Trophic Transfer Models for South River Mercury

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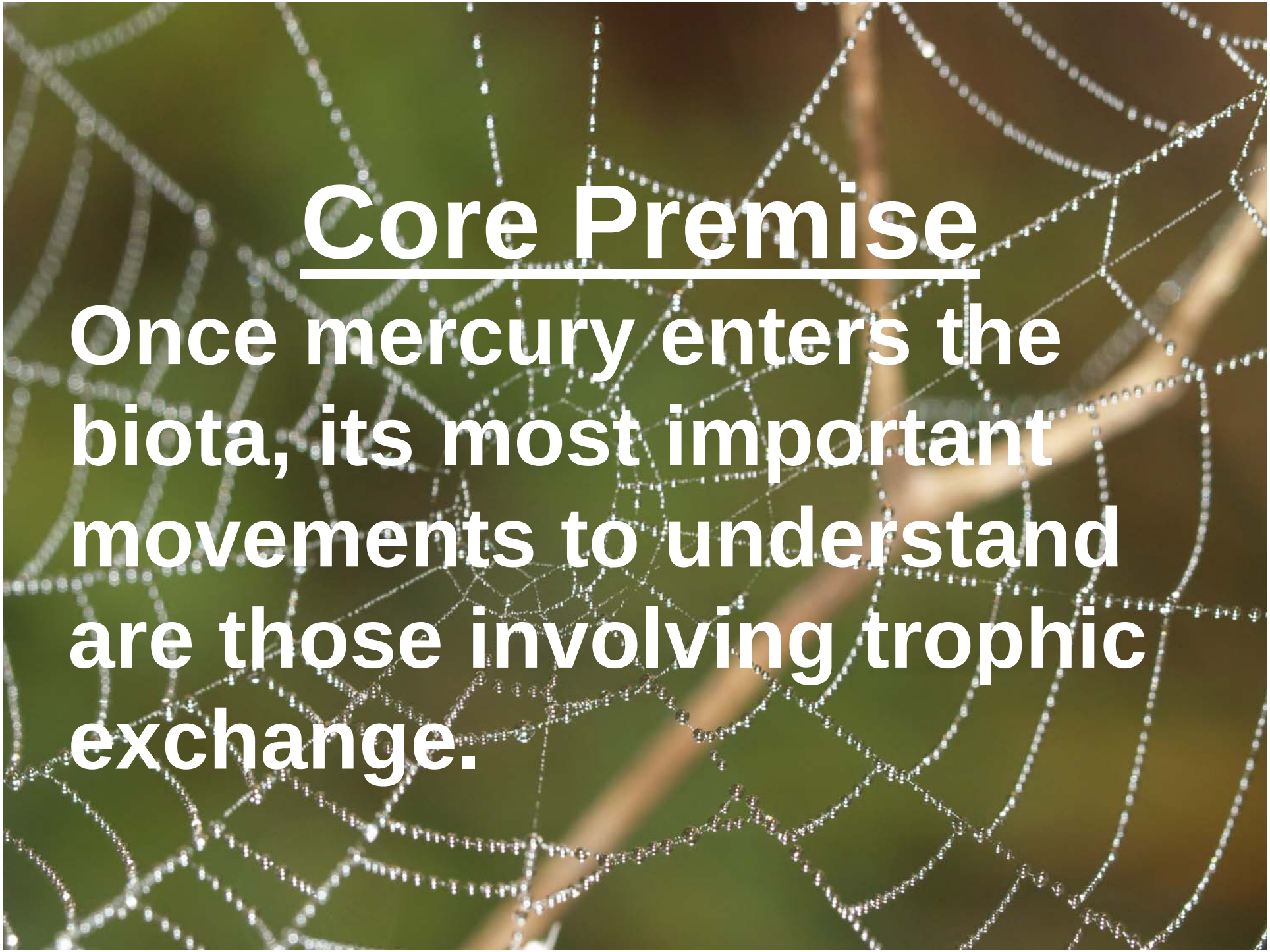


