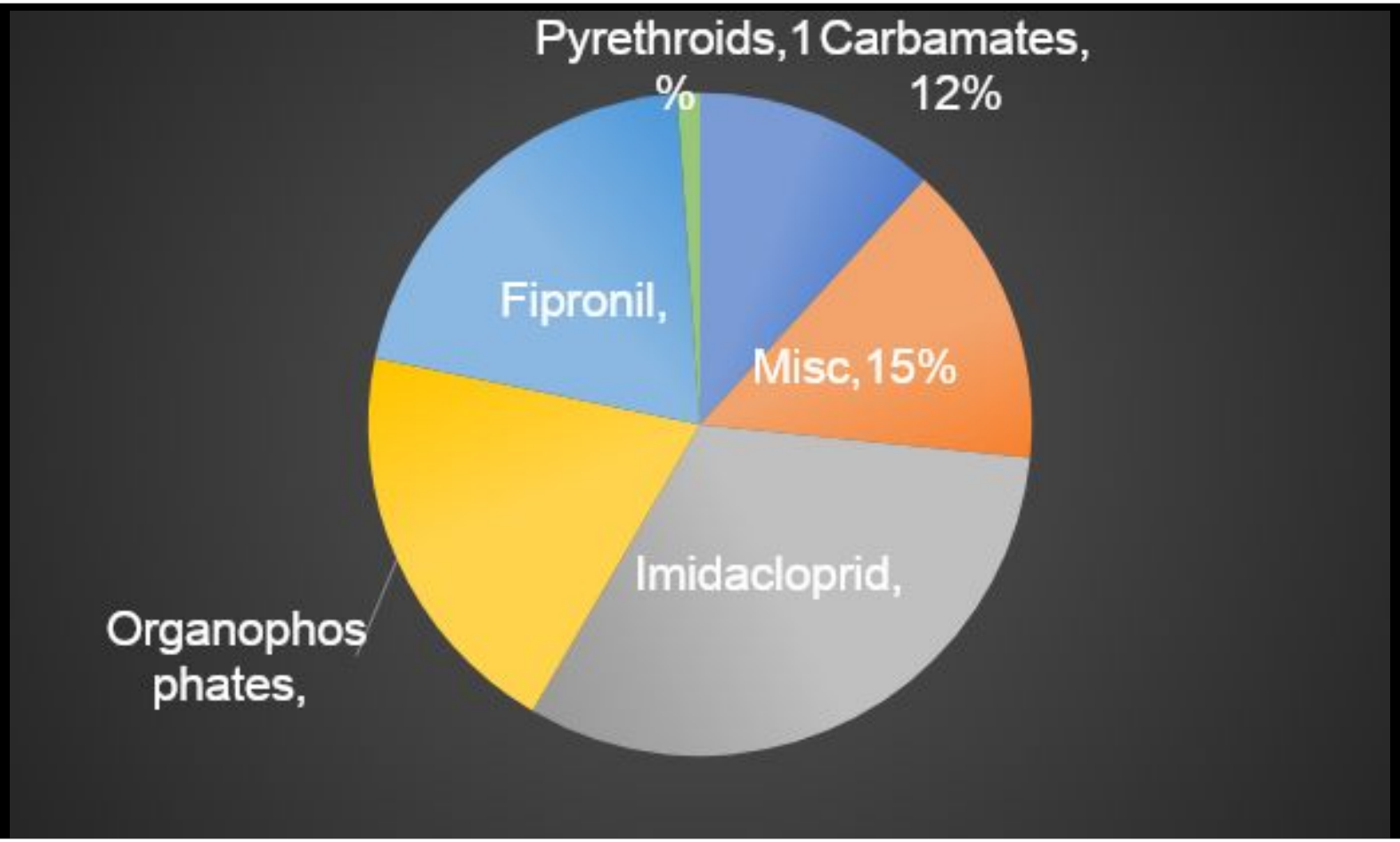


USGS

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

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

Imidacloprid was the Most Detected Insecticide in U.S. Streams



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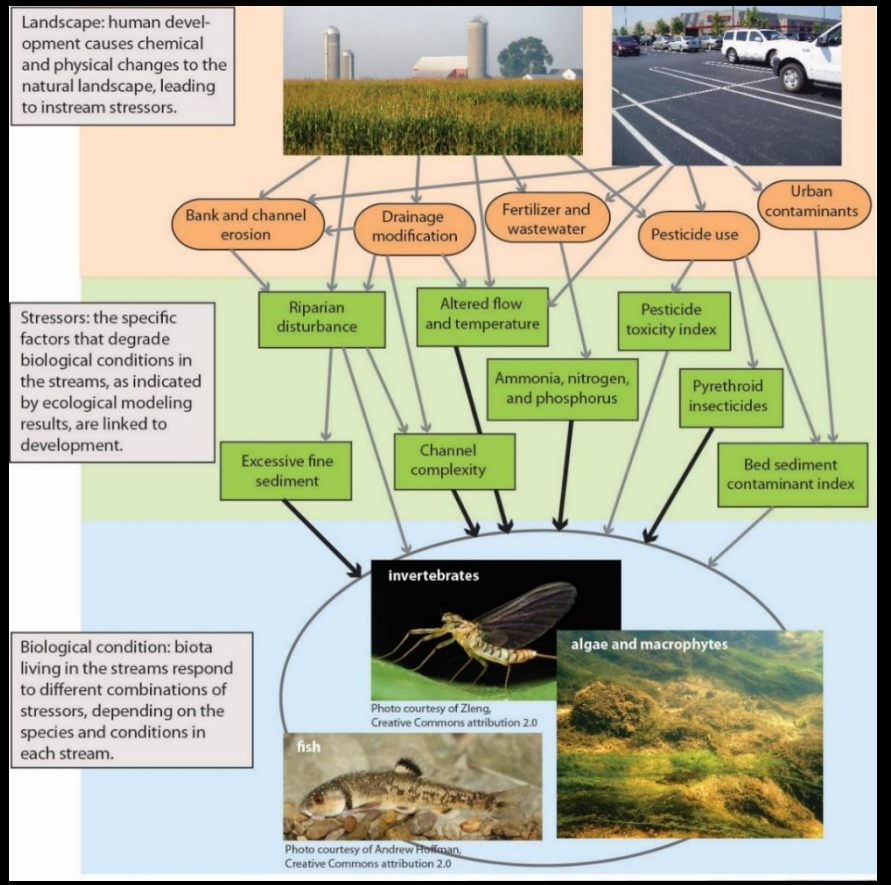
# of detected compounds in last 4 weekly samples. Reported as % of detections

