

Ecosystem structure and functional responses to pharmaceutical and personal care products in aquatic ecosystems



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Collaborators

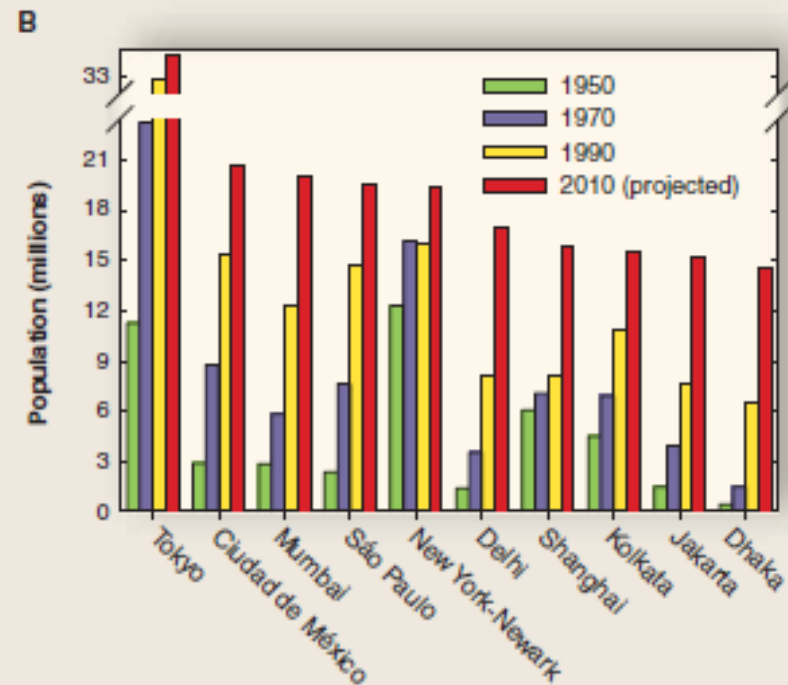
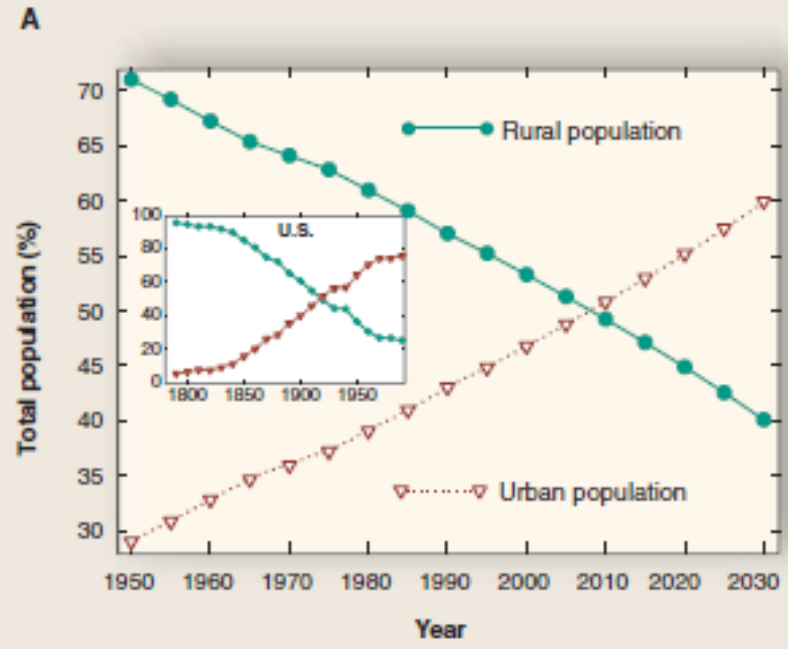
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Paul Hoppe, Daniel Snow

Funding Sources

Illinois Water Resources Association
Illinois Waste Management and Research
NSF- BES LTER

Currently there are more than 7 billion people on this planet

Most of these people live in urban areas



A typical urban stream

What you can't see

Antibiotics
Antihistamines
Antidepressants
Painkillers
Anticonvulsants
Antimicrobials
Hormones
Fragrances
Insect repellents
Sunscreen



