Welcome to the CLU-IN Internet Seminar

Using Ecological-Based Tools and Approaches to Assess Bioavailability

Sponsored by:National Institute of Environmental Health Sciences,
Superfund Research Program

Delivered: June 30, 2010, 1:30 PM - 3:30 PM, EDT (17:30-19:30 GMT)

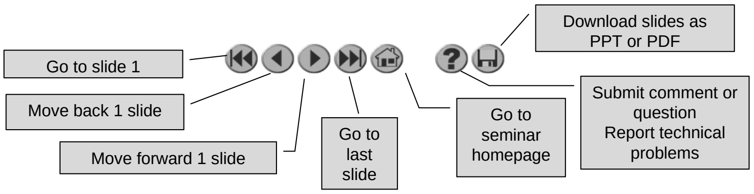
Instructor(s):
Kim Anderson, Oregon State University (kim.anderson@oregonstate.edu)
Celia Chen, Dartmouth College (celia.y.chen@dartmouth.edu)

Moderator(s):

Visit the Clean Up Information Network online at www.cluin.org

Housekeeping

- Please mute your phone lines, Do NOT put this call on hold
  - press *6 to mute #6 to unmute your lines at anytime (or applicable instructions)
- Q&A {indicate if there are breaks, or ask whenever, mention ? Submission button/form}
- Turn off any pop-up blockers
- Move through slides using # links on left or buttons



Go to slide 1

Move back 1 slide

Move forward 1 slide

Go to last slide

Go to seminar homepage

Submit comment or question
Report technical problems

Download slides as PPT or PDF

- This event is being recorded
- Archives accessed for free **http://cluin.org/live/archive/**

BRIDGES

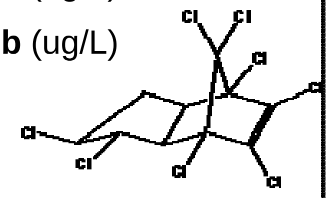
WHY BIOAVAILABLE ?

- **Estimating exposure concentration**
- Predicting environmental fate

- Understanding Environmental Factors on Diseases…
  - MUST develop new bio-analytical tools to measure exposure
    - L.S. Birnbaum, EHP, 2010

REAL WORLD-DISSOLVED CONCENTRATIONS NOT SIMPLE S_W FROM THE LABORATORY, ENVIRONMENTAL CONDITIONS EFFECT SPECIATION, BIOAVAILABILITY

Chlordane Solubility (S_w)-	**56 ppb** (ug/L)
Chlordane Rainbow trout LC50	**90 ppb** (ug/L)



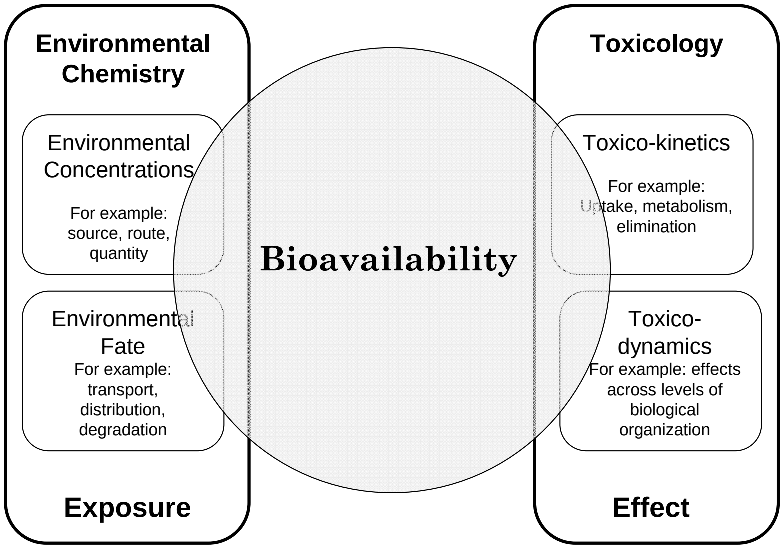
However when more REAL world conditions used

Chlordane Solubility* (S_w)-	**28,000 ppb** (ug/L)

*Water containing 34 mg/L *dissolved* organic carbon

Casarett & Doull’s Toxicology, 6th Ed, 2001, pg 1016-1020

BRIDGES



Environmental Chemistry

Environmental Concentrations

For example: source, route, quantity

Environmental Fate

For example: transport, distribution, degradation

Exposure

Bioavailability

Toxicology

Toxico-kinetics

For example: Uptake, metabolism, elimination

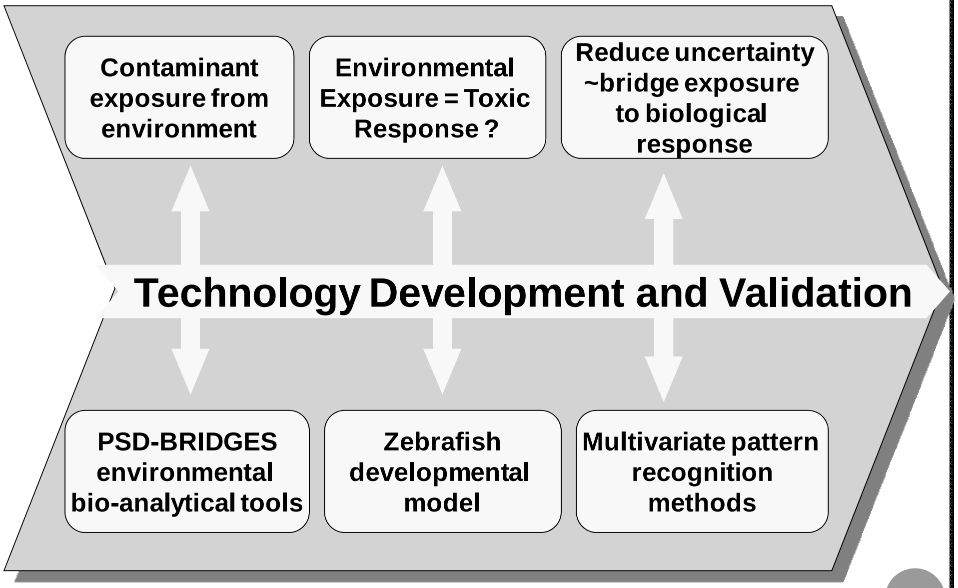
Toxico-dynamics

For example: effects across levels of biological organization

Effect

Adapted from: Anderson & Hillwalker, Ecotoxicology Bioavailability, Elsevier 2008

Adapted from: Schwartz, D.A., *et al*, 2005



Contaminant exposure from environment

Environmental Exposure = Toxic Response ?

Reduce uncertainty ~bridge exposure to biological response

Technology Development and Validation

PSD-BRIDGES environmental bio-analytical tools

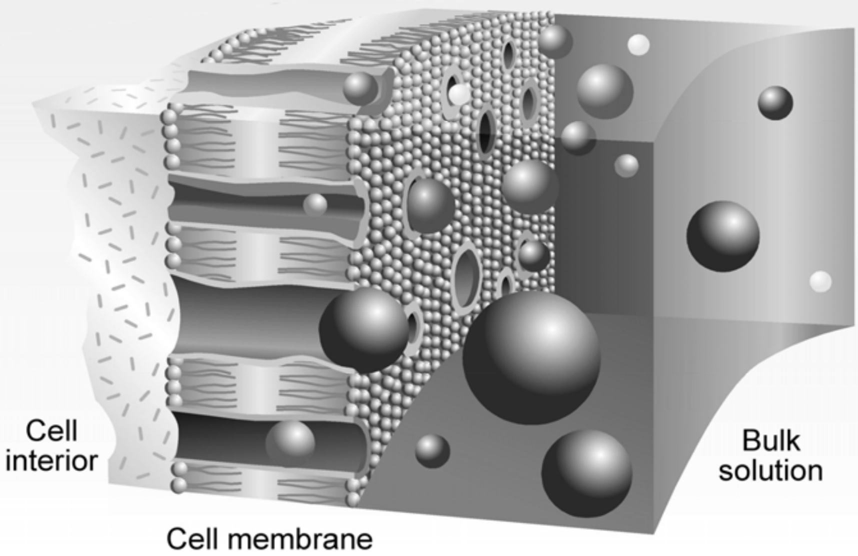
Zebrafish developmental model

Multivariate pattern recognition methods

BEYOND CHEMICAL ANALYSIS…

- Exposure dose (exposure concentration)
  - Chemical **mixtures**
  - Predicting environmental fate
- Advantage not to “lump” bioavailable processes
  - Insight will depend on *isolating* processes
  - For example FIRST step in aquatic food chain
- Integration of **space-time** into health risk framework
  - Ambient rough estimate
  - Bio-monitoring transient estimate
- Multi-media