Coastal California Streams are a Mix of Neonicotinoids

	Detection frequency	Mean (max conc./ EPA benchmark)
Sum of all pesticides	97%	7.47
Sum of all neonicotinoids	72%	7.03
Acetamiprid	5%	< 0.01
Clothianidin	45%	1.43
Dinotefuran	61%	< 0.01
Imidacloprid	42%	5.57
Sulfoxaflor	2%	< 0.01
Thiacloprid	0%	0.00
Thiamethoxam	32%	0.03

Do Neonicotinoid Mixtures Impair Invertebrate Communities in Streams?

- Difficult problem:
  - Other pesticides
  - Covariates
  - Co-limiting factors
  - Interactive effects



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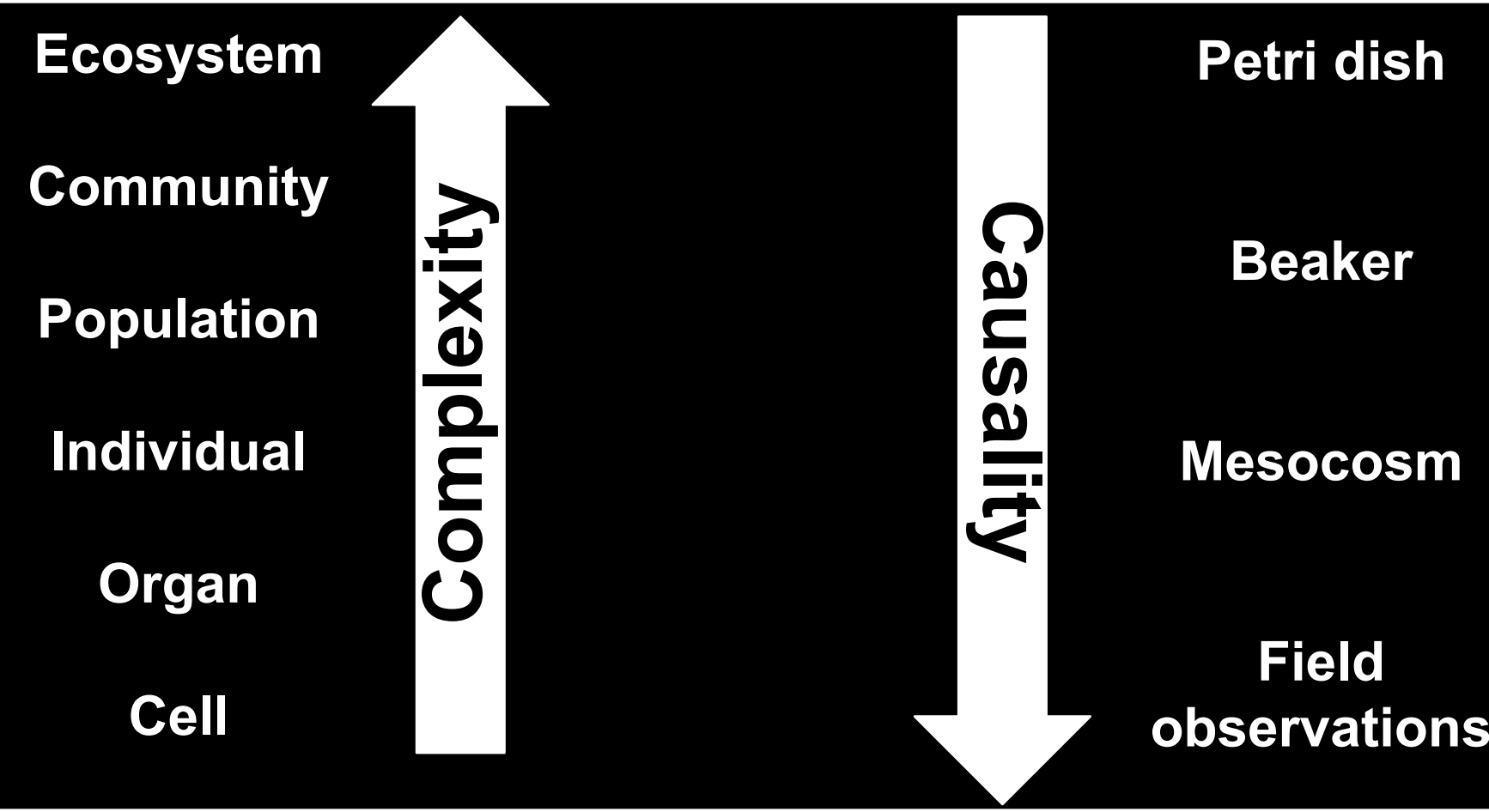
Experimentation Can Improve Cause-Effect Associations

