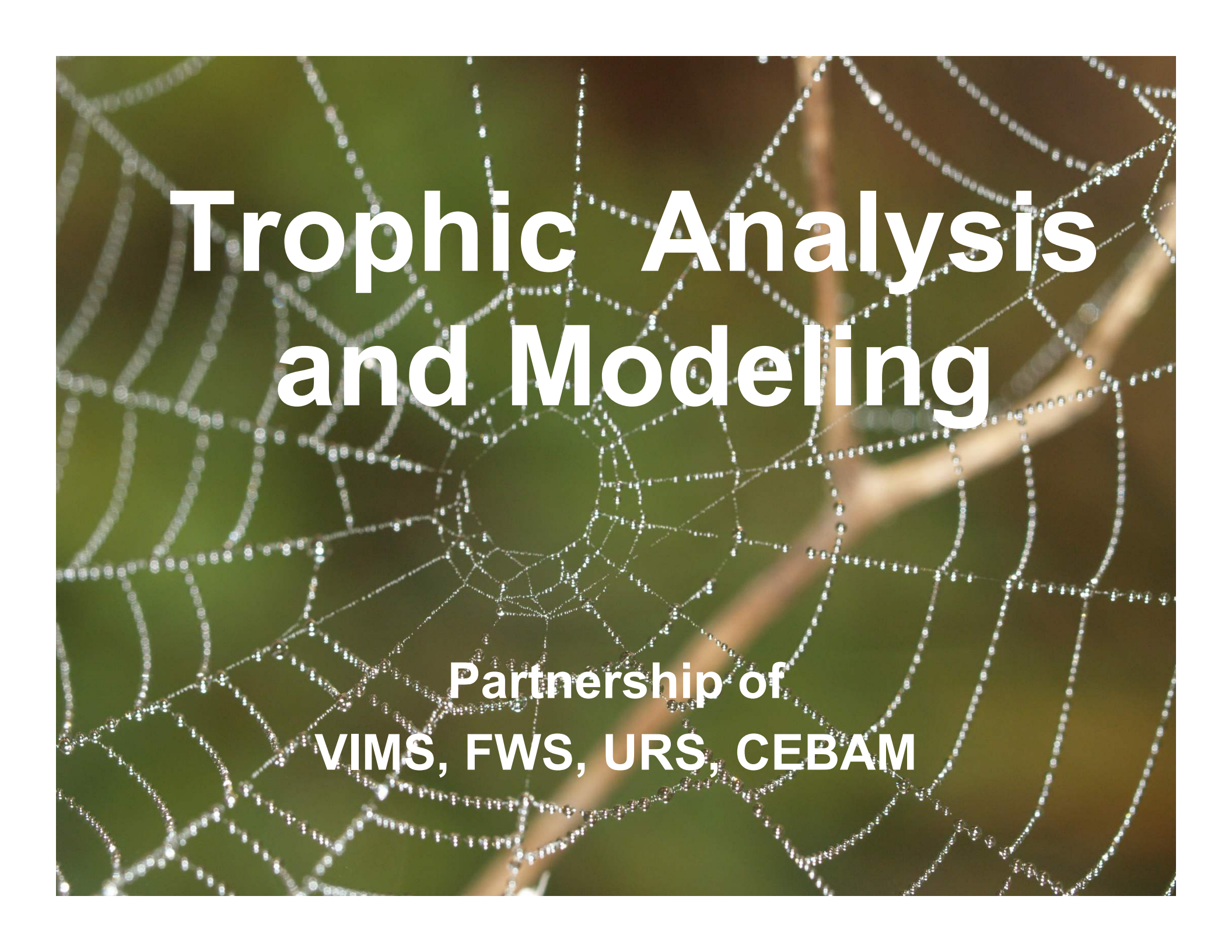
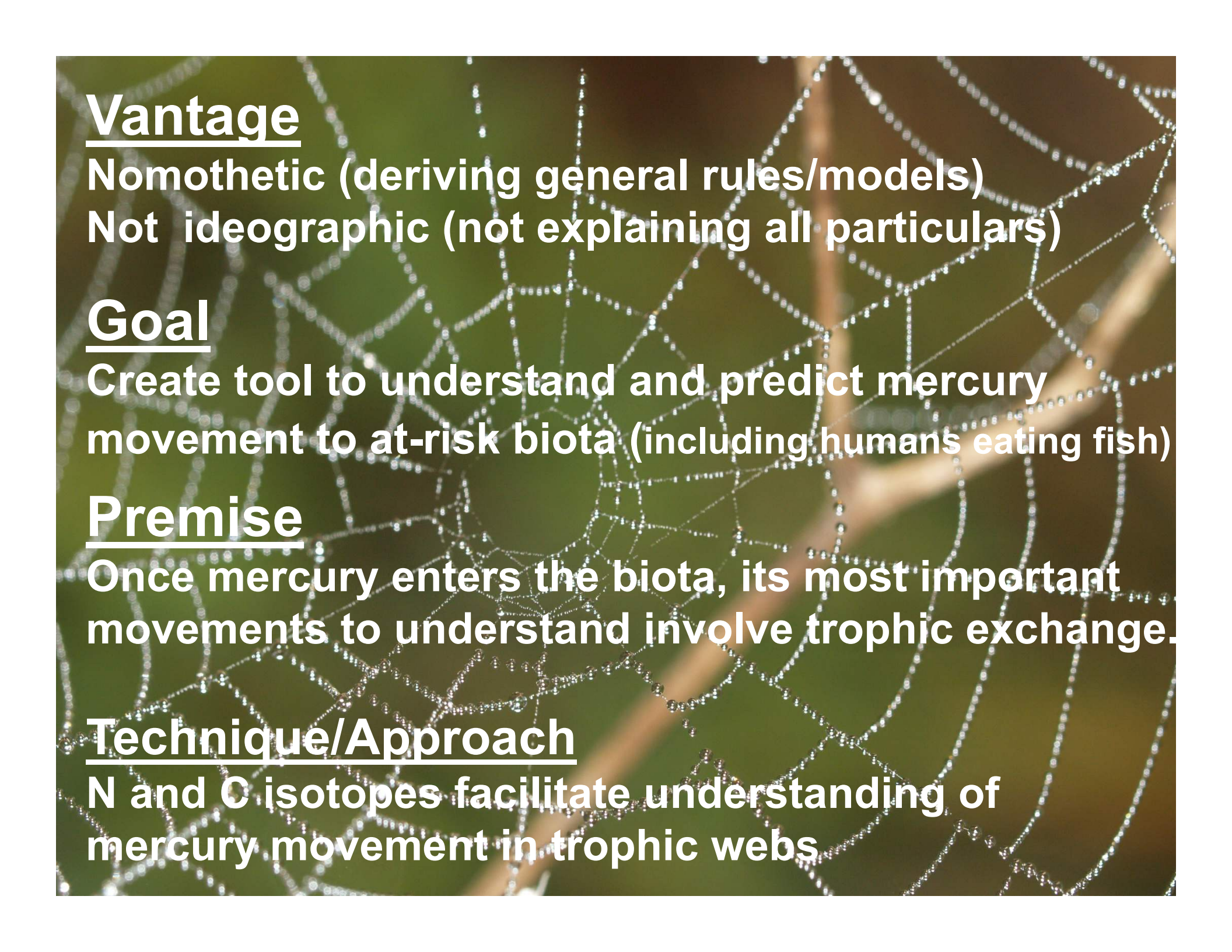




Trophic Analysis and Modeling

**Partnership of
VIMS, FWS, URS, CEBAM**



Vantage

Nomothetic (deriving general rules/models)

Not ideographic (not explaining all particulars)

Goal

Create tool to understand and predict mercury movement to at-risk biota (including humans eating fish)

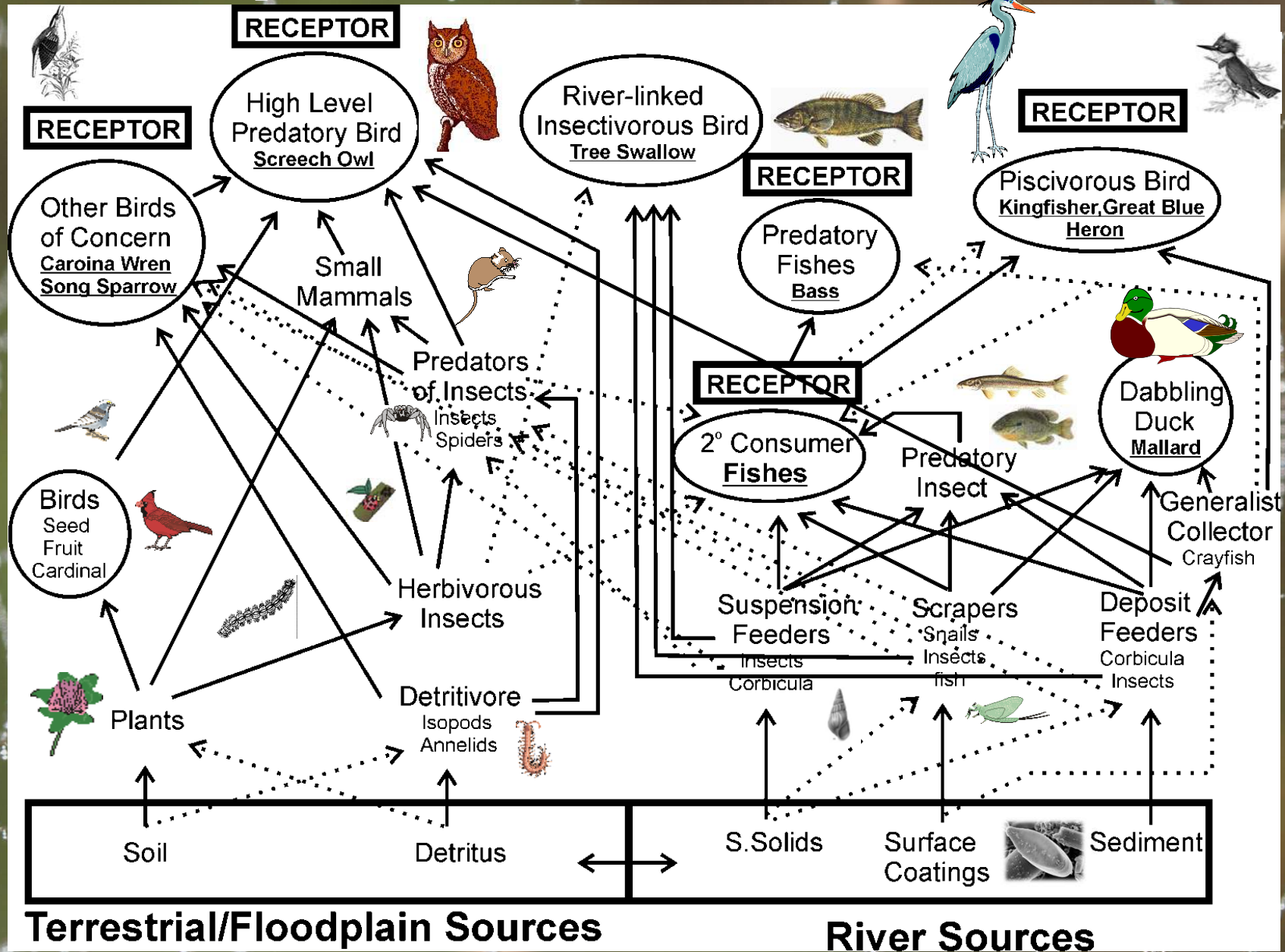
Premise

Once mercury enters the biota, its most important movements to understand involve trophic exchange.