Bioavailability



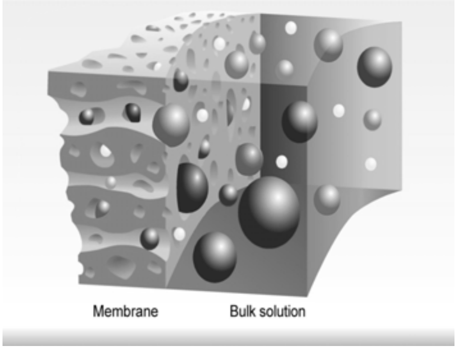
PASSIVE SAMPLING DEVICES FOR EXAMPLE: LIPID FREE TUBE (LFT)

- Bioavailability processes include
  - **chemical** (cell membrane lipophilic character) and
  - **physical** (pore size ~9.5A) control of contaminant uptake.
- Passive sampling devices (such as **LFT**) mimic both chemical and physical processes
  - lipophilic membrane character, and
  - pore size ~10A

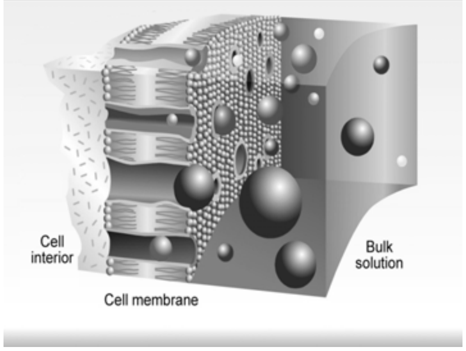
- Other types of membranes:
  - Polymer film or tubes
    - low density polyethylene
    - silicone or silastic
    - polypropylene
- Södergren, 1987 dialysis bag filled with hexane
- Huckins *et al*, 1992 developed semipermeable membrane device (SPMD) tube filled with a triolein
- **Reviewed in:** Namiesnik, J.; Zabiegalal, B.; Kot-Wasik, A.; Partyka, M.; Wasik, A., Passive sampling and/or extraction techniques in environmental analysis: a review. *Anal. Bioanal. Chem.* **2005,** 381, 279-301

PASSIVE SAMPLING DEVICE ADEQUATE BIOLOGICAL SURROGATE

LFT Membrane



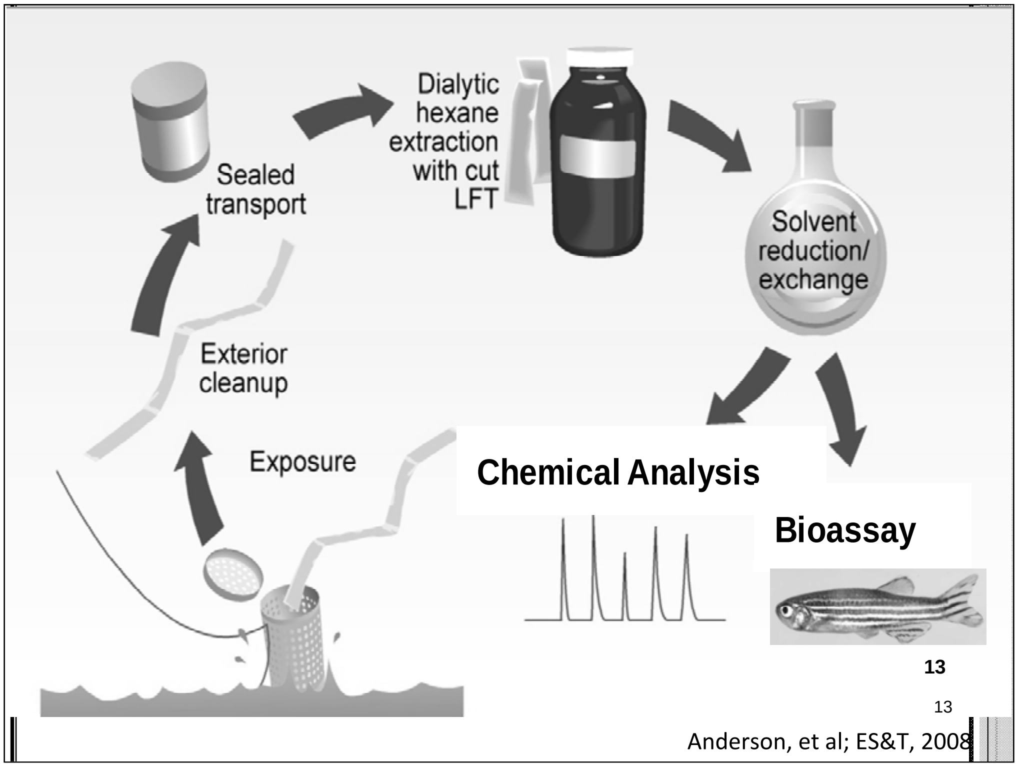
Cell Membrane



LFTs are polyethylene membranes that, similar to cell membranes, passively uptake freely dissolved (bioavailable) hydrophobic compounds.

PASSIVE SAMPLING DEVICES DEPLOYED AT SUPERFUND SITES

- **PSD theory:** our LFTs are constructed of sealed polyethylene lay flat tubes which represent an organic lipid membrane. Like a membrane, LFTs discriminate against particulate bound material. As *in situ* time integrative passive samplers, LFTs may be deployed for extended periods of time to sequester contaminants. This **overcomes potential issues such as detection limits, bioavailable fraction collection and fluctuating contaminant concentrations**.



Exposure

Exterior cleanup

Sealed transport

Dialytic hexane extraction with cut LFT

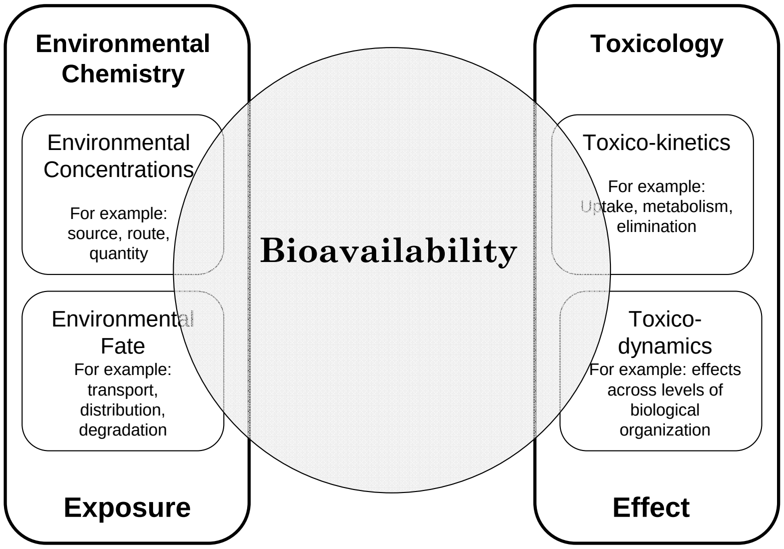
Solvent reduction/ exchange

Chemical Analysis

Bioassay

Anderson, et al; ES&T, 2008

BRIDGES: IF PROCESSES IN THE ENVIRONMENTAL SYSTEM AND IN THE BIOLOGICAL SYSTEM ARE TREATED WITH THE SAME MODELLING STRUCTURES AND TOOLS CONSISTENT EXPOSURE AND EFFECT ASSESSMENT IS POSSIBLE.



Environmental Chemistry

Environmental Concentrations

For example: source, route, quantity

Environmental Fate

For example: transport, distribution, degradation

Exposure

Bioavailability

Toxicology

Toxico-kinetics

For example: Uptake, metabolism, elimination

Toxico-dynamics

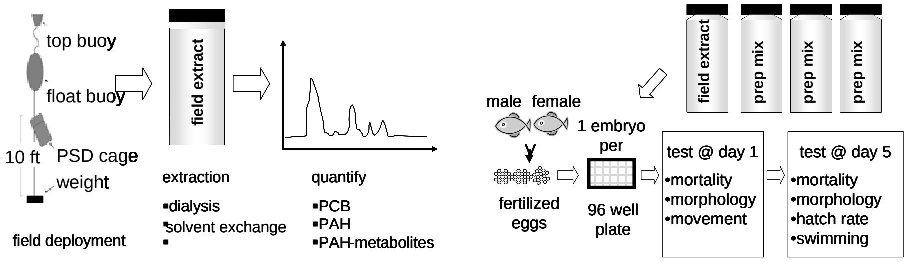
For example: effects across levels of biological organization