Mesocosm Bridge the Credibility Gap Between Bioassays and Field Observations



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Montana Experimental Stream Observatory (MESO)

USGS

Montana Experimental Stream Observatory (MESO)

USGS

Montana Experimental Stream Observatory (MESO)

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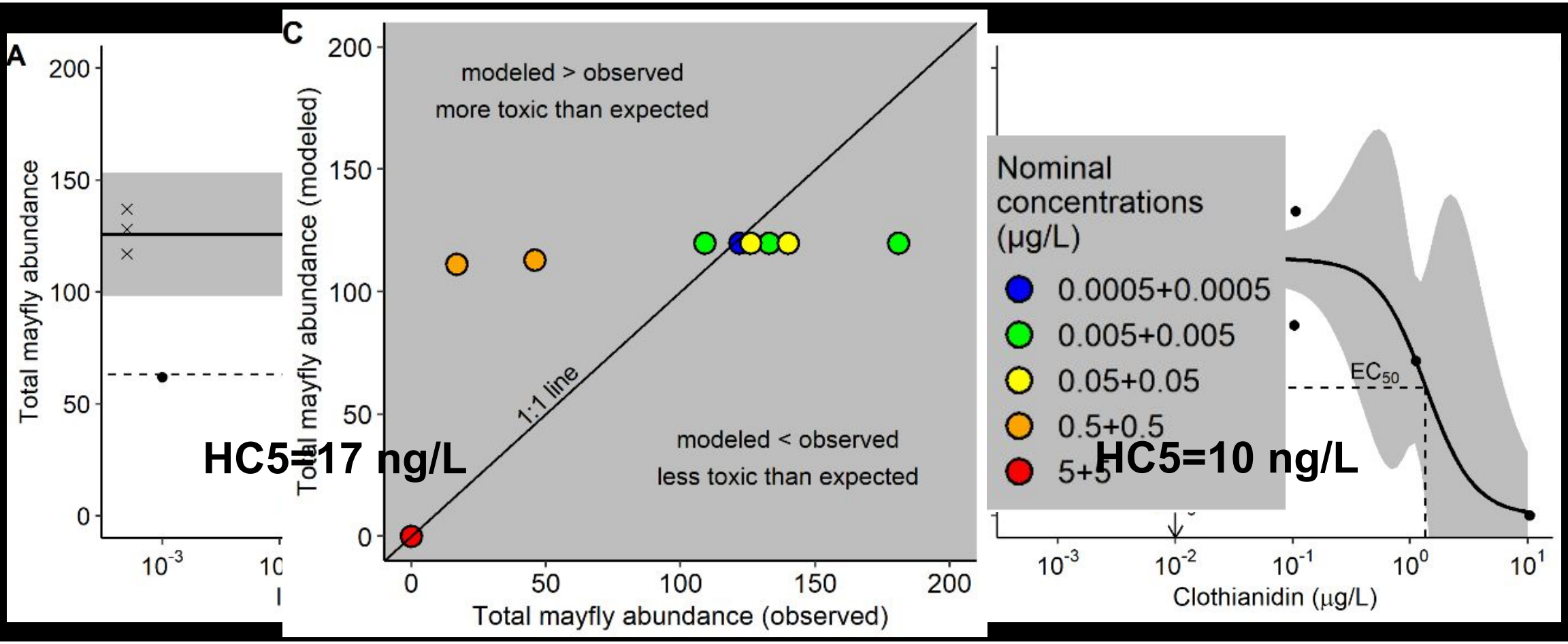
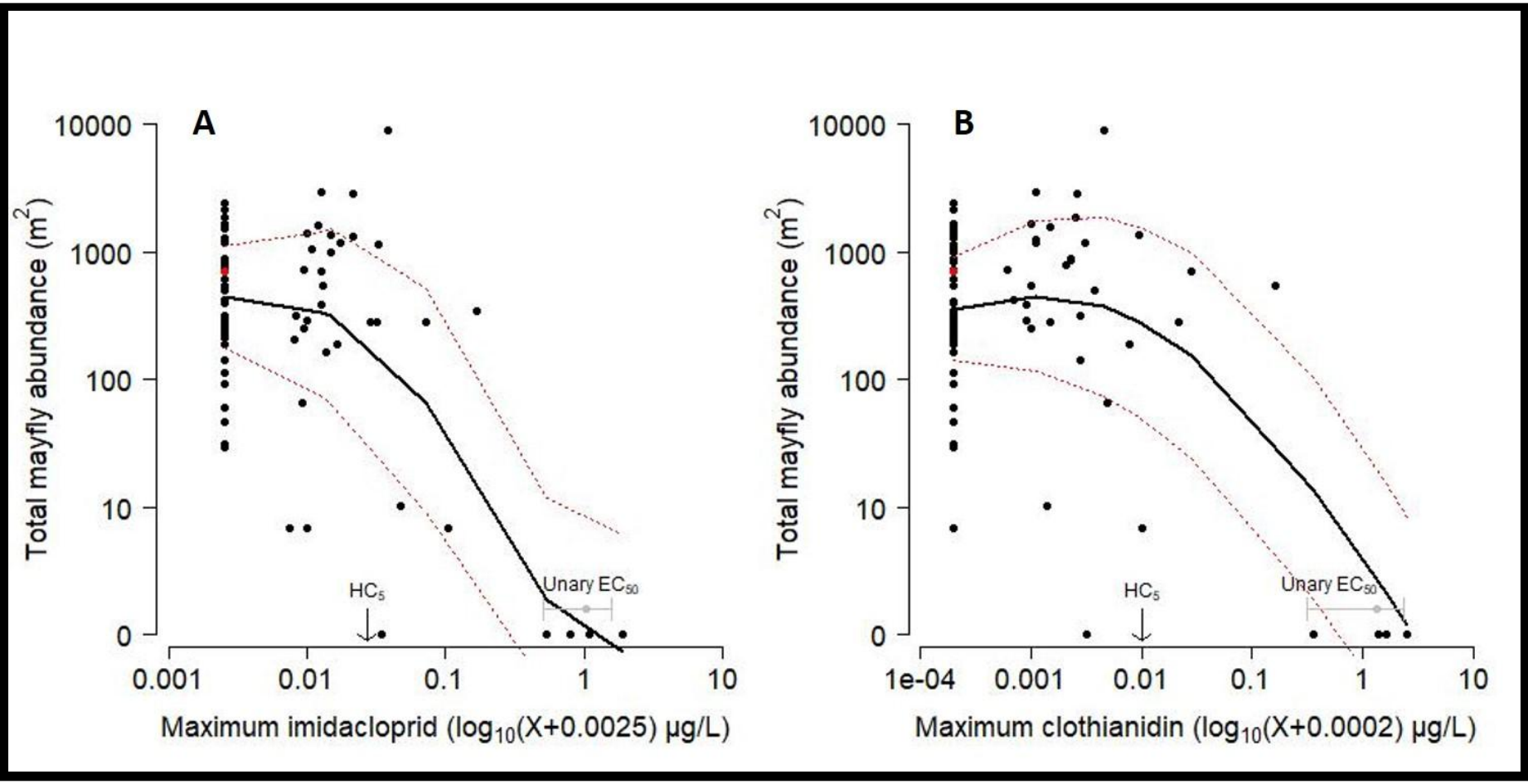
Effect of Neonicotinoid Mixtures: Lab (MESO)