Technique/Approach

N and C isotopes facilitate understanding of mercury movement in trophic webs

Trophic Web Framework



Quantification

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

1. Models with N isotope trophic discrimination
2. Mixture models/polygons to understand resource use

Nitrogen isotopes work best for trophic position

Carbon isotopes work best to identify sources

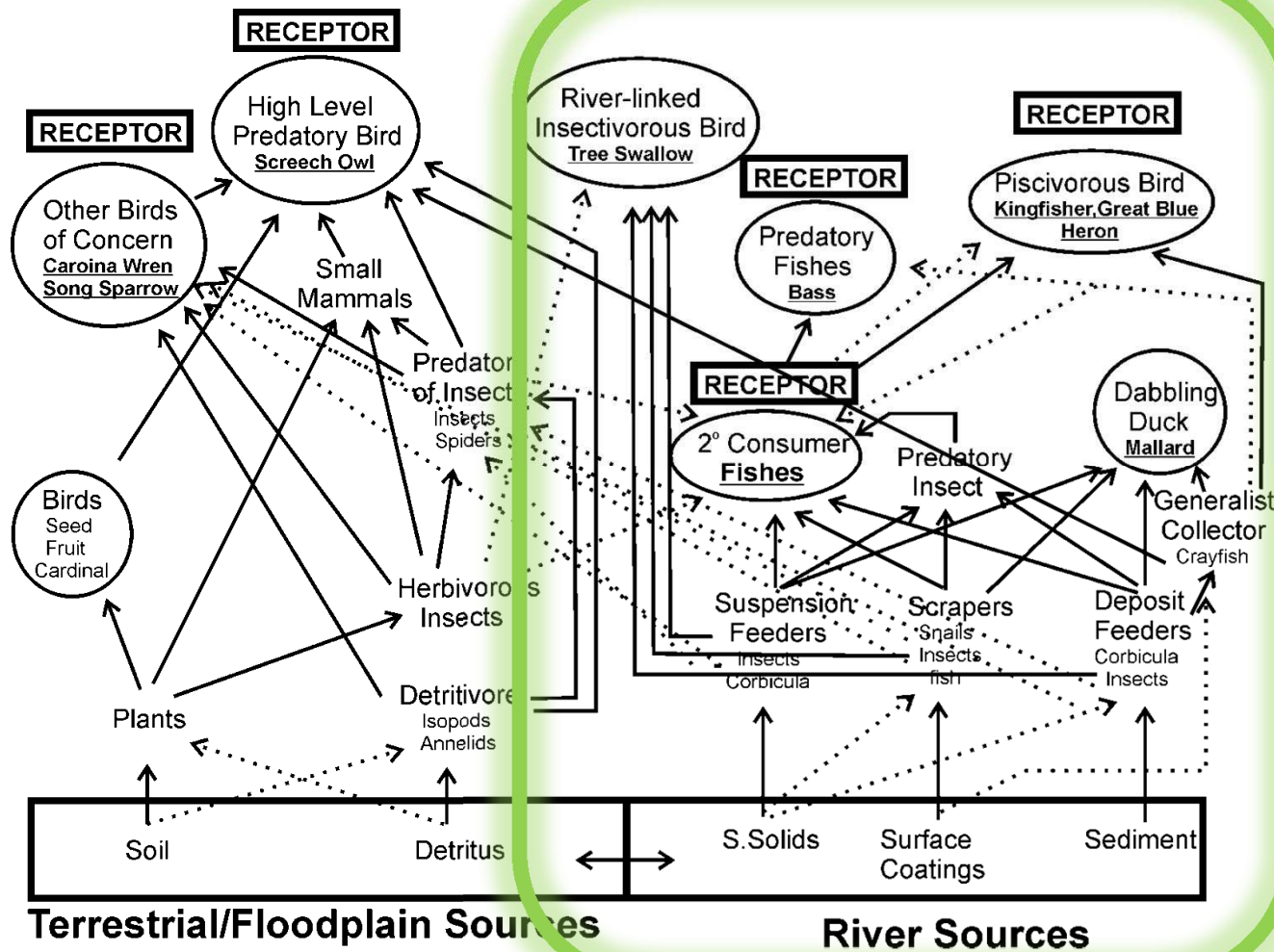
$$[Hg]_i = 10^{a+b\delta^{15}N_i} = 10^a 10^{b\delta^{15}N_i}$$