Effect

BRIDGES: **REDUCE EXPOSURE UNCERTAINTY BY ANALYZING BIOLOGICAL RESPONSES**

BRIDGES EXTRACTS WITH BIOASSAY MODELS (ZEBRAFISH, AMES, ETC) SYSTEMS

Environmental Exposure → Toxicological Responses



top buoy

float buoy

10 ft

PSD cage

weight

field deployment

field extract

extraction

- dialysis
- solvent exchange
-

quantify

- PCB
- PAH
- PAH-metabolites

field extract

prep mix

prep mix

prep mix

male female

fertilized eggs

1 embryo per

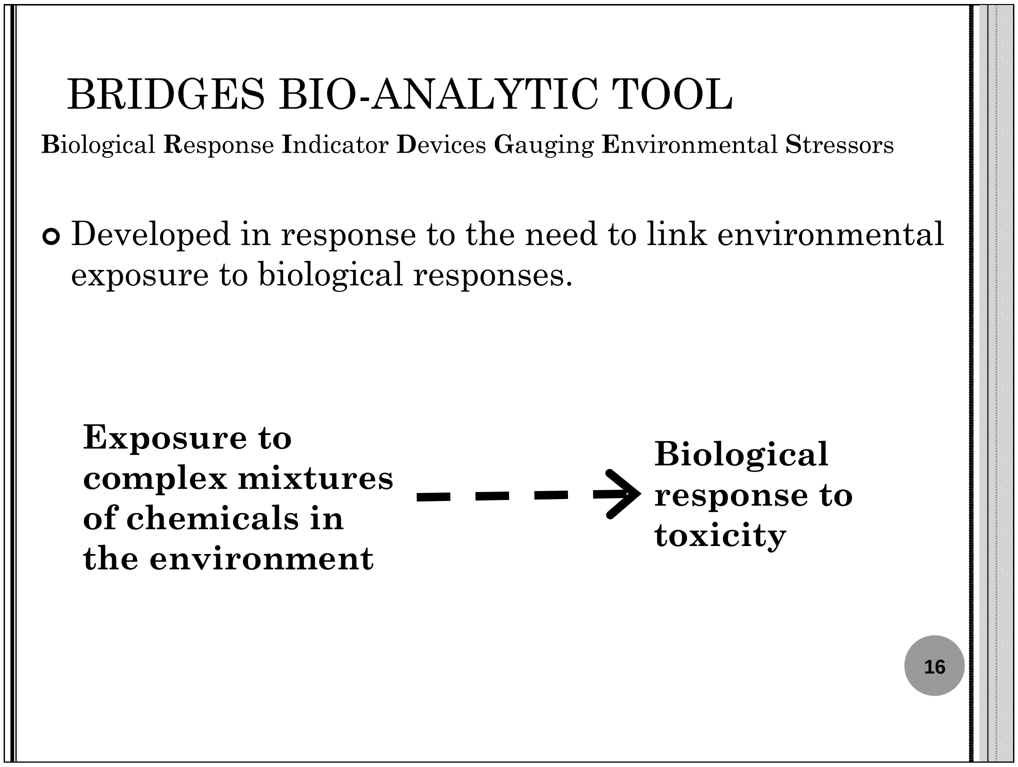
96 well plate

test @ day 1

- mortality
- morphology
- movement

test @ day 5

- mortality
- morphology
- hatch rate
- swimming



BRIDGES BIO-ANALYTIC TOOL

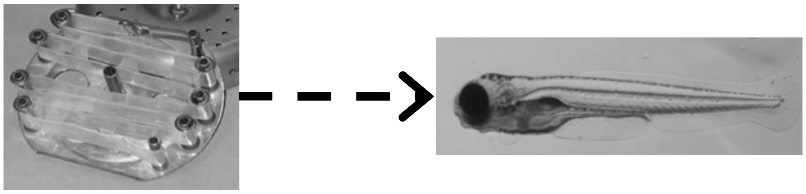
Biological **R**esponse **I**ndicator **D**evices **G**auging **E**nvironmental **S**tressors

- Developed in response to the need to link environmental exposure to biological responses.

Exposure to complex mixtures of chemicals in the environment - - - → **Biological response to toxicity**

BRIDGES BIO-ANALYTIC TOOL

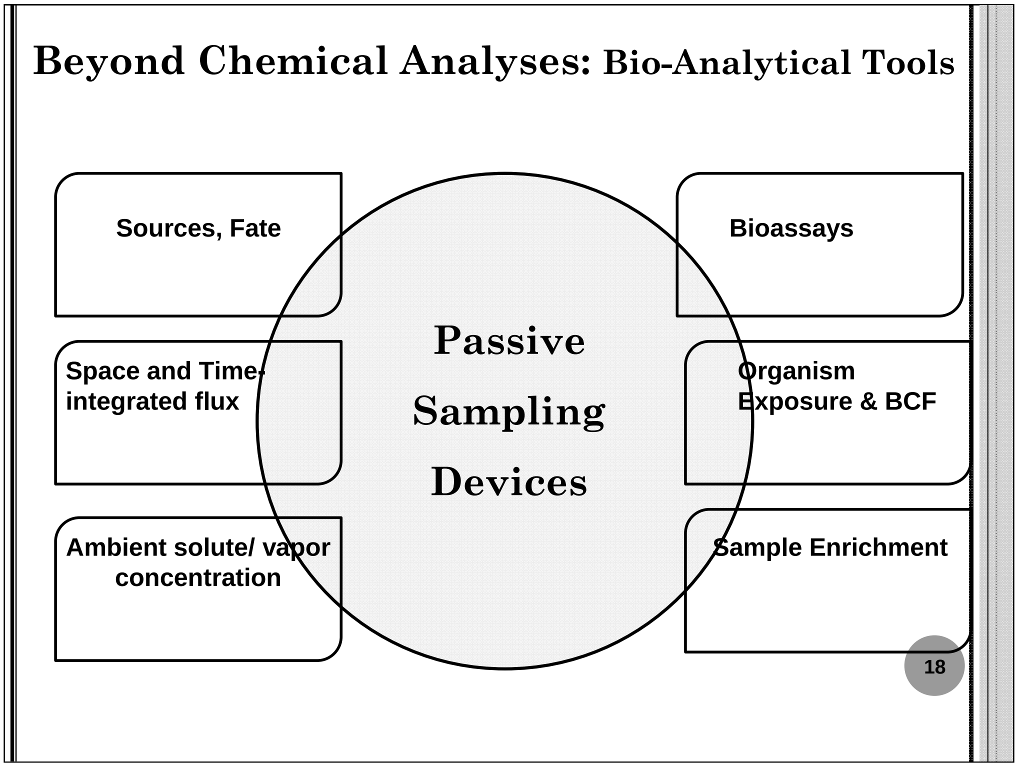
- Combines Lipid-Free Tubing (LFT) passive sampling devices with the embryonic zebrafish model.



LFTs passively concentrate the **bioavailable** fraction of chemicals from the environment:
  - time integrated, biologically relevant chemical concentrations

The embryonic zebrafish developmental model is a **high throughput, whole organism, vertebrate** bioassay widely used for toxicity assessments.

- Provides a quantitative measure of the developmental toxicity of site-specific, environmentally relevant contaminant mixtures.