No wastewater treatment plant upstream

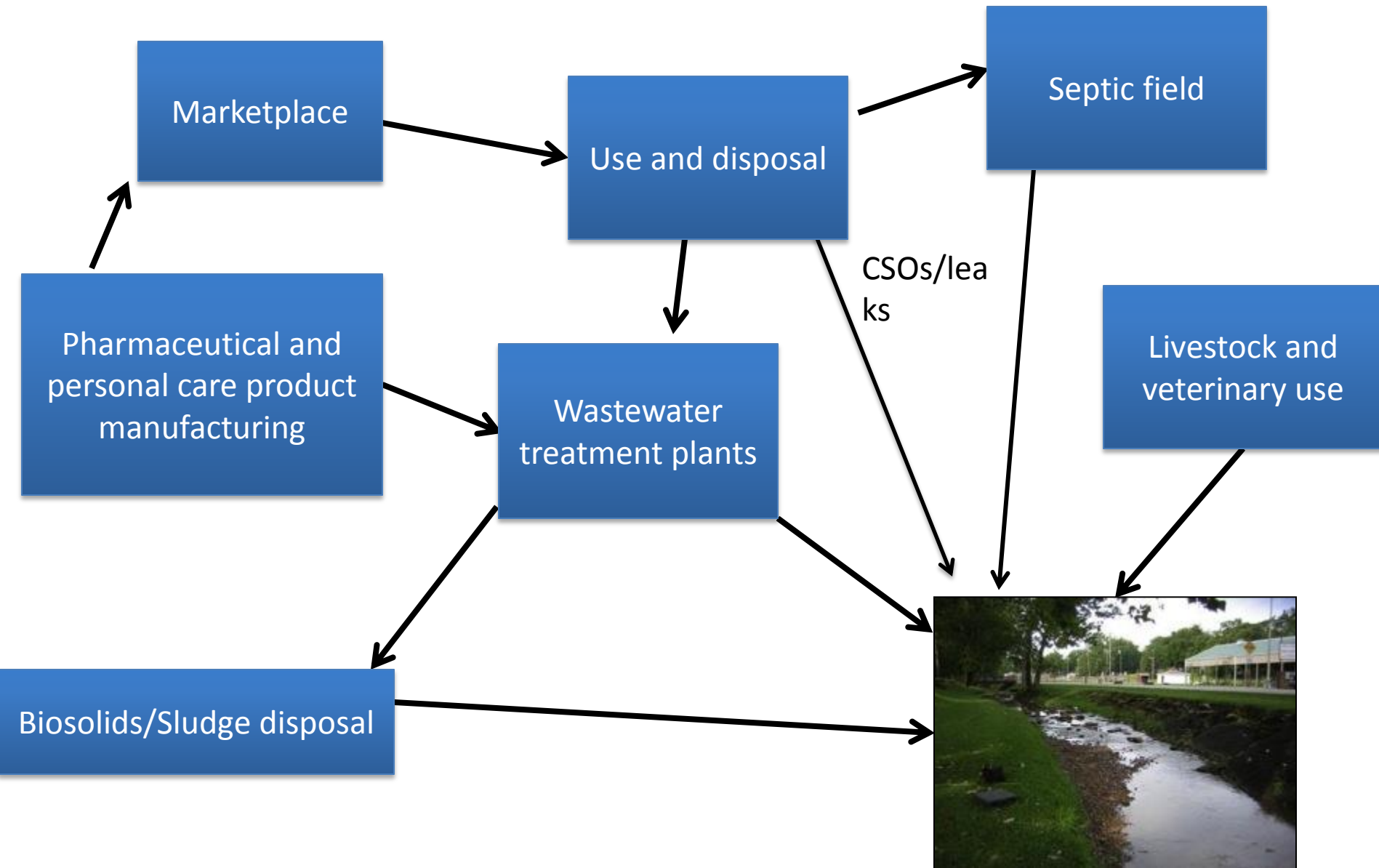
A rapidly growing global industry

Global pharma market is expected to expand to more than US \$1 trillion by 2014, driven largely by Pharmerging markets



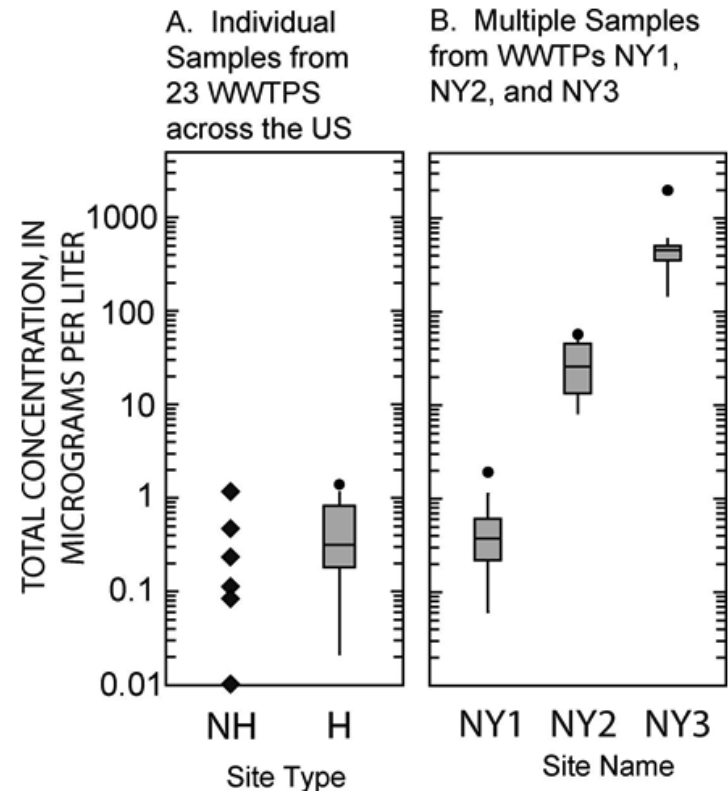
Source: IMS Health, Market Prognosis, Mar 2010. New Pharmerging definition

How do drugs get into aquatic ecosystems?



Your Pharmaceutical Footprint: Where do we get our drugs from?

Streams in New York that have pharmaceutical manufacturing facilities have much higher concentrations of PPCPs



Philips et al. 2010

Your Pharmaceutical Footprint: Where do we get our drugs from?



Ciprofloxacin
Concentration=
32 mg/L
Typical dose= 250-750
mg
From ~13% of a dose in
1 L of river water

(Larsson et al. 2007)

Pharmaceutical manufacturing
plants release waste into one
wastewater treatment plant

Global treatment of wastewater

- UN estimates that only 10% of the world's wastewater is treated
- Untreated sewage enter US surface waters via CSOs and leaking infrastructure
- 40% of global population resides in coastal areas and 80-90% of sewage discharge in coastal zones is raw and untreated
- Estimated 200 million farmers grow crops in human wastes (Report from IWMI) and the WHO estimates that 10% of the world relies on this source of food



Our rivers and lakes on drugs?