Baseline

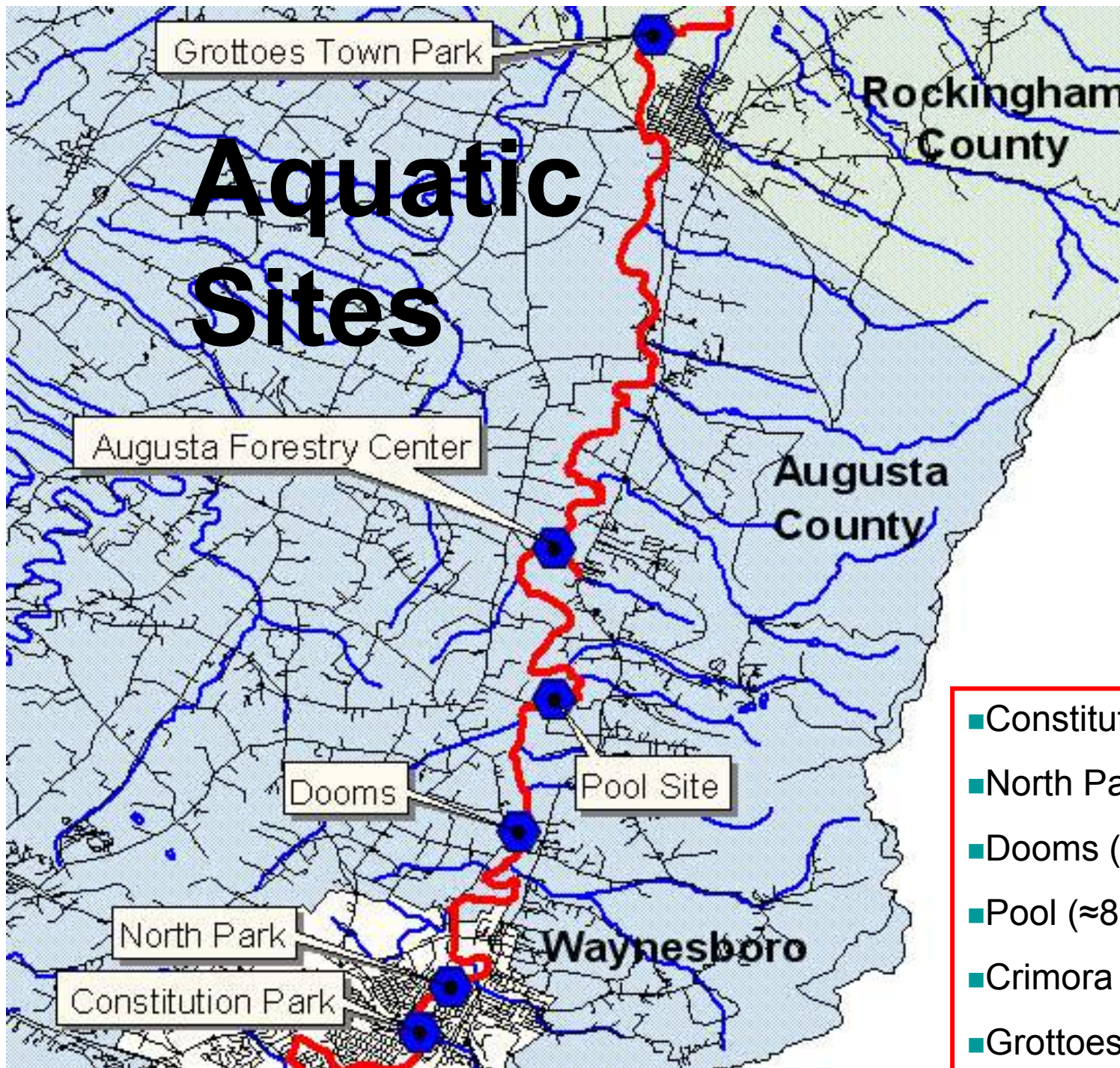
Biomagnification

I. Aquatic Component

Trophic Transfer Models



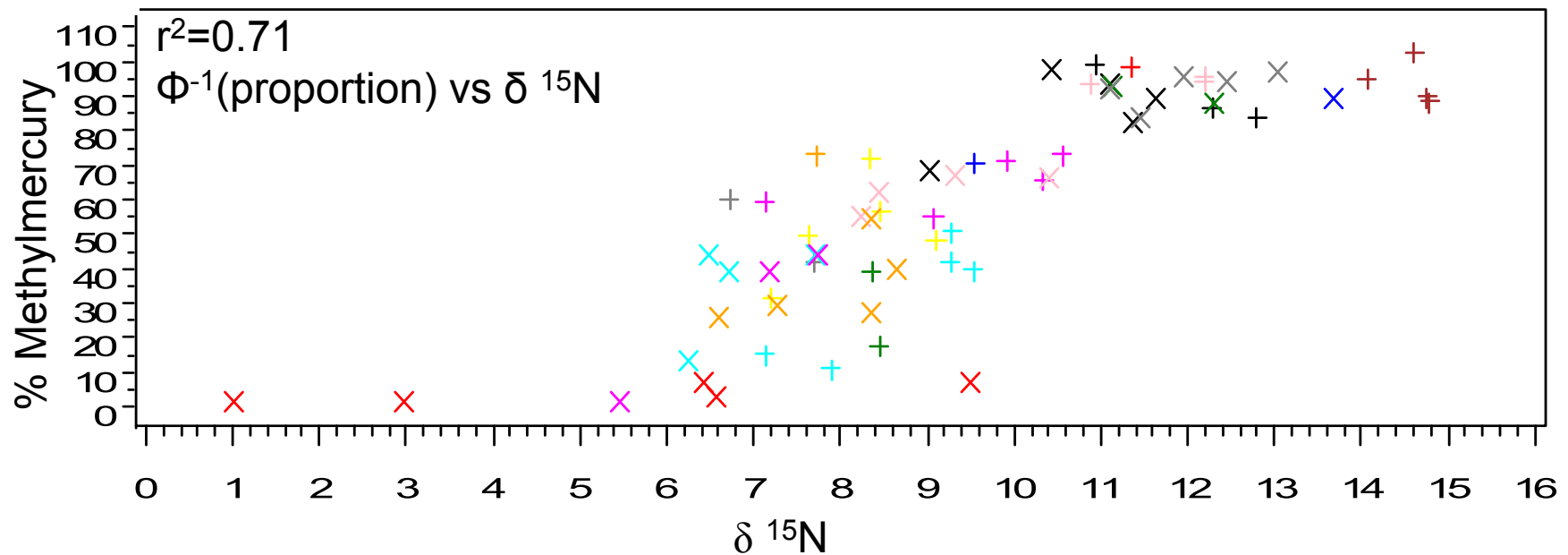
Aquatic Sites



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

Fraction Methylmercury

South River Trophic Models – Summer 2007



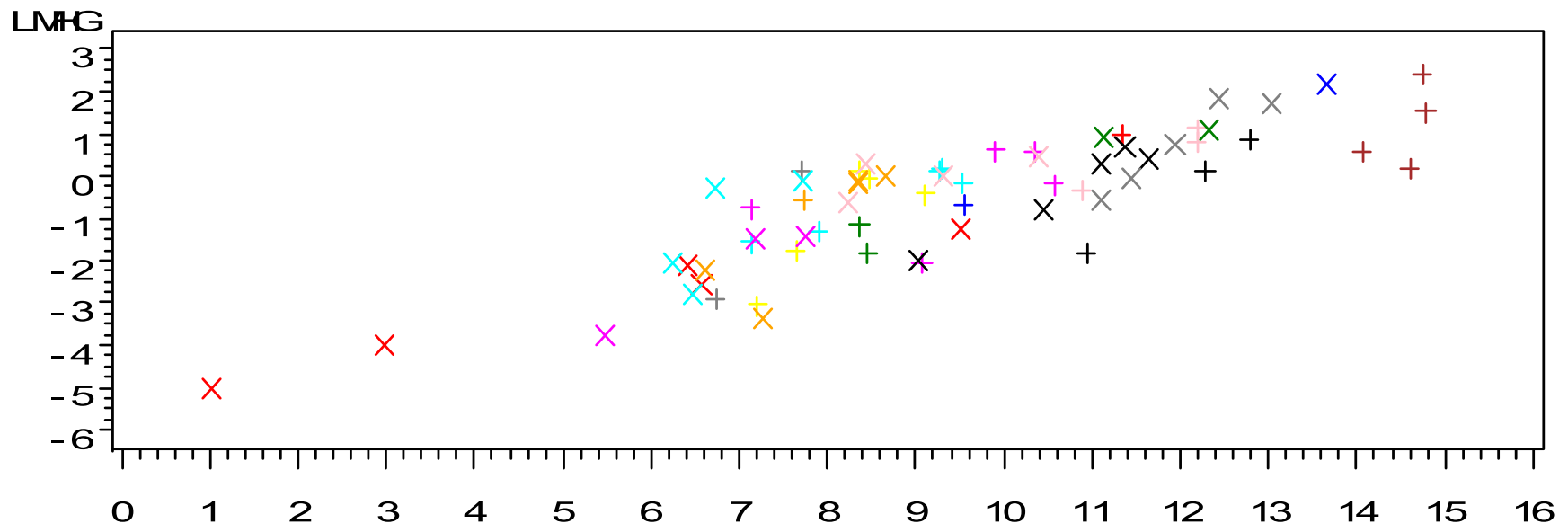
+ + + BG Sunf i sh
 + + + Chub
 + + + Ephemer el l i dae
 + + + LM Bass
 × × × Per i phyt on
 × × × St enone na
 × × × Zygopt er a

+ + + BN Minnow
 + + + Cor bi cul a
 + + + Fal l i Fi sh
 + + + Lept oxi s
 × × × RB Sunf i sh
 × × × Valt er penny
 × × × hydr opsychi dae

+ + + Baet i dae
 + + + Grayf i sh
 + + + Gonphi dae
 × × × Longnose Dace
 × × × SM Bass
 × × × Wri t e Sucker

Methylmercury - Aquatic

South River Trophic Models – Summer 2007



ORGANISM			DELN15			ORGANISM			DELN15			ORGANISM		
+	+	+	BG Sunfish	+	+	+	BN Minnow	+	+	+	Baetidae	+	+	+
+	+	+	Chub	+	+	+	Corbicula	+	+	+	Grayfish	+	+	+
+	+	+	Ephemeroptera	+	+	+	Fallfish	+	+	+	Gonphidae	+	+	+
+	+	+	LM Bass	+	+	+	Leptoxis	+	+	+	Longnose Dace	+	+	+
x	x	x	Periphyton	x	x	x	RB Sunfish	x	x	x	SM Bass	x	x	x
x	x	x	Stenonema	x	x	x	Vitripenny	x	x	x	Vitripenny	x	x	x
x	x	x	Zygoptera	x	x	x	Hydropsychidae	x	x	x	Vitripenny	x	x	x