Core Premise

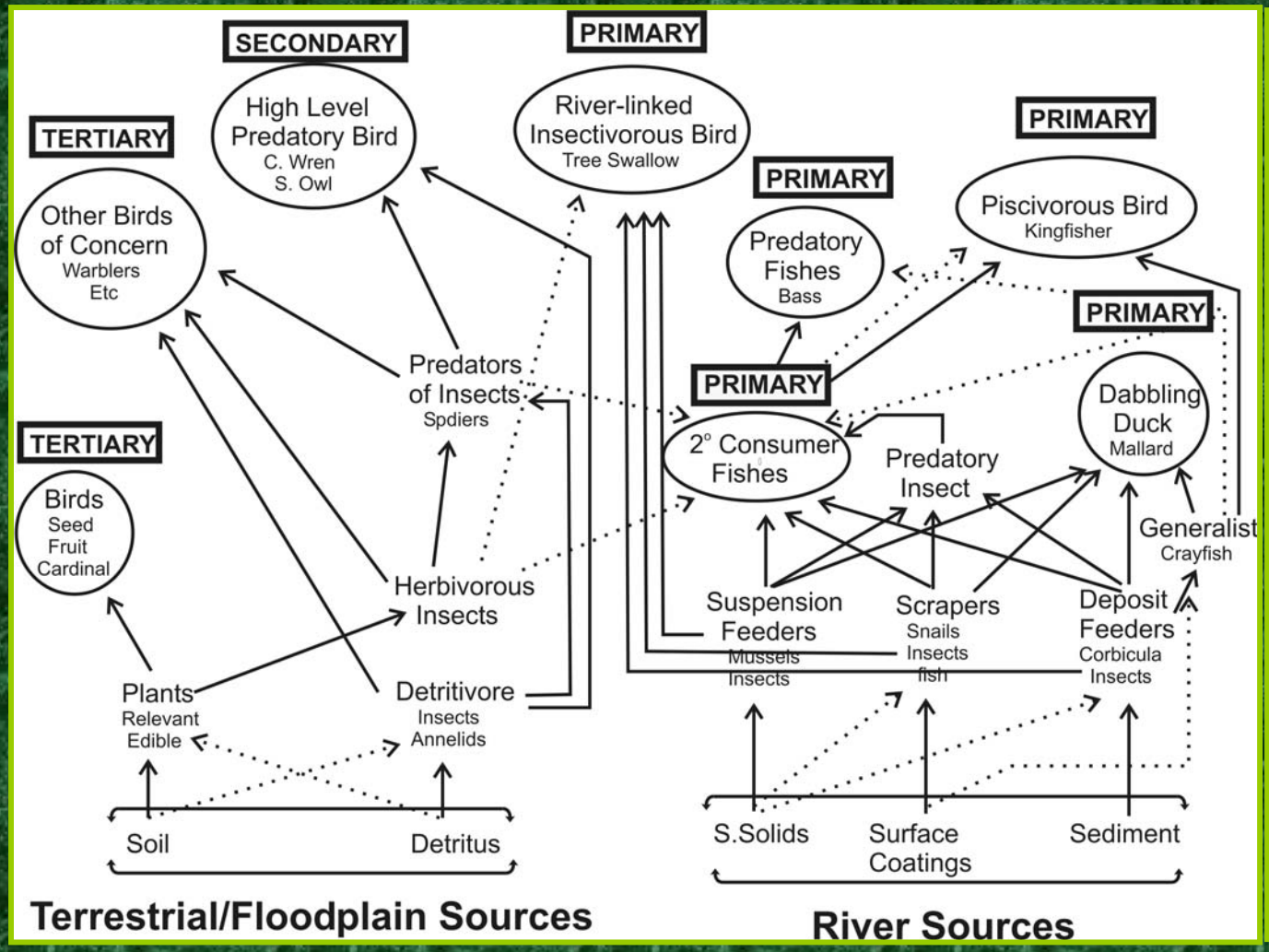
Once mercury enters the biota, its most important movements to understand are those involving trophic exchange.