Beyond Chemical Analyses: Bio-Analytical Tools

Passive Sampling Devices

Sources, Fate

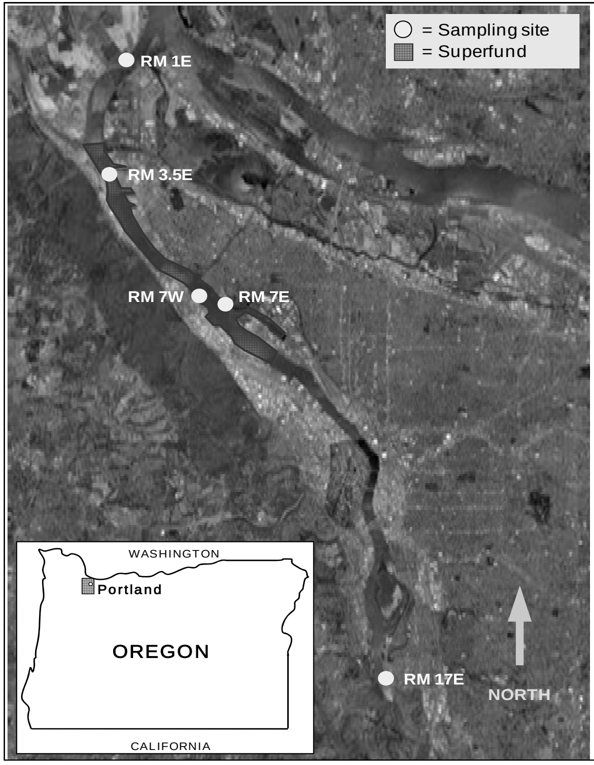
Space and Time-integrated flux

Ambient solute/ vapor concentration

Bioassays

Organism Exposure & BCF

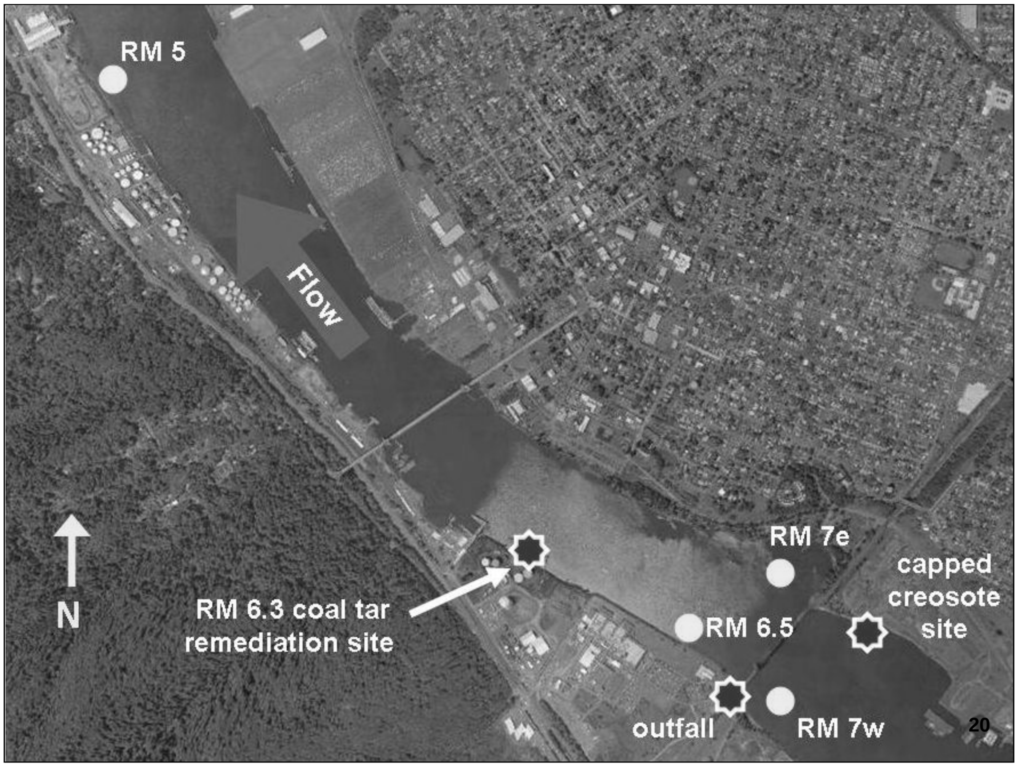
Sample Enrichment



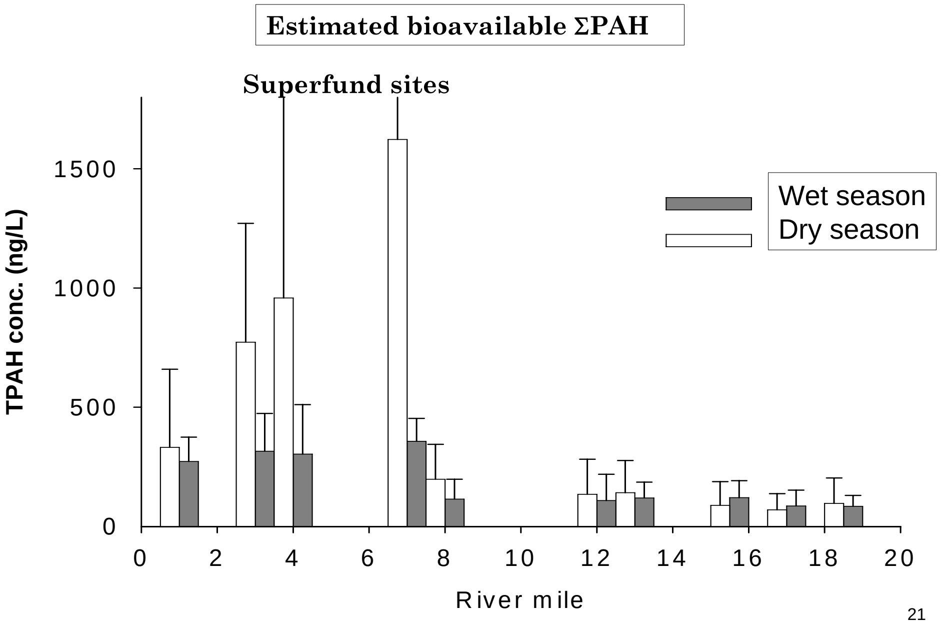
DEPLOYMENT SITES

SUPERFUND SITES

Provides a **quantitative** measure of the developmental **toxicity** of **site-specific**, **environmentally relevant contaminant mixtures**

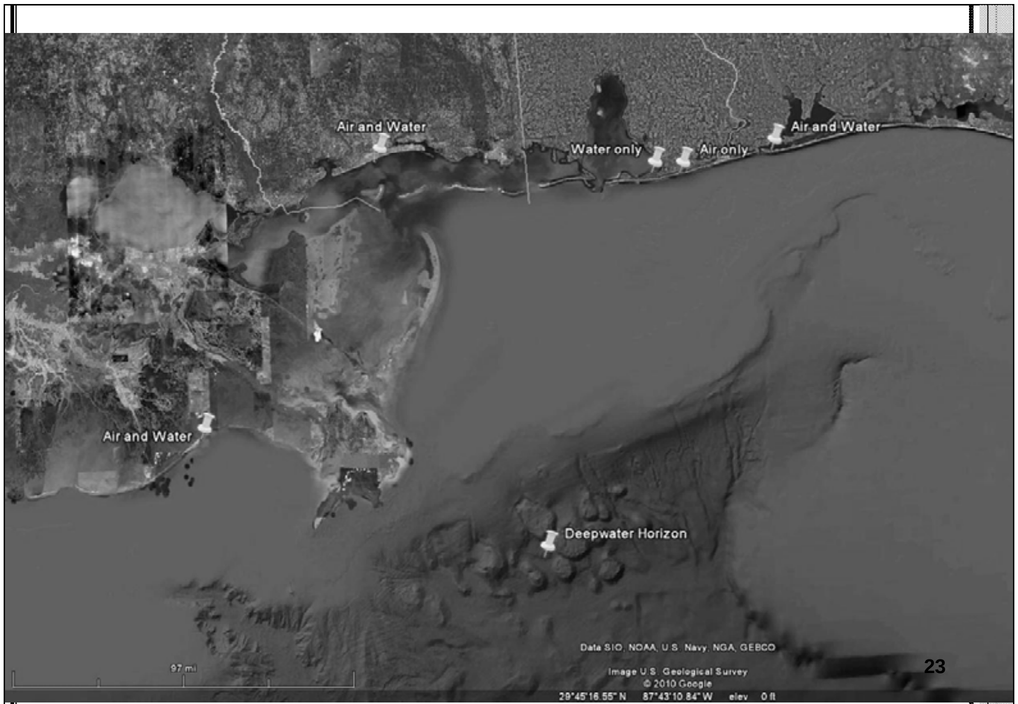

RM 5
Flow
N
RM 6.3 coal tar remediation site
RM 7e
capped creosote site
RM 6.5
outfall
RM 7w

SPATIAL AND TEMPORAL PAHS IN A MODEL HARBOR



SOURCES OF PAHS IN THE ENVIRONMENT

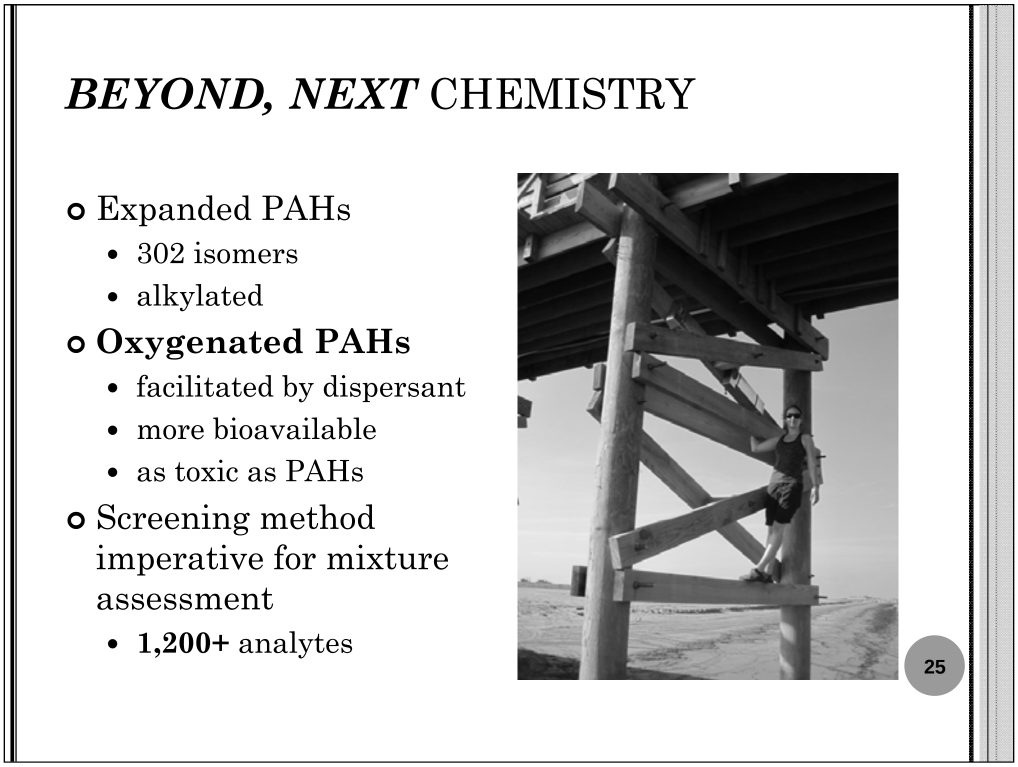
- Biogenic (minor)
- Petrogenic
  - Generated by geological processes
    - NATURAL- seeps, coal outcrops
    - ANTHROPOGENIC –fossil fuel release (0.2-7% PAHs)
- Pyrogenic
  - Generated by high temperature combustion of organic matter
    - NATURAL –forest fires, piare fires
    - ANTHROPOGENIC- wood stoves, car exhaust, coal tar



