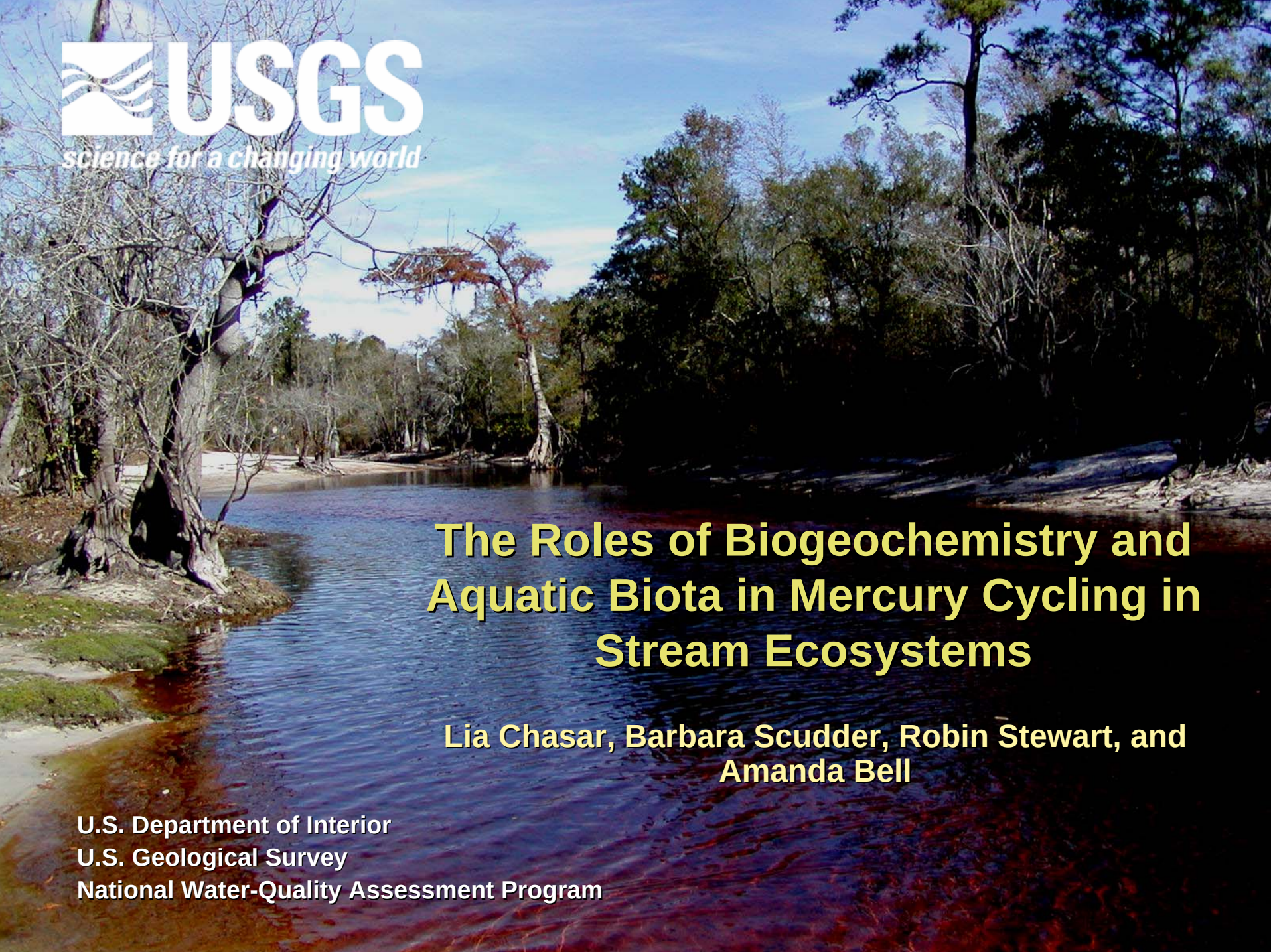


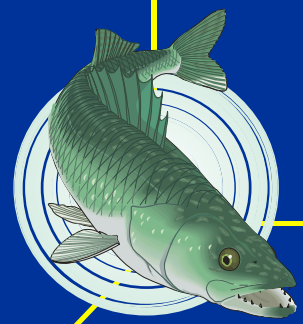
The Roles of Biogeochemistry and Aquatic Biota in Mercury Cycling in Stream Ecosystems

Lia Chasar, Barbara Scudder, Robin Stewart, and Amanda Bell

U.S. Department of Interior
U.S. Geological Survey
National Water-Quality Assessment Program

NAWQA Mercury Bioaccumulation Study

Mercury source strength



Food web complexity

Structure

Food chain length

Methylation efficiency

After : T.E. Mumley & K.E. Abu-Saba, WEF National TMDL Science and Policy Conference Proceedings, Nov. 13-16, 2002

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Objective

- Evaluate the influence of environment and food web characteristics on mercury contamination in top predator fish
  - Environmental factors
    - Climate/hydrodynamics
    - Physicochemical
    - Substrate
  - Food web complexity
    - food web structure
    - food chain length

Ecological Approach

- Physical setting
  - Hydrology
  - Water chemistry
- Food web base
  - Periphyton (attached algae)
  - Microbial biofilms
  - Detritus
  - Seston
- Consumers
  - Primary and secondary
  - Locally/regionally common species
  - Feeding relationships
- Life history of target species

Lookout Creek, Oregon
Reference site, low % wetland

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Site Selection

- 3 study areas
  - 2 to 3 sites each
- Landscape type
  - 1 urban
  - 1-2 reference
    - Rural or non-cultivated
    - Low and high % wetland
- Nearby atmospheric monitoring sites for Hg
- Availability of target predator fish species
- Range of food web complexity

Evergreen River, Wisconsin
Reference site, low % wetland,
wetlands close proximity

Multimedia Sampling

- Surface Water
  - Dissolved and particulate THg and MeHg
  - DOC, SO_4, suspended sediment
  - Major ions
  - Nutrients
  - DO, pH, conductance, alkalinity
  - Streamflow
- Biota
  - Benthic algae (THg and MeHg)
  - Aquatic invertebrates (THg and MeHg)
  - Predator and forage fish (THg)

Little Wekiva River, Florida
Urban site

Conceptual Food Web

Predator Fish

Forage Fish sp. 1

Forage Fish sp. 2

Invertebrate sp. 1

Invertebrate sp. 2

Seston

Detritus

Biofilms

Periphyton

Aqueous MeHg

Predator and Forage Fish

- Predator
  - 1 target species
  - Skin-off fillets
- Forage
  - 2 species
  - Headless/gutless
- 12 individuals per species
  - Age, length, weight, sex
  - Gut contents
  - THg
  - Stable isotopes ($\delta^{13}C$, $\delta^{15}N$)

Continued…

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Benthic Invertebrates

- Two species
  - Locally common
  - Whole-body
- Target 30+ individuals per species
- Collectors and grazers
  - THg and MeHg
  - Stable isotopes ($\delta^{13}C$, $\delta^{15}N$)

Continued…

Periphyton

- Twice, seasonal
- Target substrates
  - woody debris
  - rocks
  - sediment
- Analyses
  - THg and MeHg
  - Stable isotopes ($\delta^{13}C$, $\delta^{15}N$)
- Bell and Scudder (USGS - OFR 2004-1446); Bell & Scudder (JAWRA Journal, in press)

Expected Food Webs

	WILL	WIMC	GAFL
Predator Fish A	Cutthroat	Brown Trout	Largemouth Bass
Predator Fish B		Brook Trout	
Forage Fish A	Sculpin	Creek Chub	Juvenile Sunfish
Forage Fish B	Dace	Shiner/Dace	Gambusia
Invertebrate A	Caddisfly	Caddisfly	Crayfish Grass Shrimp
Invertebrate B	Mayfly	Mayfly	Mosquito Larvae