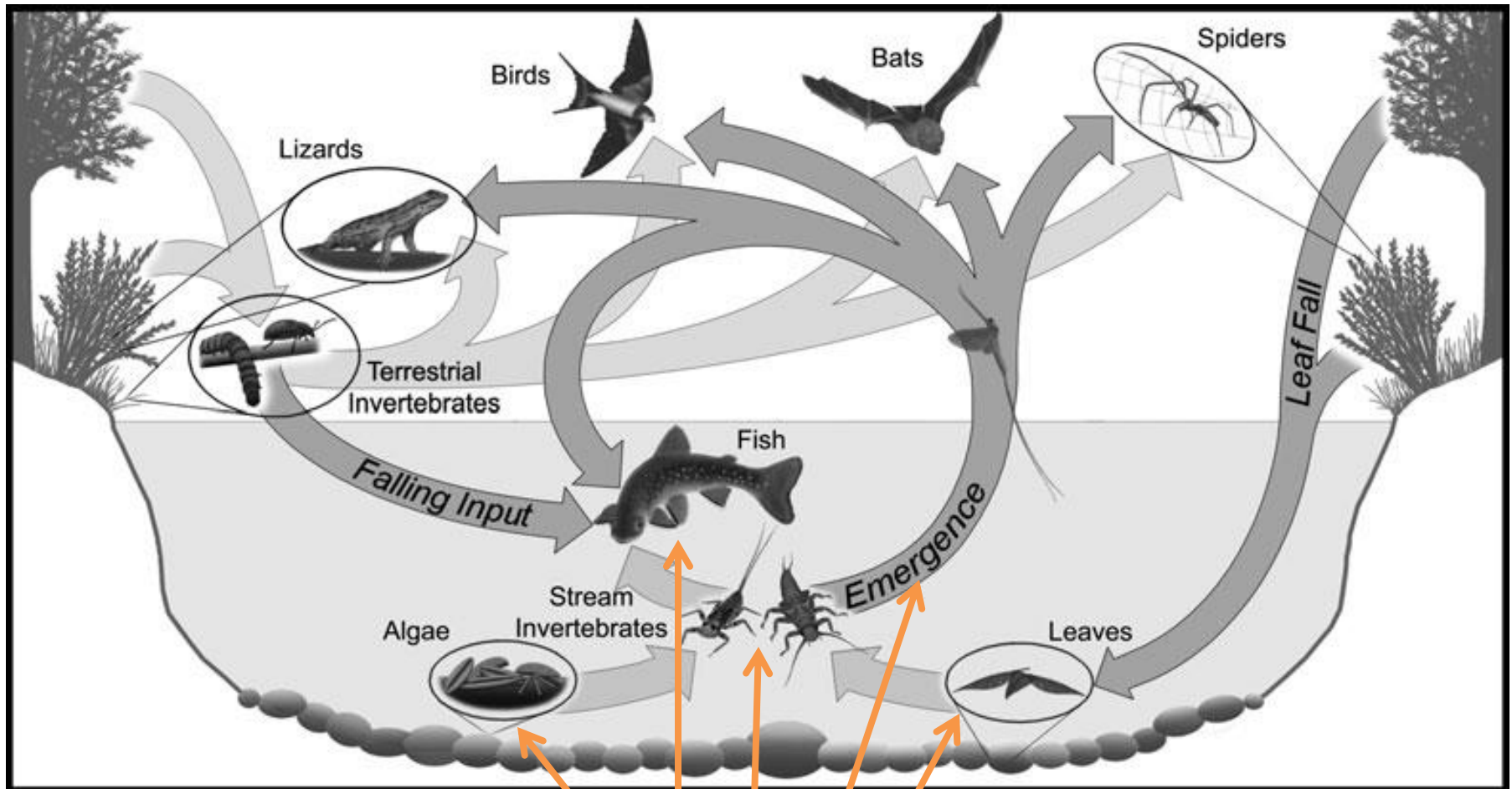
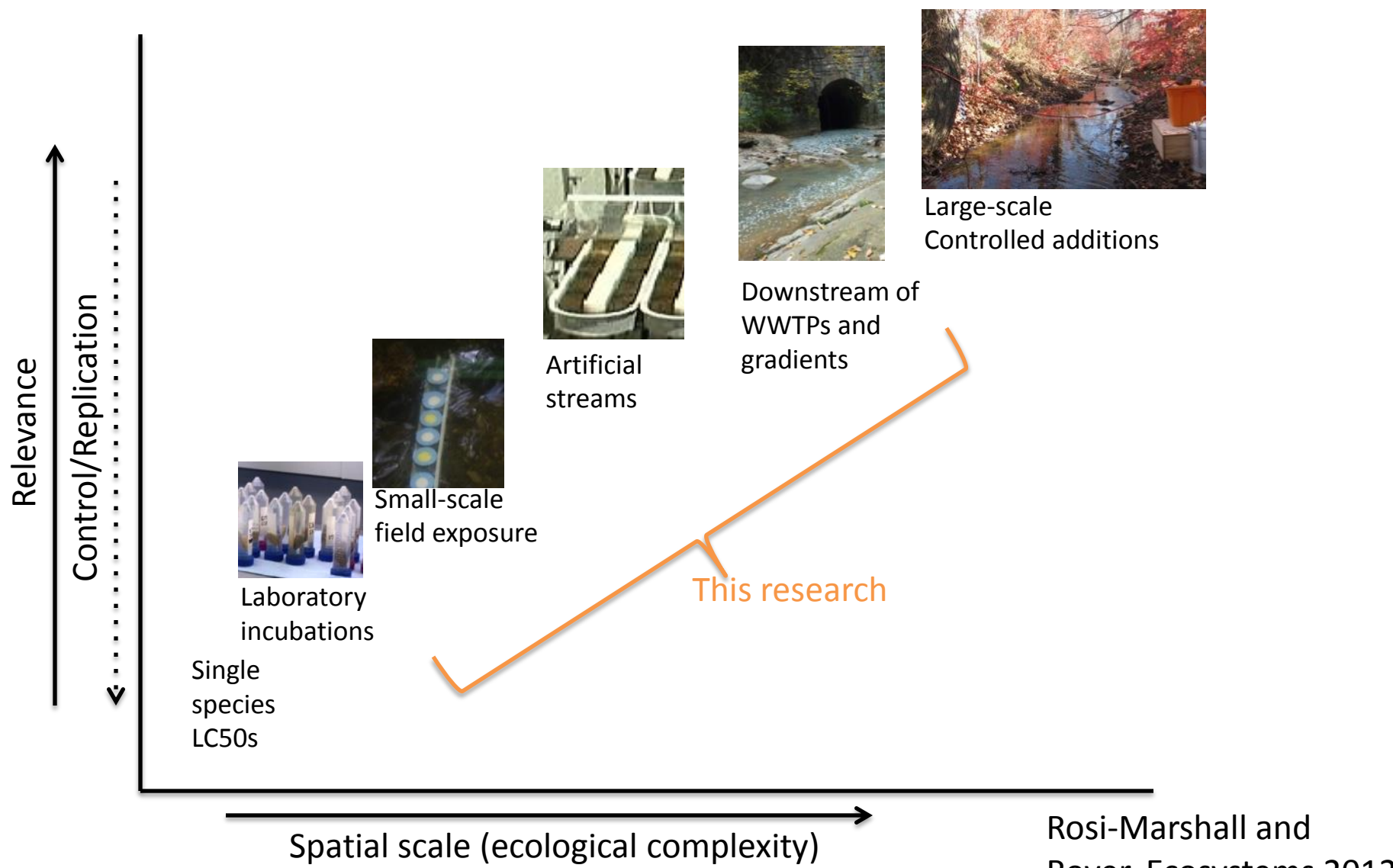


Image courtesy of C.V Baxter

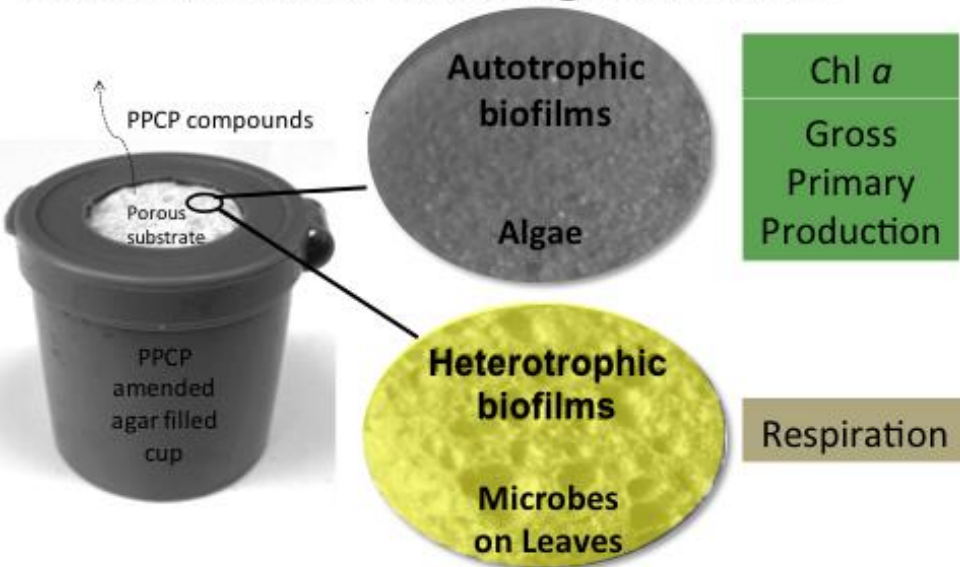
Pharmaceuticals and
personal care products