ANDERSON’S SAMPLING SITES, deployed May 11-13, June 8-10, June10- x, 2010

EXAMPLES:
PASSIVE SAMPLING DEVICES IN GULF OF MEXICO
PRE-, POST-IMPACT DEEPWATER HORIZON BLOWOUT

- 4 sites FL, AL, MS, LA
- Early, May, Early June
- *Paired* Air and Water
- *Paired* Chem- and Bio-
- Grande Isle hit by oil



BEYOND, NEXT CHEMISTRY

- Expanded PAHs
  - 302 isomers
  - alkylated
- **Oxygenated PAHs**
  - facilitated by dispersant
  - more bioavailable
  - as toxic as PAHs
- Screening method imperative for mixture assessment
  - **1,200+** analytes

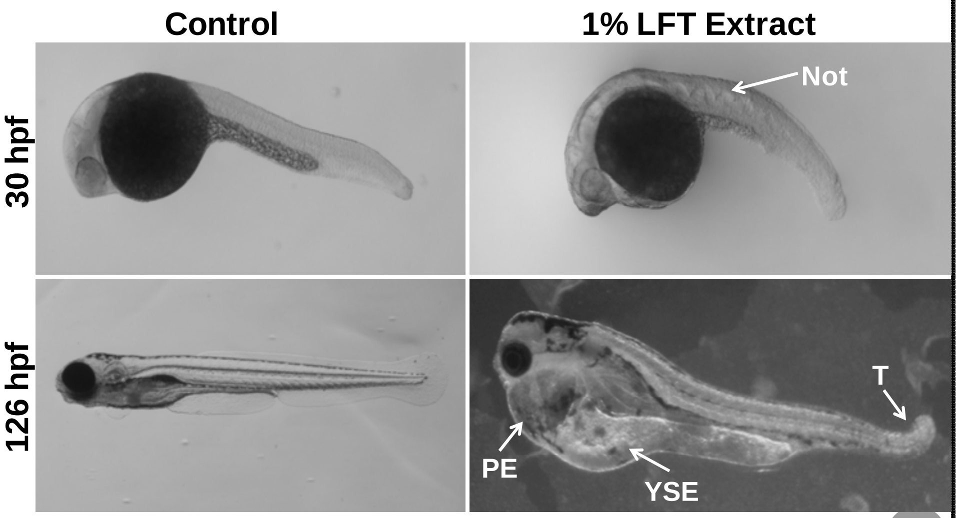
PAHS FROM DEEPWATER HORIZON SPILL

OVER 40 PAHS QUANTIFIED, OVER 1200 CONTAMINANTS SCREENED

Over 40 PAHs quantified, as but a few examples of those detected include:(x=present, nd=none detected):

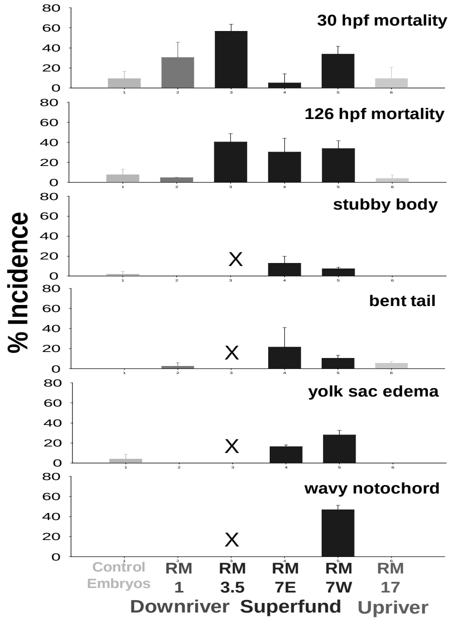
PAHS	Fl air	AL air	MS air	LA air	FL water	AL water	MS water	LA water
Naphthalene	x	x	x	x	x	x	x	x
Naphthalene-2methyl		x	x	x	x	x	x	x
Naphthalene-1methyl	x	x	x	x	x	x	x	x
Fluoranthene	x	x	x	x	x	x	x	x
Benzo[a]anthracene	x	x	nd	nd	x	x	x	x
Benzo[a]pyrene	nd	nd	nd	nd	nd	nd	x	nd

SITE-SPECIFIC BIOLOGICAL RESPONSES



Not= notochord waviness; PE= pericardial edema; YSE= yolk sac edema; T= bent tail

SITE-SPECIFIC BIOLOGICAL RESPONSES

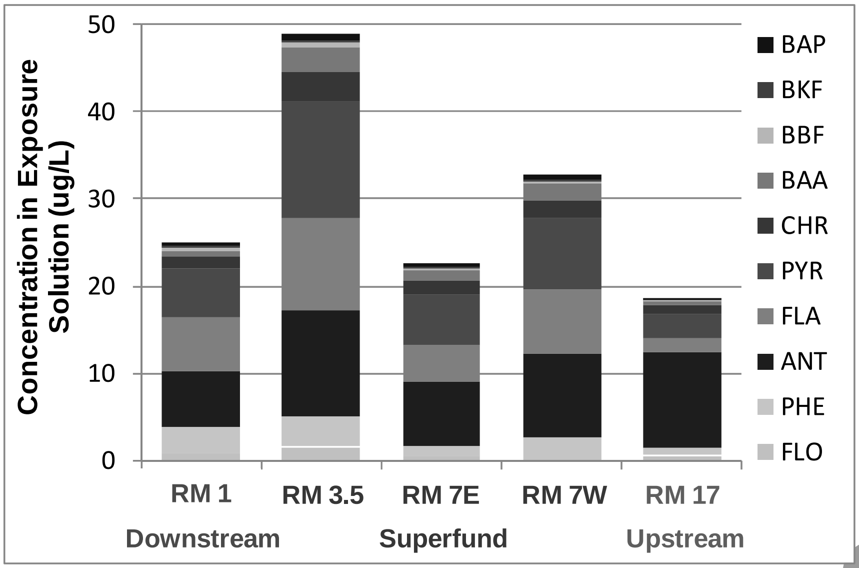


- 6 of 18 biological responses were significantly different in exposed embryos compared to controls (MLR, likelihood ratio, $p<0.05$; n=941)

- Significant differences between sites were observed for biological responses.