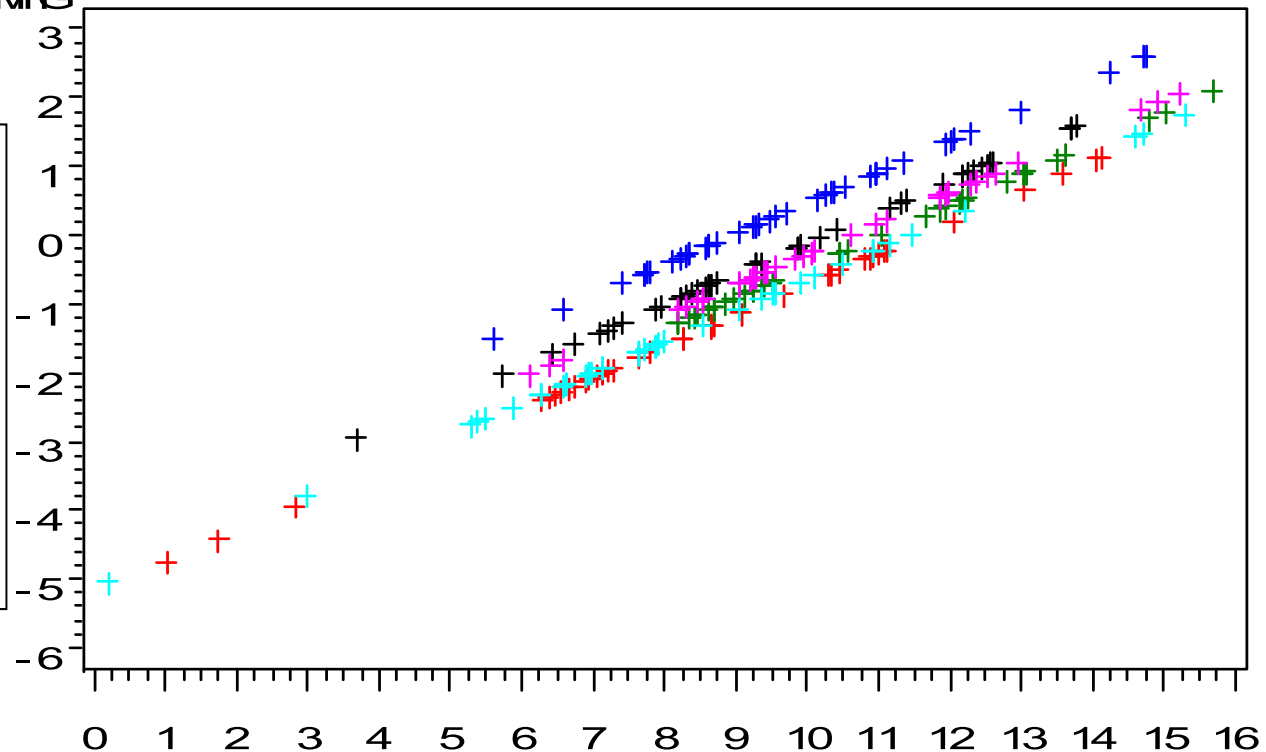
Methylmercury - Aquatic

South River Trophic Models – Summer 2007

Predicted Value of LMHG

Biomagnification
factor 4.6-fold
per trophic level

Baseline increases
slightly with
distance from
source

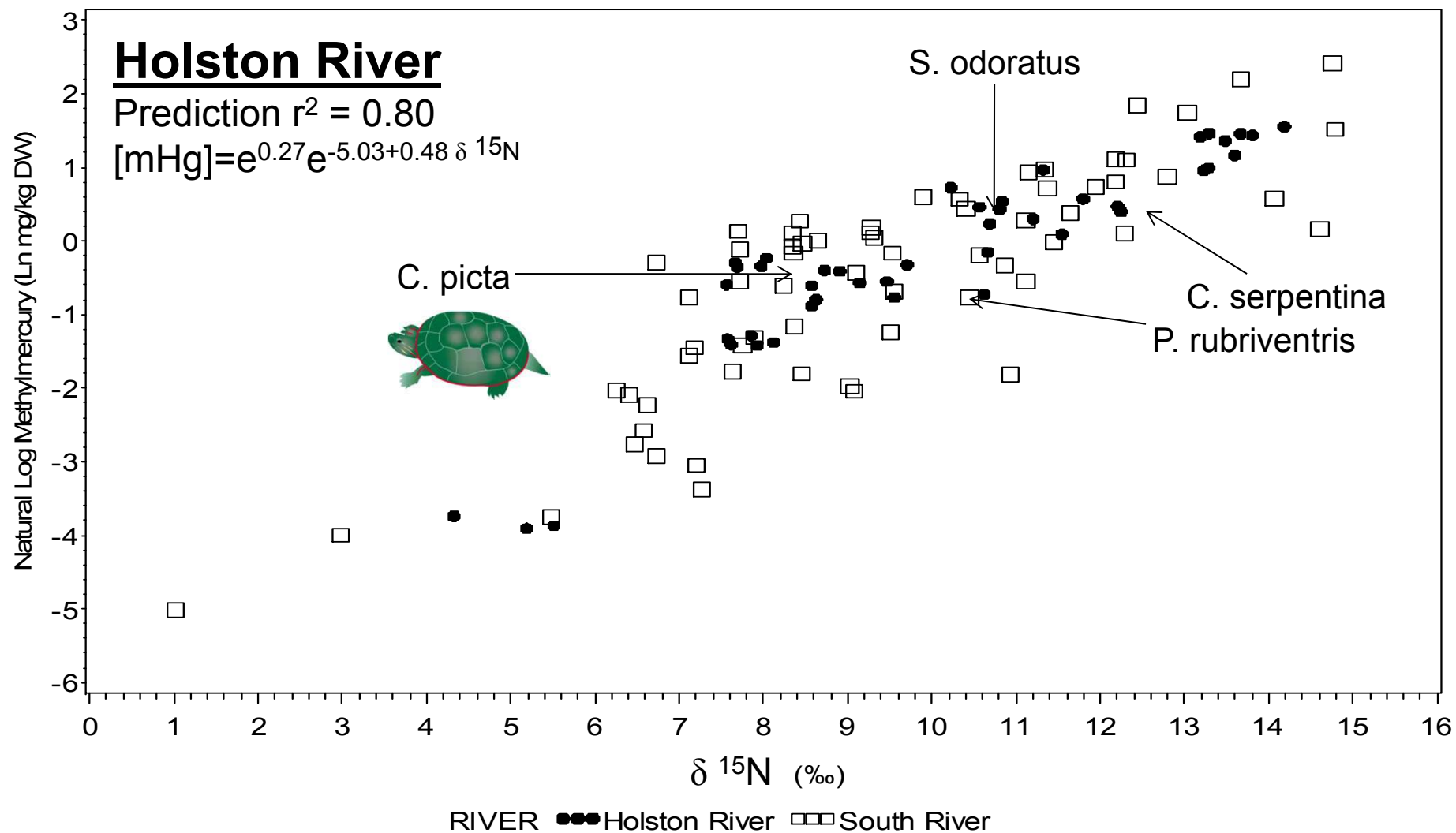


DELN15

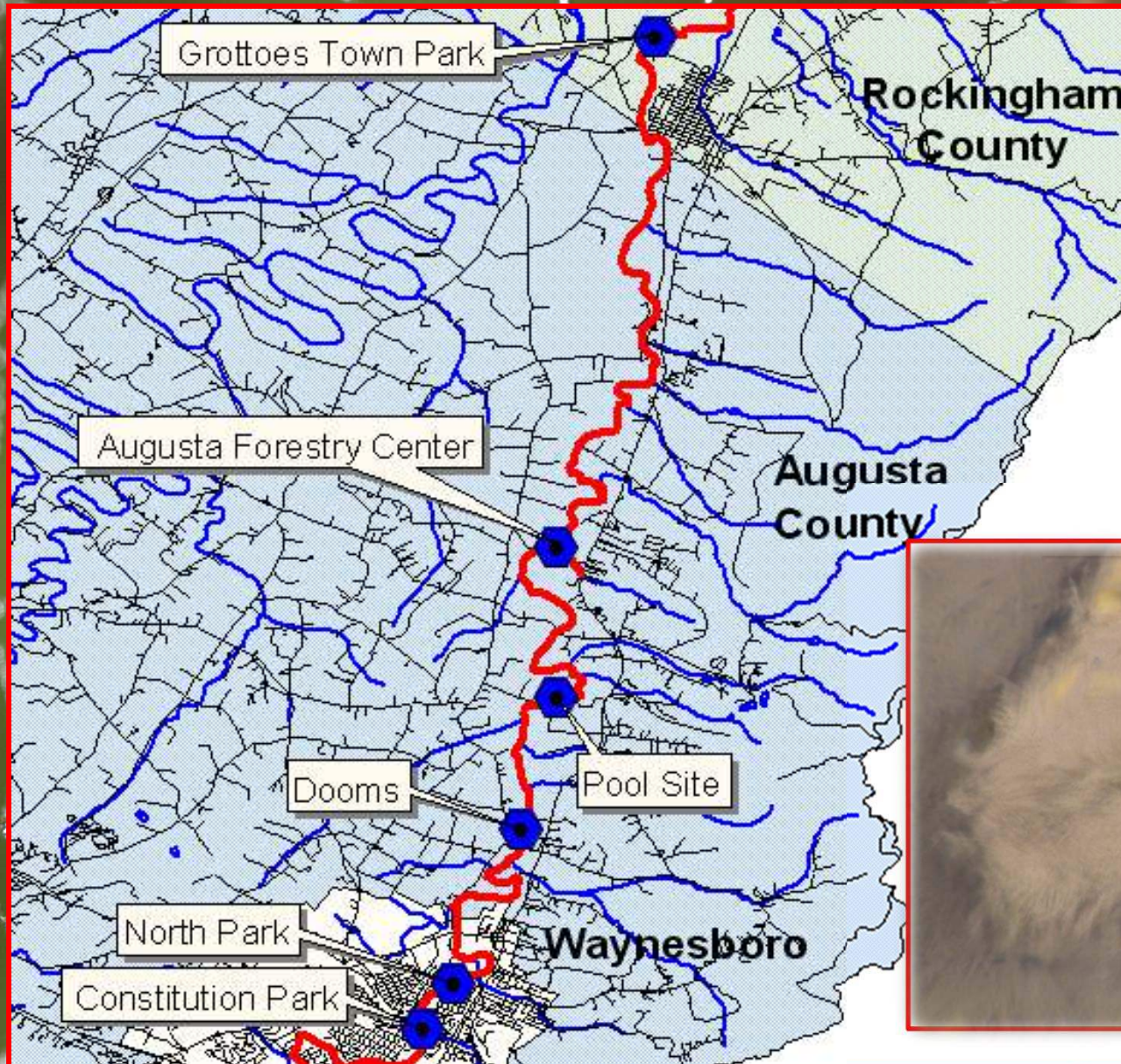
SITE + + + AFC + + + Const + + + Doons
 + + + GIP + + + North + + + Pool

Methylmercury – Two Rivers Combined

Natural Log Methylmercury Concentration vs Del $\delta^{15}\text{N}$



Biota Linked to Solids in 2008



6 Locations

Samples

Settled Sediments

Nat. Sediments

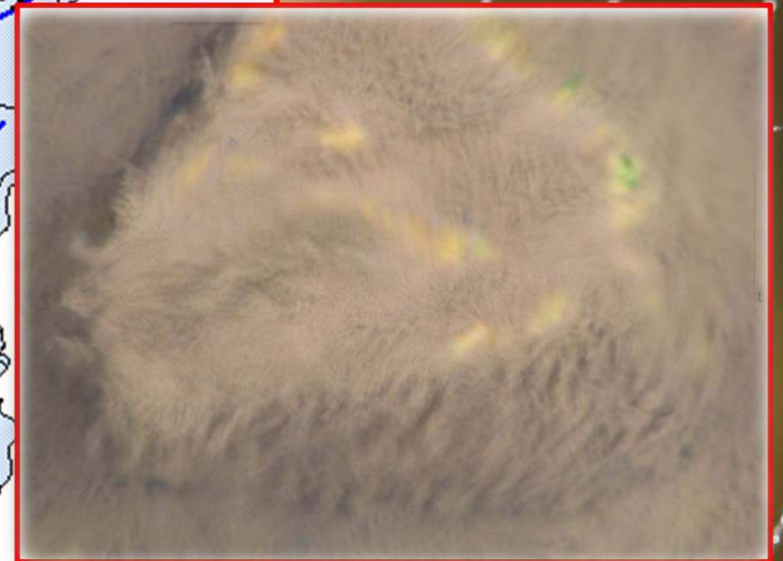
Nat. Periphyton

Art. Periphyton

Link biota to

Suspended solids

& surficial sediments

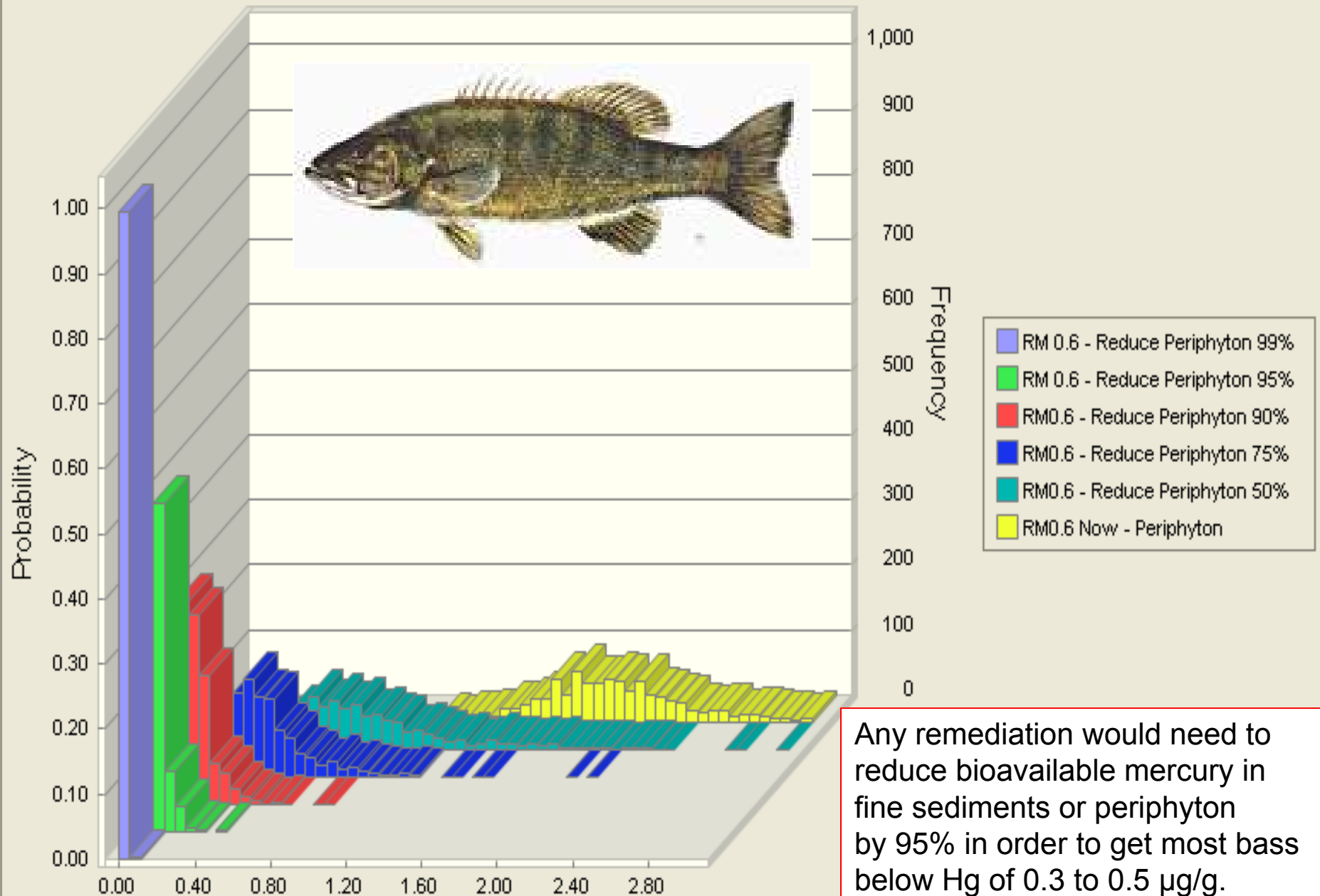


1,000 Trials

Frequency View

☐ Enable Rotation

Tertiary Consumer - Bass - (ug Hg/g WW)

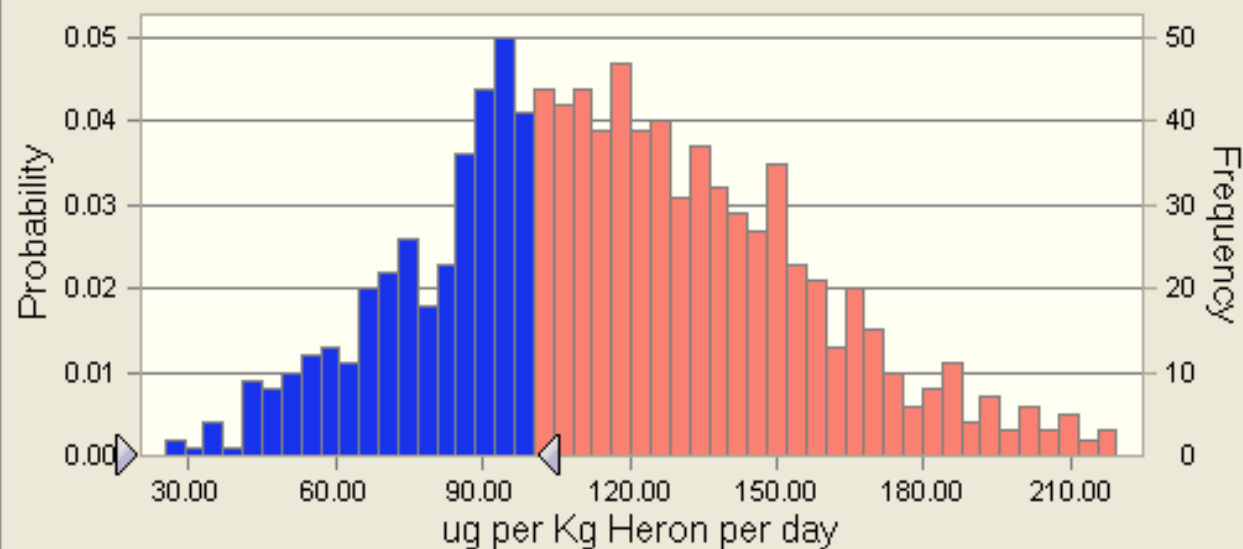
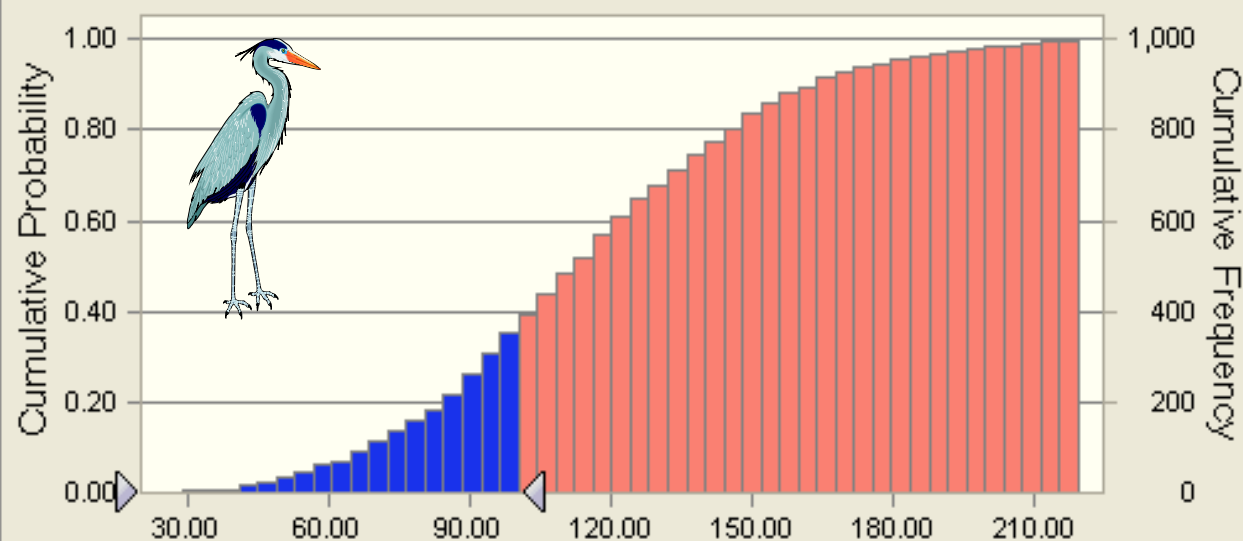