Questions Being Addressed

Can N isotope-based models effectively predict mercury biomagnification in South River?

- –One model for contaminated region or several?
- –Trend in model parameters with distance from past source?
- –Is the predictive capability sufficient? (Quantify by cross-validation.)
- –Can % methylHg be quantified with trophic position?
- –Can these models be used to predict mercury bioaccumulation in other rivers?

Conceptual Model
General Trophic Web Structure



General Objectives

- Quantify trophic transfer of Hg in scraper/ gatherer trophic web (leading to edible fish species)
- Also quantify what the proportion of total mercury in biota tissue is methylmercury at various trophic levels

- Apply careful experimental designs
  - Optimize information/unit cost
  - Enhance soundness of conclusions
  - Enhance quality of predictions/projections
  - Enhance legal defensibility

General Trophic Model

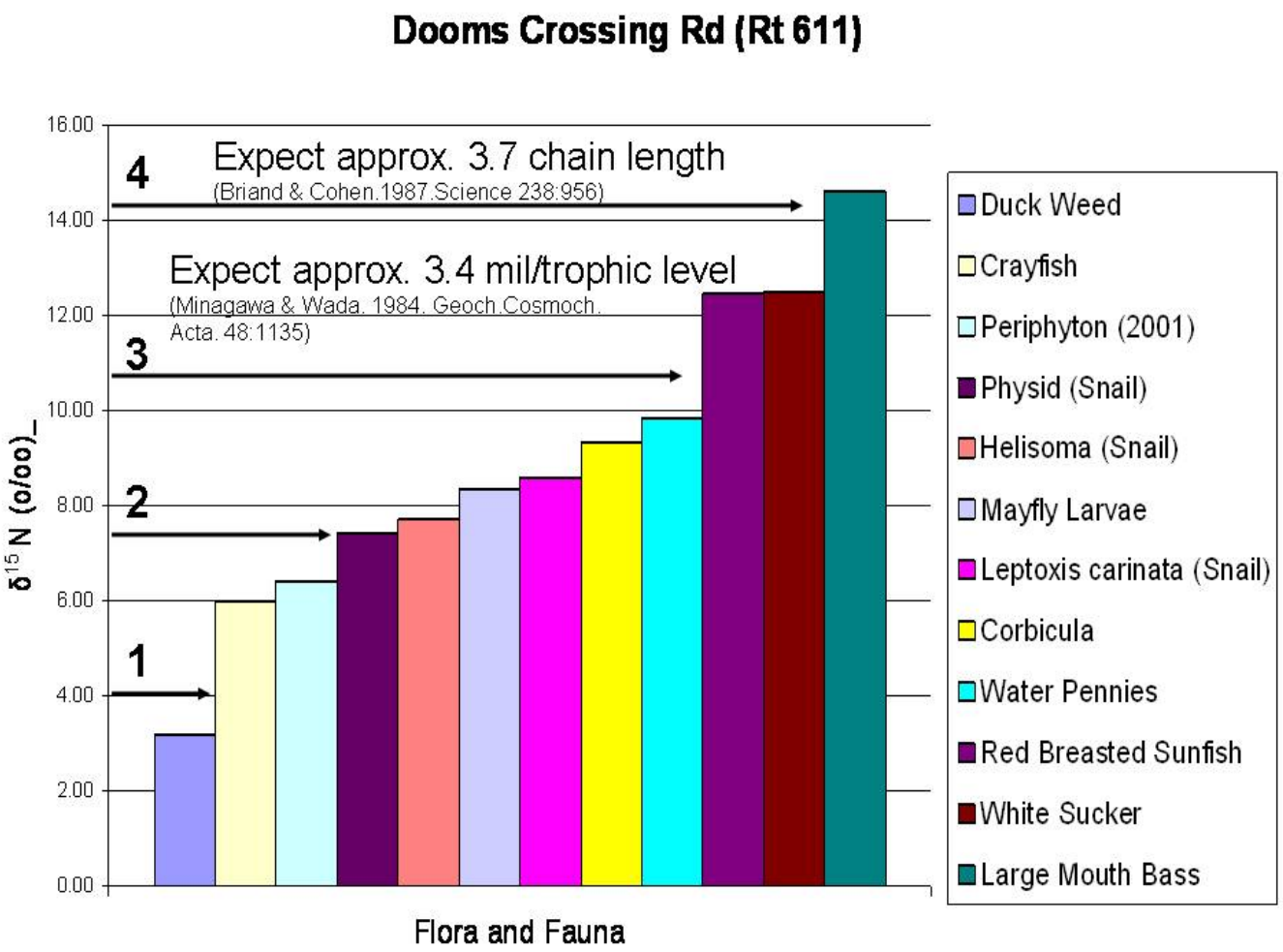
In situ regression via Isotopic Discrimination Technique