Measuring effects of drugs on streams using multiple scales of inquiry: from bottles to ecosystems



Small-scale field exposure: New method

Pharmaceutical diffusing substrates



Compound	Medical Use
Caffeine	Stimulant
Cimetidine	Antihistamine (heartburn)
Ciprofloxacin	Antibiotic
Diphenhydramine	Antihistamine (allergens)
Metformin	Antidiabetic
Ranitidine	Antihistamine (heartburn)

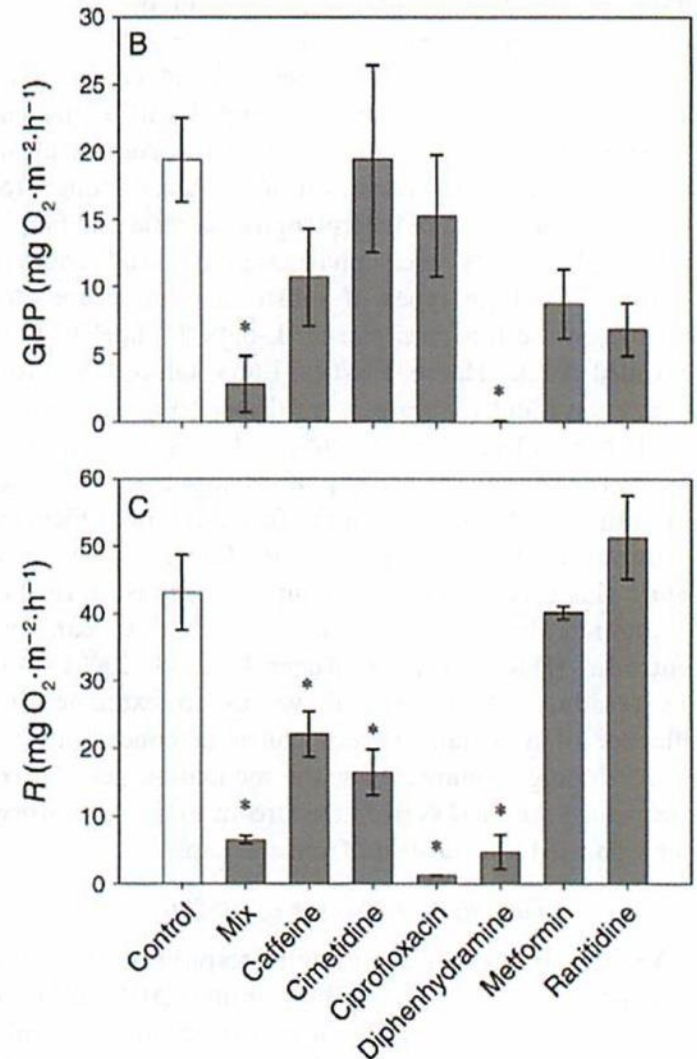
Pharmaceuticals can influence ecosystem function

The responses vary by compound.

82% reduction in algal biomass by the Mix treatment.

Algal activity (GPP) was significantly suppressed by diphenhydramine (99% reduction) and Mix (86% reduction)

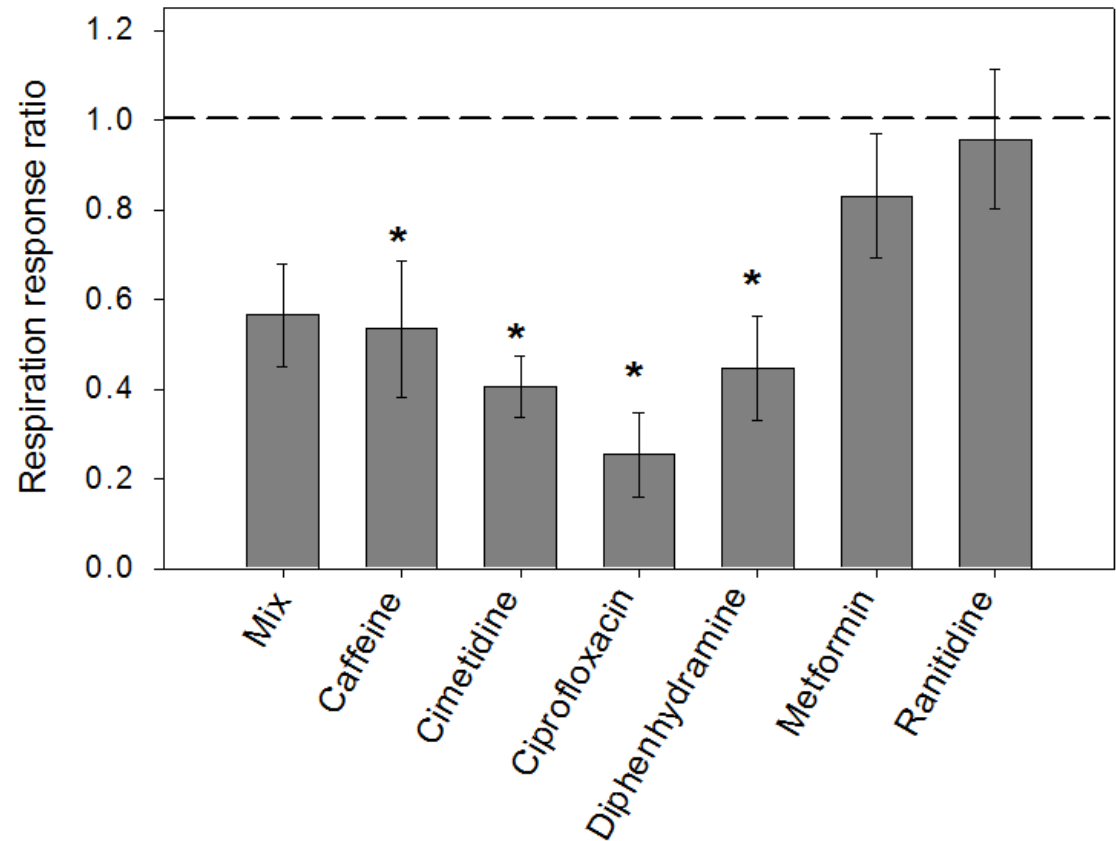
Respiration was significantly reduced by Cipro (97%), Diphenhydramine (89%), Caffeine (49%) Cimetidine (62%) and Mix (85%)



Consistent responses among seasons and streams

3 seasons in NY
1 season in IN
1 season in MD

Respiration of
heterotrophic biofilms



Diphenhydramine can influence bacterial community structure

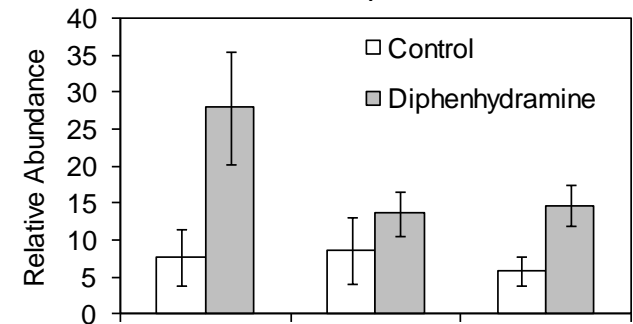


SIMPER Analysis of 16S rRNA tag pyrosequencing data sets for the control and diphenhydramine treatments from each site. OTU 4, OTU 1, and OTU 25 accounted for 14.33%, 12.25% and 3.43% of the variation between the control and diphenhydramine treatments.

