The Missing Link: Biological Transport of Hg Between the South River and the Floodplain

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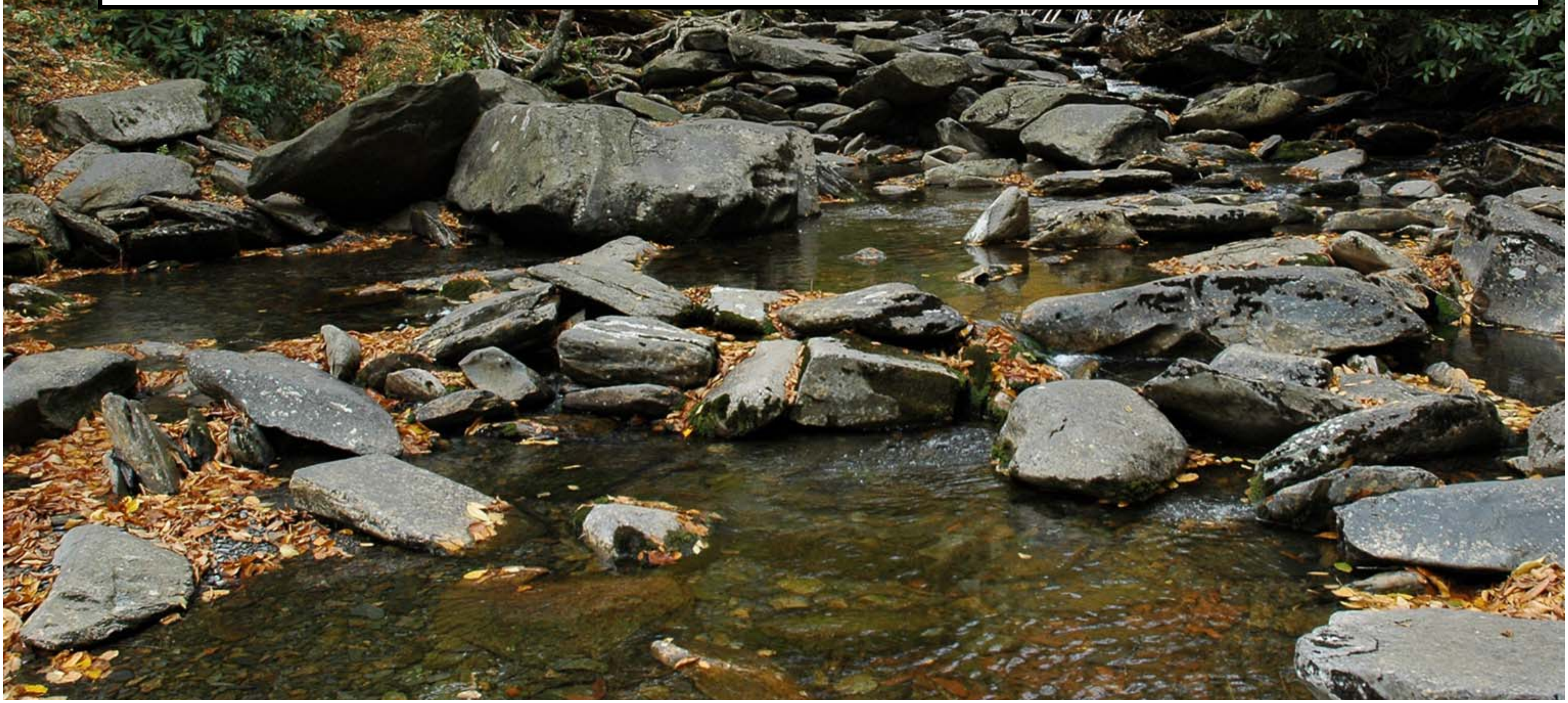
Outline

I. How do biota connect aquatic and terrestrial habitats?
   a) Classic Examples of Subsidies (Turtles and Terrestrial Inverts)
   b) Complex life cycles (Amphibians and Aquatic inverts)
   c) “The Dark Side of Subsidies” (PCB and Hg examples)

II. What do we know about Hg transport by biota in the South River?



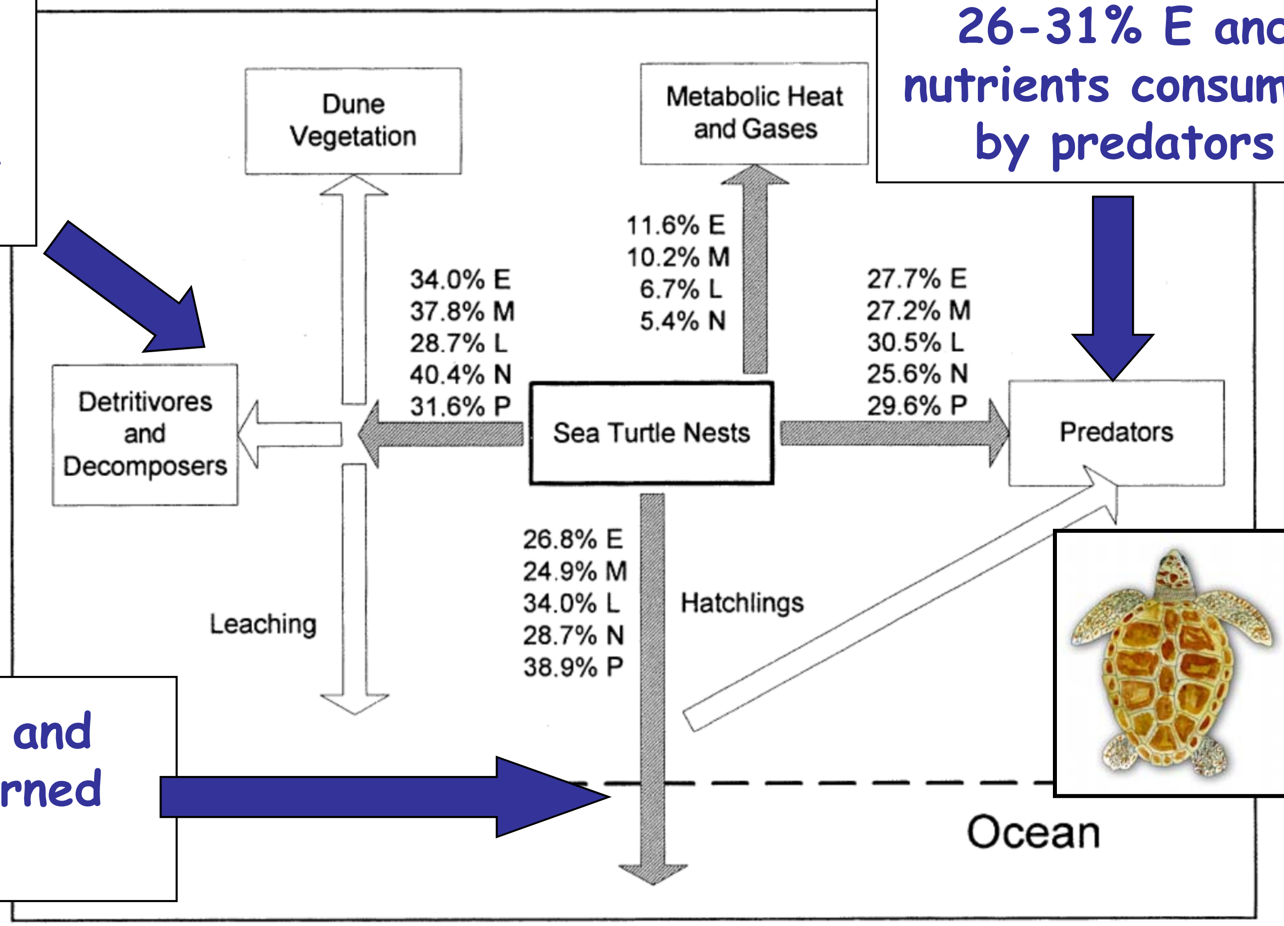
Energy & Nutrient Transport

Loggerhead sea turtles (*Caretta caretta*)