Isotopic discrimination reduces the amount of lighter isotopes (^{12}C, ^{14}N, or ^{32}S) in organisms relative to that of the heavier isotopes (^{13}C, ^{15}N, or ^{34}S)

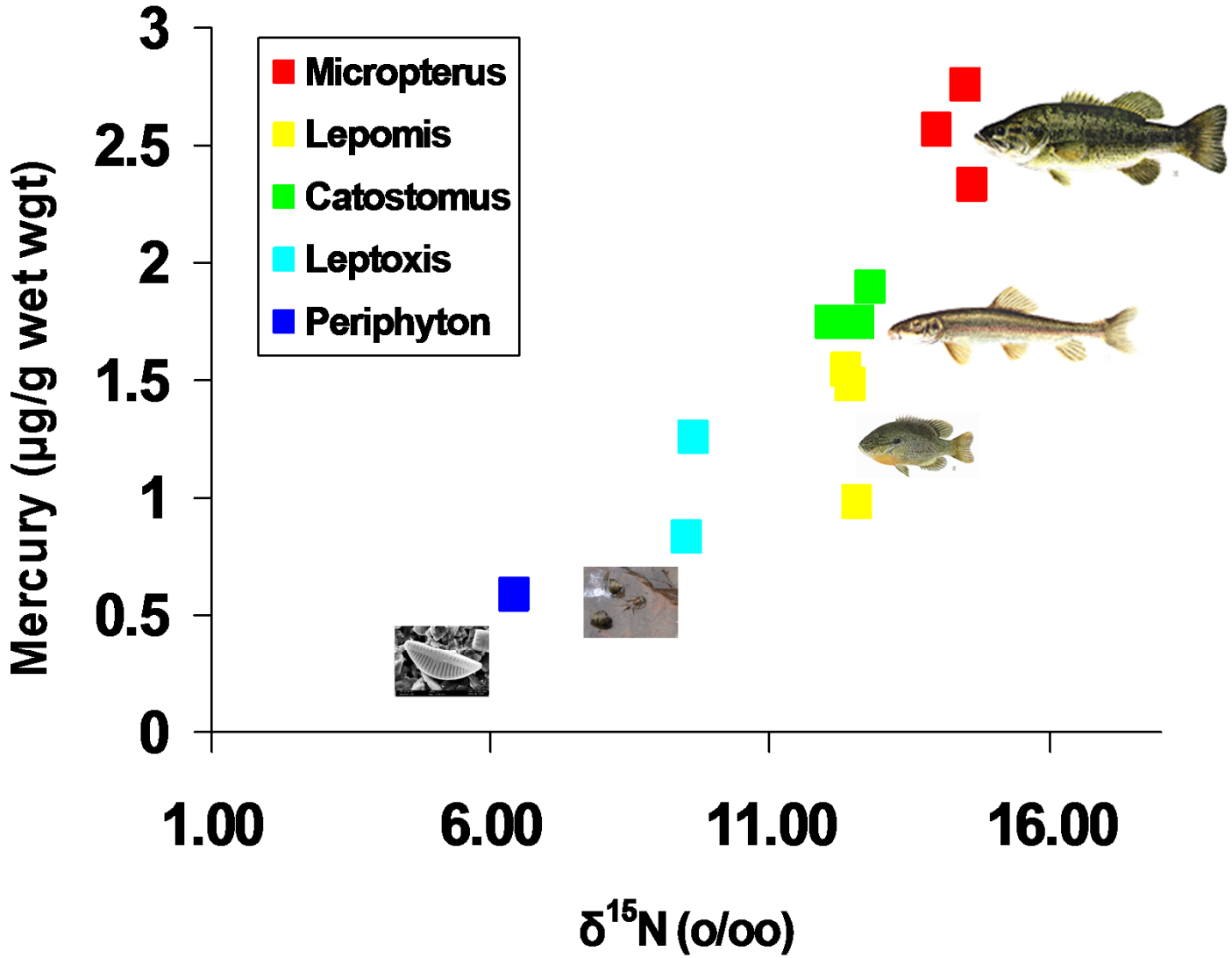
Nitrogen isotopes work best for trophic position