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Sampled Food Webs

	WILL	WIMC	GAFL
Predator Fish A	Cutthroat	Brown Trout	Largemouth Bass
Predator Fish B	***Rainbow***	***Green Sunfish***	
Forage Fish A	Sculpin	Creek Chub	Juvenile Sunfish
Forage Fish B	Dace ***Gambusia***	Dace ***Sculpin***	Gambusia ***Shiners/Mollys***
Invertebrate A	Caddisfly ***Snails***	Caddisfly	Crayfish Grass Shrimp ***Amphipods***
Invertebrate B	Mayfly ***Crayfish***	Mayfly	***Caddisfly***

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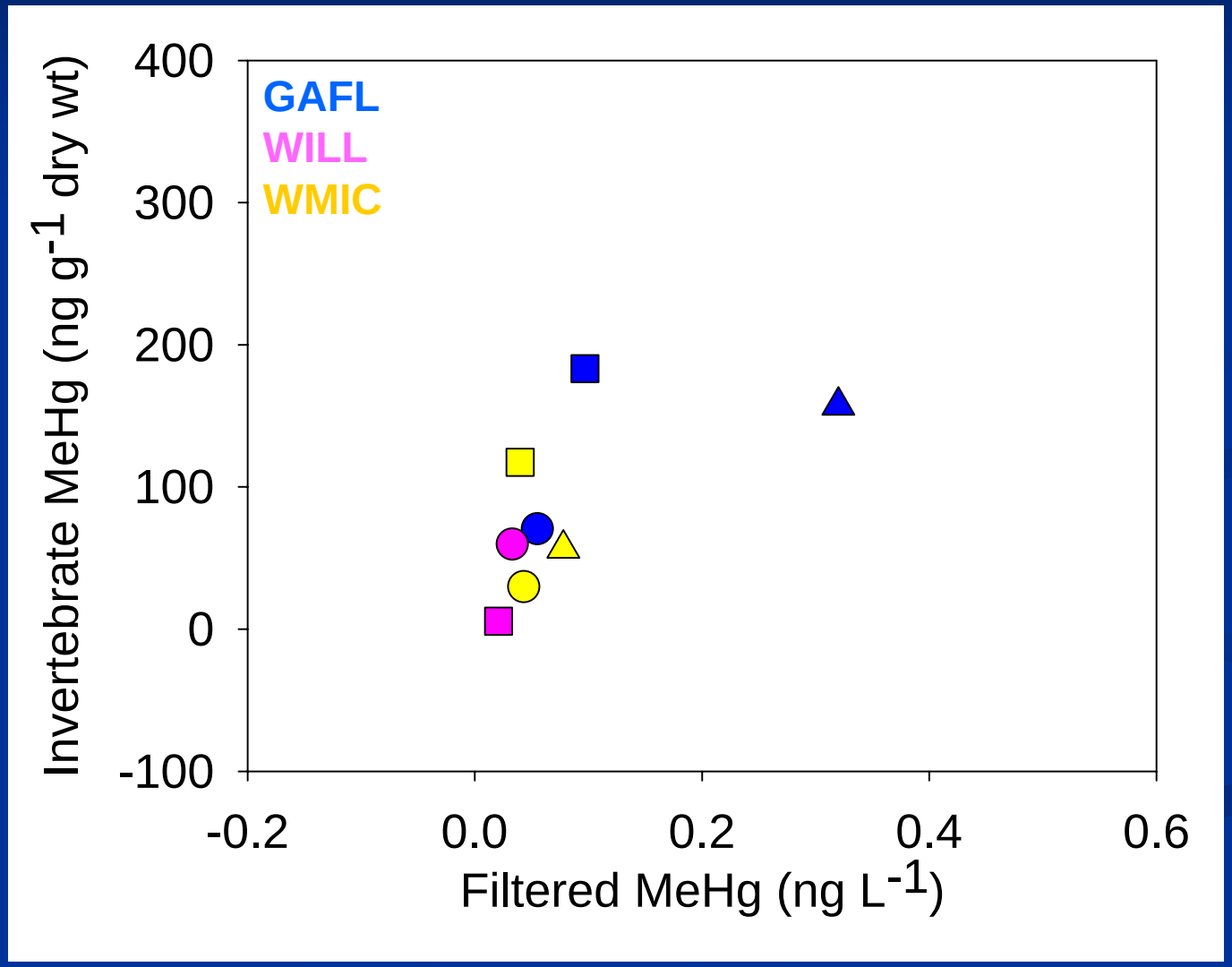
Results

Relationship of invertebrate MeHg to aqueous MeHg



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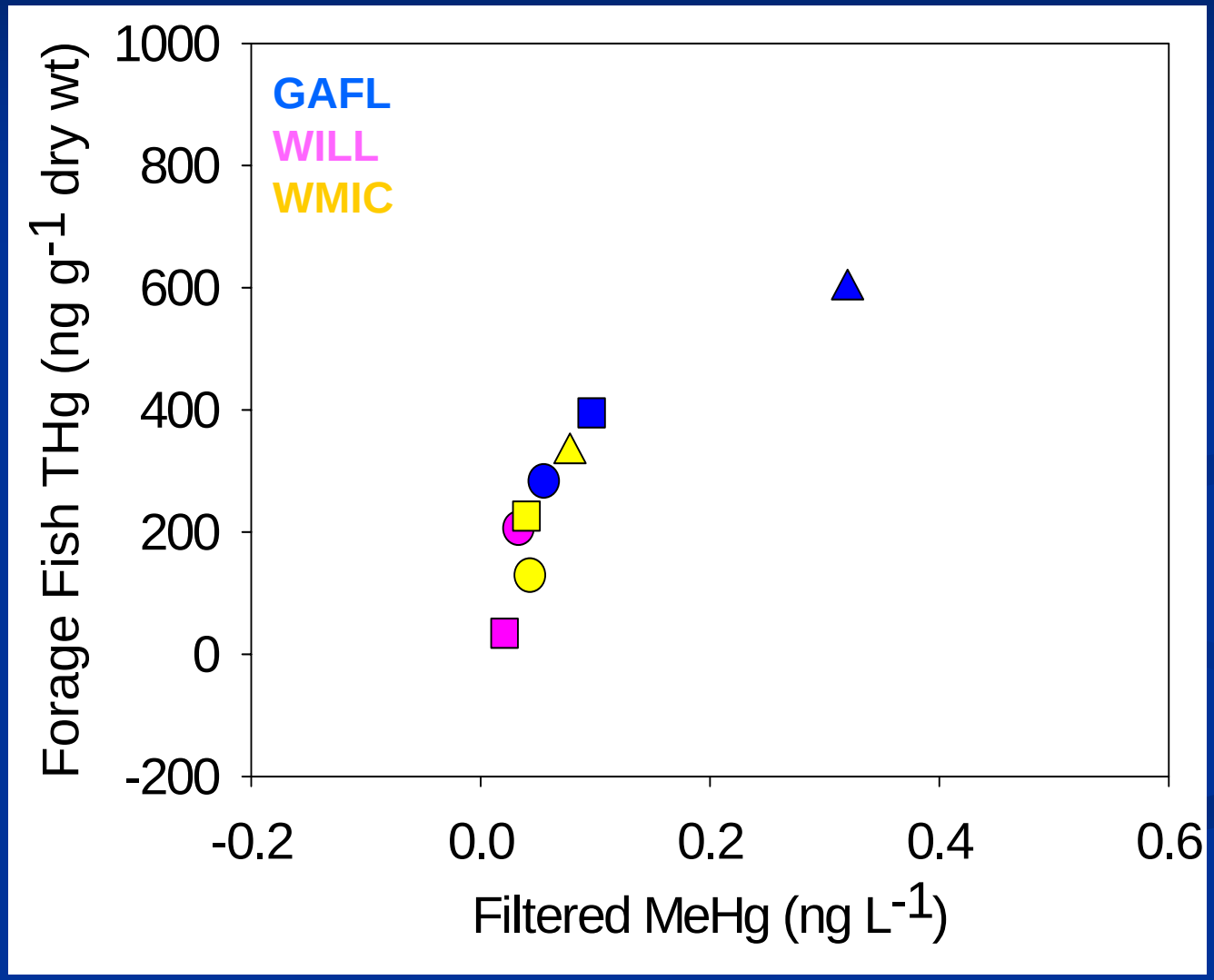
Relationship of forage fish THg to aqueous MeHg