Dose response curves used to calculate modeled values in response addition plot (C)

Response addition plots

Effect of Neonicotinoid Mixtures: Field vs Lab



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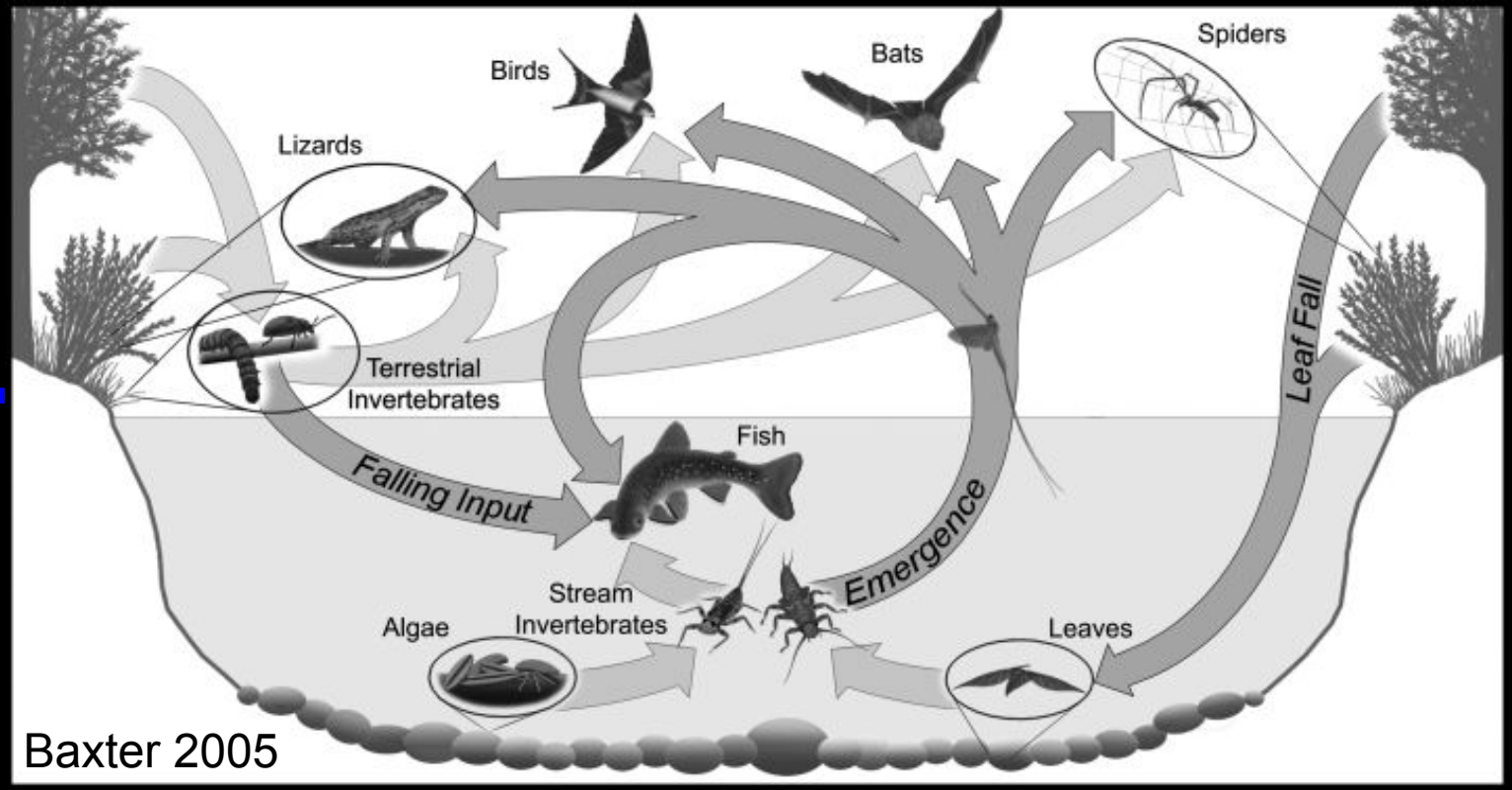
Aquatic Insects are Important to Terrestrial Ecosystem Too!