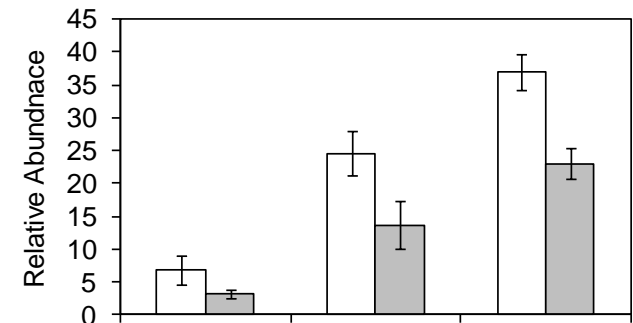
Increase in a bacterial species known to degrade organic contaminants

Decrease in bacterial species known to rely of algal C

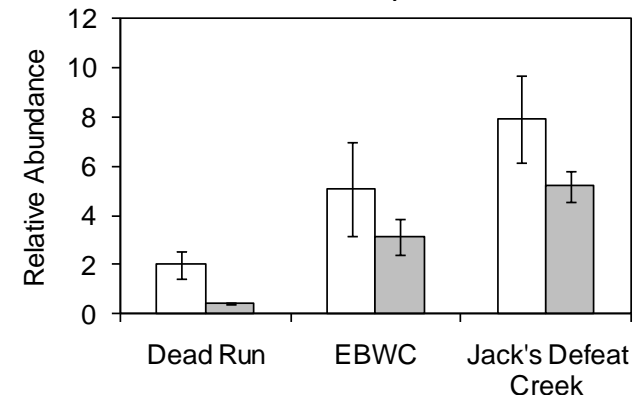
Pseudomonas sp.



Flavobacterium sp.



Flavobacterium sp.



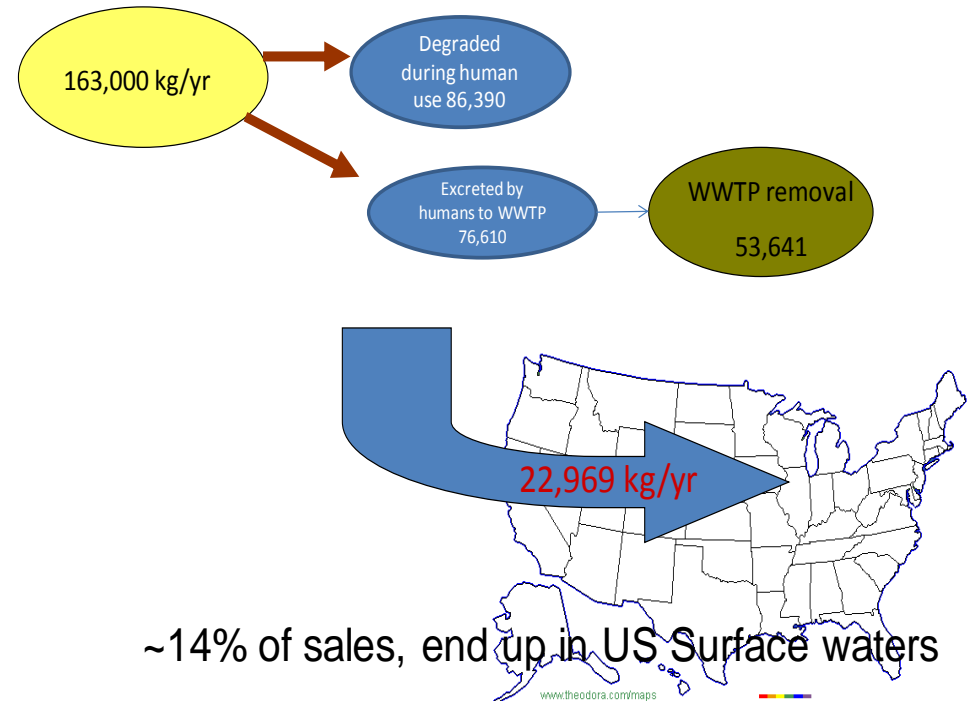
Artificial streams



- Increases scale, duration of experiments, and ecological complexity
- Allows for examination of various endpoints and organisms

Effects of a PPCP on aquatic invertebrates

- Tagamet® - H₂ histamine antagonist that prevents secretion of stomach acid
- Cimetidine was approved by the FDA in 1977 and was the first drug ever to reach more than 1 billion dollars a year in sales.
- Histamine activates photoreceptors, olfactory receptors, and stomatogastric neurons (which control the motion of gut and foregut) in invertebrates
- These activities can be blocked by administration of antihistamines (Claiborne and Selverston 1984, Hardie 1988, Wachowiak 2002, Christie et al. 2004).



(Anderson et al. 2004)