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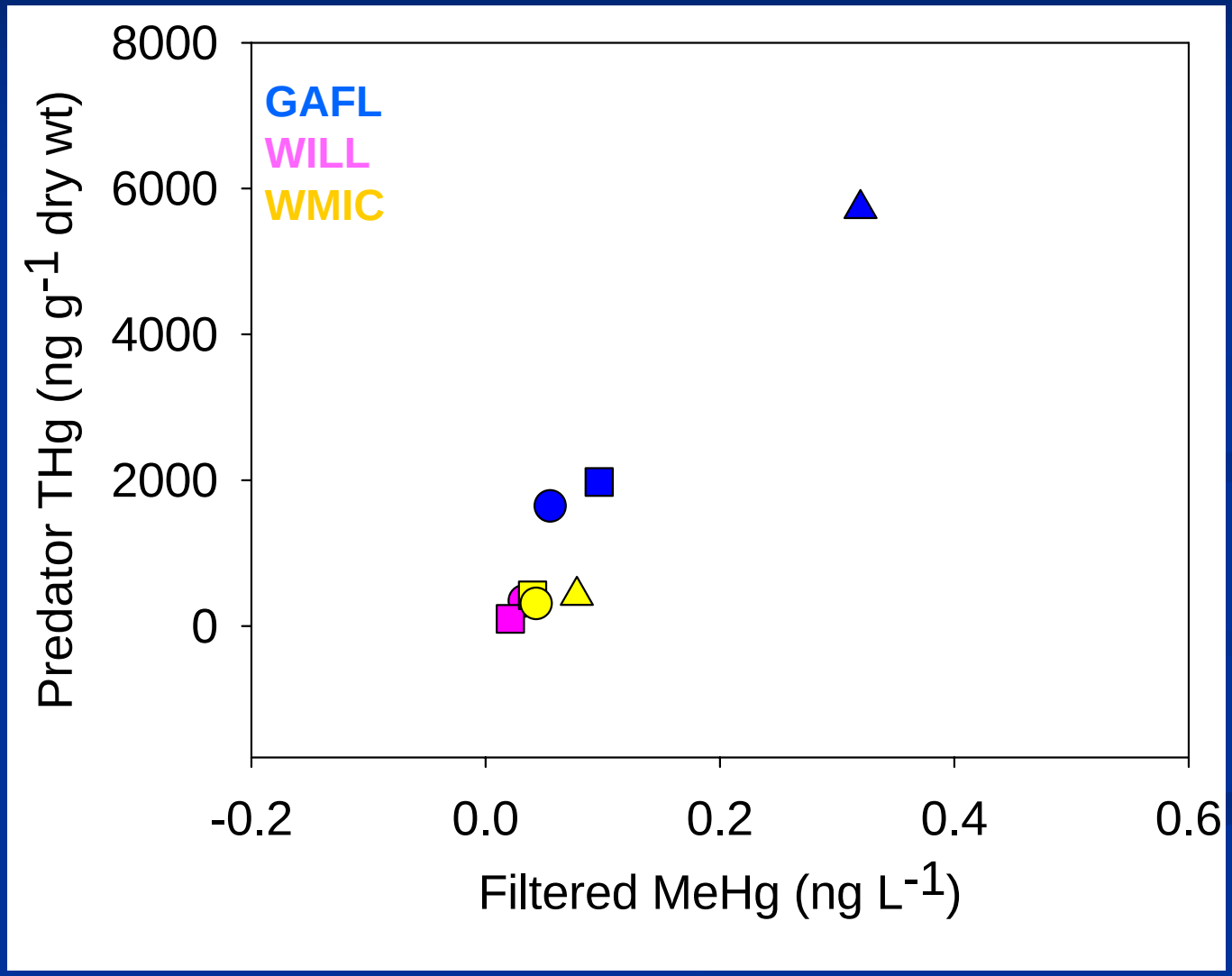
Relationship of predator fish THg to aqueous MeHg