Baxter 2005

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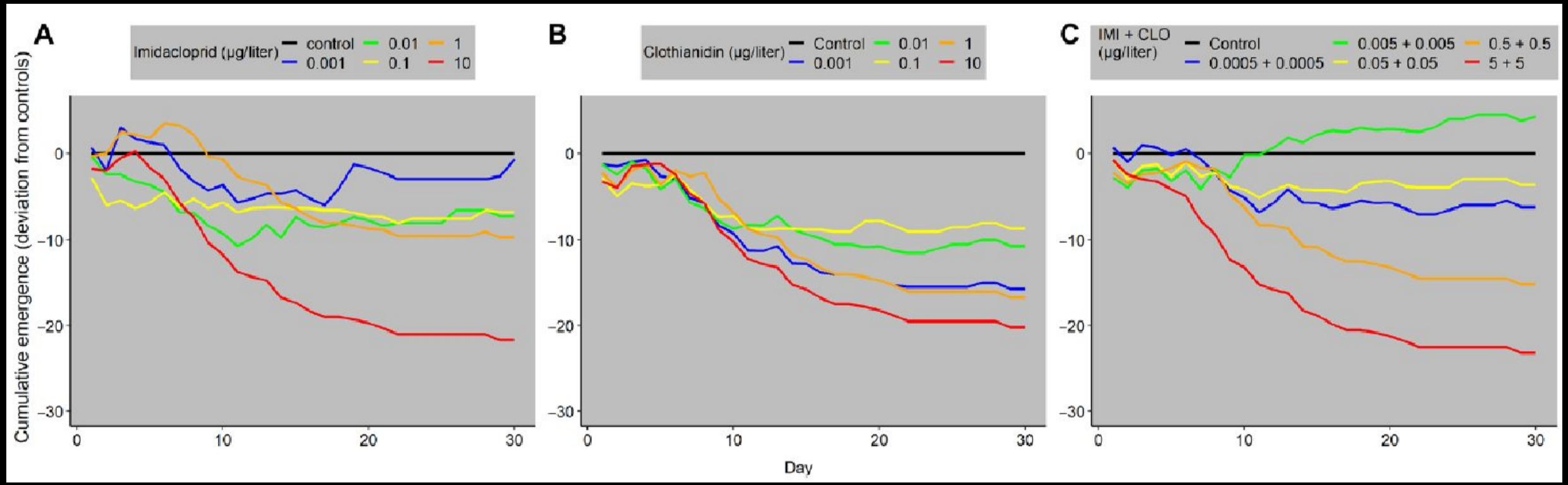
Neonicotinoids Disrupt Aquatic Insect Emergence



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Neonicotinoids Mixtures in Streams have Ecological Consequences

- Imidacloprid was observed in 32% of US streams
- Mixtures of neonicotinoids were common, where measured
- The most common neonicotinoid mixtures (Clothianidin + Imidacloprid) caused synergistic effects in the lab and field
- Neonicotinoids limited aquatic communities in 4 of 5 regions studied
- Agriculture and urban land uses were associated with pesticides and effects to stream ecosystems

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Follow Up and Questions

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ECOLOGY

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Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/scitotenv