29-40% was available to detritivores, decomposers, and plants

26-31% E and nutrients consumed by predators

E = energy
M = organic matter
L = lipids
N = nitrogen
P = phosphorous



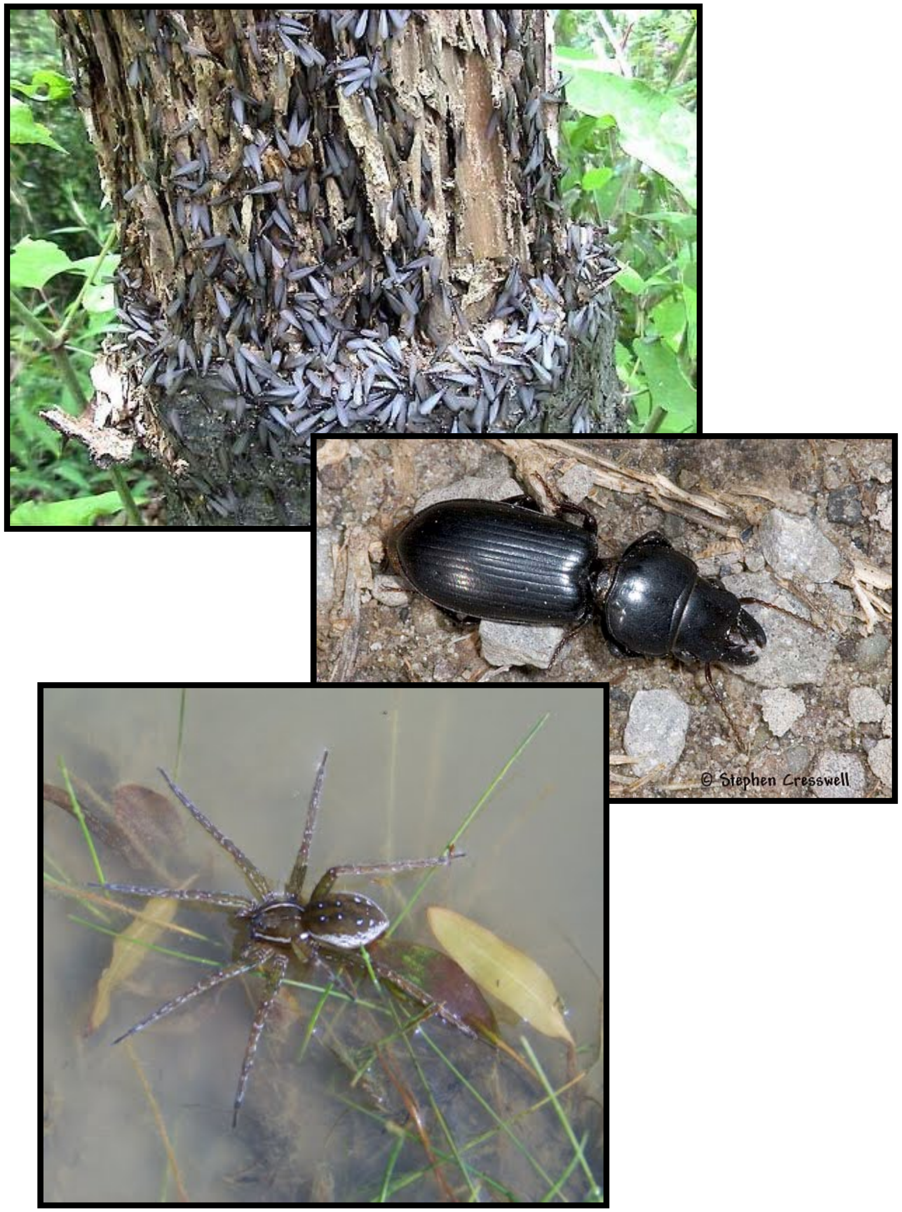
25-39% of E and nutrients returned to ocean

FIG. 1. Movement of nutrients and energy introduced into nests at Melbourne Beach, Florida, by loggerhead sea turtles. Values are percentages of energy (E) and each nutrient (M = organic matter, L = lipids, N = nitrogen, and P = phosphorus) that followed each pathway. Shaded arrows indicate pathways for which values have been determined. Open arrows indicate pathways for which the quantities of nutrients and energy have not been estimated.

Bouchard & Bjorndal, 2000. Ecology

Predators/Scavengers "Luv Them Some" Turtles

Terrestrial Insects Subsidize Streams



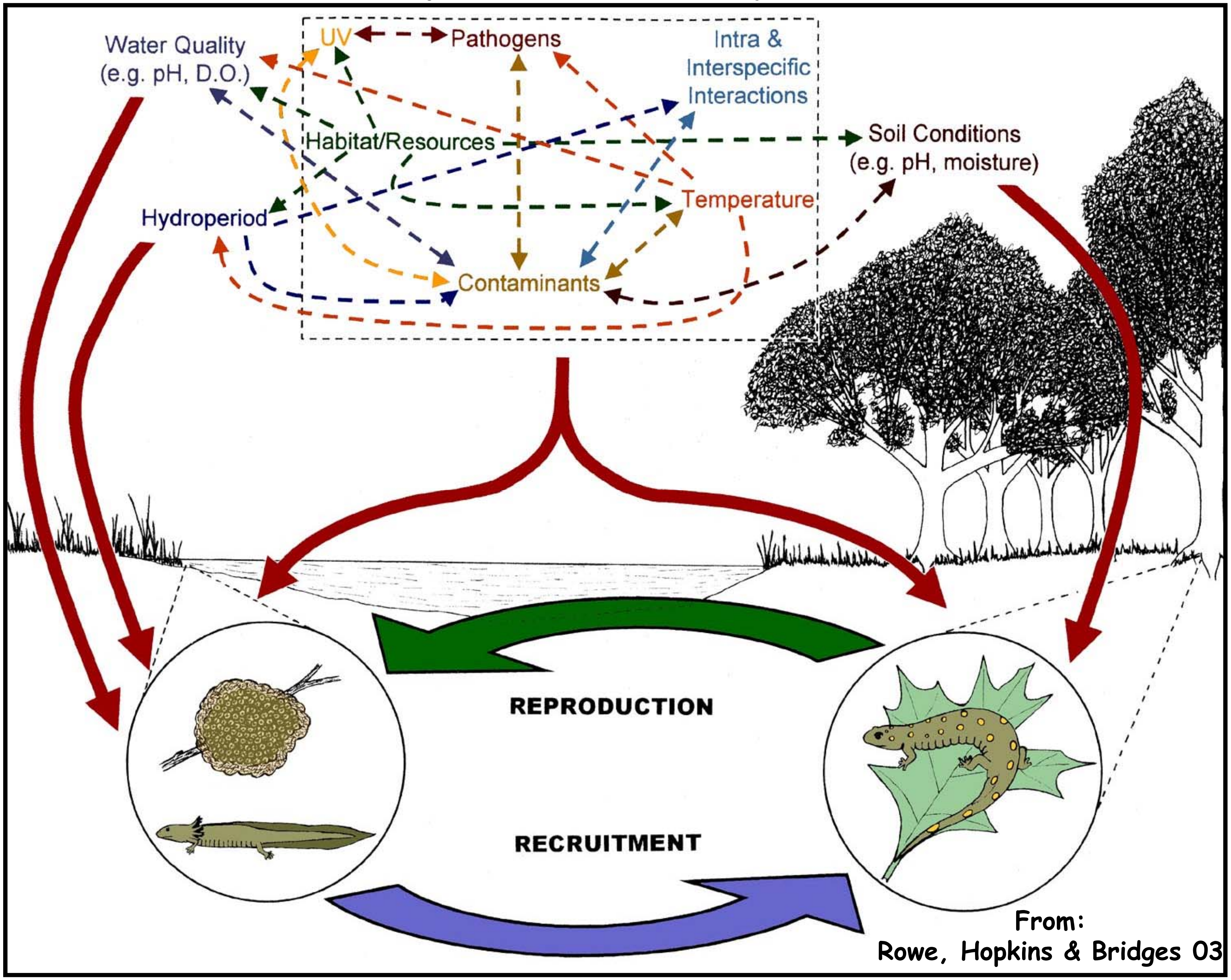
Incredible biomass to streams:
<u>In headwaters</u>
Terrestrial input = benthic production_

<u>James River Drainage</u>
Summer inputs AVG = 111 ind/m^2/d

Terrestrials can account
for 50-100% of fish diet

Even when only a minor % (10-15%)
of available prey, terrestrials can
account for >33% of fish diet

Complex Lifecycles

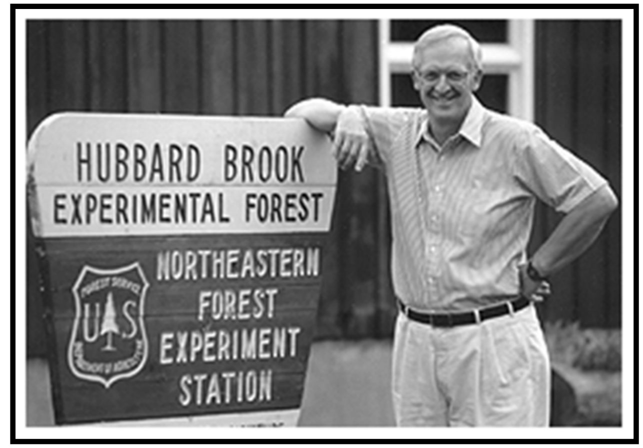


From:
Rowe, Hopkins & Bridges 03

High conversion efficiencies permit high biomass

<u>Hubbard Brook (New Hampshire, 1970s)</u>

- 5 salamander species (*P. cinereus* = 90%)
- biomass = 1.17 kg/ha
- 2.6x biomass of all birds (breeding season)
- equal to small mammals (shrews and mice)
- salamanders higher in protein (57%) than birds and mammals (20-31%)