$$\delta^{15}N = 1{,}000\left[\frac{(^{15}N_{sample})/(^{14}N_{sample})}{(^{15}N_{air})/(^{14}N_{air})} - 1\right]$$

Initial 2006 Models
General Trophic Web Structure

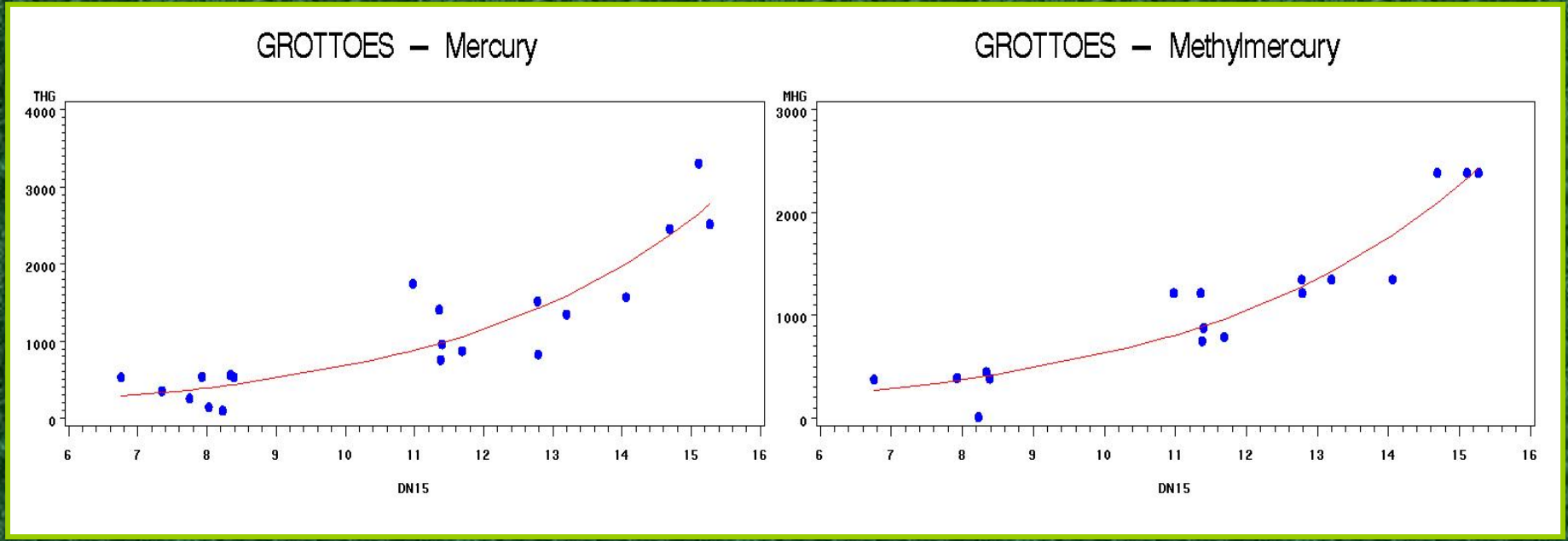


Initial Trophic Models - 2006



Initial 2006 Models
General Trophic Web Structure

$$[Hg]_i = e^{a+b\delta^{15}N_i} = e^a e^{b\delta^{15}N_i}$$



- Relationships clear at three sites in high [Hg] region of river.
- Using sample types from different sources and years.