  - Hillwalker *et al*, 2010

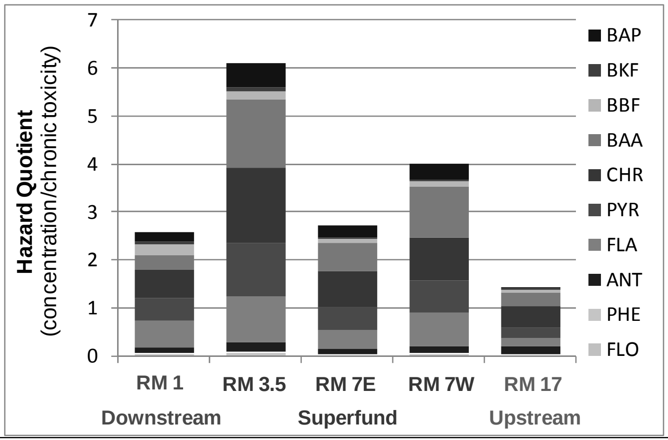
SITE-SPECIFIC CHEMICAL PROFILES

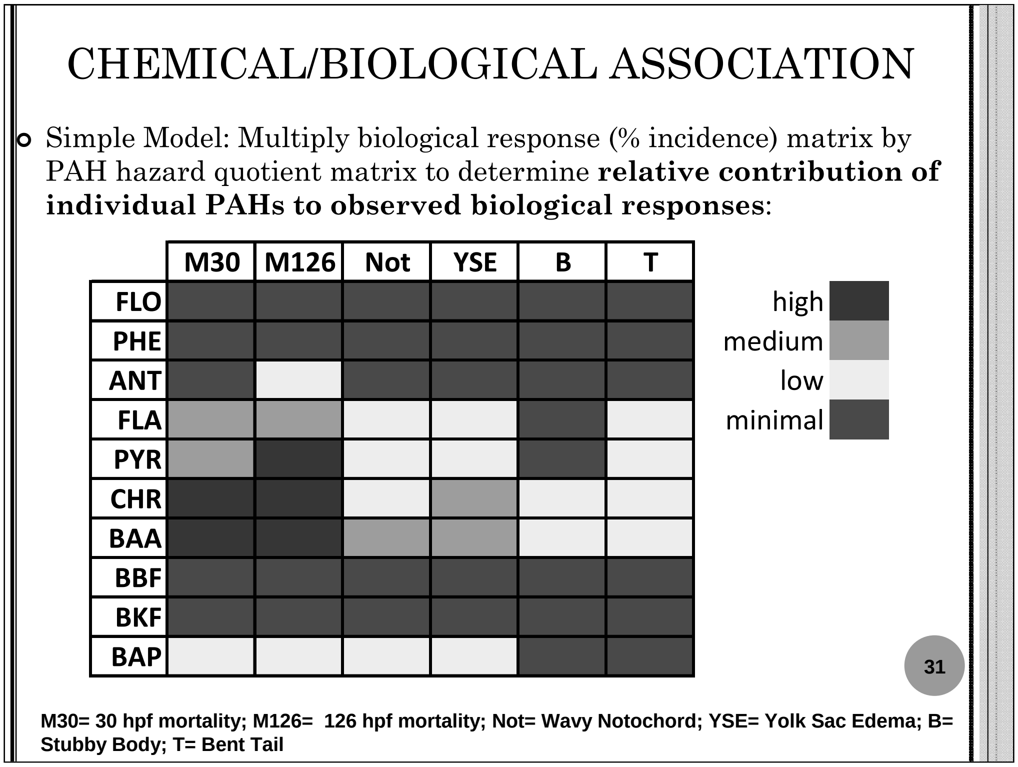


BAP= Benzo(a)pyrene; BKF= Benzo(k)fluoranthene; BBF= Benzo(b)fluoranthene; BAA= Benz(a)anthracene; CHR= Chrysene; PYR= Pyrene; FLA= Fluoranthene; ANT=Anthracene; PHE=Phenanthrene; FLO=Fluorene

SITE-SPECIFIC HAZARD QUOTIENT PROFILES

- Divide the concentration by the chronic toxicity value
  - (Neff *et al*, Integr. Environ. Assess. Manage., 2005)
- Normalizes the concentrations by relative toxicity
- Provides a more realistic estimate of the relative contribution of each chemical to the observed biological responses





CHEMICAL/BIOLOGICAL ASSOCIATION

- Simple Model: Multiply biological response (% incidence) matrix by PAH hazard quotient matrix to determine **relative contribution of individual PAHs to observed biological responses**:

	M30	M126	Not	YSE	B	T
FLO	▨	▨	▨	▨	▨	▨
PHE	▨	▨	▨	▨	▨	▨
ANT	▨	□	▨	▨	▨	▨
FLA	▒	▒	□	□	▨	□
PYR	▒	■	□	□	▨	□
CHR	■	■	□	▒	□	□
BAA	■	■	▒	▒	□	□
BBF	▨	▨	▨	▨	▨	▨
BKF	▨	▨	▨	▨	▨	▨
BAP	□	□	□	□	▨	▨

high ■
medium ▒
low □
minimal ▨

M30= 30 hpf mortality; M126= 126 hpf mortality; Not= Wavy Notochord; YSE= Yolk Sac Edema; B= Stubby Body; T= Bent Tail

INTEGRATED ENVIRONMENT AND HEALTH

- embryonic zebrafish exposed to environmental contaminant mixtures obtained from passive samplers deployed in a model river system show site-specific biological responses that can be associated with differences in the chemical profiles of the sites

BRIDGING: AN INNOVATIVE APPROACH TO QUANTIFYING RISK AT A MGP REMEDIATION PROJECT USING PASSIVE SAMPLING DEVICES

$$Exposure = \frac{C \times CF \times IR \times EF \times ED}{BW \times AT}$$

PSD mass-to-mass concentrations replace the shellfish/fish tissue concentrations normally used here

CHEMISTRY + BIOLOGY

INTEGRATED ENVIRONMENTAL AND HUMAN HEALTH

- Adding passive sampler concentrations to health risk models increases spatial and temporal precision, improves risk estimates, reduces animal collection, and reduces costs.

- Passive samplers can supplement fish/shellfish data in health assessments to provide specific spatial and temporal contaminant information and thereby help public health and remediation professionals more precisely evaluate and relate exposure and risk

INTEREST IN PASSIVE SAMPLING DEVICES

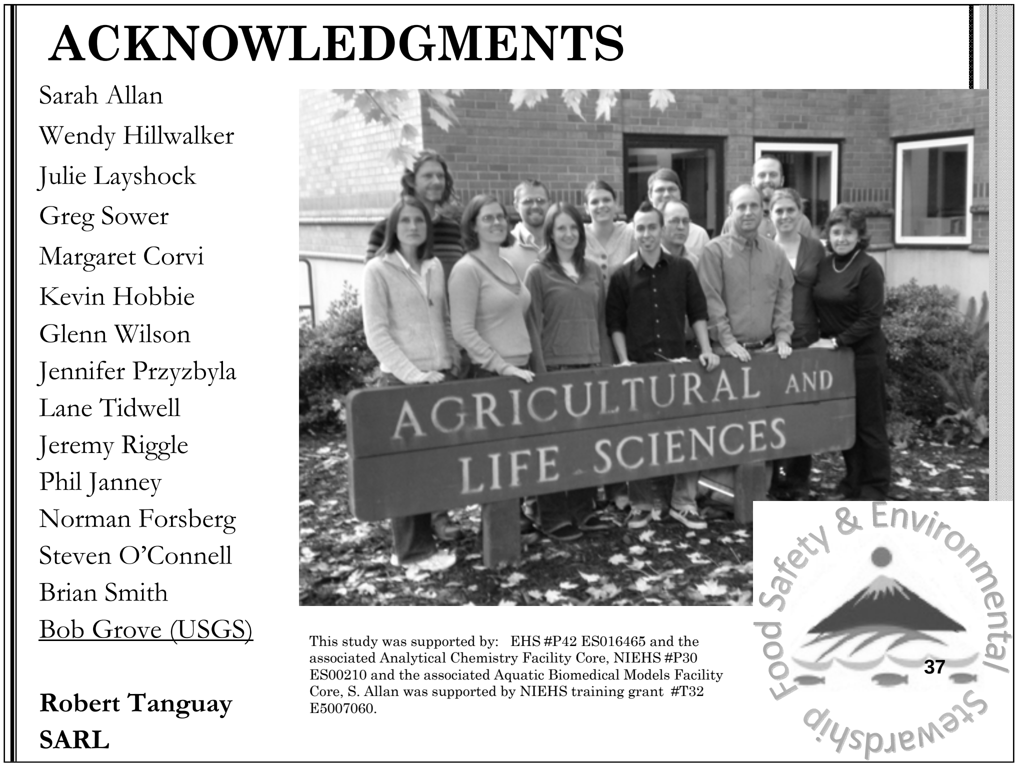
PSD PROVIDED TO SBR RESEARCHERS UPON REQUEST

- **Passive Sampling Devices Attributes:**
  - sequesters specific fraction (dissolved, bioavailable)
  - comparative data rapidly developing
  - iterative (captures episodic events)
  - composite without mechanical equipment or on-site power requirements
  - no seasonal issues with PSD compared w/ organisms
  - very low detection limits possible with relative analytical ease
  - minimizes decomposition or chemical change transport/storage
  - does not lump biological processes
  - Less expensive
  - Easier to replicate spatially
  - Greener technology
  - adequately mimics biological
  - not as many negatives as organisms with more positives than grabs…
  - *in-situ* assessment of environmental contaminants that are most biologically relevant
  - have ability to use in bio-assays
  - easily able to do exposure concentration dependent bio-assays

- **Using PSDs for Risk Assessment**
- Advantages
  - Inexpensive
  - Easy to analyze
  - Site specific
  - Bio-available fraction
  - No metabolic activity
  - Nondestructive

≅

Bioavailable Air and Water Passive Sampling Gear for Gulf of Mexico and Deepwater Horizon Oil Spill
BRIDGES: Biological Response Indicator Devices for Gauging Environmental Stressors pictured: K.Hobbie, K.Anderson, S.Allan, L.Tidwell
Funded in part by NIEHS Superfund Center "PAHs: New technologies and emerging human health risks" P42ES016465 and
Environmental Health Science Center NIEHS P30ES000210



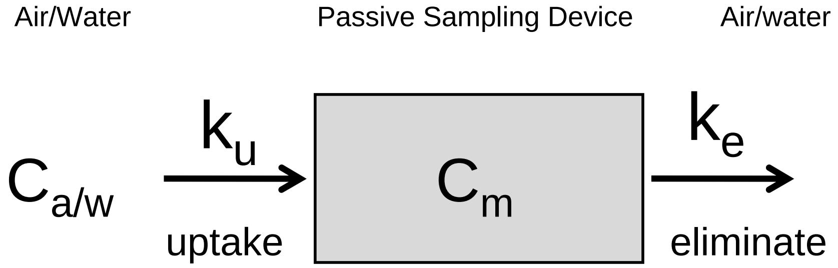
ACKNOWLEDGMENTS

Sarah Allan
Wendy Hillwalker
Julie Layshock
Greg Sower
Margaret Corvi
Kevin Hobbie
Glenn Wilson
Jennifer Przyzbyla
Lane Tidwell
Jeremy Riggle
Phil Janney
Norman Forsberg
Steven O'Connell
Brian Smith
<u>Bob Grove (USGS)</u>

Robert Tanguay
SARL

This study was supported by: EHS #P42 ES016465 and the associated Analytical Chemistry Facility Core, NIEHS #P30 ES00210 and the associated Aquatic Biomedical Models Facility Core, S. Allan was supported by NIEHS training grant #T32 E5007060.