High conversion efficiencies permit high biomass

More recent estimates of biomass are much higher…

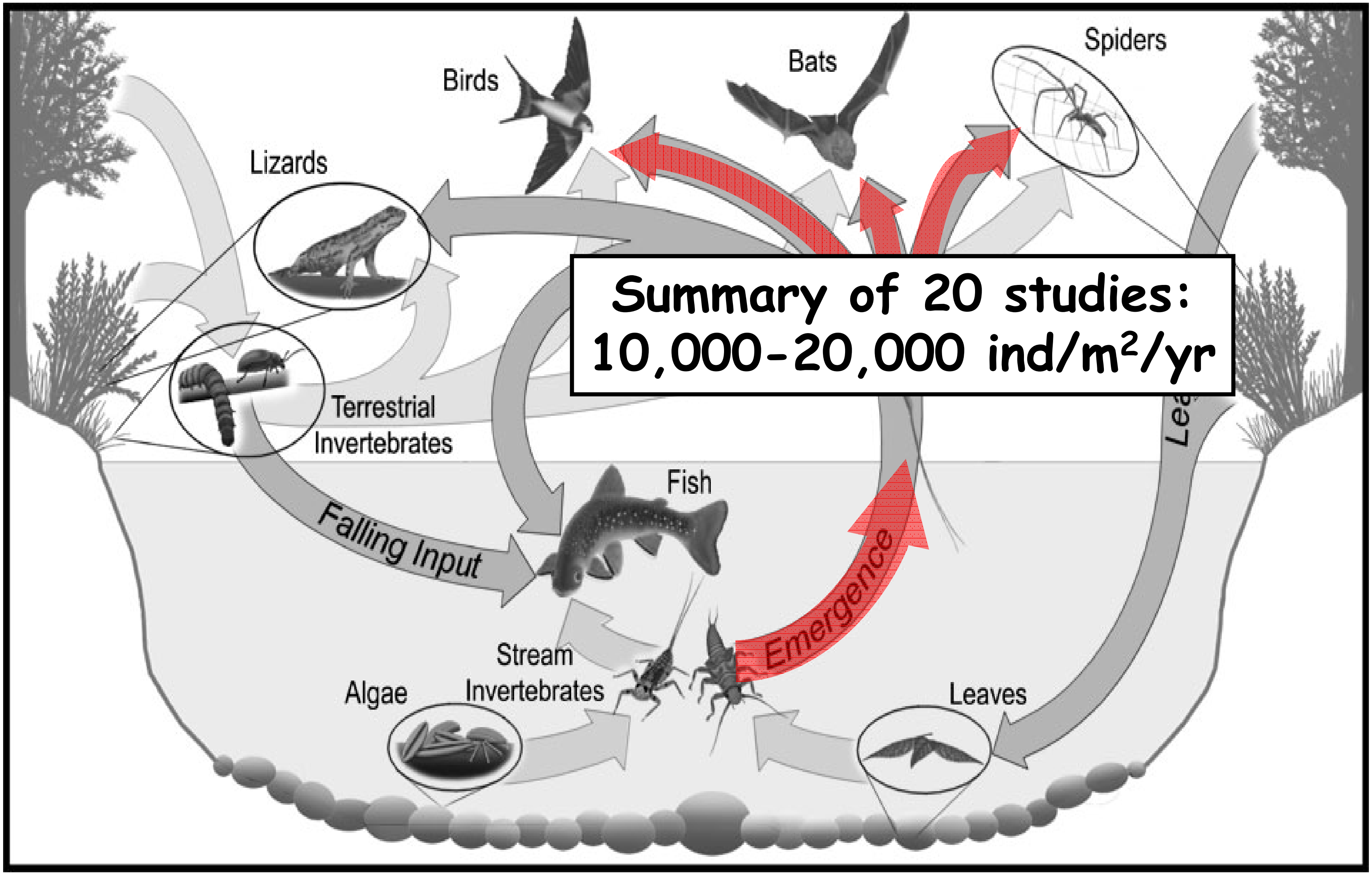
<u>Mountain streamside community (2001)</u>
9 salamander species
(*D. carolinensis* and *D. wrighti* = 77%)
biomass = 16.53 kg/ha
14x greater than Burton and Likens

<u>Ephemeral wetland (South Carolina, 2006)</u>
17 anuran and 7 salamander species
96% of biomass from *R. sphenocephala*
Biomass (total for year) = 159 kg/ha

Amphibians are and important nutrient linkage between aquatic and terrestrial environments

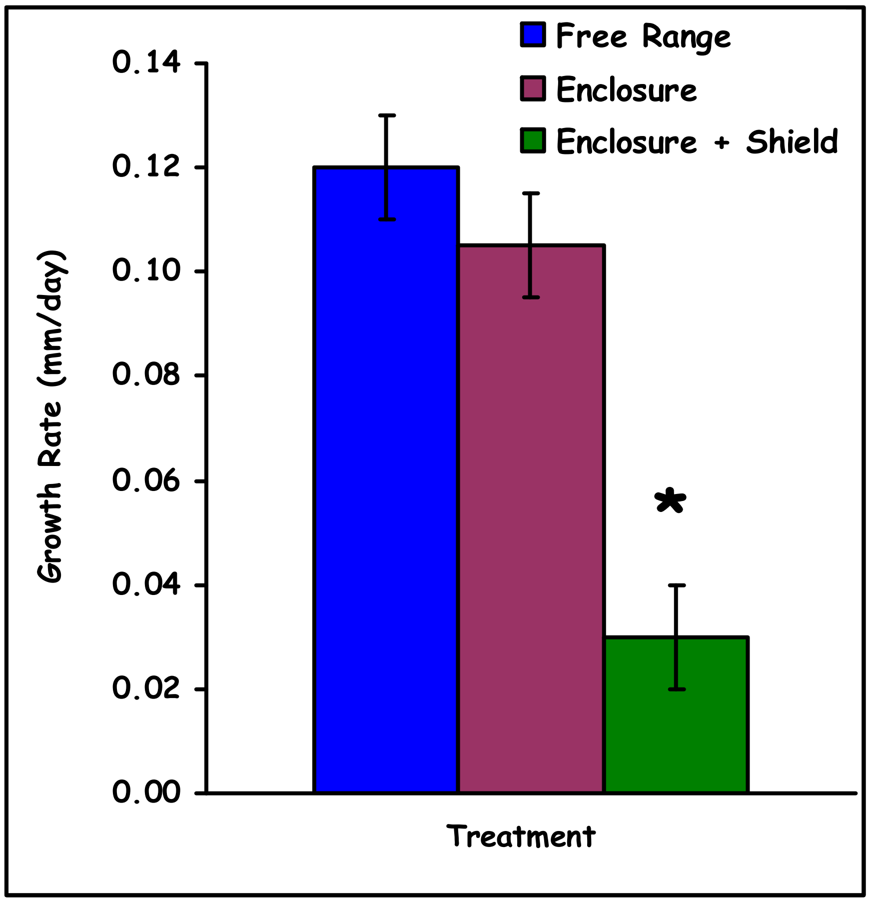
(Brodie 1977; Petranka 1998)

Reciprocal flows of insects link streams and riparian zones



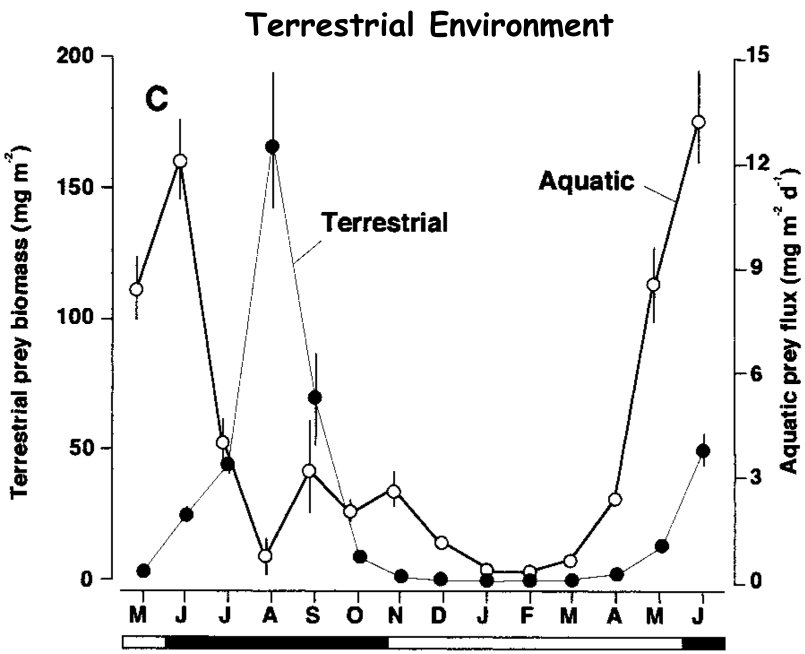
Baxter et al. 2005. *Freshwater Biology*