Effects of a PPCP on an aquatic invertebrate

Long-term chronic exposure to 4 concentrations of cimetidine

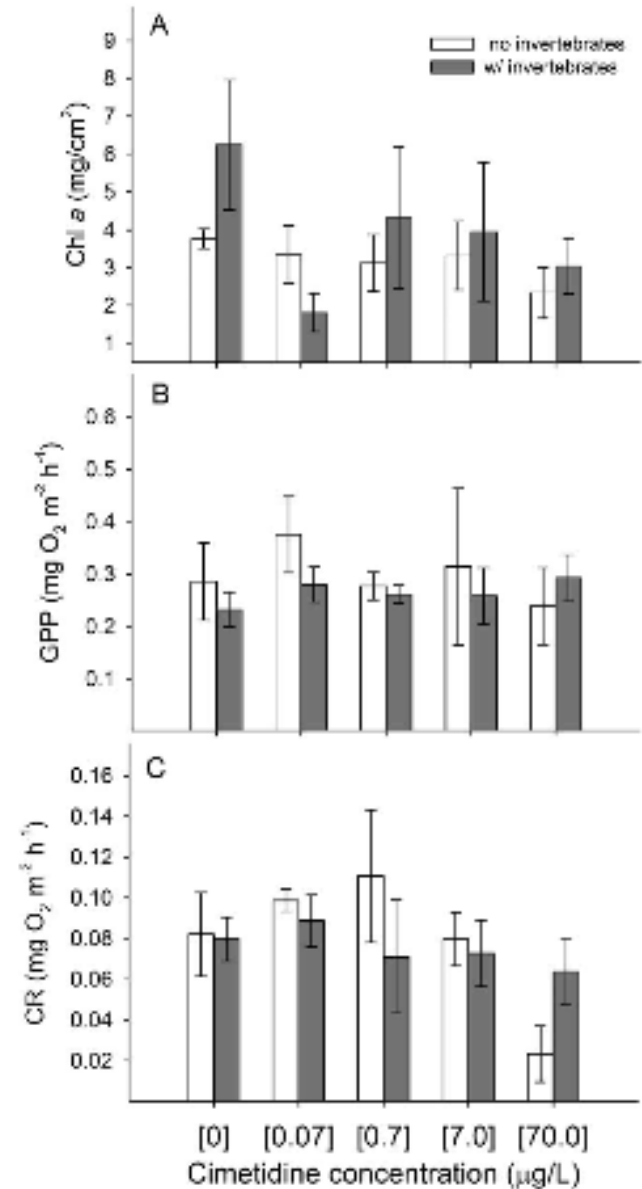
Added cimetidine for 82 days to 32 streams.

No detectable effects on basal resources (algae and bacteria)

Artificial Streams at Loyola Univ. Chicago



Hoppe, Rosi-Marshall and Bechtold, 2012, Freshwater Science



Effects of a PPCP on aquatic invertebrates

Long-term chronic exposure to 4 concentrations of cimetidine

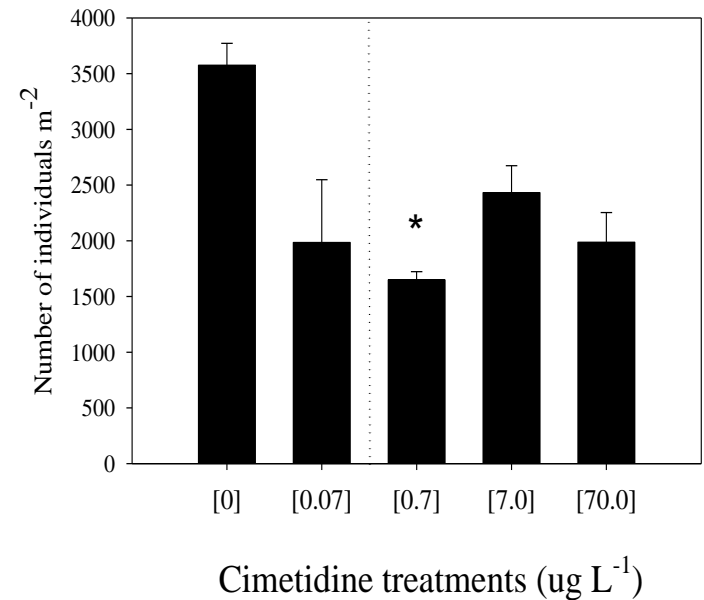
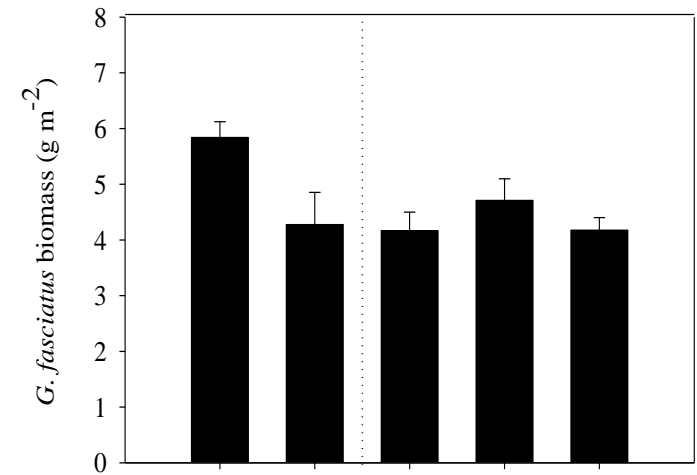
Had reproducing populations of invertebrates in streams

Significant reduction in population growth and growth at concentrations of cimetidine observed in streams

Artificial Streams at Loyola Univ. Chicago



Hoppe, Rosi-Marshall and Bechtold, 2012, Freshwater Science



Effects of triclosan on riverine microbial communities

Triclosan: a generalized antimicrobial (bacteria, fungi and algae)

- Patented in 1966
- Nearly half of soaps in US contain triclosan
- Triclosan has been detected in surface waters, sediments, fishes, dolphins, human urine and breastmilk

What are the effects of triclosan on ecosystem structure and function?

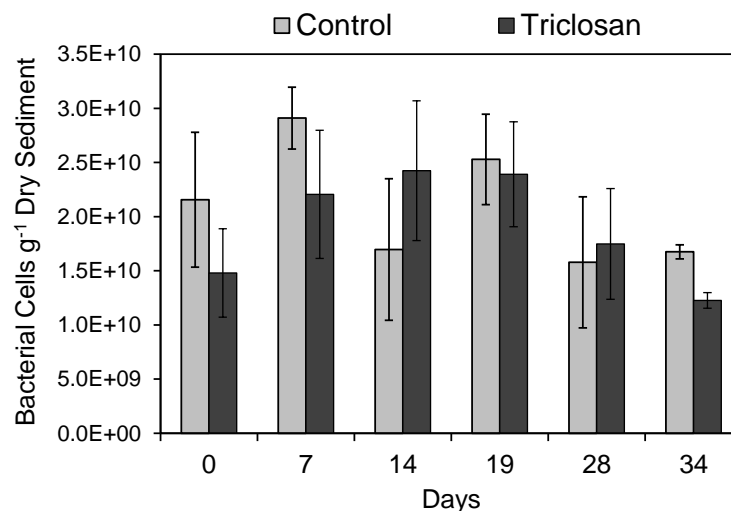


Image from Drury et al. 2013. ES&T

Effects of triclosan on riverine microbial communities

Added triclosan in realistic concentrations to streams with active algal and bacterial communities

- Initial decline in bacterial cells, with recovery after 7 days



Artificial Streams at Loyola Univ. Chicago



ENVIRONMENTAL
Science & Technology

Article

pubs.acs.org/est

Triclosan Exposure Increases Triclosan Resistance and Influences Taxonomic Composition of Benthic Bacterial Communities

Bradley Drury,[†] John Scott,[‡] Emma J. Rosi-Marshall,[§] and John J. Kelly^{†,*}