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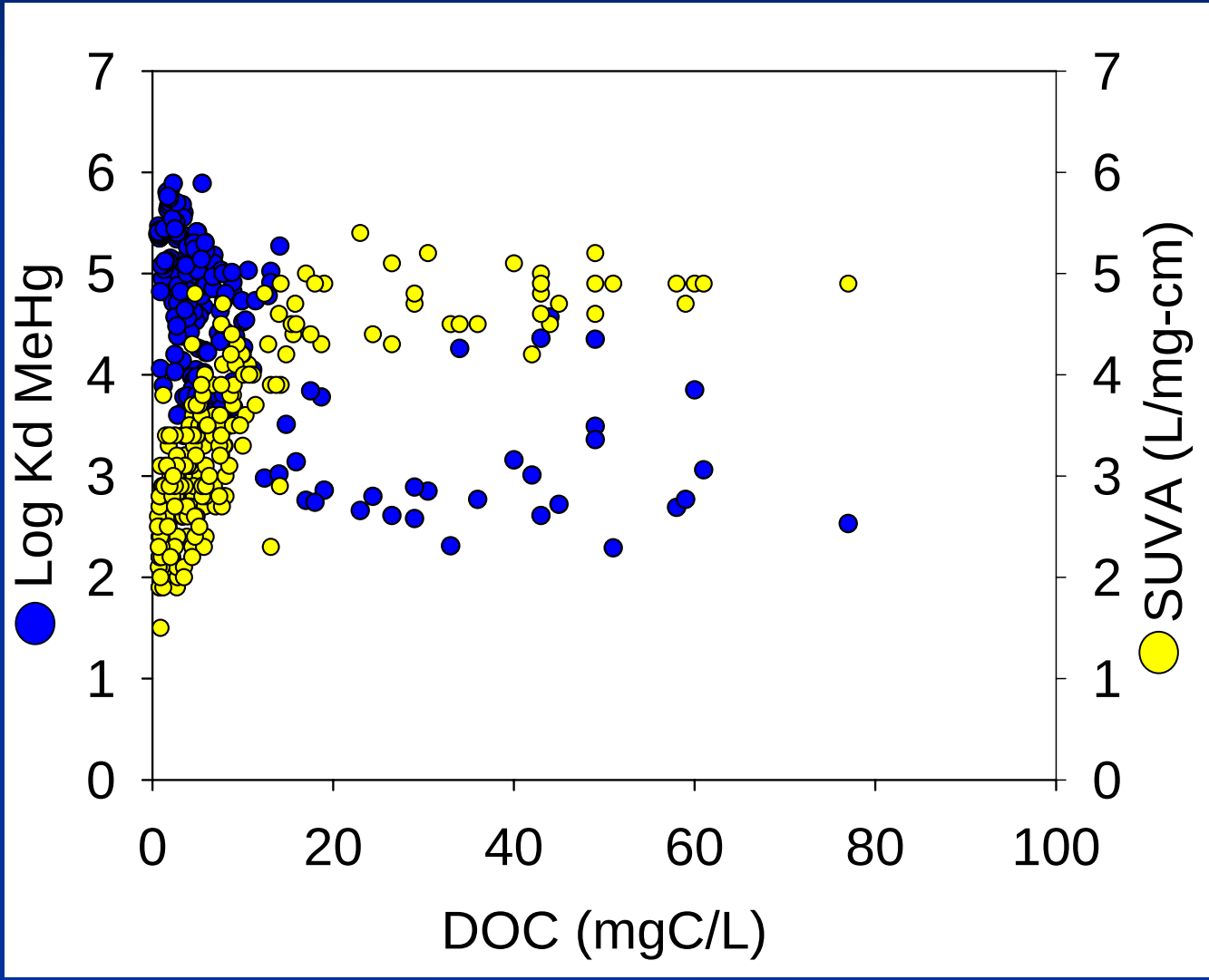
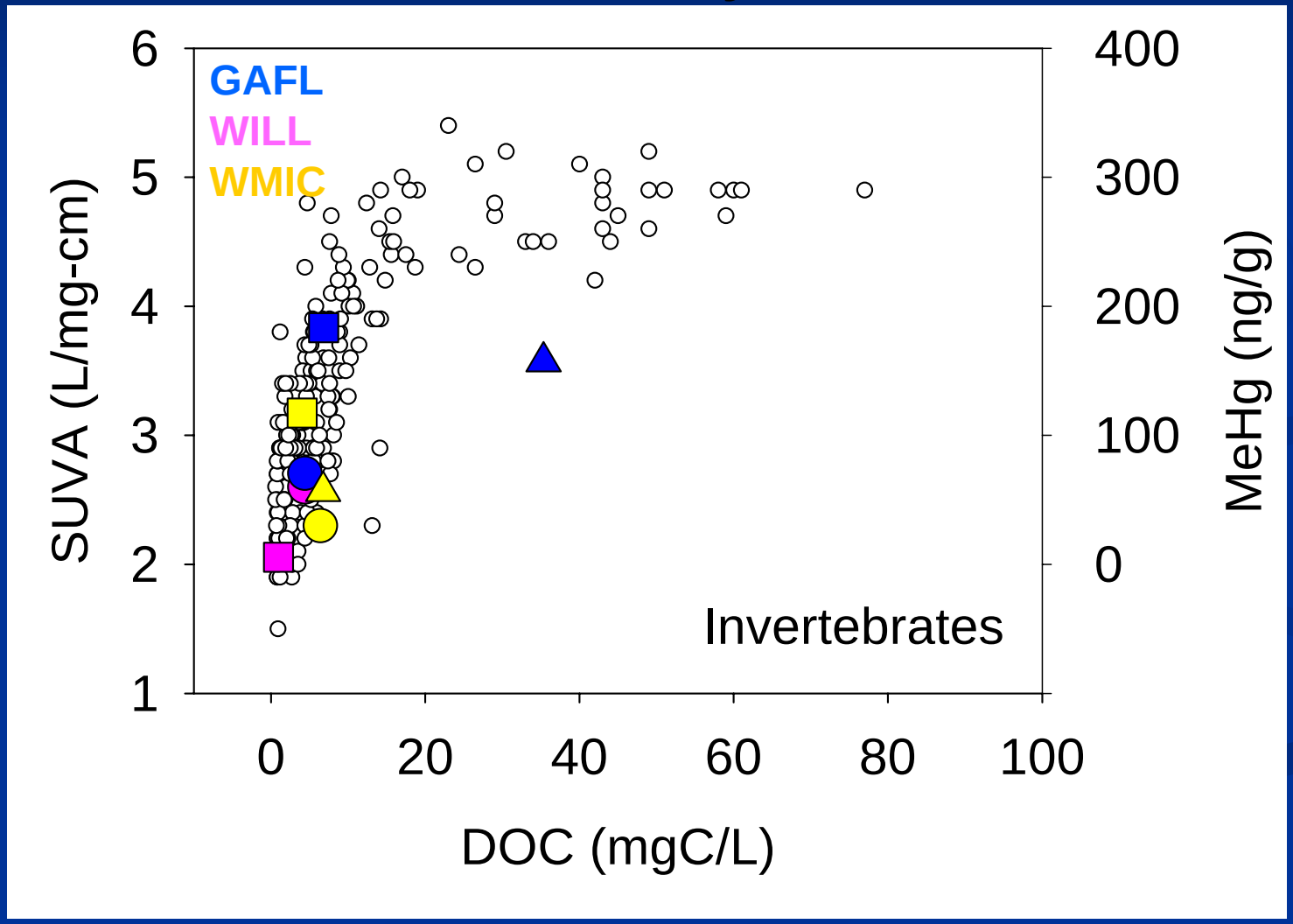
Partitioning of Hg appears to depend on DOC Quantity and Quality



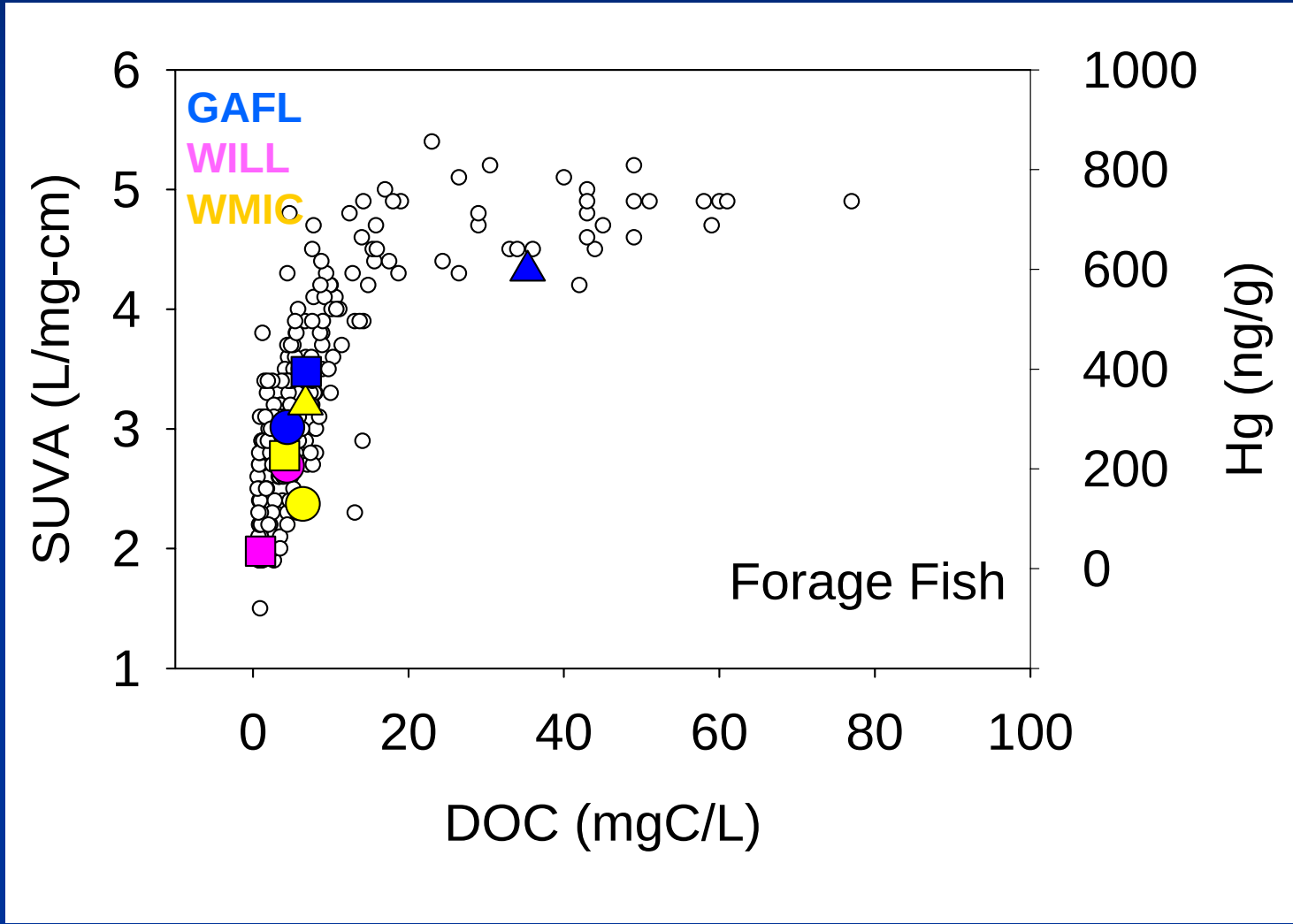
USGS

Bioaccumulation of Hg in invertebrates appears to depend on DOC Quantity and Quality