1,000 Trials

Split View

997 Displayed

Daily Intake - Great Blue Heron



Statistic	Forecast values
Trials	1,000
Mean	116.50
Median	114.30
Mode	---
Standard Deviation	36.73
Variance	1,349.11
Skewness	0.3099
Kurtosis	3.00
Coeff. of Variability	0.3153
Minimum	25.10
Maximum	258.68
Mean Std. Error	1.16

Toxicity Ref. Value (TRV):

Circa 65 to 100 ug/kg bw-day

**Great Heron, Bald Eagle,
Wood Stork PRA**78 (LOAEL), 26 (NOAEL)
(Ecotox.17:632, 2008)

► 0.10

Certainty: 34.90 %

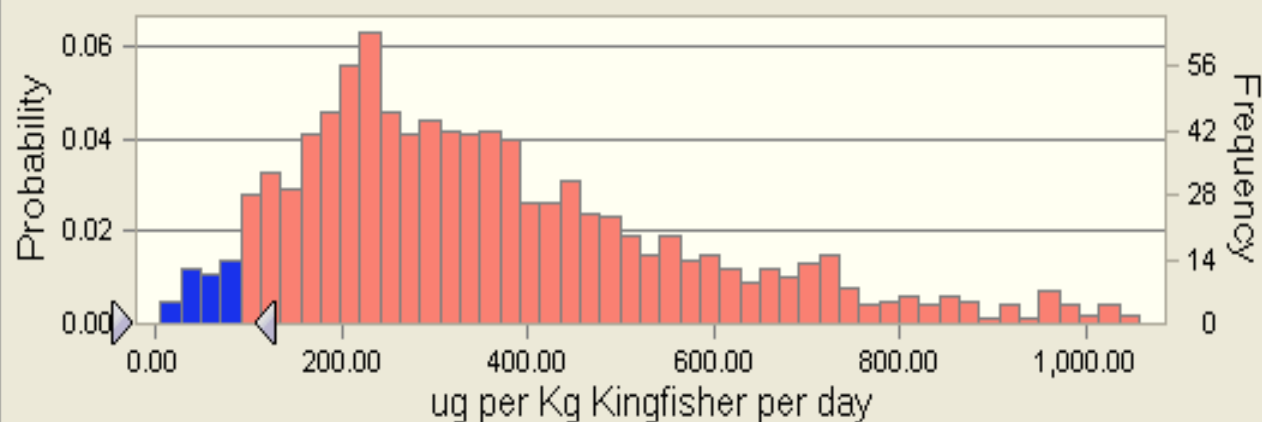
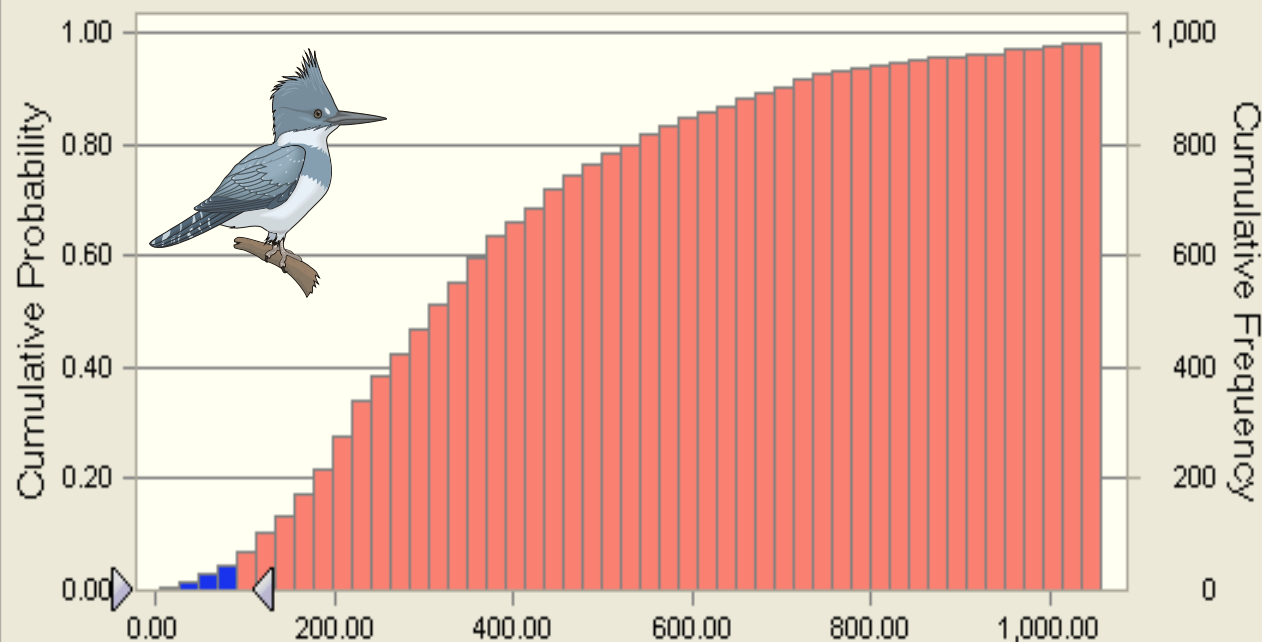
◄ 100.12

1,000 Trials

Split View

980 Displayed

Daily Intake - Kingfisher



Statistic	Forecast values
Trials	1,000
Mean	377.98
Median	319.57
Mode	---
Standard Deviation	242.51
Variance	58,810.02
Skewness	1.38
Kurtosis	5.33
Coeff. of Variability	0.6416
Minimum	4.59
Maximum	1,466.90
Mean Std. Error	7.67

Toxicity Ref. Value (TRV):

Circa 65 to 100 ug/kg bw-day

**Great Heron, Bald Eagle,
Wood Stork PRA**78 (LOAEL), 26 (NOAEL)
(Ecotox.17:632, 2008)

► 10.10 Certainty: 5.34 % ◀ 100.75

Significance

- Trophic dynamics determine relative [mHg] in biota
- Trophic dynamics can be predicted quantitatively
- Effectiveness needed in any remedial activities is near 95%
- Likely, a mixture of activities needed
- Avian piscivores potentially impacted, esp. kingfisher
 - Nesting sites limiting for kingfisher in this reach
 - Compensate by building artificial nesting berms/sites
- TROPHIC MANIPULATIONS
 - Modify river to favor sport fish feeding lower in food web* (trout)
 - Shift sports fishing focus to lower trophic level species
 - Modify Hg (esp. MHg) input into food web base
 - Modify river to shift
 - possible trophic cascade dynamics
 - keystone/dominant species
 - Invertebrate/forage fish prey (Δ substrate/hydrology/SAV)

*Swanson et al. 2006. Env. Sci. Technol. 40(5):1439-1446

Lepak et al. 2009. Ecotoxicol. DOI 10.1007/s10646-009-0306-5

Phase II Study

Define Present Trophic Linkages

Simple 1 Isotope and 2 Sources

$$\delta^{13}C_{Consumer} = f_{Source A} \delta^{13}C_{Source A} + f_{Source B} \delta^{13}C_{Source B}$$

$$1 = f_{Source A} + f_{Source B}$$



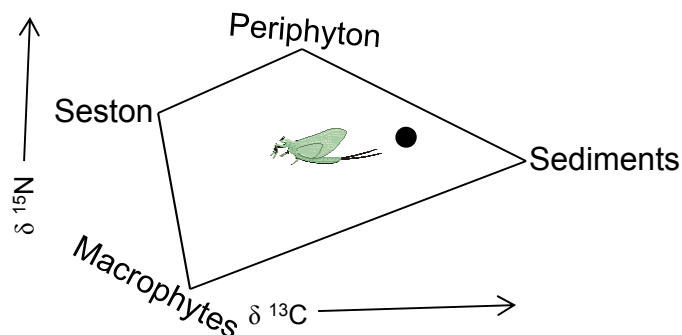
$$f_{Periphyton} = \frac{\delta^{13}C_{Waterpenny} - \delta^{13}C_{Sediments}}{\delta^{13}C_{Periphyton} - \delta^{13}C_{Sediments}} = 0.57$$

BUT $\delta^{13}C$ of consumer adjusted for trophic-related changes?