Initial 2006 Models
General Trophic Web Structure

$$[Hg]_i = e^{a+b\delta^{15}N_i} = e^a e^{b\delta\ ^{15}N_i}$$

Preliminary Biomagnification Models for 2006 Sites

Site	Form	Estimate of e^a	Estimate of b	Increase (x)
Dooms Crossing	THG	65.3 (27.3)	0.25 (0.03)	2.34 x fold
	MHG	30.4 (16.2)	0.29 (0.04)	2.68 x fold
Crimora (AFC)	THG	78.6 (60.4)	0.26 (0.06)	2.42 x fold
	MHG	54.2 (51.0)	0.28 (0.08)	2.59 x fold
Grottoes (TP)	THG	45.6 (22.8)	0.29 (0.08)	2.68 x fold
	MHG	47.4 (17.4)	0.27 (0.03)	2.50 x fold

Increase = predicted increase expressed as a "fold increase" in concentration with a change of one trophic level at the middle of the trophic web, i.e., a ✉ ^{15}N change from 8 to 11.4 ‰ (= (EXP(b*11.4)/(EXP(b*8)).

- General models successfully built from preliminary data for various sources.
- Clear proof of concept established (consistent with substantial literature).
- Approximately 2.5x increase in Hg with each trophic level.

Trophic Modeling - 2007

$$[Hg]_i = e^{a+b\delta^{15}N_i} = e^a e^{b\delta\ ^{15}N}$$

Objectives

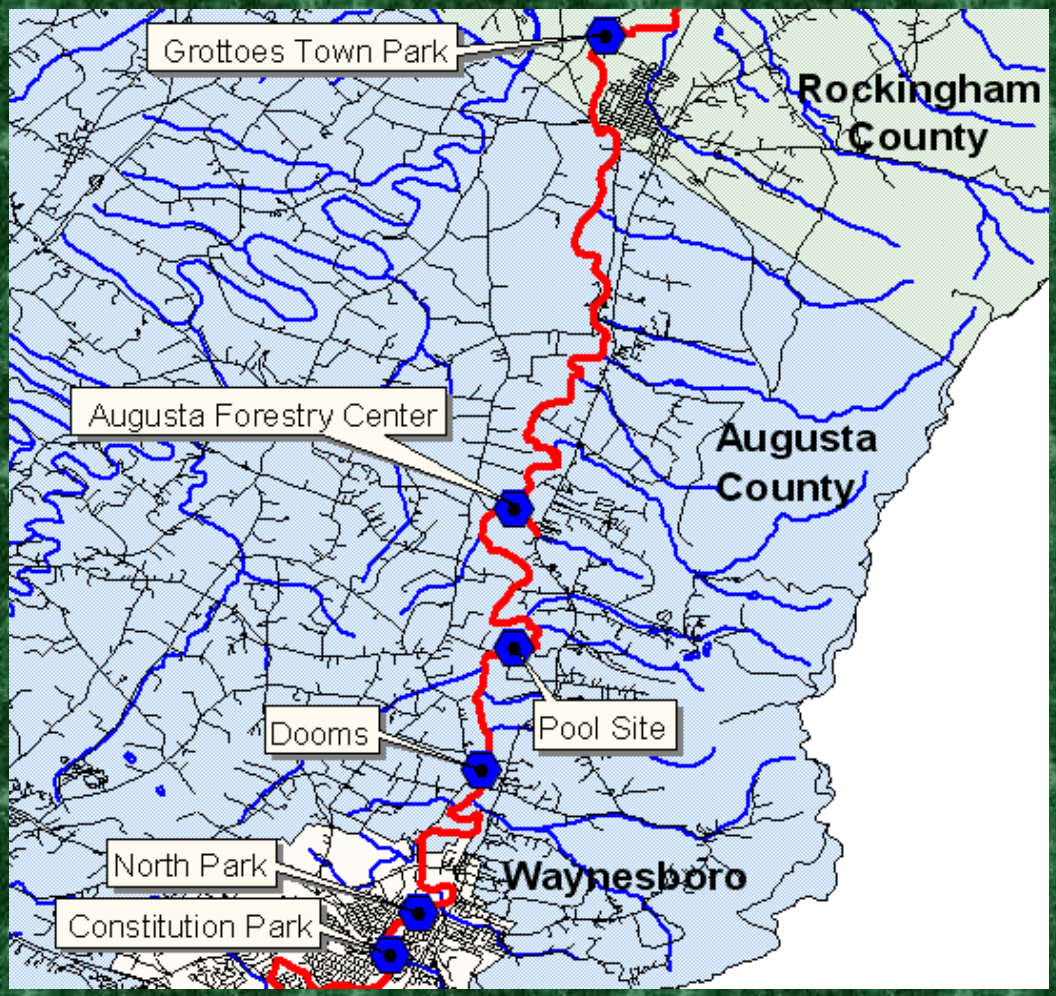
Generate and cross-validate aquatic trophic transfer models with a careful May/June 2007 sampling of six sites:

Constitution Park	North Park
Dooms Crossing	**Pool Site**
Crimora (AFC)	Grottoes

Test H (with model slopes): Downriver movement of mercury is slowed by its conversion to mHg and efficient trophic incorporation.

Sampling Sites - 2007

- Constitution Park (0.6 mi)
- North Park (2.0 mi)
- Dooms (5.2 mi)
- Pool (≈8.7 mi)
- Crimora (AFC) (11.8 mi)
- Grottoes (22.4 mi)



Trophic Modeling - 2007

$$[Hg]_i = e^{a+b\delta^{15}N_i} = e^a e^{b\delta^{15}N_i}$$

Approach

For triplicates of 16 different sample/species types at 6 sites …

- Analyze all for total Hg and one of replicates for mHg also.
- Use 2 samples/type to generate a model for a site.
- Use remaining samples for cross-validation.
- Also generate prediction residuals and compare to regression residual for models built with all replicates.

For mHg samples (16/site or 88 samples from biota ranging entire trophic web):

- Estimate change in % Hg that is mHg in biota of different trophic positions

Product

Six (or one general) trophic models predicting [Hg] of aquatic species for planning and decision making.

Test of hypothesis of Hg retention in the South River below the historic source.

2007 Sampling

- URS/VIMS gathered 5 fish species at each site

Samples for Modeling - 2007

- Collected periphyton (natural & artificial substrates)
- Collected 8 types of invertebrates at each location
  - Snails & *Corbicula*
  - Crayfish
  - Mayflies & Other 1° consumer insects
  - Predatory insects

Samples for Modeling - 2007

Constitution Park

Organism	Amount
Periphyton	3(N)/3(S)
Macrophyte B	1 Bag
Macrophyte C	1 Bag
Leptoxis Snails	90
Helisoma Snails	21
Stenonema (Scraper Mayfly)	≈85
Corbicula	60
Hydropsychidae	102
Ephemerellidae Ephemerella/Serratella	59
Crayfish	9
Enallagma: Zygoptera (Damsel Fly)	24
Long nose Dace	15
Fall Fish	15
Blue Gill	3
White Sucker	3
Large Mouth Bass	3
Macrophyte	1Bag
Physid Snails	6