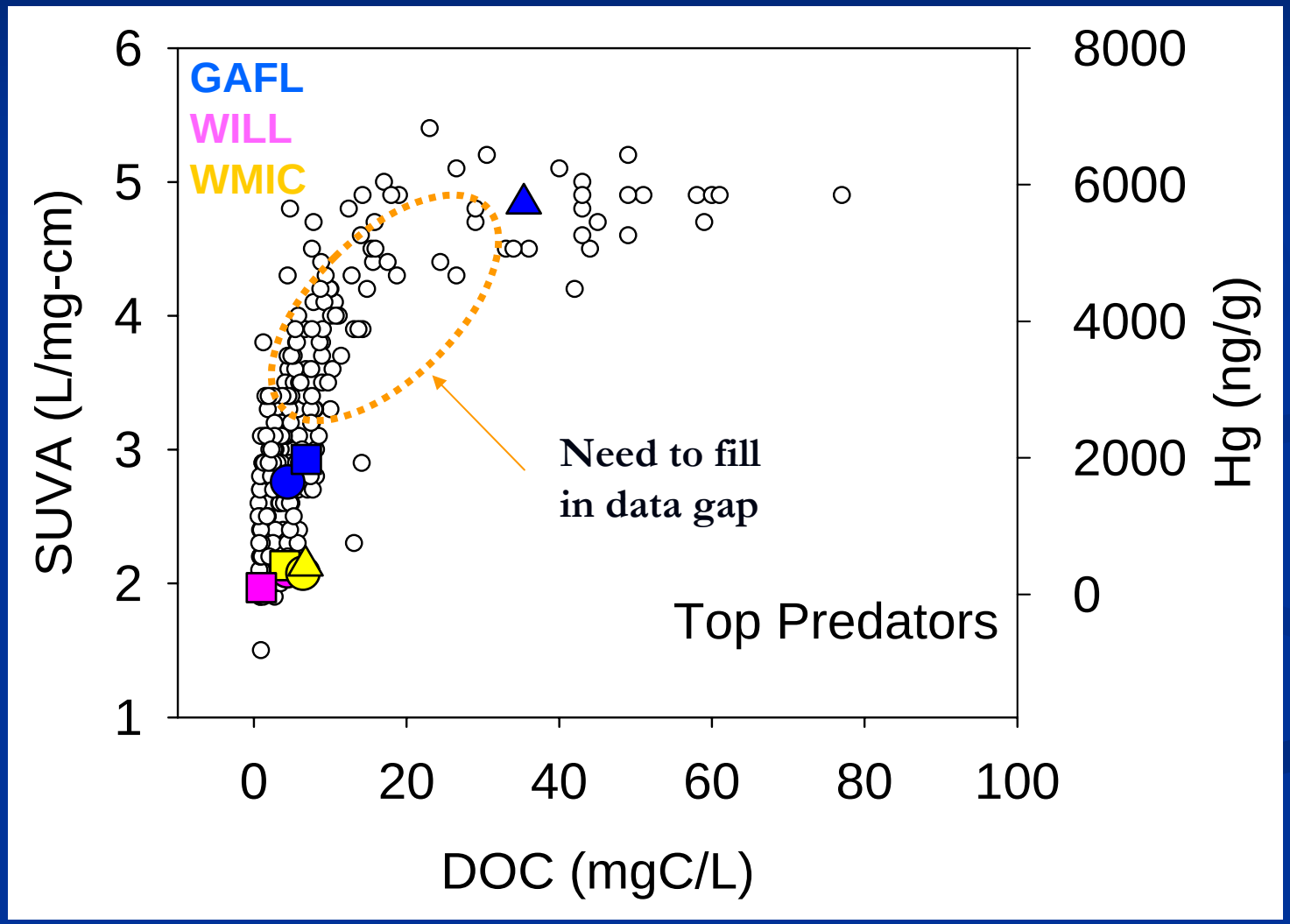
USGS

Bioaccumulation of Hg in forage fish appears to depend on DOC Quantity and Quality



USGS

Bioaccumulation of Hg in predator fish appears to depend on DOC Quantity and Quality



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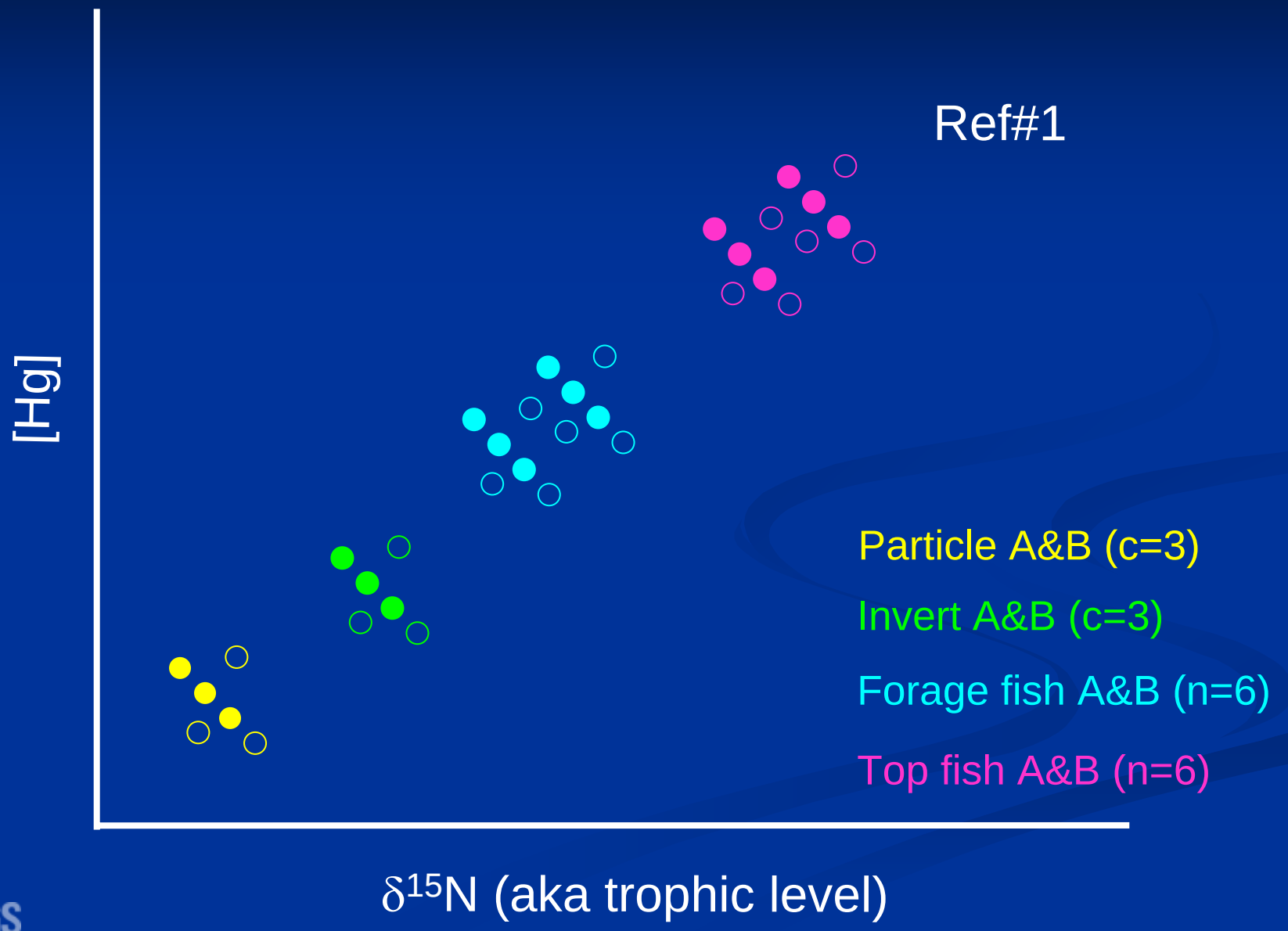
Raw Data