Effects of aquatic insects on terrestrial predators



Sabo and Power 2002, Ecology

Many Species are Reliant Upon Subsidies



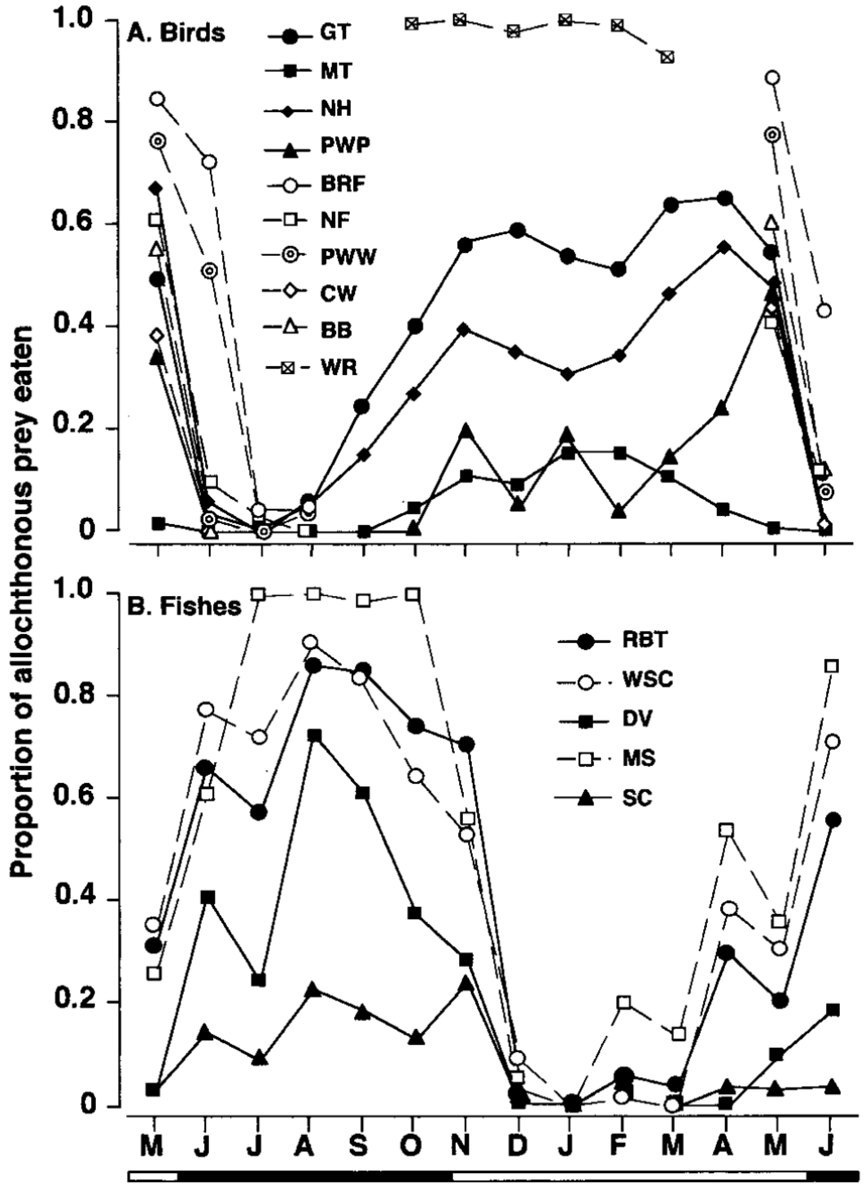
Nakano & Murakami 2001, PNAS

Many Species are Reliant Upon Subsidies

7,200 birds (10 species)
1,409 fish (5 species)

Aquatics account for 26% of annual E budget of bird community

Terrestrials account for 44% of annual E budget of fish community



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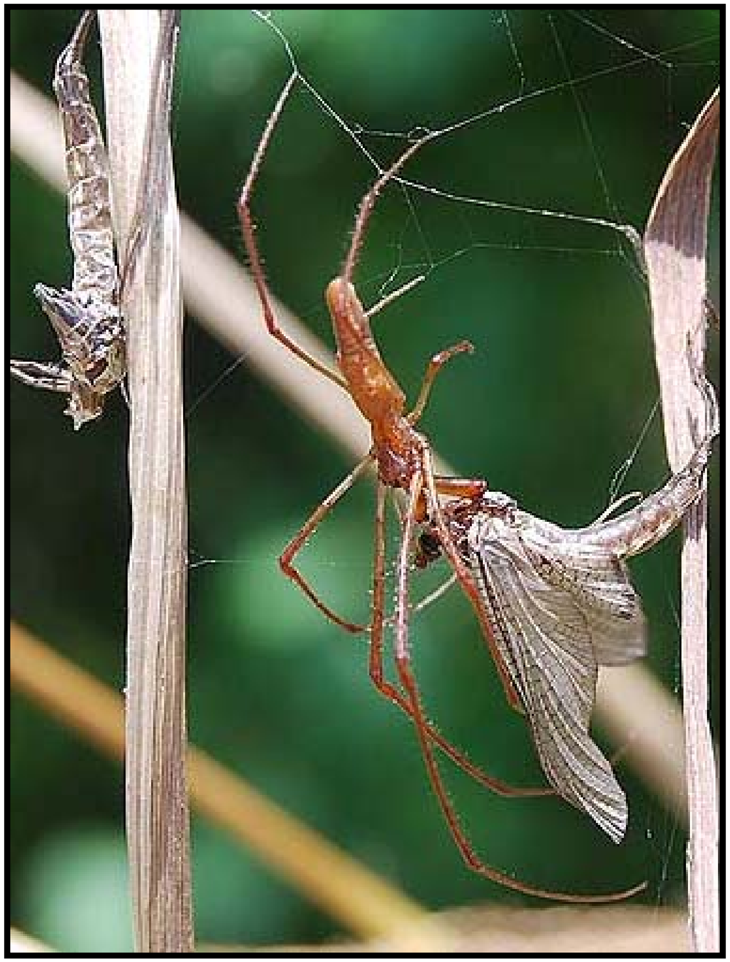
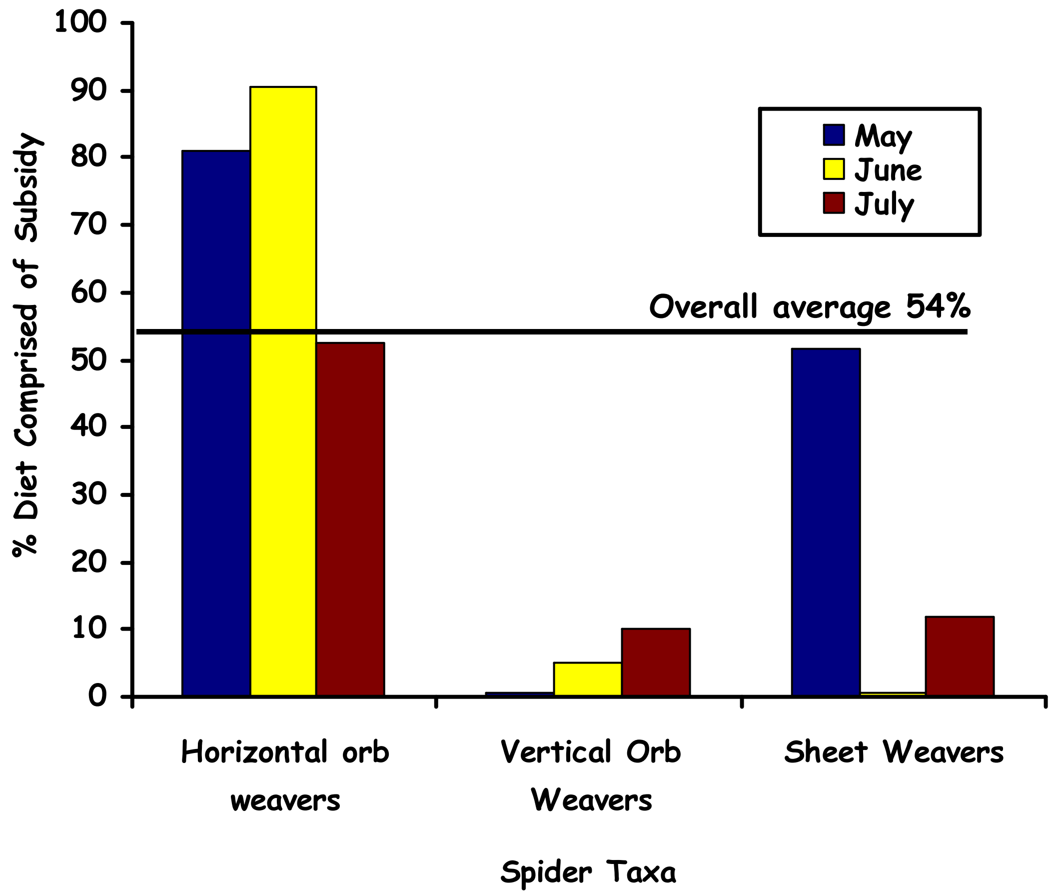
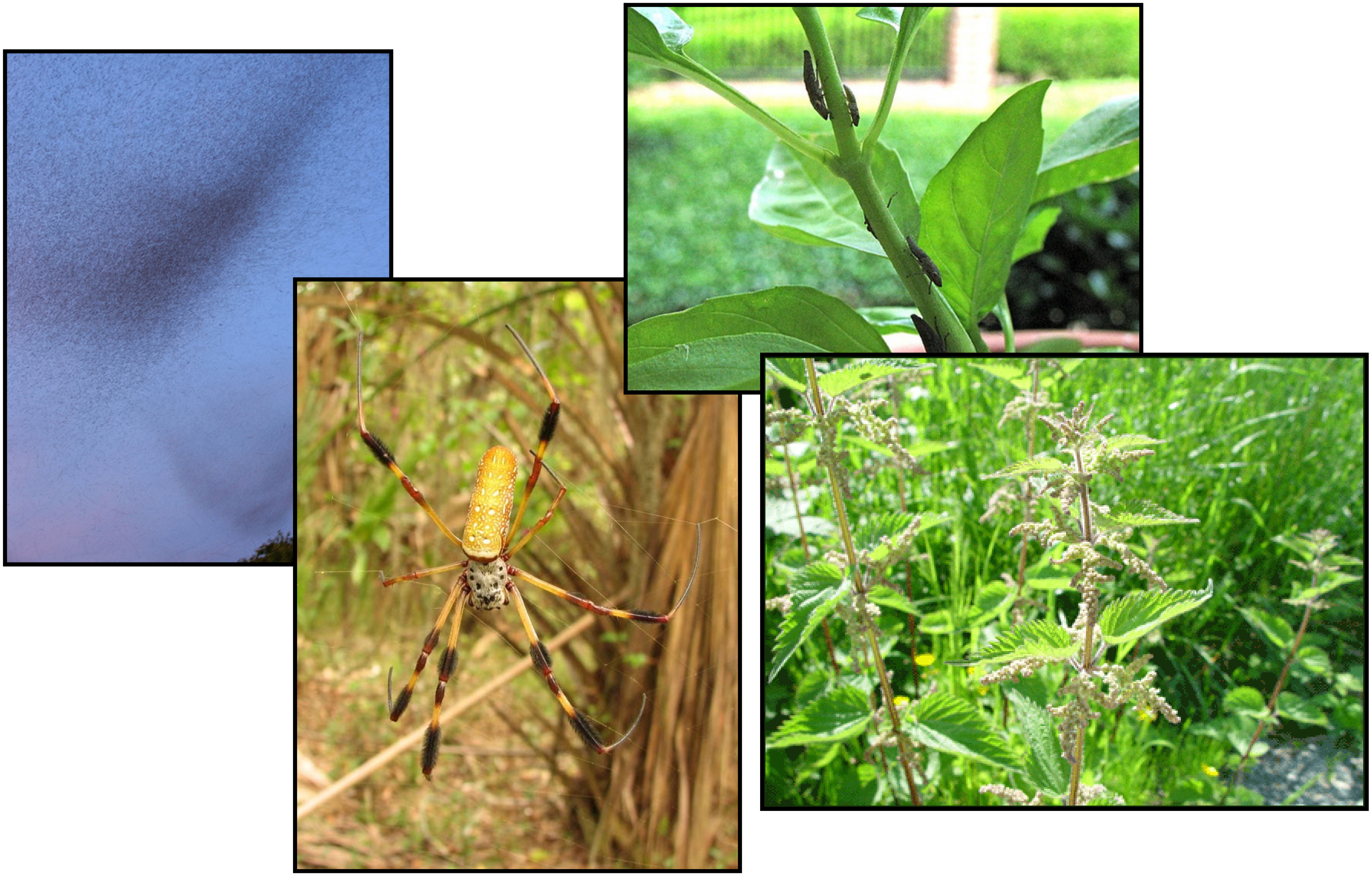