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

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

USGS

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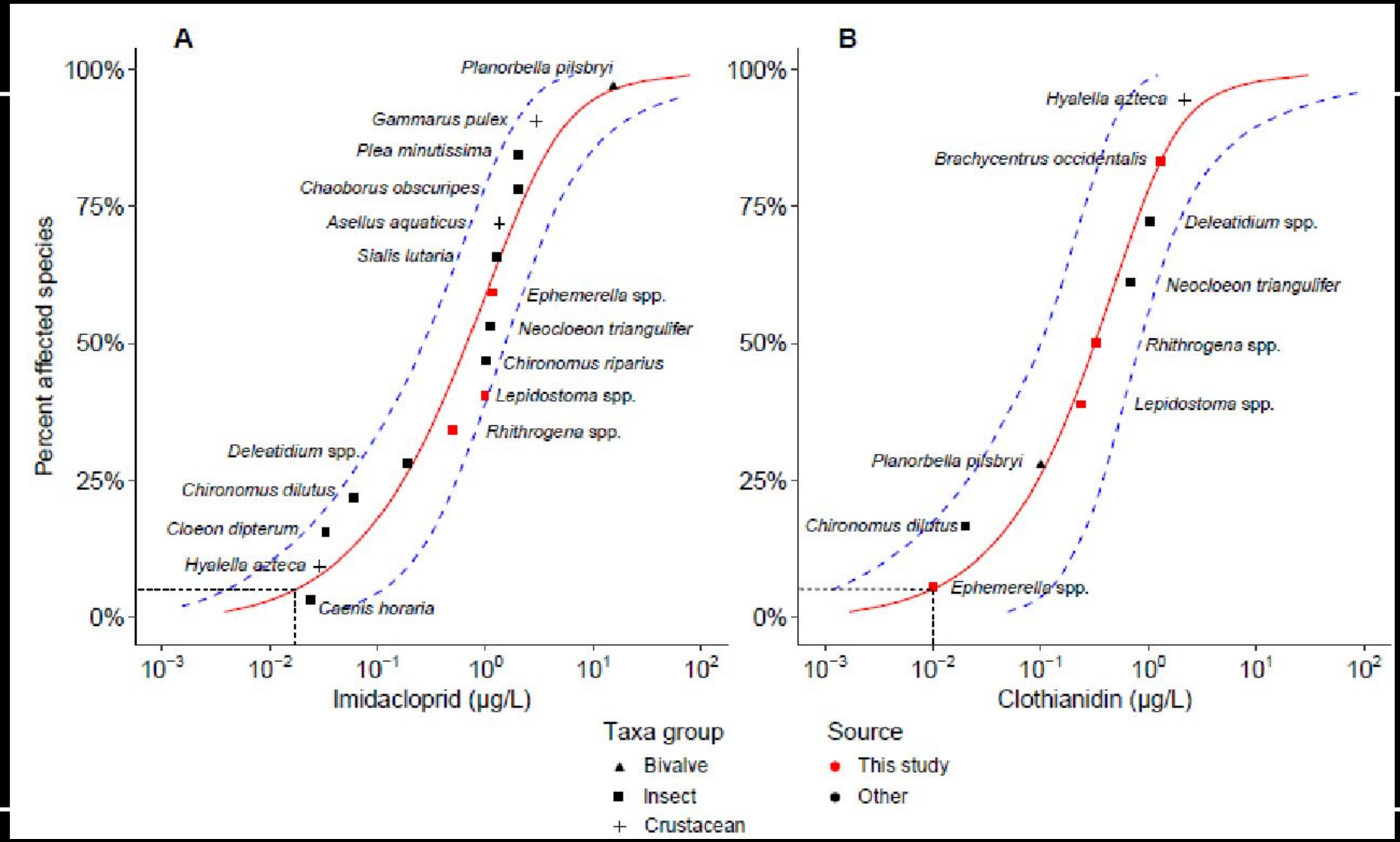
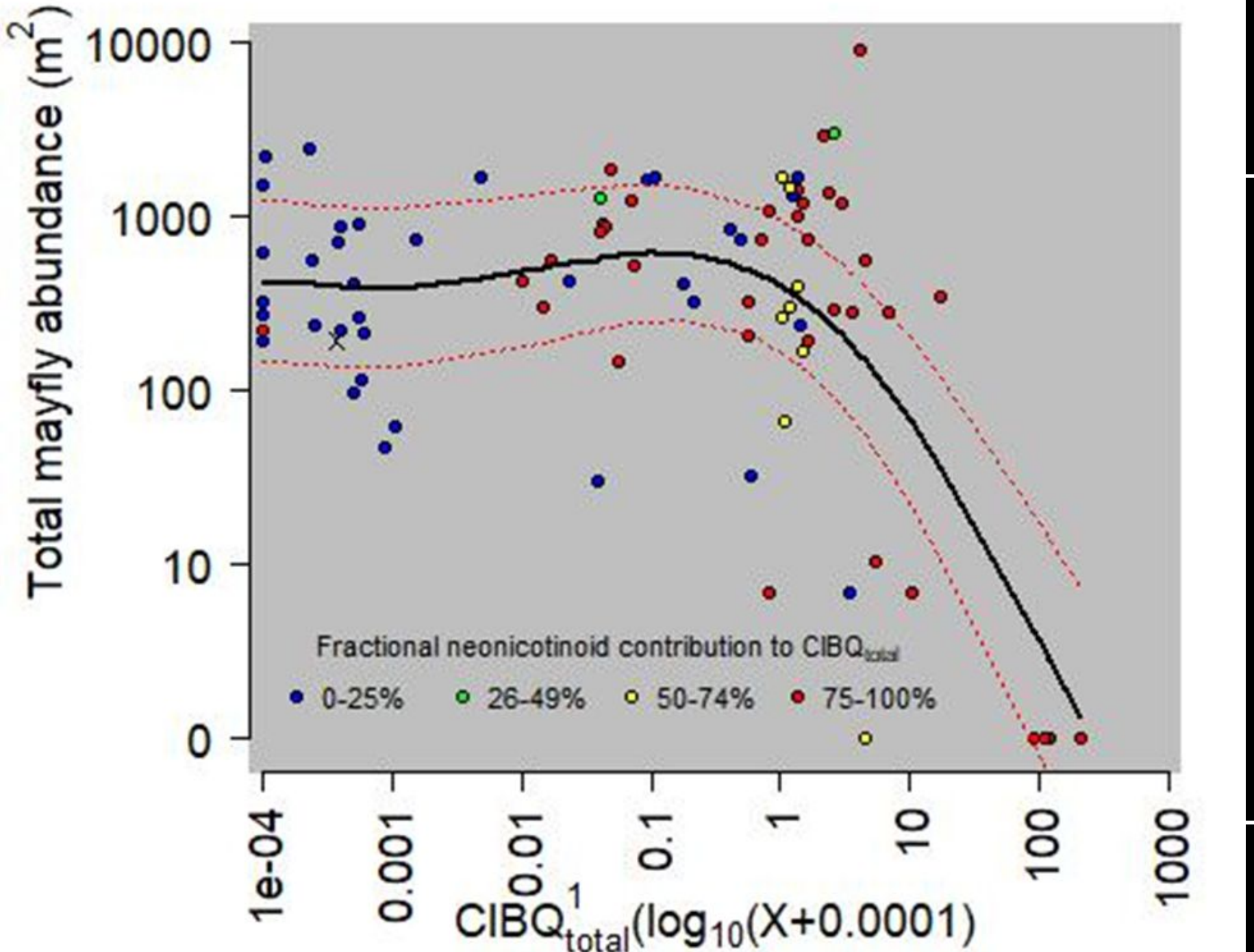