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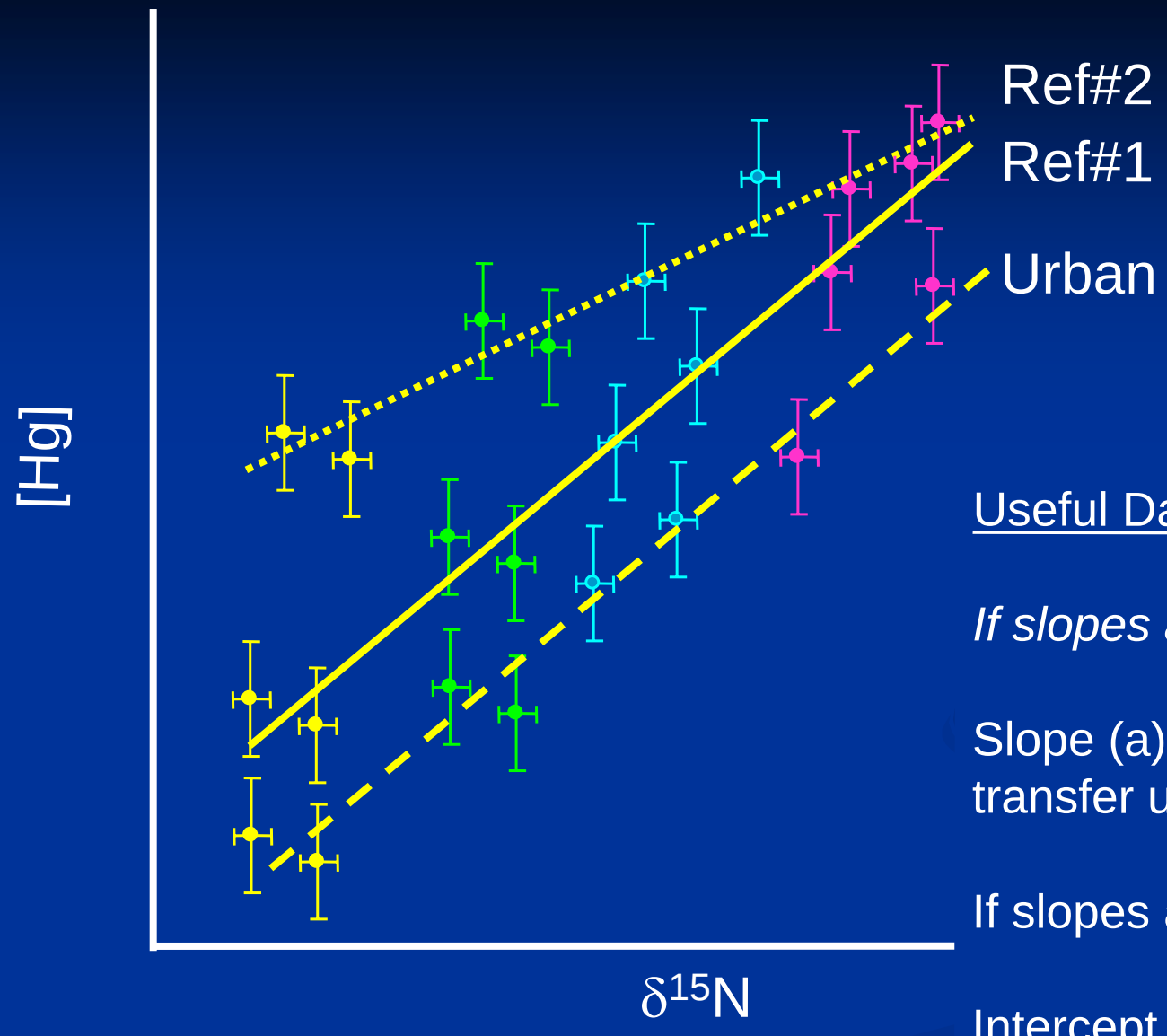

Useful Data

If slopes are different…

Slope (a) = efficiency of Hg transfer up food web

If slopes are similar…

Intercept = relative degrees of Hg contamination among sites and/or regions.

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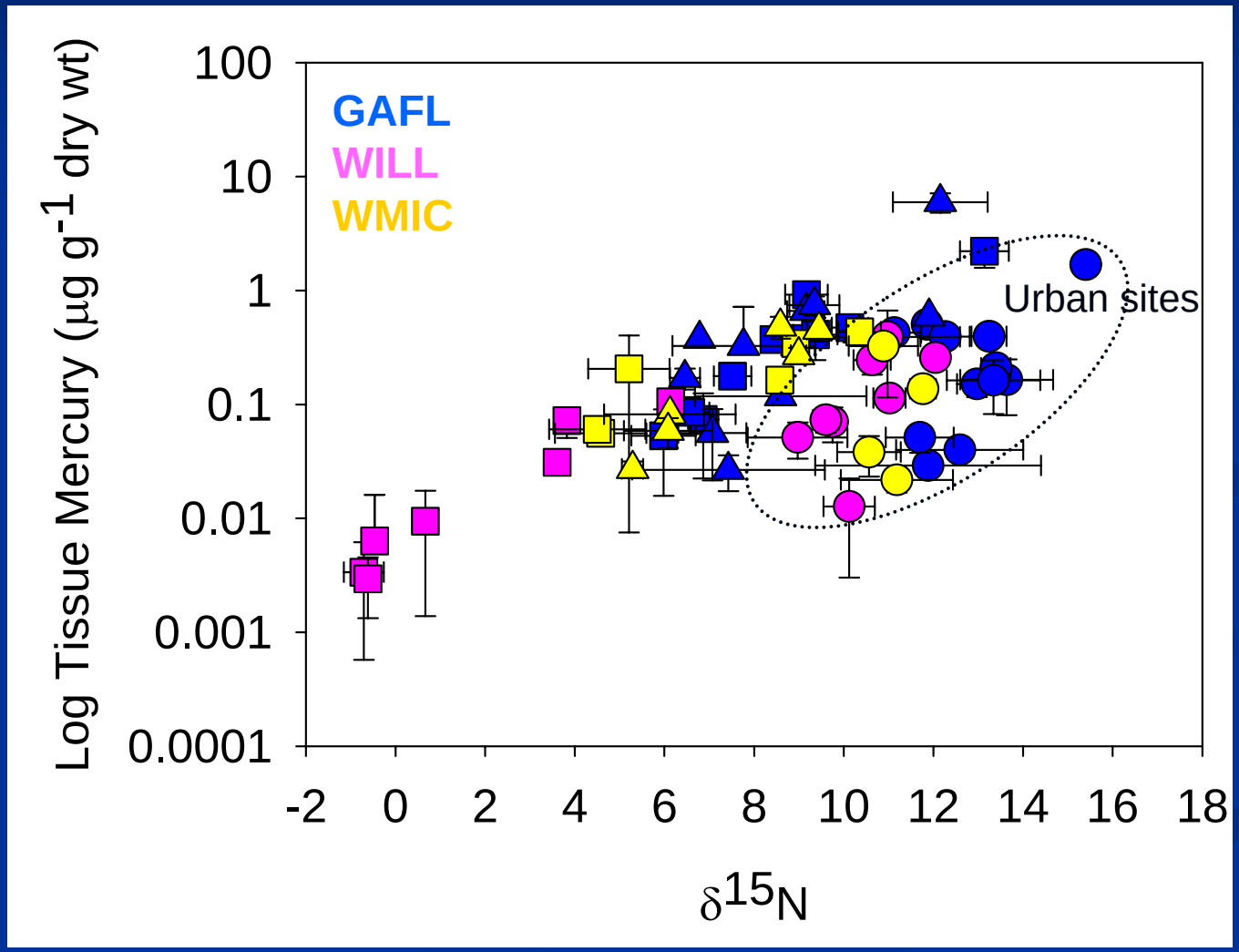
Tissue Hg increases with Trophic Position