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Effects of triclosan on riverine microbial communities

Increase bacterial resistance over time

This was evident after only 7 days and continued to increase until day 34

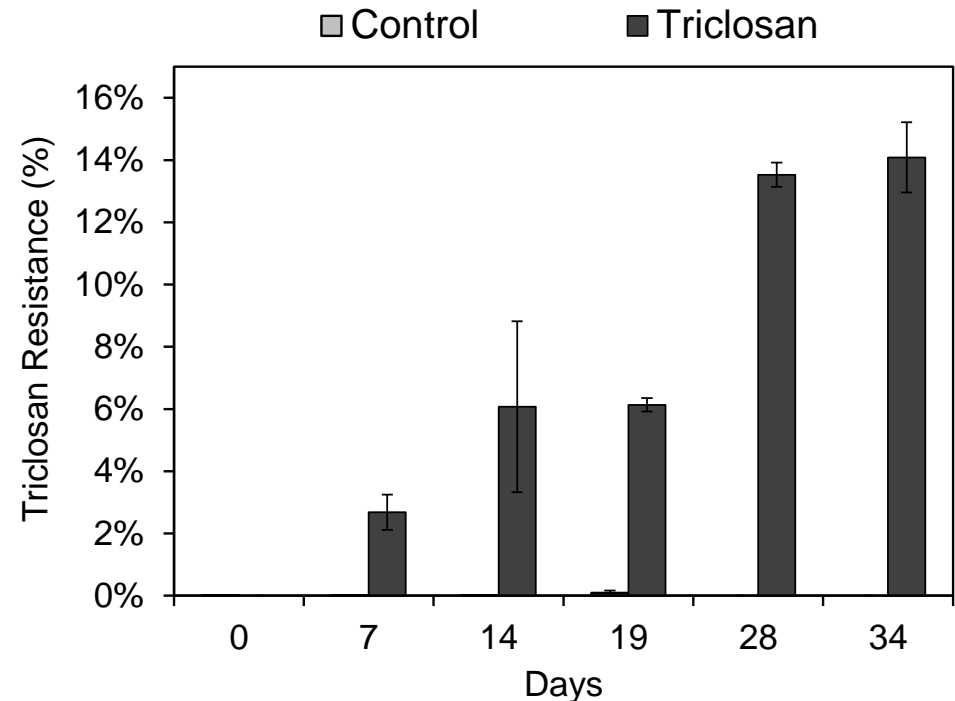
Examined the composition of bacterial communities with 16S rRNA tag pyrosequencing analysis

Significant change in the bacterial communities in response to triclosan additions

Artificial Streams at Loyola Univ. Chicago



Drury et al. 2013.



“Natural” environmental releases: point sources

- Take advantage of release of PPCPs in the environment
- WWTPs, combined sewer overflows, sludge applications, artificial treatment wetlands, etc.

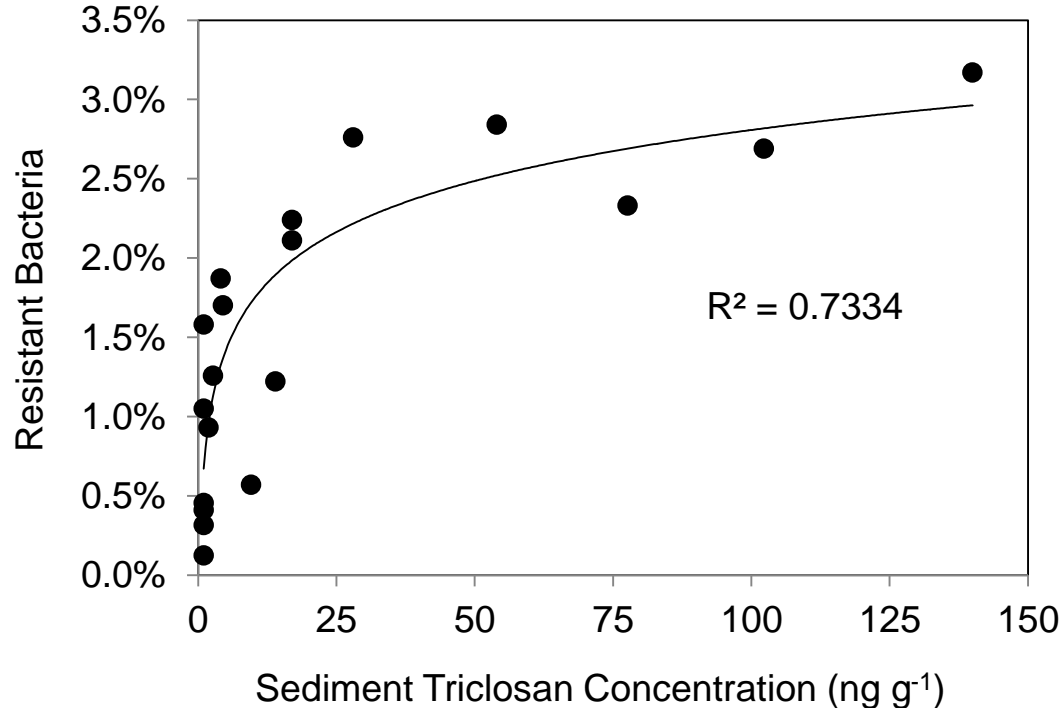
Influence of wastewater effluent and triclosan on bacterial communities

- Conducted research in Chicago, IL
- Examined the microbial communities and function downstream of two wastewater treatment plants