Kato et al., 2003. Oikos

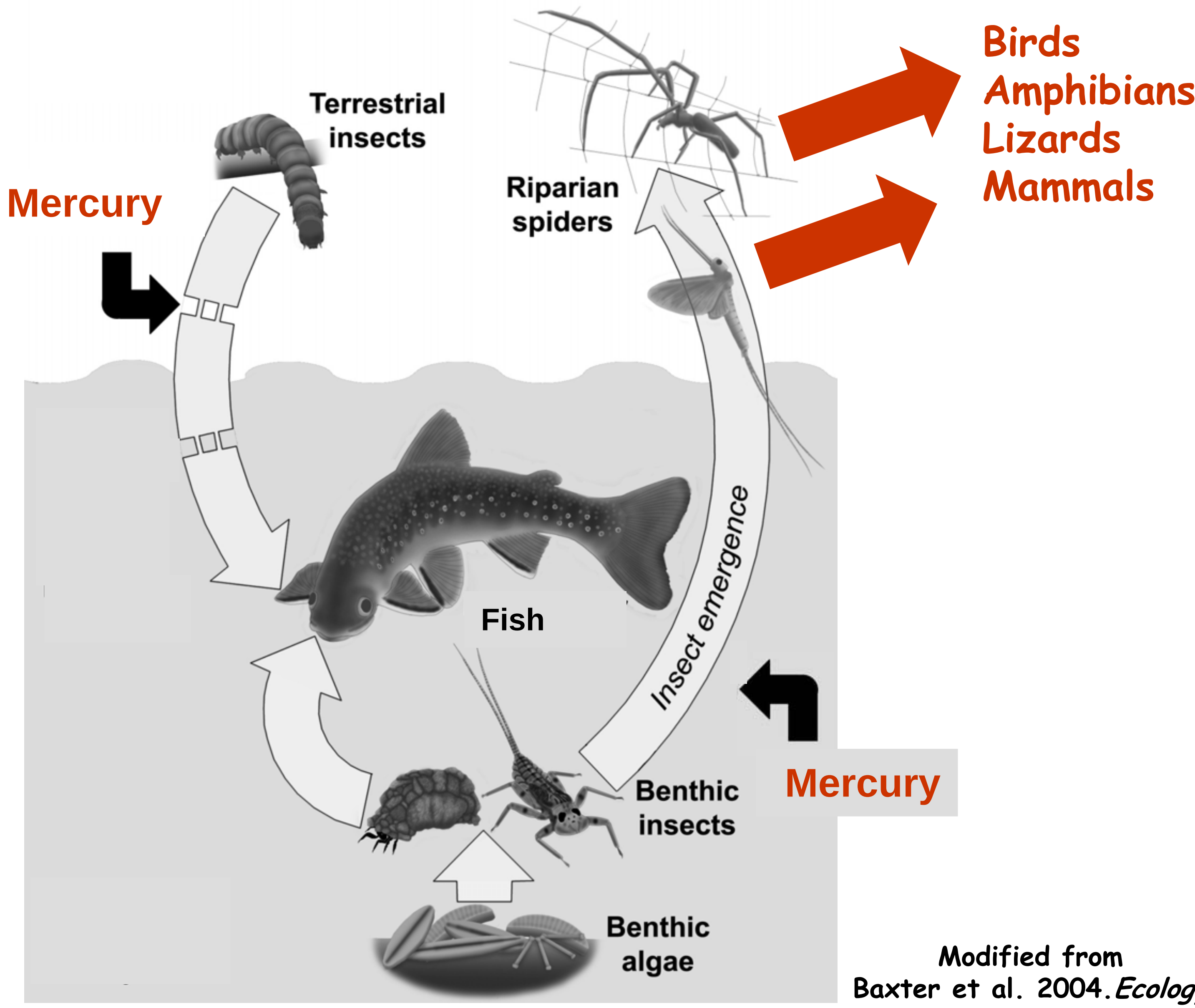
Subsidies Shape Entire Communities & Influence Ecosystem Processes



Henschel et al. 2001, Oikos

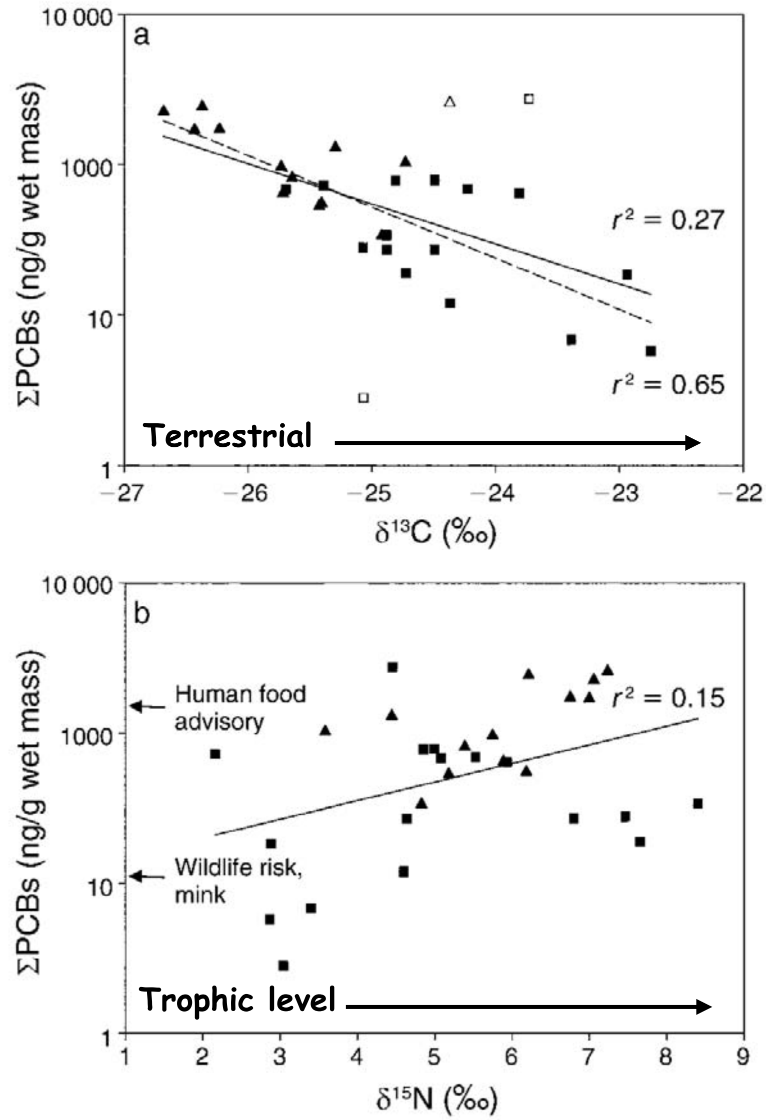
Photos from McCann & Flicker.com

"The Dark Side of Subsidies"