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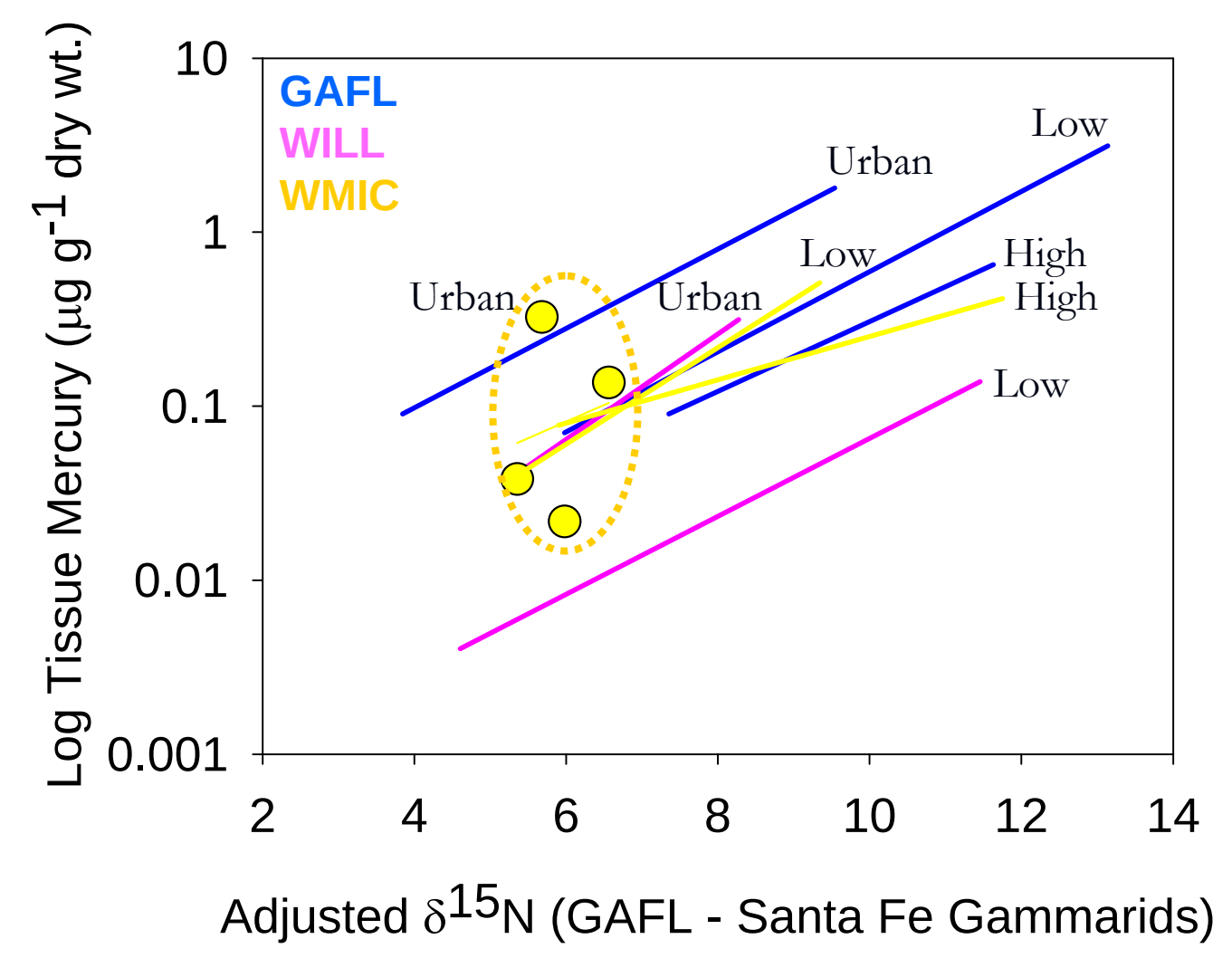
Patterns of Hg Bioaccumulation are similar among most sites (≈ slopes)



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Regression Statistics

	Florida			***Oregon***		***Wisconsin***		
	Little Wekiva	Santa Fe	St. Mary's	Beaver-ton	Look-out	Evergreen	Oak	Pike
Slope	**0.20**	**0.23**	**0.23**	**0.30**	**0.22**	**0.12**		**0.28**
Adjusted Intercept	**-2.52**	**-2.53**	**-1.92**	**-3.01**	**-3.43**	**-1.84**		**-2.89**
R^2	**0.20**	**0.89**	**0.52**	**0.38**	**0.94**	**0.73**		**0.92**

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Summary

- Aqueous methylmercury concentration apparently strong predictor for body burden in aquatic biota

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Summary

- Aqueous methylmercury concentration apparently strong predictor for body burden in aquatic biota
- Bioavailability of methylmercury tightly linked to both quantity *and* quality of dissolved organic carbon
- Efficiency of trophic transfer similar across most sites
- Body burden of mercury in top predators controlled primarily by amount of bioavailable methylmercury
- BAFs not sensitive to local/regional differences in Hg body burdens of top predator fish

Acknowledgments

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St. Johns River Water Mangaement District (FL)
Florida Dept. of Environmental Protection
Florida Fish and Wildlife Conservation Commission
Wisconsin Department of Natural Resources
H. J. Andrews Experimental Forest, Oregon