0.8 /TL (Rounick/Winterbourn 1986), 0.4/TL (Post 2002), 0.11/TL for Inverts (Caut et al. 2009)

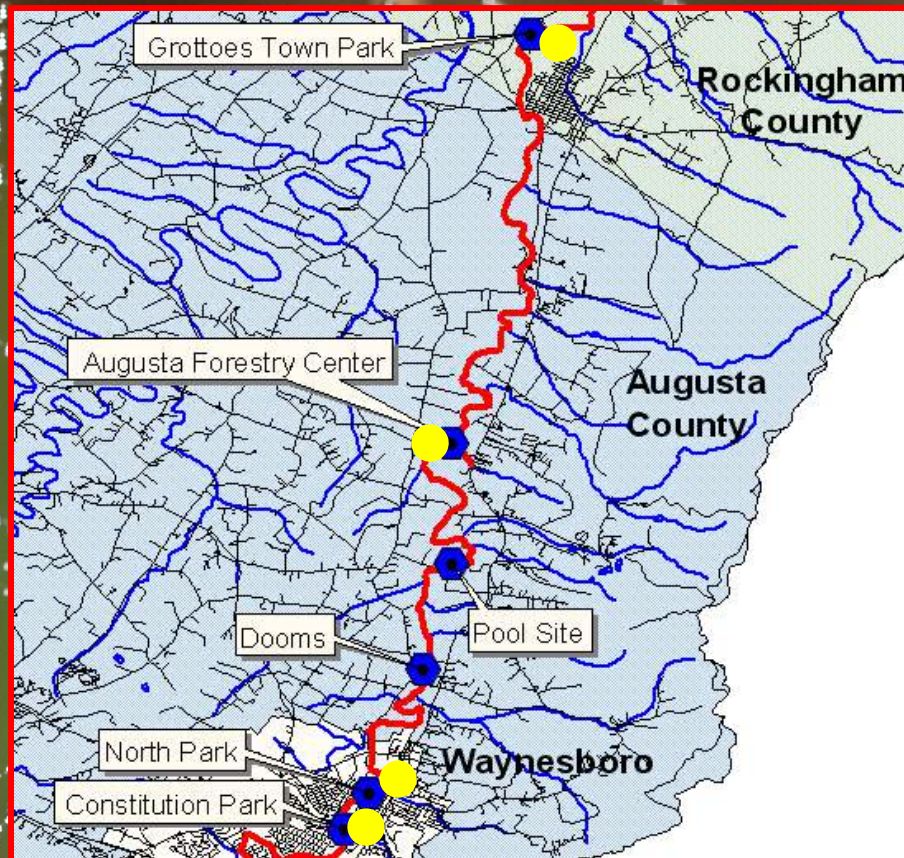
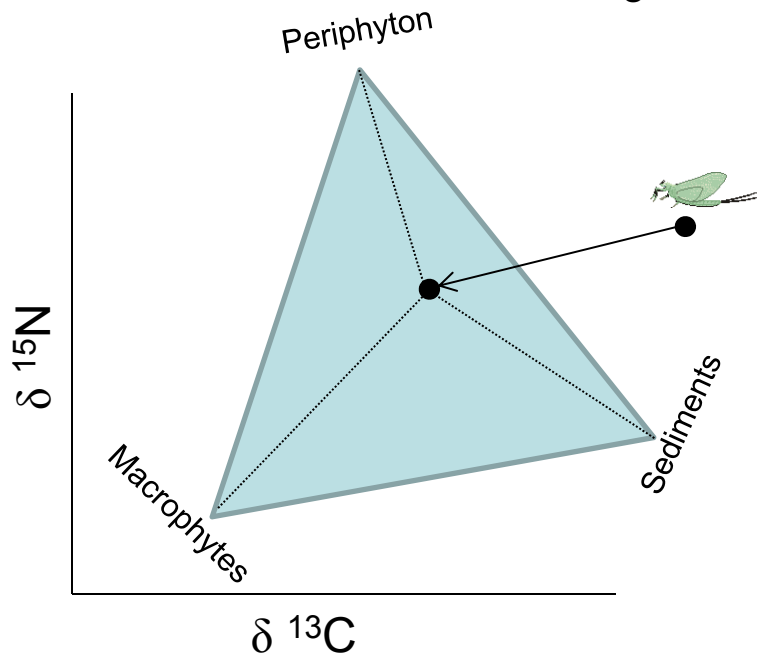
$$f_{Periphyton} = \frac{(\delta^{13}C_{Waterpenny} - 0.8) - \delta^{13}C_{Sediments}}{\delta^{13}C_{Periphyton} - \delta^{13}C_{Sediments}} = 0.34$$

Minimally Define with Polygon



2 Isotopes and 3 Sources

Estimates three source fractions
Also include sources' [C] and [N]
EPA IsoConc Excel Add-in Program



SAMPLINGS

May/June

August

Oct/Nov

SOURCES

Periphyton

Sediment/Seston

Macrophytes

BIOTA

Baetidae

Ephmerellidae

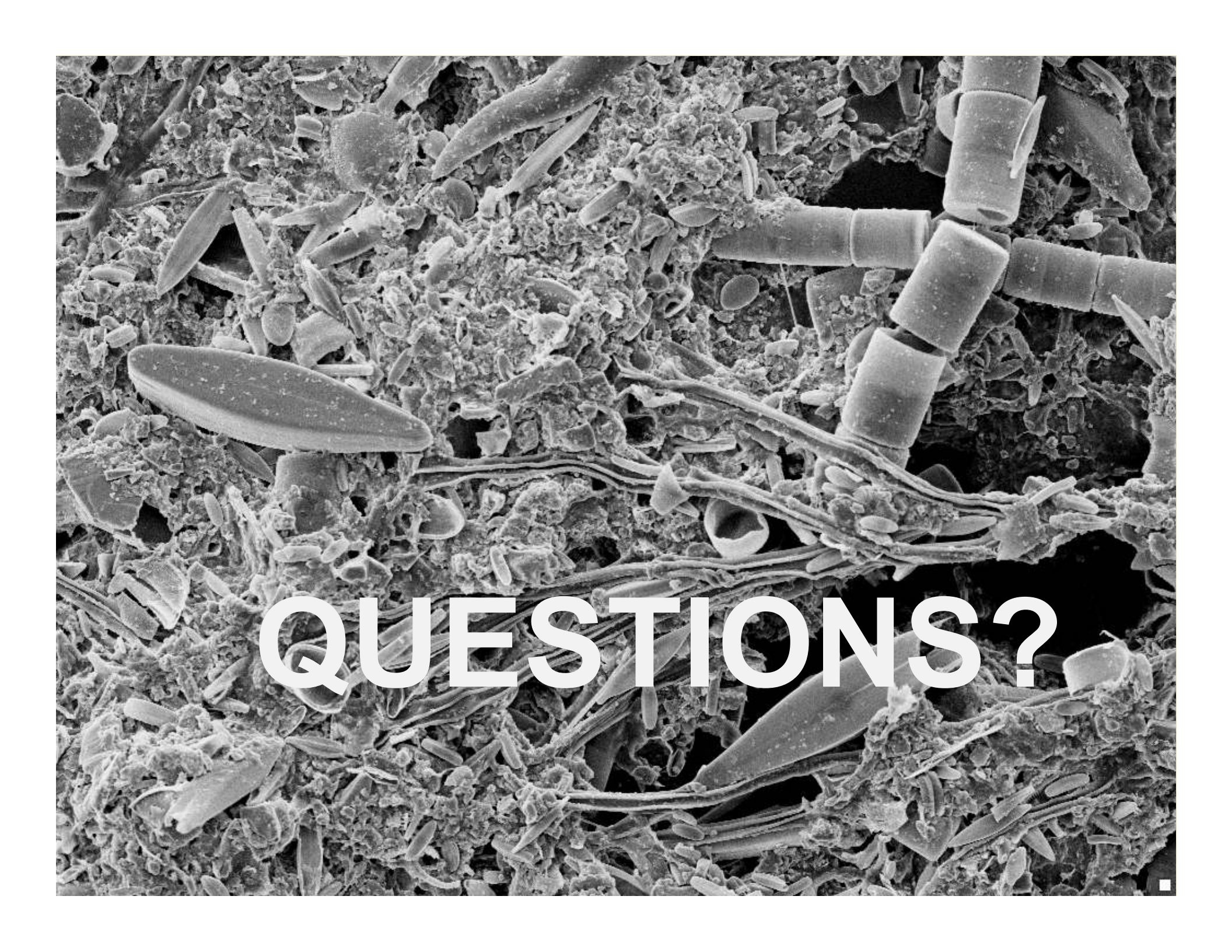
Heptageniidae

Hydropsychidae

Crayfish

Forage fish species

Small/Largemouth Bass

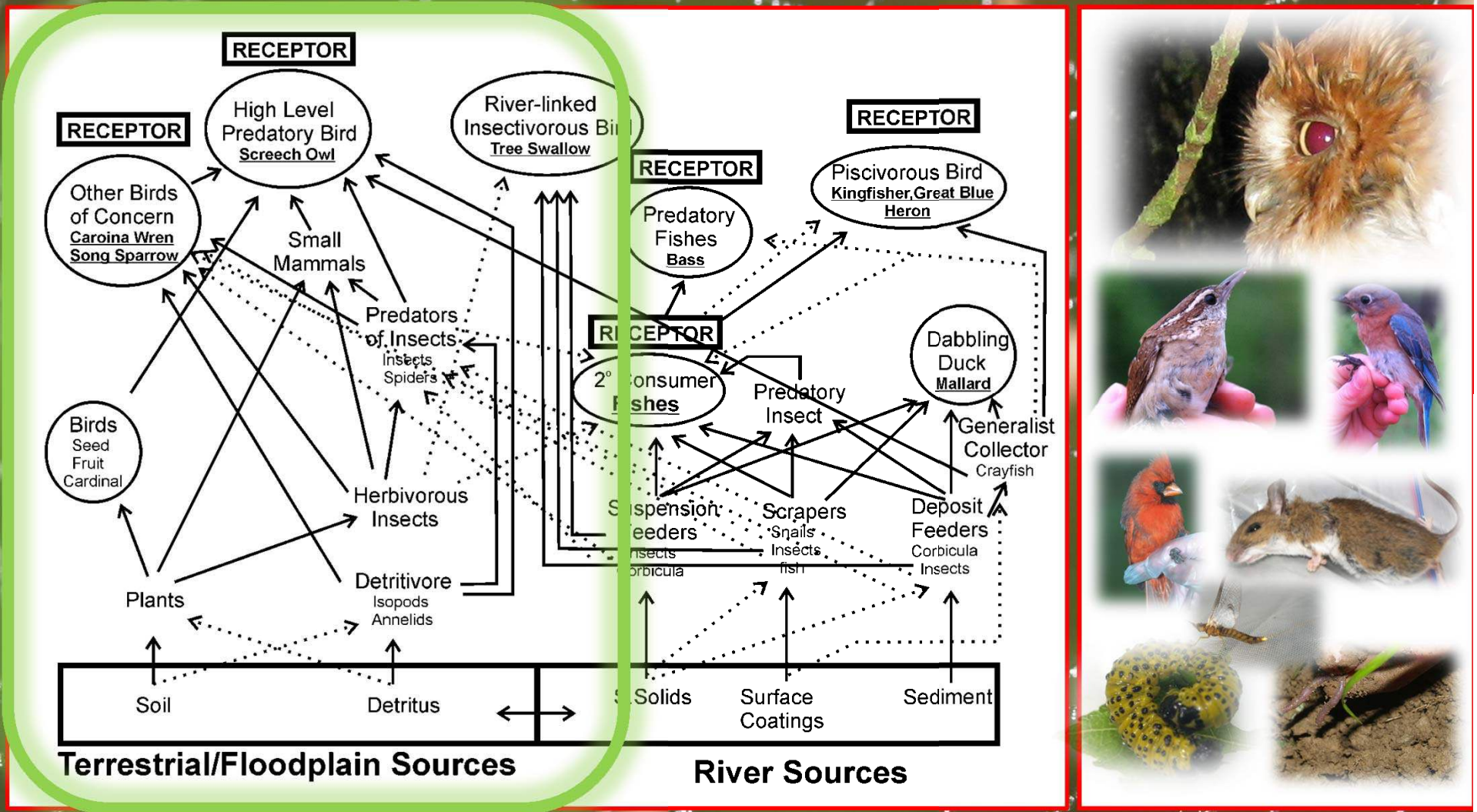
A scanning electron micrograph (SEM) showing a complex biological structure. The image features several elongated, segmented, tube-like structures, possibly representing parts of a microorganism or a plant stem. These structures are surrounded by a dense, granular matrix of smaller, irregular particles. The overall texture is highly detailed and three-dimensional. The word "QUESTIONS?" is overlaid in large, white, sans-serif capital letters across the center of the image.