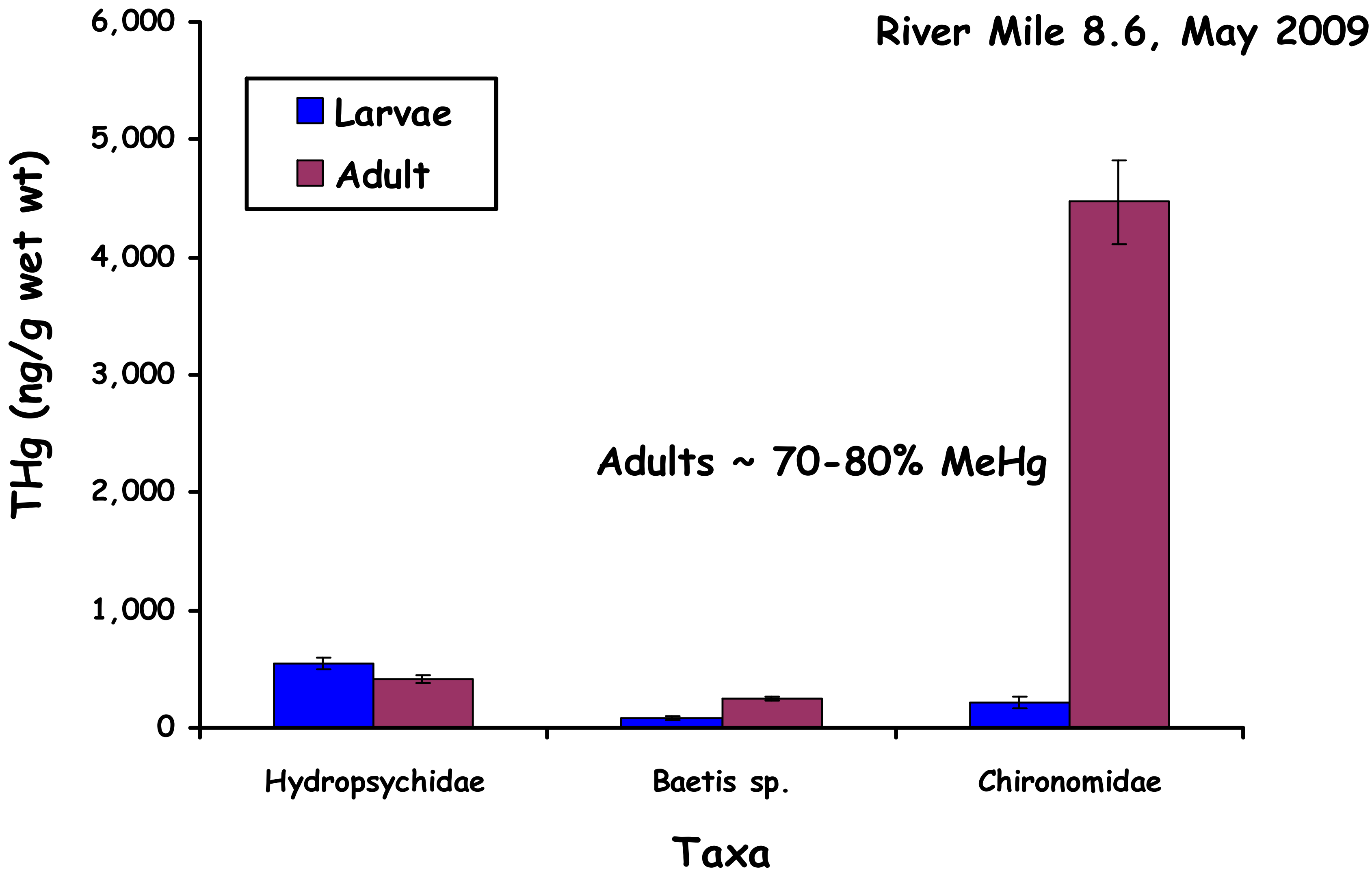
Modified from
Baxter et al. 2004. *Ecology*

Animals most reliant on aquatic subsidies at greatest exposure risk



Walters et al., 2008. Ecological Applications

Aquatic Insects Along the South River



Data Courtesy of Todd Morrison


Photo: Cristol Entertainment, Inc.

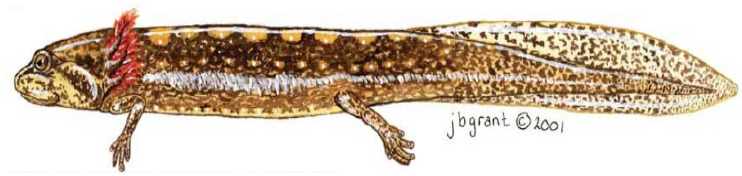
Larval Amphibians are Loaded with Mercury

***Bufo americanus* larvae**

American Toad (*Bufo americanus*)

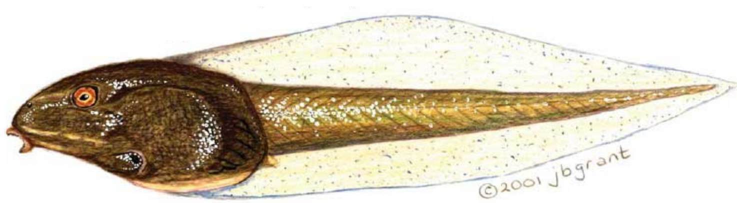
Reference: 536 ± 136 ng/g
Contaminated: 2,132 ± 602 ng/g

***Eurycea bislineata* larvae**



Reference: 115 ± 18 ng/g (62%)
Contaminated: 2,470 ± 171 ng/g (57%)

***Rana sylvatica* larvae**



Control diet: 28 ± 3.5 ng/g (75%)
Low Hg diet: 1,059 ± 184 ng/g (25%)
High Hg diet: 3,535 ± 128 ng/g (10%)

***Rana sylvatica* metamorphs**

Control diet: 54 ± 8.7 ng/g (64%)
Low Hg diet: 849 ± 51 ng/g (37%)
High Hg diet: 2,568 ± 567 ng/g (23%)

Diets - Control 10 ng/g (57%) – Low Hg 2,500 ng/g (3%) – High Hg 10,100 ng/g (1%)

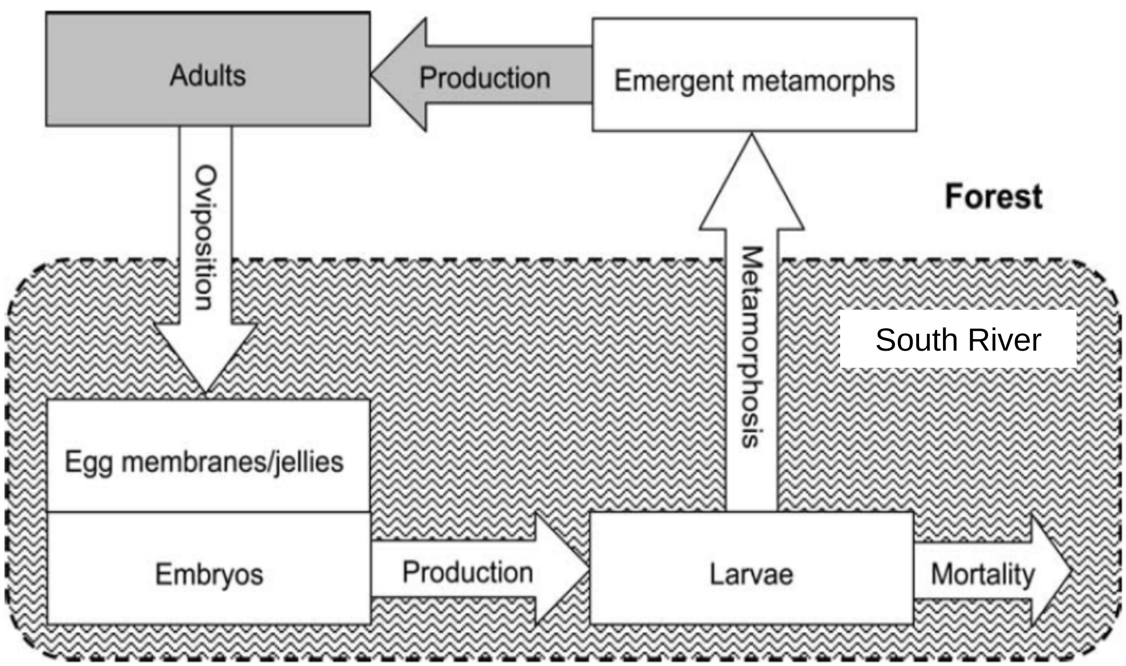
Amphibians are critical trophic link to some predators

Hopkins et al., 1999 ET&C;Hopkins et al., 2001 Environ Pollution;
Hopkins et al., 2002 ET&C; Rania et al., 2003 J Herpetol

Major Unknowns

Is the South River "Feeding Hg to the forest"? And Vice Versa?

- What is the abundance, biomass, and Hg content of aquatic insects and amphibians entering/exiting the South River?



Task: Address these questions.

1) What are the significant modes of mercury transport in the terrestrial environment? Soil particles transported by floods? Spiders? Amphibians?

2) What is the source of methylmercury in the floodplain biota? Aquatic methylmercury that is transported out of the river? Terrestrial mercury that is methylated in the floodplain?