“Natural” environmental releases: point sources

- Measured triclosan, triclosan resistance, and bacterial composition

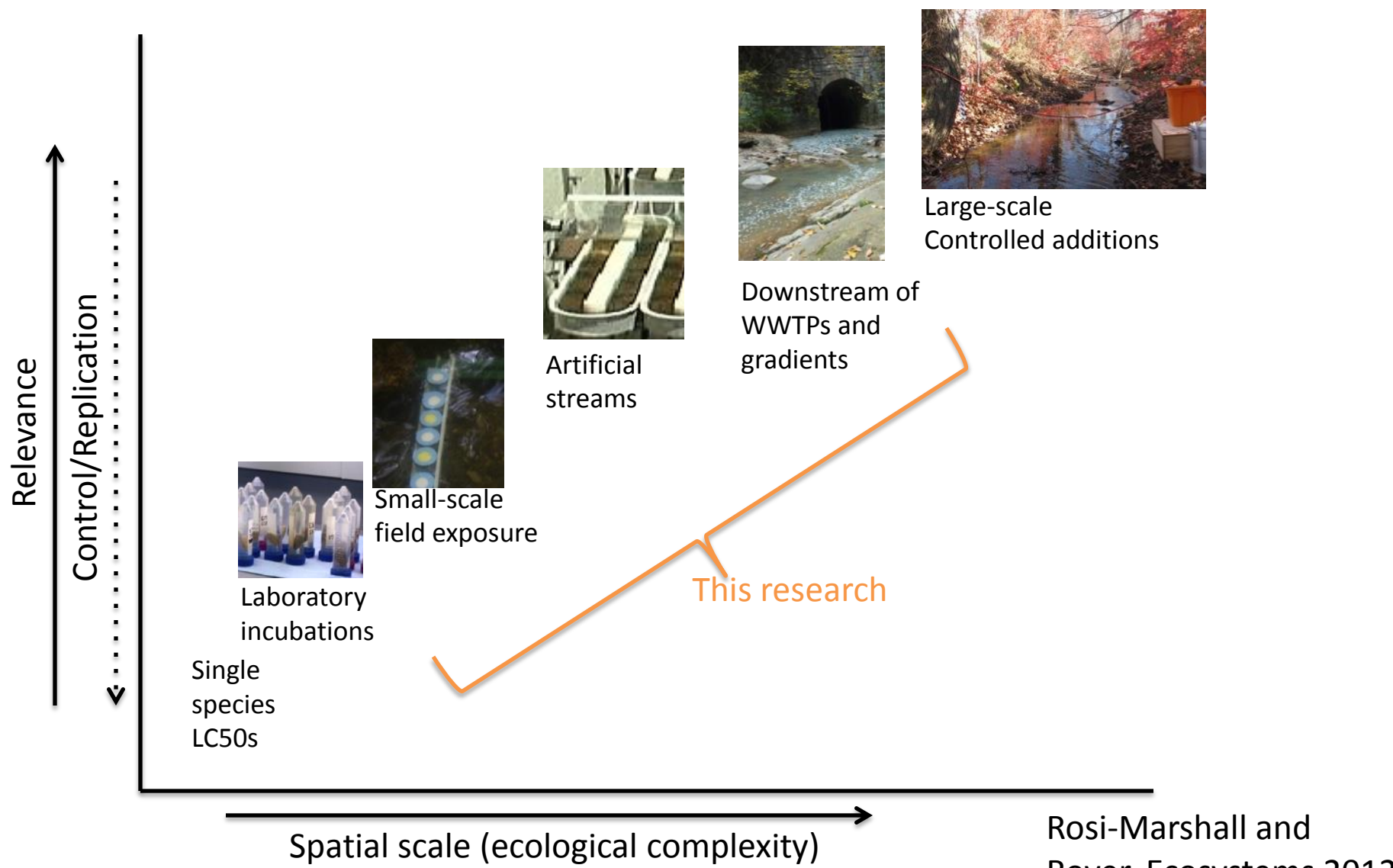


Triclosan concentrations in sediments correlated with resistant bacteria

Composition shifted in the field and some shifts were similar to shifts seen in artificial stream experiment

However, in another study we found that sewage discharges homogenize bacterial species composition (Drury et al. 2013 AEM)

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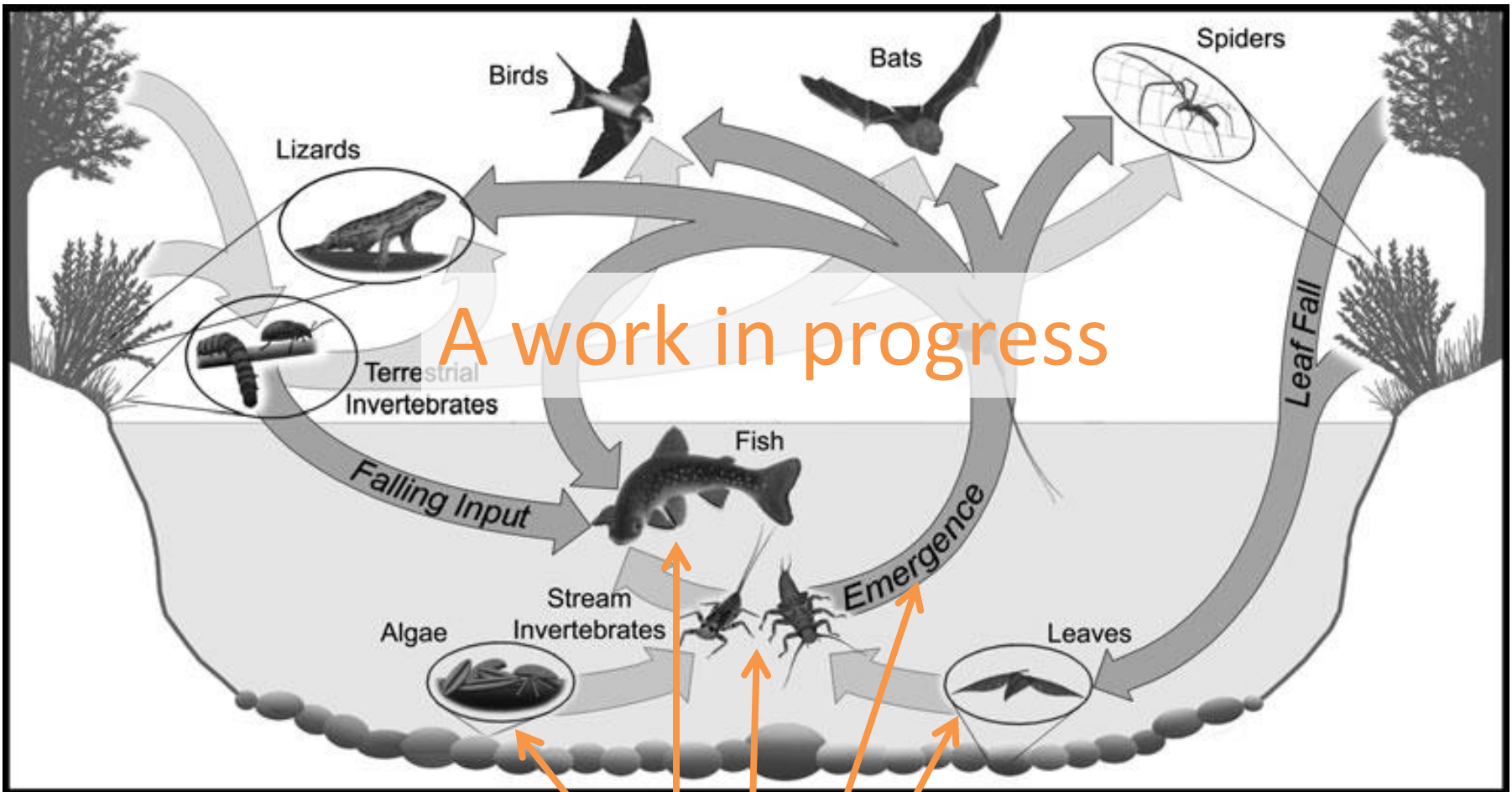


Image courtesy of C.V Baxter

Pharmaceuticals and
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