A
B
100%
75%
50%
25%
0%
Percent affected species
Planorbella pilsbryi
Gammarus pulex
Plea minutissima
Chaoborus obscuripes
Asellus aquaticus
Sialis lutaria
Ephemerella spp.
Neocloeon triangulifer
Chironomus riparius
Lepidostoma spp.
Rhithrogena spp.
Deleatidium spp.
Chironomus dilutus
Cloeon dipterum
Hyalella azteca
Caenis horaria
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
Imidacloprid (µg/L)
Brachycentrus occidentalis
Deleatidium spp.
Neocloeon triangulifer
Rhithrogena spp.
Lepidostoma spp.
Planorbella pilsbryi
Chironomus dilutus
Ephemerella spp.
Clothianidin (µg/L)
Taxa group
Bivalve
Insect
Crustacean
Source
This study
Other


Total mayfly abundance (m^2)
10000
1000
100
10
0
Fractional neonicotinoid contribution to $CIBQ_{total}$
0-25%
26-49%
50-74%
75-100%
1e-04
0.001
0.01
0.1
1
10
100
1000
$CIBQ^1_{total}(\log_{10}(X+0.0001)$

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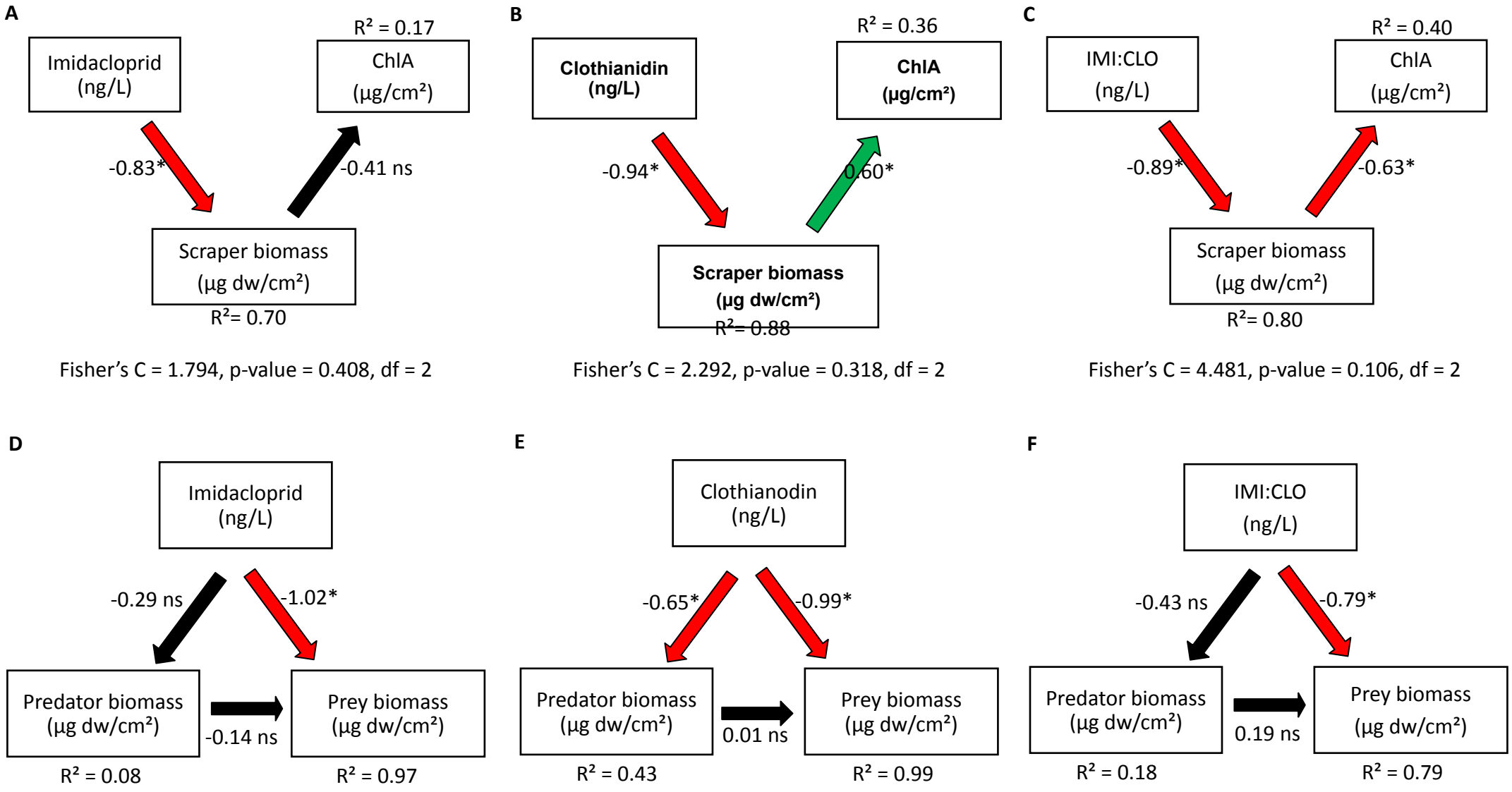
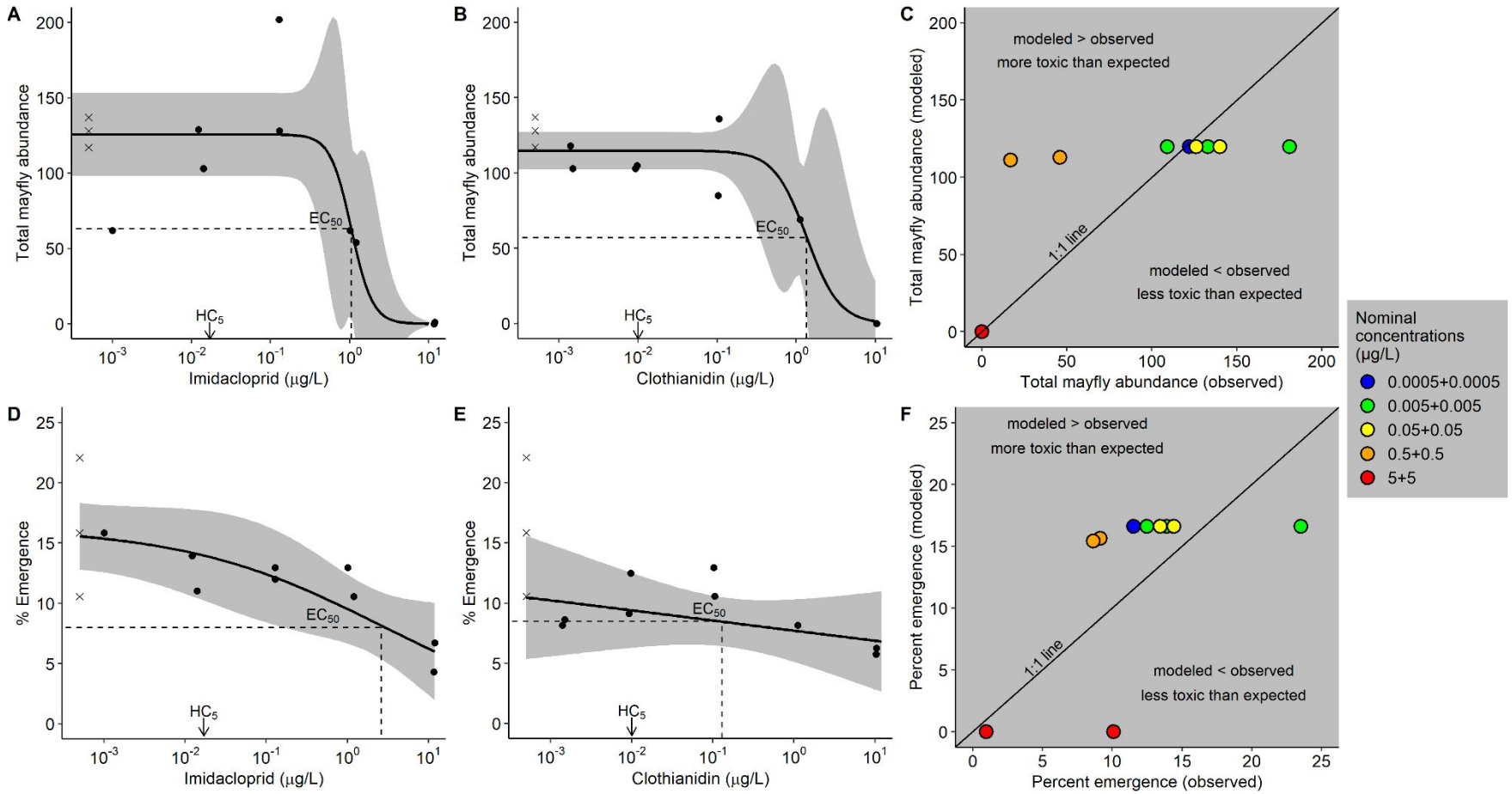