Chemical Reaction Kinetics Model
uptake and release of contaminant



Rate to change of the concentration:

$$dC_m/dt = k_uC_w - k_eC_s$$

Conc at any *t* is determined by competing rates of uptake and release

Performance Reference Compounds Uptake and Release of Contaminant

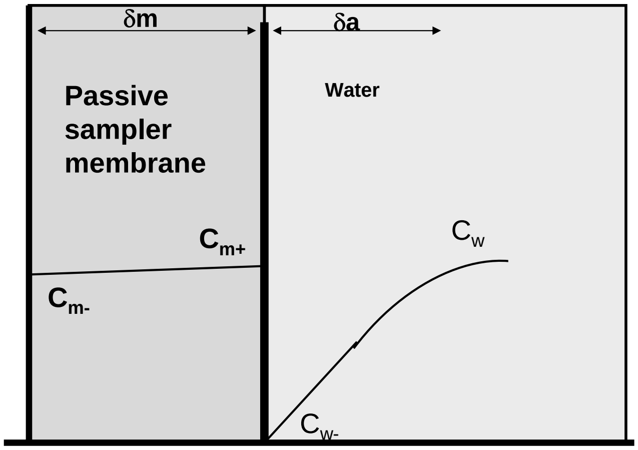
$$N = N_0 \exp(-k_e t)$$

Where N_0 is the amount present at $t = 0$, N is the amount present after

$$k_e = -\ln(N/N_0)/t$$

MASS TRANSFER COEFFICIENT MODEL

SCHEMATIC OF CONC DISTRIBUTION INSIDE AND OUTSIDE THE PSD

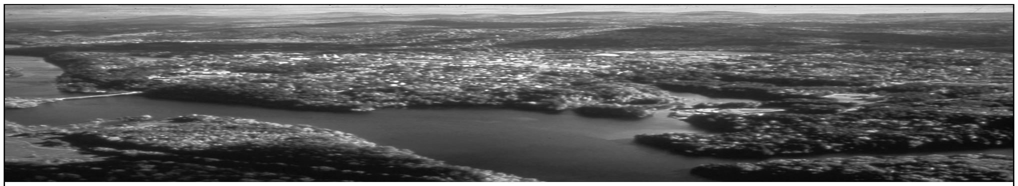


WATER (OR AIR) CONCENTRATION

$$R_s = V_m\ K_{mw}k_e$$

Rs = sampling rate

$$C_w=N/V_mK_{mw}(1-\ \exp((-R_s\mathit{t}/V_mK_{mw}))$$



Ecological Factors Controlling Mercury Bioaccumulation in Aquatic Food Webs

June 30, 2010

Celia Chen

Department of Biological Sciences

Dartmouth College

Hanover, NH

Where, What, and How

Illustration by W. Scavone

- Aquatic Ecosystems
  - Lakes
  - Estuaries
- Metals
  - Hg
- Approaches
  - Field studies
  - Mesocosm studies

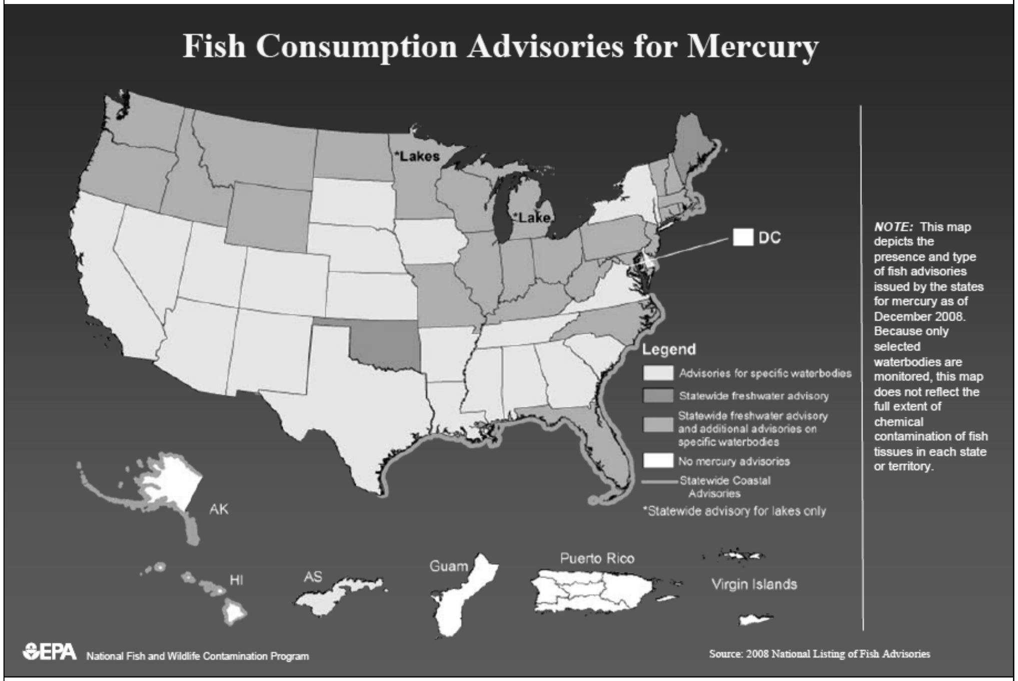
Ecological Processes

Trophic Transfer occurs when concentrations in predators are related to concentrations in their prey.

Biomagnification occurs when metal concentration increases with each level of a food chain.

Biomass dilution occurs when metal concentration decreases with increasing plankton biomass

Feeding Pathway distinguishes the route through which metals are transferred in food webs (benthic vs. pelagic)



Fish Consumption Advisories for Mercury

Legend

- ░ Advisories for specific waterbodies
- ▓ Statewide freshwater advisory
- ▒ Statewide freshwater advisory and additional advisories on specific waterbodies
- ⬜ No mercury advisories
- — Statewide Coastal Advisories

*Statewide advisory for lakes only

NOTE: **This map depicts the presence and type of fish advisories issued by the states for mercury as of December 2008. Because only selected waterbodies are monitored, this map does not reflect the full extent of chemical contamination of fish tissues in each state or territory.**

EPA National Fish and Wildlife Contamination Program

Source: 2008 National Listing of Fish Advisories

Toxicity of MeHg

In Humans:
>95% retained from diet

Main organs affected:

- Brain
- Kidney
- Fetal CNS

Effects: Impairs hearing, speech, vision, gait

Most damage thought to be irreversible.

drfrenchfry.wordpress.com

Mad Hatter's Syndrome 1800's

Minimata Disease 1956

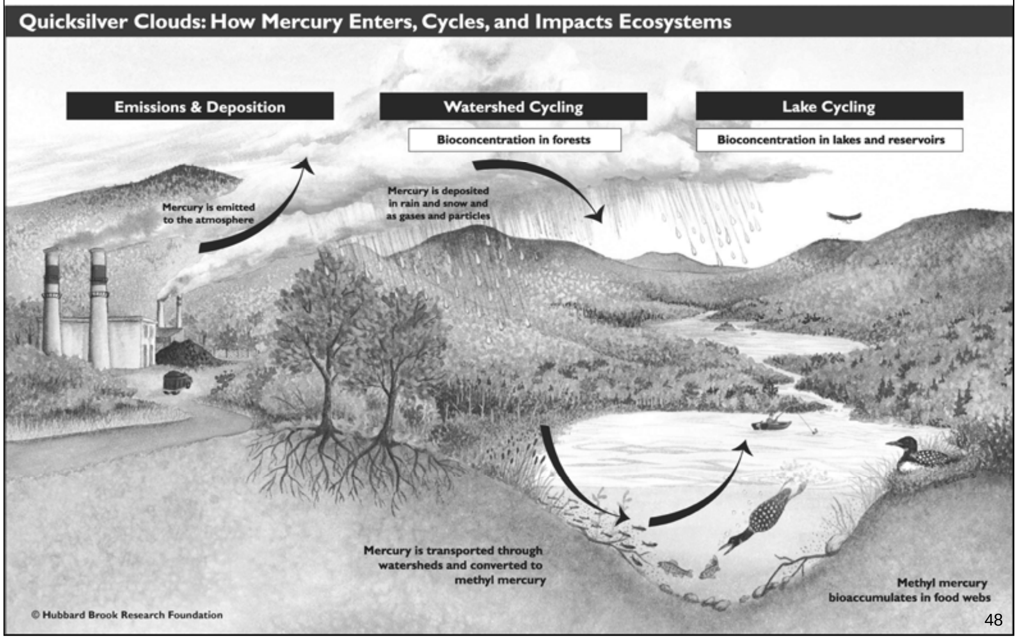
Chemical Forms of Hg

- Elemental Hg^0
  - Mostly atmospheric
  - Long residence time 0.5-2 yrs

- Oxidized Hg^{2+}
  - Dominant form in atmosphere and water
  - Reactive gaseous Hg (RGM)
  - Particulate Hg (PHg)