QUESTIONS?

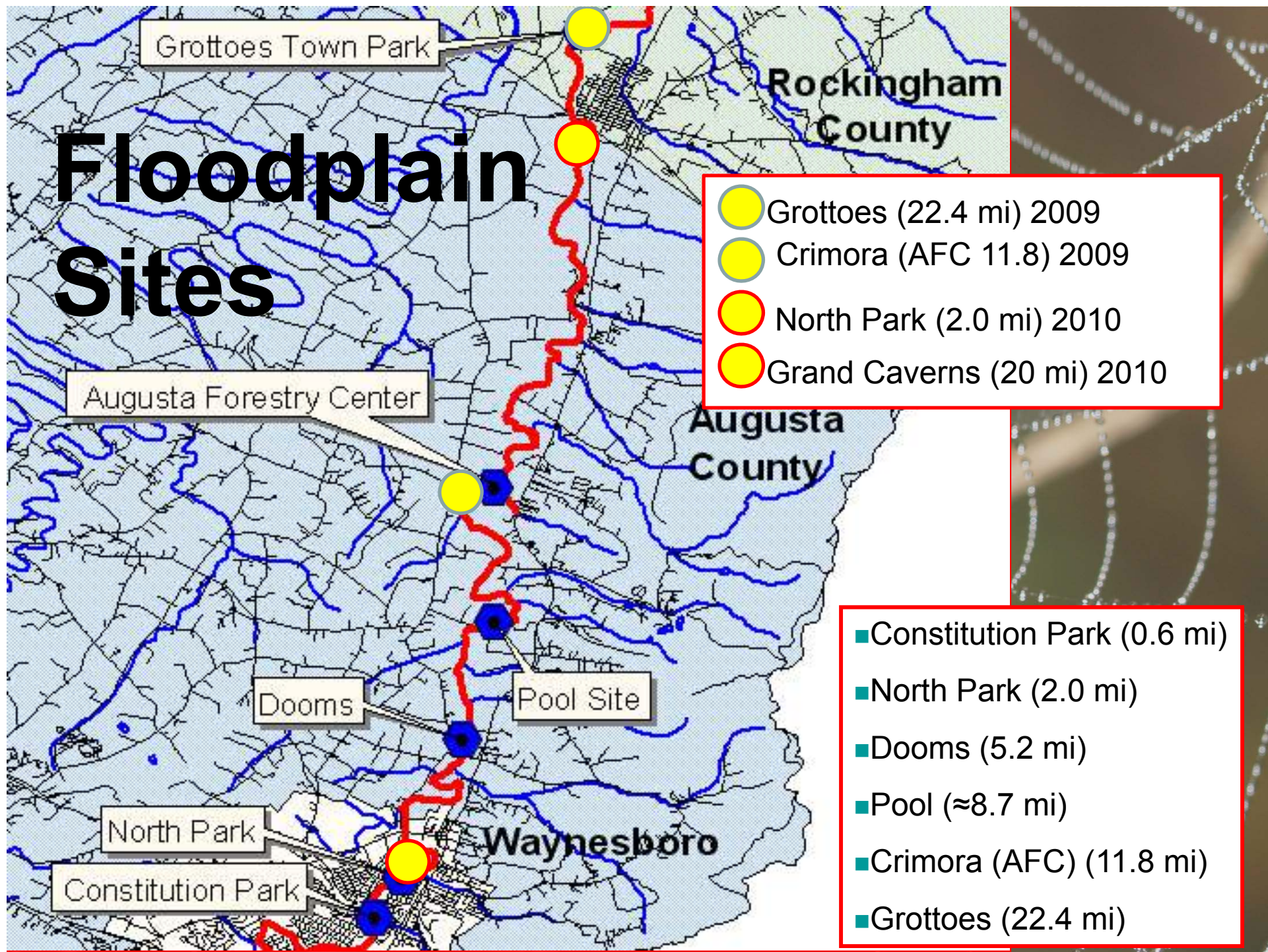
II. Floodplain Food Web



Floodplain Component

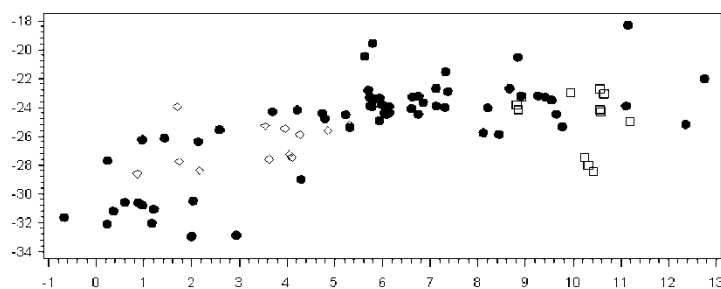


Floodplain Sites

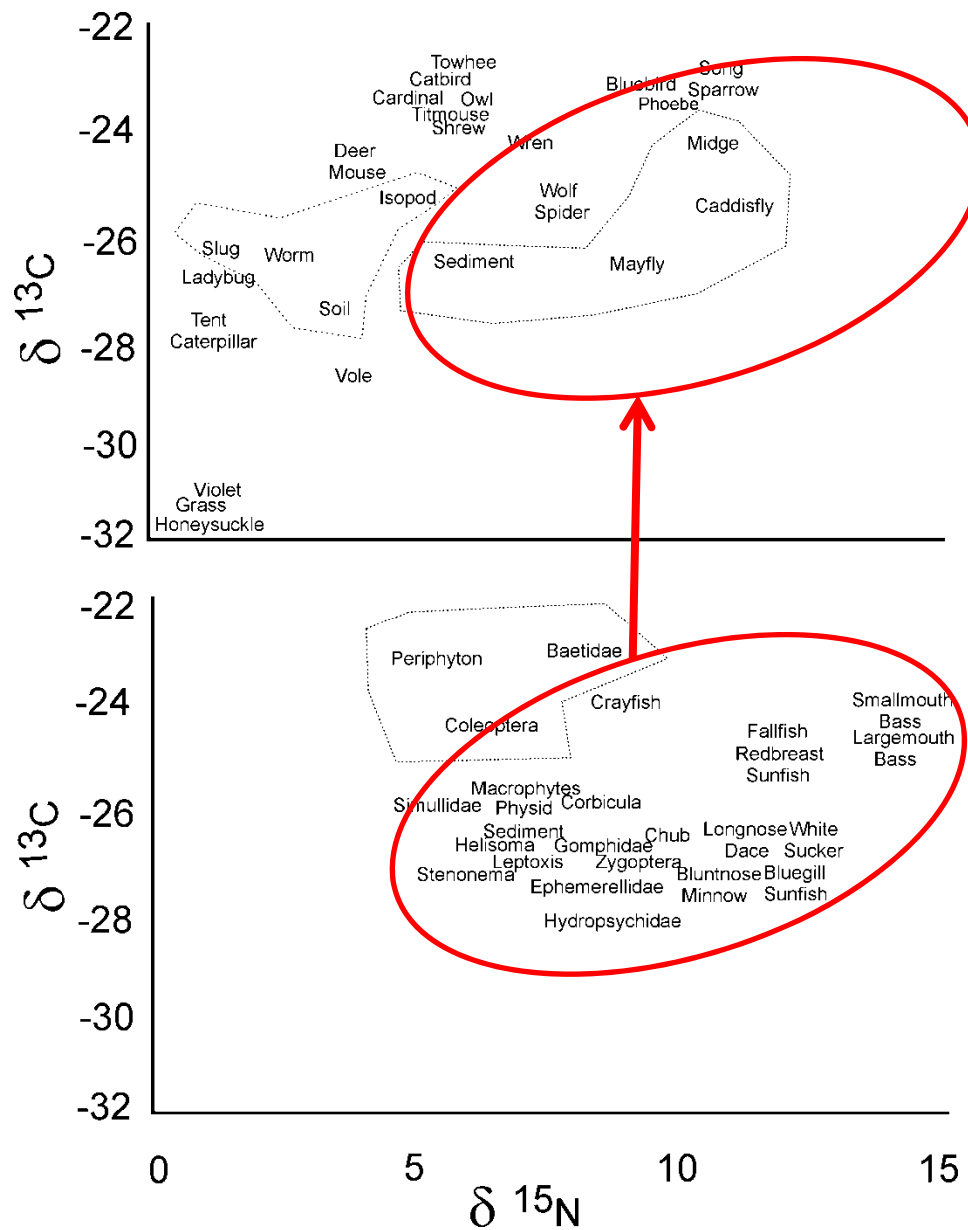
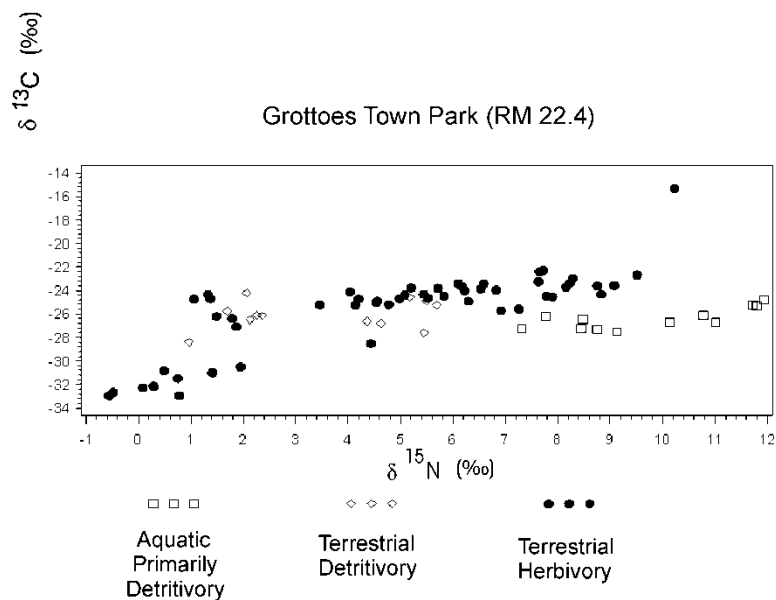