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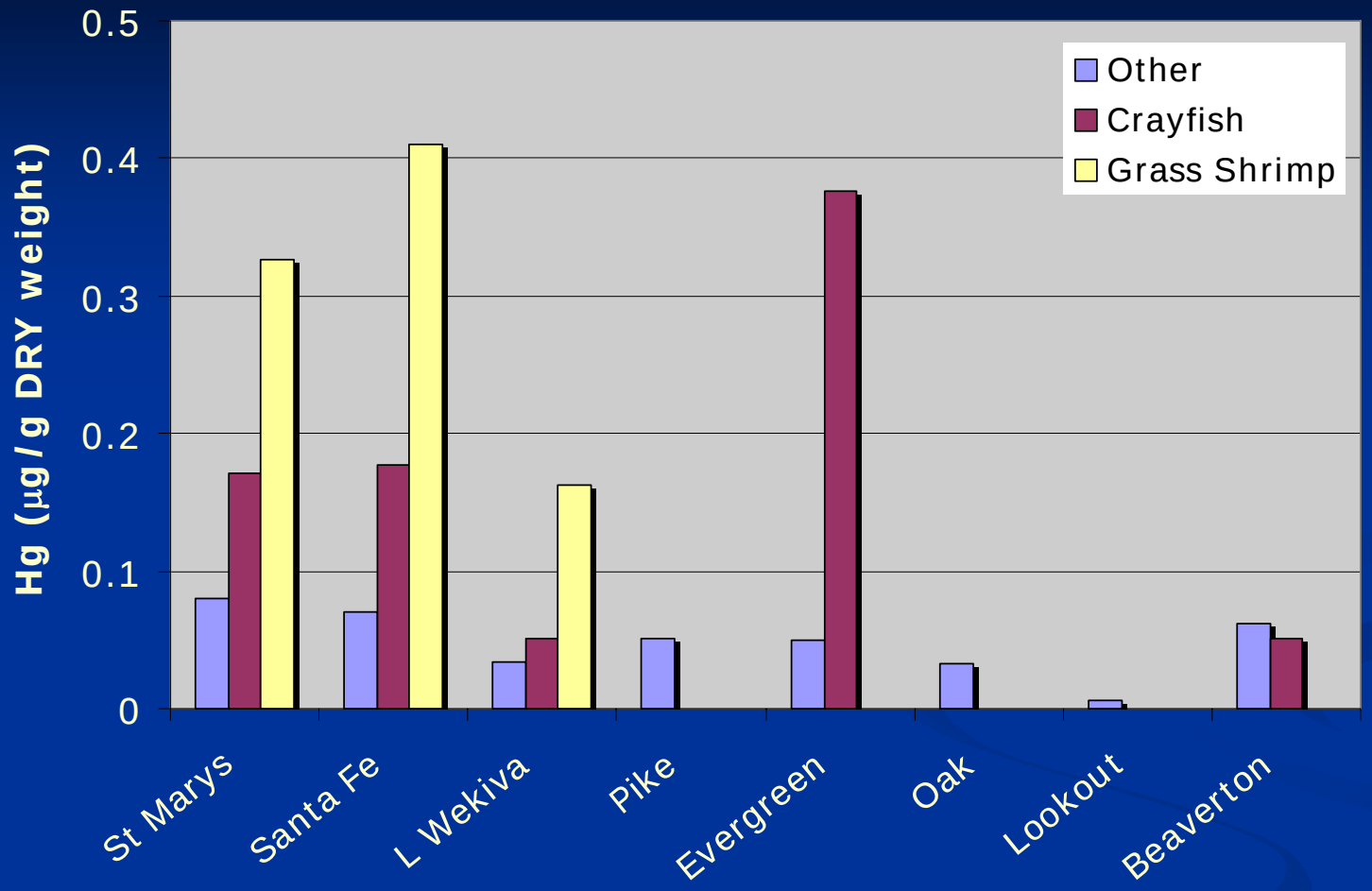
Hg in Biota



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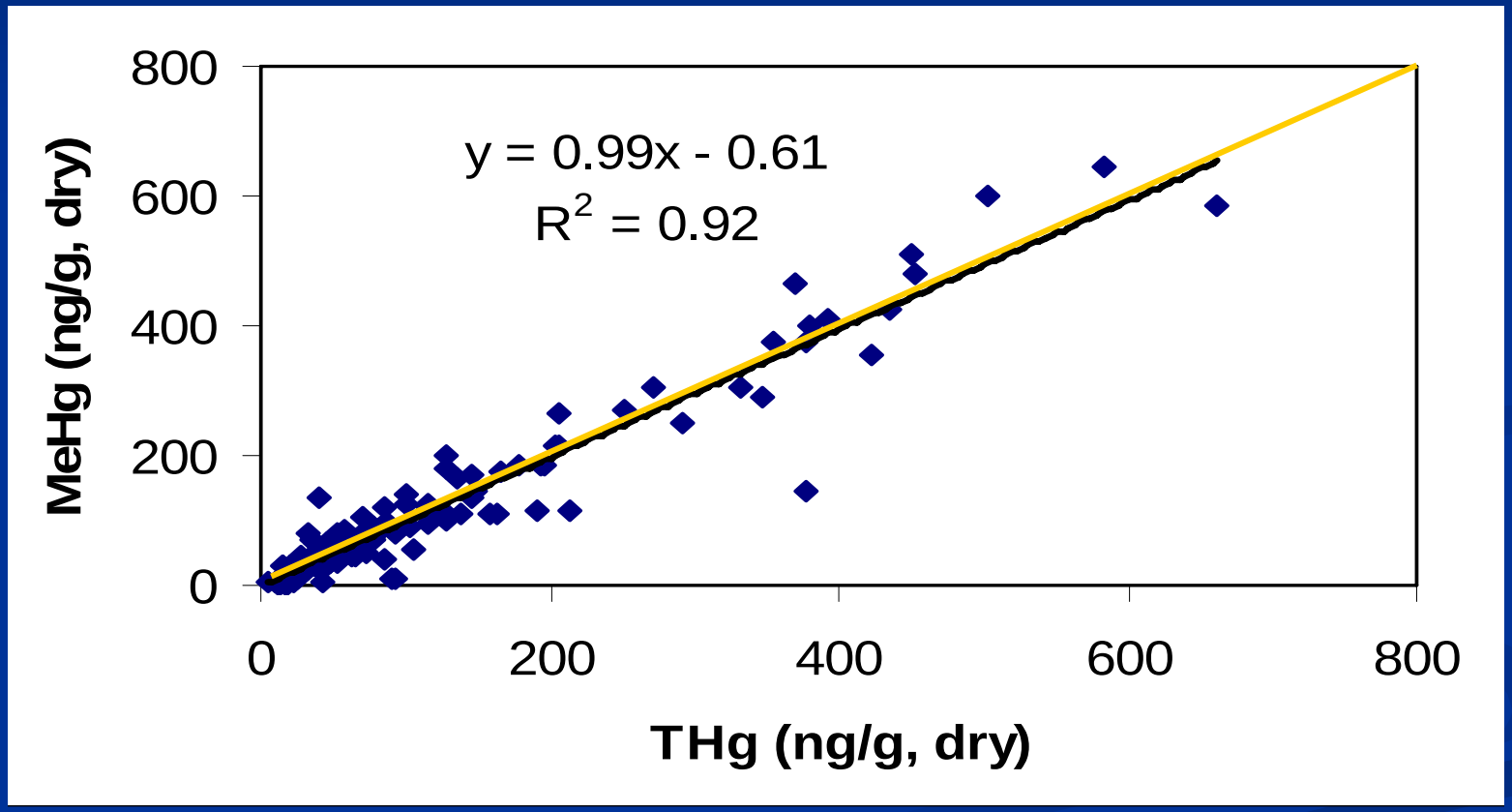
Total Mercury in Invertebrates is largely Methylmercury



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Log_{10}BAF for each Trophic Category

	Florida			***Oregon***		***Wisconsin***		
	Little Wekiva	Santa Fe	St. Mary's	Beaver-ton	Look-out	Evergreen	Oak	Pike
Periphyton								
Rock				**5.30**	**4.53**	**5.55**	**5.11**	**5.04**
Wood	**5.05**	**4.22**	**4.19**					
Sediment	**5.18**	**5.65**	**4.63**	**5.25**	**5.16**	**5.89**	**5.44**	**5.01**
Invertebrates	**5.99**	**6.10**	**5.59**	**6.16**	**5.34**	**6.29**	**5.82**	**5.82**
Forage Fish	**6.71**	**6.61**	**6.27**	**6.80**	**6.21**	**6.76**	**6.48**	**6.63**
Predator Fish	**7.48**	**7.31**	**7.25**	**7.02**	**6.68**	**7.03**	**6.86**	**6.73**

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Small variations in $\log_{10}$BAF can lead to *significant* variations in predicted tissue Hg concentrations

BAF	***Florida***			***Oregon***		***Wisconsin***		
Trophic Category	Little Wekiva	Santa Fe	St. Mary's	Beaver-ton	Look-out	Evergreen	Oak	Pike
Predator Fish	**7.48**	**7.31**	**7.25**	**7.02**	**6.68**	**7.03**	**6.86**	**6.73**
Tissue Hg								
Site Average FMeHg	**1.65**	**1.12**	**0.98**	**0.57**	**0.26**	**0.58**	**0.40**	**0.30**

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