North Park

Organism	Amount
Periphyton A	3(N)/4(S)
Macrophyte A	1 Bag
Macrophyte B	1 Bag
Leptoxis Snails	100
Stenonema (Scraper Mayfly)	48
Water Pennies	66
Corbicula	41
Hydropsychidae	75
Helisoma Snails	21
Crayfish	12
Gomphidae (Dragon Fly)	17
Longnose Dace	15
Chub (Rur Chub)	12
Redbreast Sunfish	3
White Sucker	3
Large Mouth Bass	3
Stenacron	Bottle
Physid Snails	3
Ephemerellidae	81

Dooms Crossing

Organism	Amount
Periphyton A	3(N)/4(S)
Macrophyte A	1 Bag
Macrophyte B	1 Bag
Leptoxis Snails	100
Simullidae	705
Physid Snails	>60
Hydropsychidae	91
Corbicula	60
Baetidae	343
Cambris Crayfish	9
Enallagma (Damsel Flies)	30
Long Nose Dace	15
Fall Fish	15
Blue Gill	3
White Sucker	3
Large Mouth Bass	3
Stenonema (Scraper Mayfly)	8
Serratella	9
Leach	16
Helisoma Snails	4

Samples for Modeling - 2007

Augusta Forestry Center

Organism	Amount
Periphyton	3(N)/3(S)
Macrophyte A	1 Bag
Macrophyte B	1 Bag
Leptoxis Snails	200
Water Pennies	25
Stenonema (Scraper Mayfly)	60
Corbicula	60
Hydropsychidae	103
Baetidae	306
Crayfish	9
Enallagma (Damsel Fly)	63
Longnose Dace	15
Fall Fish	12
Redbreast Sunfish	3
White Sucker	3
Small Mouth Bass	3
Unknown	2
Ephemerellidae	12

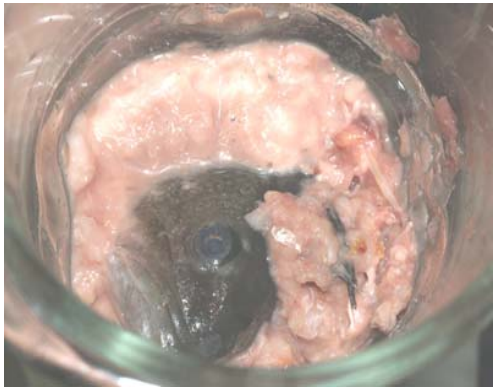
Grottoes Town Park

Organism	Amount
Periphyton	3(N)/5(S)
Macrophyte A	1 Bag
Macrophyte B	1 Bag
Leptoxis Snails	90
Stenonema (Scraper Mayfly)	60
Water Pennies	≈60
Corbicula	38
Hydropsychidae	54
Ephemerellidae	≈90
Crayfish	12
Enallagma (Damsel Fly)	45
Longnose Dace	15
Bluntnose Minnow	15
Blue Gill	3
White Sucker	3
Large Mouth Bass	3
Open-shell Beetle	4
Baetidae	5

Pool Site

Organism	Amount
Periphyton	3(N)/4(S)
Macrophyte A	1 Bag
Macrophyte B	1 Bag
Leptoxis Snails	100
Simullidae	≈462
Physid Snails	44
Corbicula	60
Hydropsychidae	90
Ephemerellidae	151
Crayfish	9
Gomphidae (Dragonfly)	6
Bluntnose minnow	15
Fall Fish	15
Redbreast Sunfish	3
White Sucker	3
Large Mouth Bass	3
Helisoma Snails	15
Baetidae	30+
Enalagma (Damselflies)	41

Sample Processing - 2007



Overall Utility

- Allow prediction of Hg in biota with time, location, or management action.
  - If sediment or periphyton Hg was reduced to …
  - How long until the bass concentrations are lower than …
  - How far down river until the bass concentrations are …
  - What would occur if the trophic structure was changed by …
  - What would happen with nutrient reduction …
  - What would happen with introduction of more particulate organic carbon sources such as detritus …
- Tool for interpolation to other species of interest.
- Explicitly define uncertainty while doing the above.
- Could do Monte Carlo computations of risk with model providing input.
  - Probability of a valued species exceeding an oral TRV?