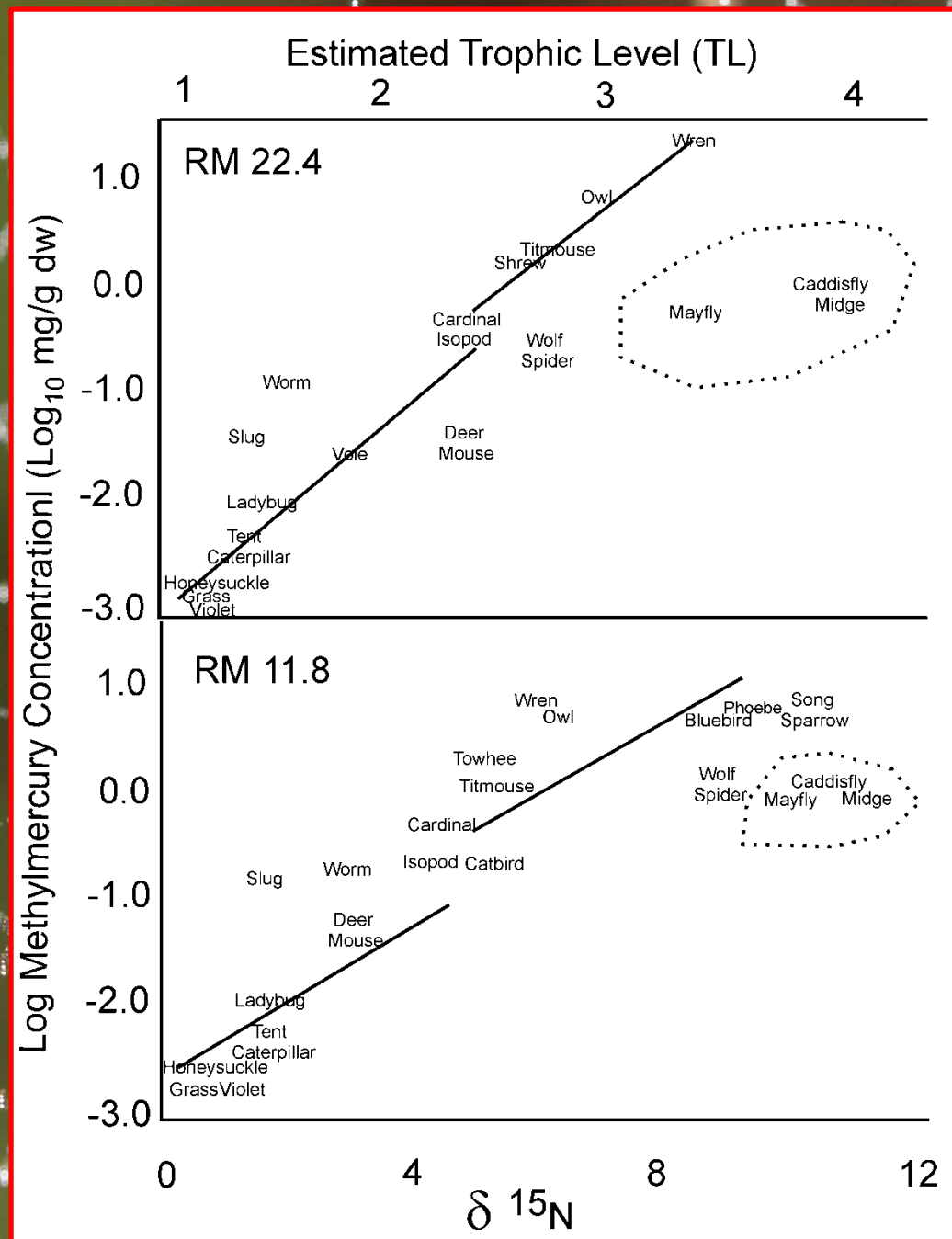
2009

Adjacent to Augusta Forestry Center (RM 11.8)



Grottoes Town Park (RM 22.4)





$$\log_{10} [Hg \text{ or } MHg] = a + b \delta^{15}N + c(RM \text{ or } MS) + \epsilon$$

Mercury and Methylmercury Models (terrestrial herbivory-related samples after excluding feathers).

	r^2	a (95% CI)	b (95% CI)	c (95% CI)	MSE	$r^2_{\text{Prediction}}$
$\delta^{15}N$			TOTAL MERCURY			
RM 11.8	0.70	-1.47 (-1.76 to -1.18)	0.20 (0.14 to 0.27)	0.37 (-0.04 to 0.78)	0.274	0.53
RM 22.4	0.75	-1.82 (-2.11 to -1.54)	0.29 (0.21 to 0.37)	0.14 (-0.31 to 0.58)	0.241	0.62
TL						
RM 11.8	0.70	-2.03 (-2.44 to -1.62)	0.69 (0.48 to 0.91)	0.37 (-0.04 to 0.78)	0.274	0.53
RM 22.4	0.75	-2.63 (-3.08 to -2.17)	0.98 (0.70 to 1.26)	0.14 (-0.30 to 0.58)	0.241	0.62
$\delta^{15}N$			METHYLMERCURY			
RM 11.8	0.83	-2.66 (-2.99 to -2.34)	0.29 (0.21 to 0.36)	0.89 (0.43 to 1.34)	0.343	0.79
RM 22.4	0.87	-3.11 (-3.42 to -2.82)	0.41 (0.32 to 0.50)	0.55 (0.08 to 1.03)	0.273	0.85
River	0.78	-2.26 (-2.55 to -1.98)	0.19 (0.16 to 0.22)	0.02 (0.01 to 0.03)	0.100	0.76
TL						
RM 11.8	0.83	-3.45 (-3.91 to -3.00)	0.97 (0.73 to 1.21)	0.89 (0.43 to 1.35)	0.343	0.79
RM 22.4	0.87	-4.26 (-4.74 to -3.77)	1.40 (1.10 to 1.70)	0.55 (0.08 to 1.03)	0.273	0.85
River	0.78	-1.09 (-1.23 to -0.94)	0.66 (0.56 to 0.76)	0.02 (0.01 to 0.03)	0.100	0.76

Terrestrial models: c = 0 for poikilotherms or the shown parameter estimate for homeotherms. River model: c = the effect of downriver distance from the historic source (RM 0). The number of observations in the river, AFC09, and GTP models was 66, 43, and 40, respectively, for total and methylmercury models. The river model was generated for 6 locations from RM 0.6-22.4.

Methylmercury Food Web Magnification Factors (FWMF in fold increase per TL)

River	4.6	Floodplain RM 11.8	9.3 (14.8?)
(Similar to Holston & general literature)		Floodplain RM 22.84	25.1

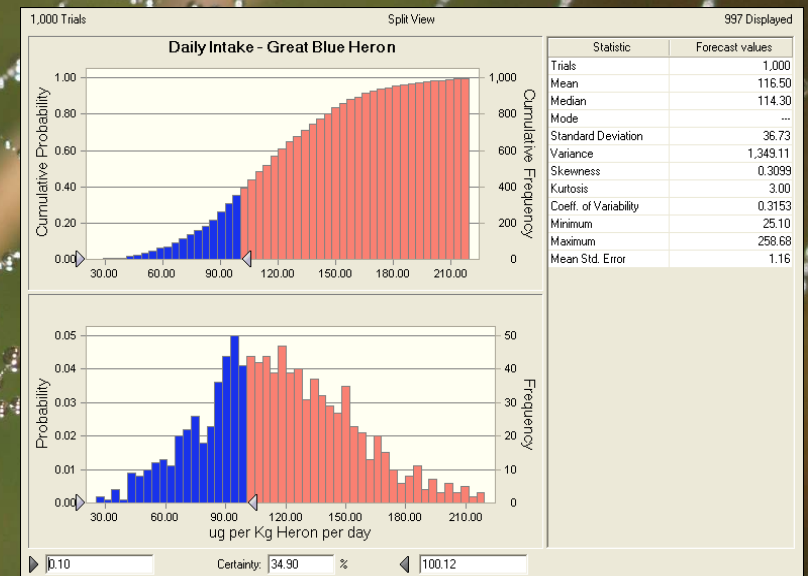
“FASTER ON LAND”

Birds – Exposure Assessment

Carolina Wren, Song Sparrow and Screech Owl Dietary Information

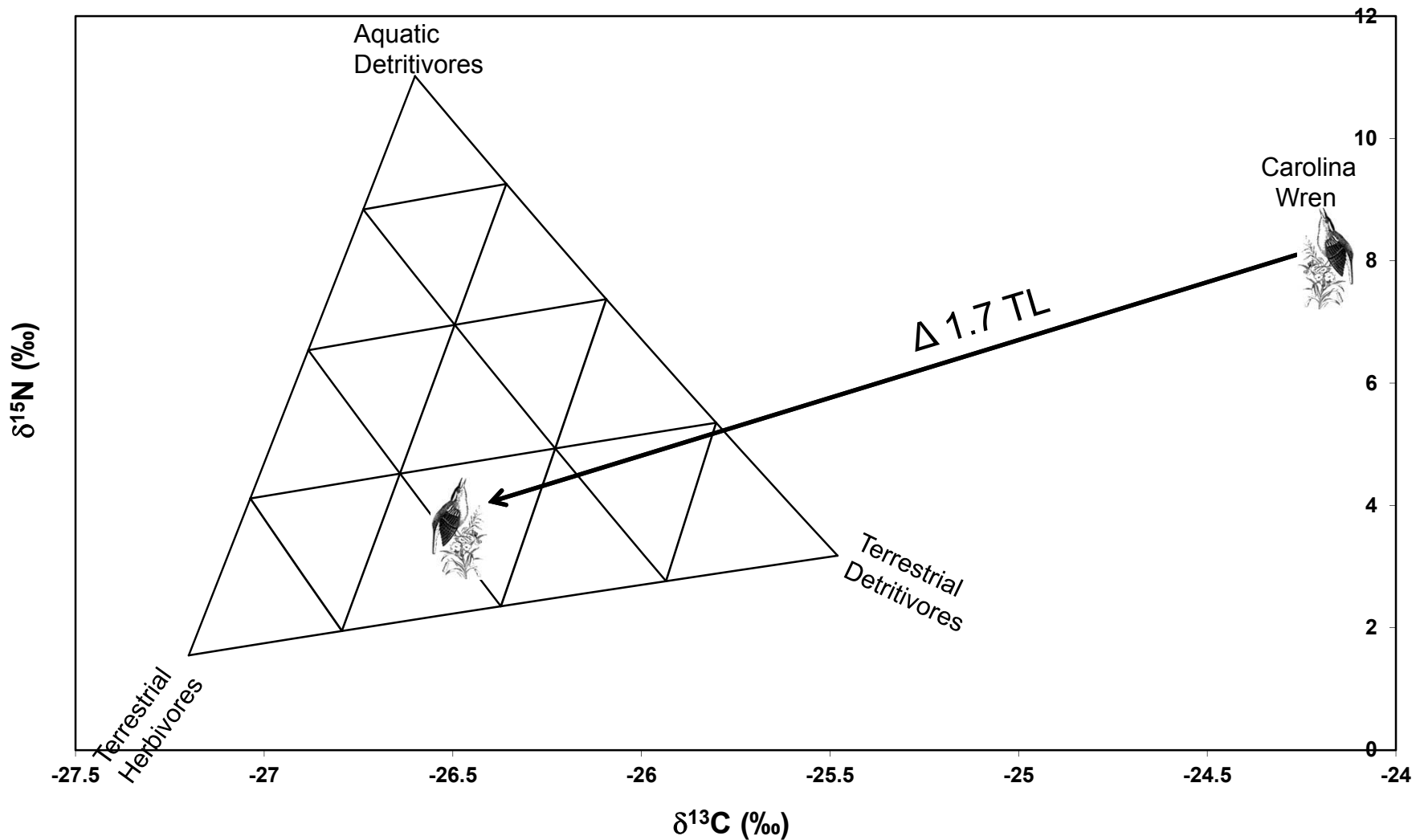
- Mercury in Dietary Items
 - Data from past and 2010 Survey
- Expert Elicitation (Modified Delphi Method)
 - Frequency of Consumption of food Items
 - Amounts eaten of food items

Monte Carlo Simulation for Exposure Assessment



Refine Trophic Linkages Insights

Concentration Dependent Mixing Triangle – Floodplain RM 22.4





Significance - Floodplain

- Trophic dynamics determine relative [Hg] in floodplain biota
- MHg is dominant Hg form in apex species of interest
- Trophic dynamics can be predicted quantitatively
- Predictive tool for judging effectiveness of any remediation action
- Floodplain remediation more difficult (impractical?)
- Compensate by replacing habitat?
- Create attractive feeding or nesting habitat away from river edge?