A
Imidacloprid (ng/L)
ChlA (µg/cm²)
R² = 0.17
-0.83*
-0.41 ns
Scraper biomass (µg dw/cm²)
R²= 0.70
Fisher's C = 1.794, p-value = 0.408, df = 2
B
Clothianidin (ng/L)
ChlA (µg/cm²)
R² = 0.36
-0.94*
0.60*
Scraper biomass (µg dw/cm²)
R²= 0.88
Fisher's C = 2.292, p-value = 0.318, df = 2
C
IMI:CLO (ng/L)
ChlA (µg/cm²)
R² = 0.40
-0.89*
-0.63*
Scraper biomass (µg dw/cm²)
R²= 0.80
Fisher's C = 4.481, p-value = 0.106, df = 2
D
Imidacloprid (ng/L)
-0.29 ns
-1.02*
Predator biomass (µg dw/cm²)
-0.14 ns
Prey biomass (µg dw/cm²)
R² = 0.08
R² = 0.97
E
Clothianodin (ng/L)
-0.65*
-0.99*
Predator biomass (µg dw/cm²)
0.01 ns
Prey biomass (µg dw/cm²)
R² = 0.43
R² = 0.99
F
IMI:CLO (ng/L)
-0.43 ns
-0.79*
Predator biomass (µg dw/cm²)
0.19 ns
Prey biomass (µg dw/cm²)
R² = 0.18
R² = 0.79


A
B
C
D
E
F
Total mayfly abundance
Imidacloprid (µg/L)
Clothianidin (µg/L)
EC50
HC5
Total mayfly abundance (modeled)
Total mayfly abundance (observed)
modeled > observed
more toxic than expected
modeled < observed
less toxic than expected
1:1 line
% Emergence
Percent emergence (modeled)
Percent emergence (observed)
Nominal concentrations (µg/L)
0.0005+0.0005
0.005+0.005
0.05+0.05
0.5+0.5
5+5