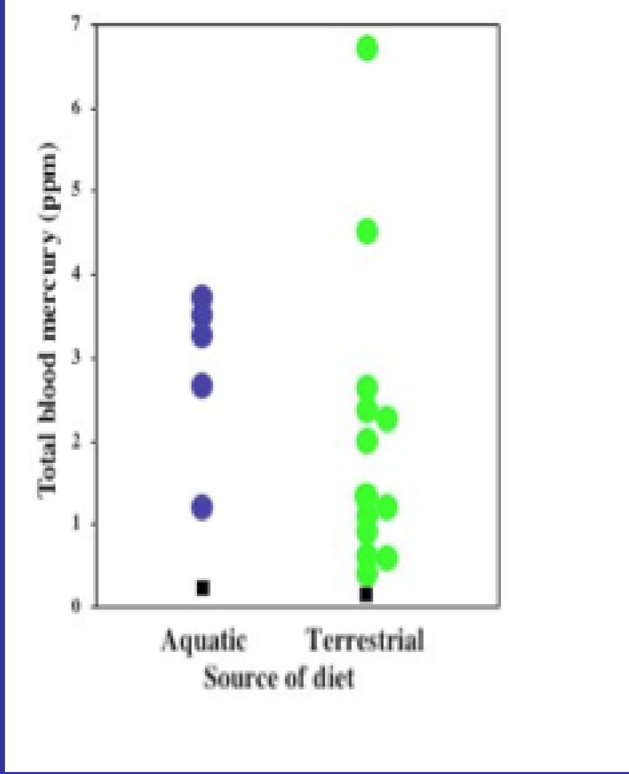
3) What controls the fate / transport of mercury in terrestrial environments? Events in the aquatic system? Land use?

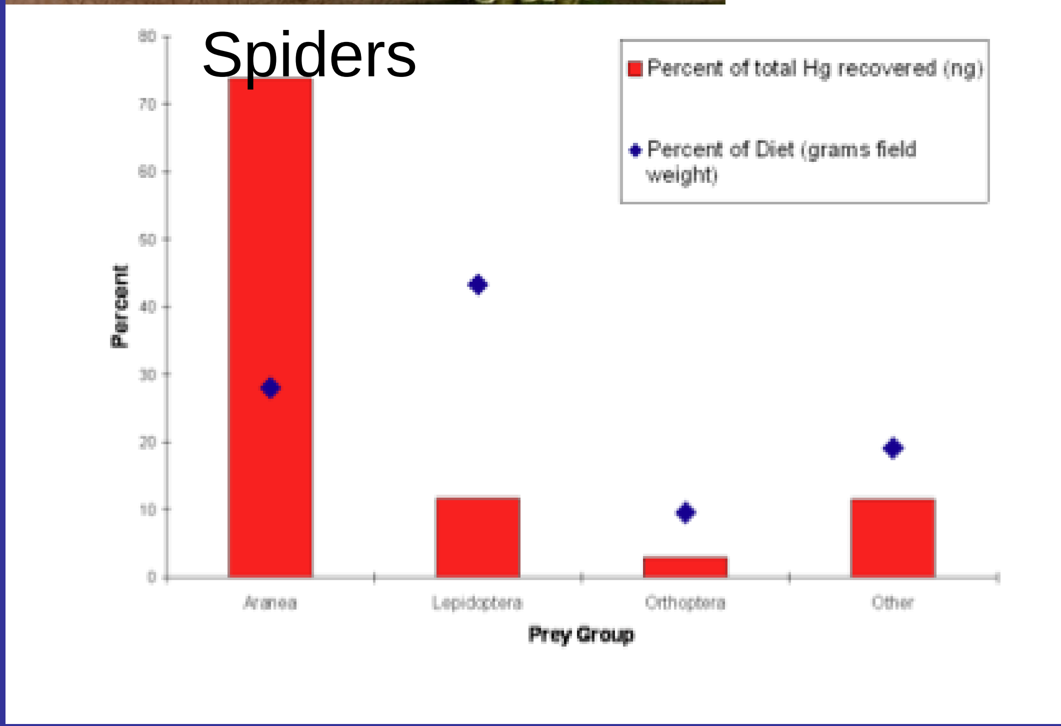
4) Are there actions/management strategies that could lead to decreased mercury in floodplain biota?

-Erin Mack

Background: What we know about mercury and biota in the river and on the floodplain:*There is a lot in biota and it extends far into the floodplain*

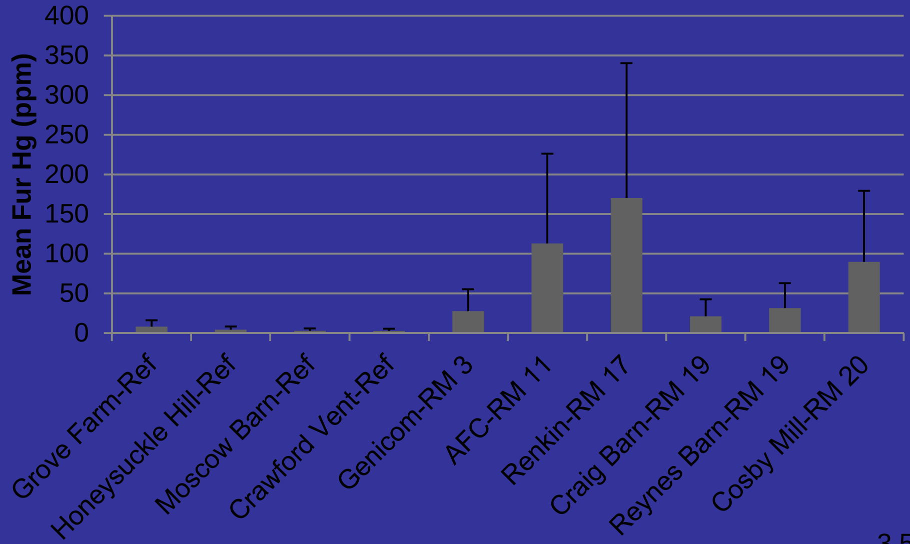
- *Amphibian/reptile Hg levels well documented, not prey*
- *Avian endpoints and their prey well characterized*
- *Mammalian endpoints, including domestic and hunted species, less well known*
- *Relationship between mercury and trophic level has been characterized for aquatic organisms*
- *Soon to be completed for terrestrial organisms*



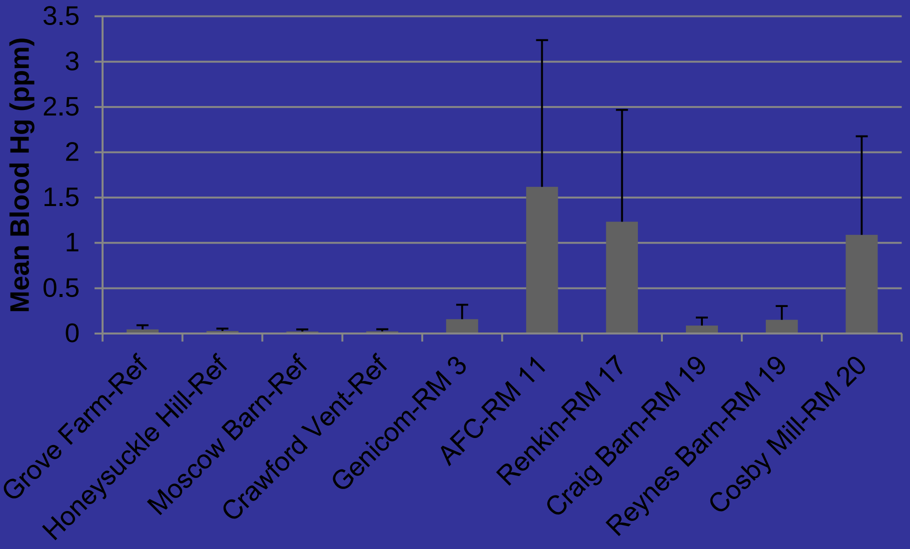


Data from Dan Cristol

Bat Summary

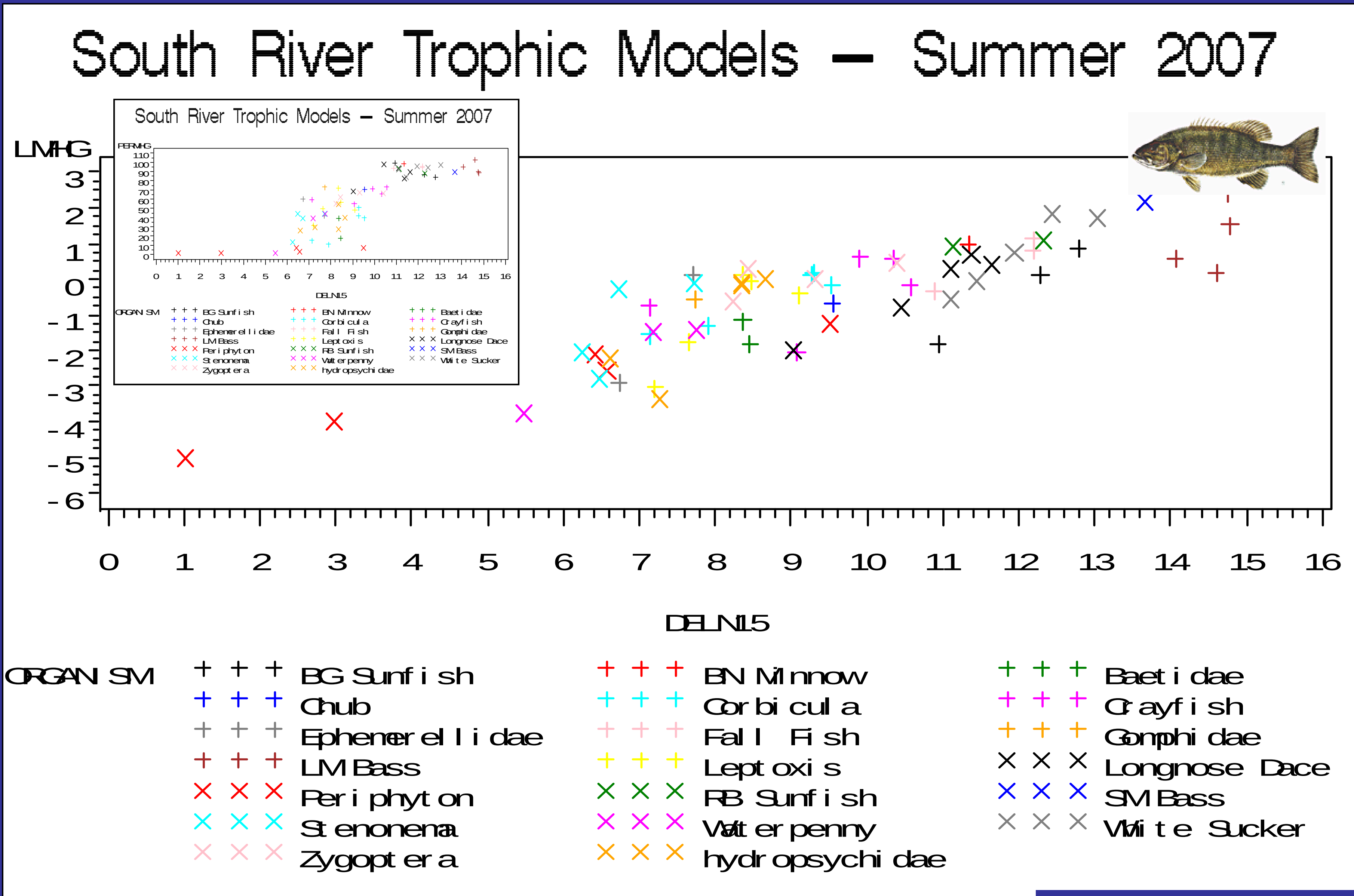


*All species pooled together



Data from Biodiversity Research Institute

Aquatic Trophic Model – DONE



Data from Mike Newman

Preliminary Floodplain Data - 2009

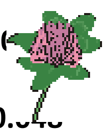
Grottoes Town Park Site- Hg/MeHg

TYPE	Mean Hg(mg/kg dry)	Mean MeHg (mg/kg)	Mean %MeHg
Carolina Wren (blood)	1[illegible]	12.453	90.7
Screech Owl (blood)	7.[illegible]	6.499	87.8
Shrew(muscle)	2.316	2.216	95.7
T. Titmouse (blood)	[illegible]	2.020	90.3
Cardinal (blood)	[illegible]	0.680	80.6
Wolfspider	0.[illegible]	0.275	36.5
Deer mouse (muscle)	[illegible]	0.045	41.3
Vole (muscle)	[illegible]	0.021	59.8
Ladybug	[illegible]2	0.011	48.1
Tent caterpillar	0.[illegible]	0.003	17.1
Plants (3 species)	0.[illegible]	0.001	2.8
Soil	4.428	0.021	0.5
Isopods	[illegible]	0.288	21.6
Earthworm	[illegible]	0.122	7.3
Adult Mayfly	0.672	0.694	104.0










Data from Mike Newman

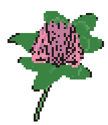
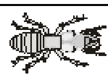
Preliminary Floodplain Data - 2009

Forestry Center - Hg/MeHg Data, Isotope Data Available Soon







TYPE	Mean Hg(mg/kg dry)	Mean MeHg (mg/kg)	Mean %MeHg
Carolina Wren (blood)	8.	7.650	89.1
Screech Owl (blood)	4.850	3.824	77.1
Song sparrow (blood)	6.351	6.300	102.0
R-S. Towhee (blood)	l	2.988	92.5
Cardinal (blood)	1.461	1.330	76.6
Wolfspider	2.882	1.175	53.8
Deer mouse (muscle)	l54	0.090	62.6
Ladybug	0.025	0.013	53.9
Tent caterpillar	0.025	0.011	43.0
Plants (3 species)	0.142	0.003	3.9
Soil	35.060	0.068	0.2
Isopods	2.736	0.211	10.2
Earthworm	283	0.376	1.6
Adult Mayfly		0.867	83.7

Data from Mike Newman

Very Preliminary Floodplain Findings

- Results more variable for floodplain
- Hg increases 50-100 fold from plants to owl/wren
- MeHg increases 2,000-10,000 fold
- %MeHg increases from <1% to 85%
- High Hg prey are emergent insects, spiders, and detritivores

Data from Mike Newman

Erin's Questions:

1) ***What are the significant modes of mercury transport in the terrestrial environment? Soil particles transported by floods?***

Preliminary analysis of spatial distribution of Hg in floodplain birds suggests likelihood of past flooding is important…

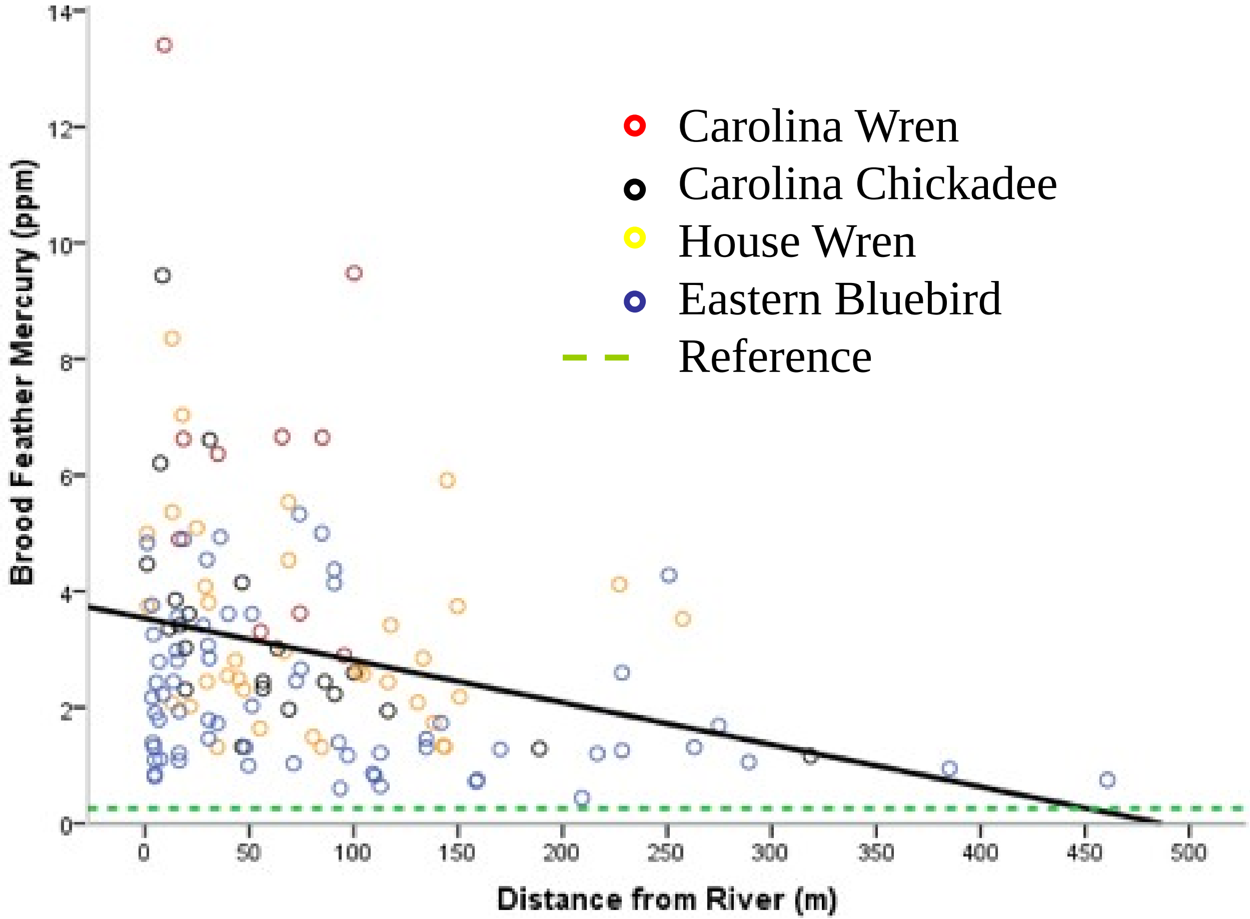
…but soil Hg was not a strong predictor…

…and distance, a proxy for emergent insect availability, did explain additional variance, so this analysis is still inconclusive

Spiders? *Clearly important for first songbirds*

Amphibians? *Could be a concentrated, pulsed vector, especially via amphibian-eating snakes into predators*

Biotic mercury extends far into floodplain



Data from Dan Cristol

2) What is the source of methylmercury in the floodplain biota? Aquatic methylmercury that is transported out of the river?

Do <u>emergent insects</u> directly contaminate songbirds with mercury?
No, except for swallows and flycatchers.

Do they directly contaminate bats and herps?
Yes bats, maybe herps.

Do they directly contaminate spiders?
Don't know yet but...

- *Spider gut content study could confirm/refute spider link to mayflies*
- *Water-treatment plant isotope tracer study could confirm/refute spider link to aquatic nutrients in general*

Terrestrial mercury that is methylated in the floodplain?
This is the new research frontier! Soil study was a great start.

Future research questions for SRST:

3) What controls the fate / transport of mercury in terrestrial environments? Events in the aquatic system? Land use?

4) Are there actions/management strategies that could lead to decreased mercury in floodplain biota?