- CH_3Hg^+ monomethylmercury (MeHg)
  - Toxic form
  - Bioavailable form

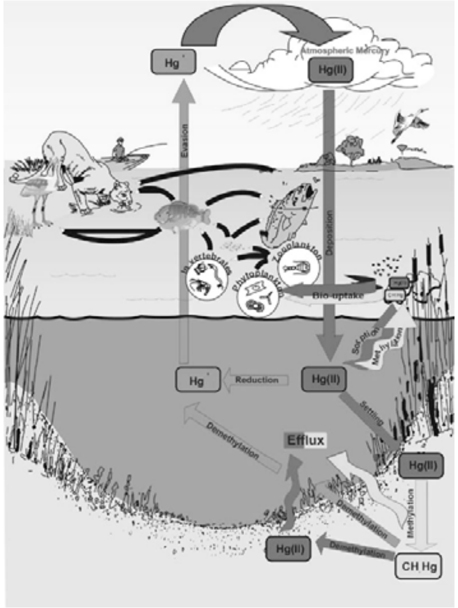
Mercury Sources, Transport, and Fate



Quicksilver Clouds: How Mercury Enters, Cycles, and Impacts Ecosystems

© Hubbard Brook Research Foundation

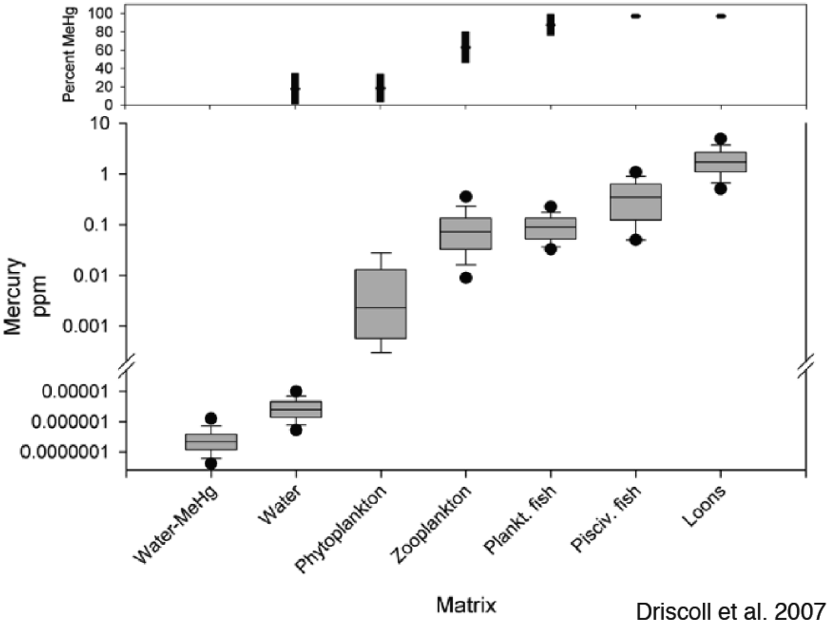
In-Lake Mercury Processes



USGS SOFIA 2000

- Hg enters lake as Hg(II)
- Hg methylation occurs in sediment producing MeHg
- MeHg and Hg(II) are fluxed from sediments to water
- MeHg and Hg(II) are taken up by particulates and phytoplankton
- MeHg is preferentially assimilated and transferred up the food web

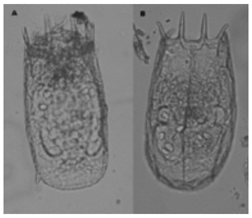
Biomagnification of MeHg



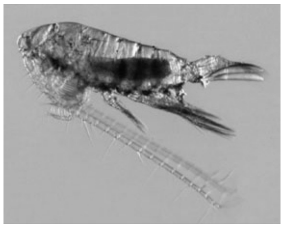
Driscoll et al. 2007

1. Field Approaches in Lakes to Investigate Metal Bioaccumulation and Trophic Transfer

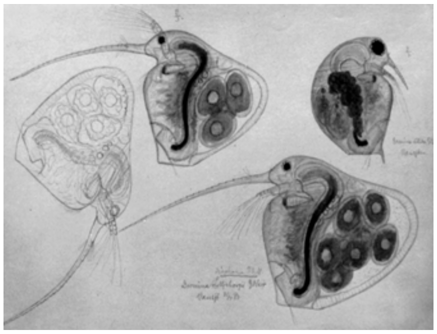
Pelagic Food Webs in Lakes



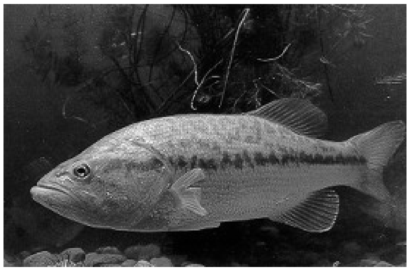
Rotifers, Herbivores



Copepods,Omnivores

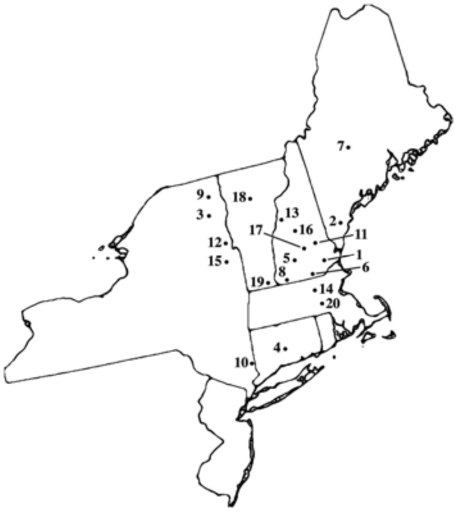


Cladocerans, Herbivores



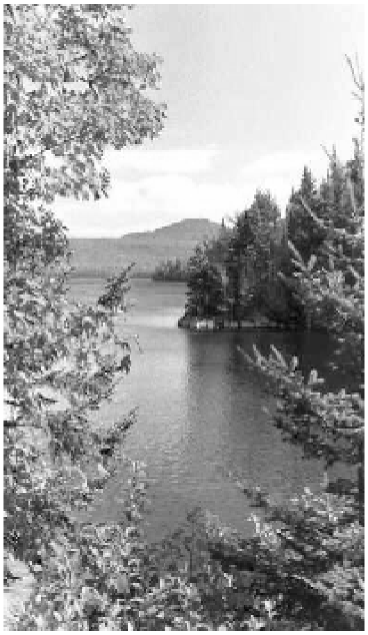
Planktivores, Piscivores

Field Survey of 20 Lakes in the Northeast US



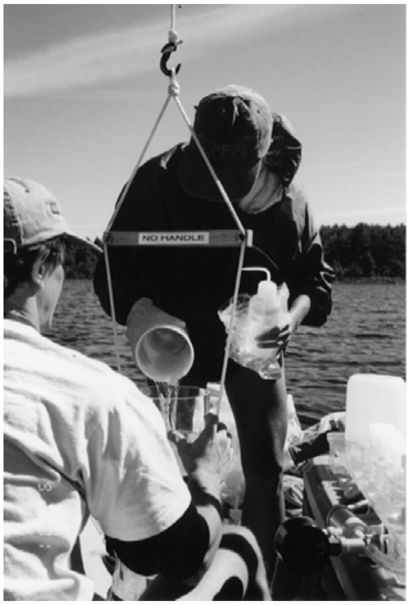
- Environmental variables
- Phytoplankton and zooplankton metal concentrations
- Phytoplankton and zooplankton taxonomy
- Concentrations of metals in fish tissue

Lake Characteristics



Variable	Range
Lake area	5.5 – 902 hectares
Watershed Area	0.9 – 799 hectares
Maximum Depth	2.0 – 20.9 meters
pH	6.0 – 9.3

Field Sampling and Sample Analysis

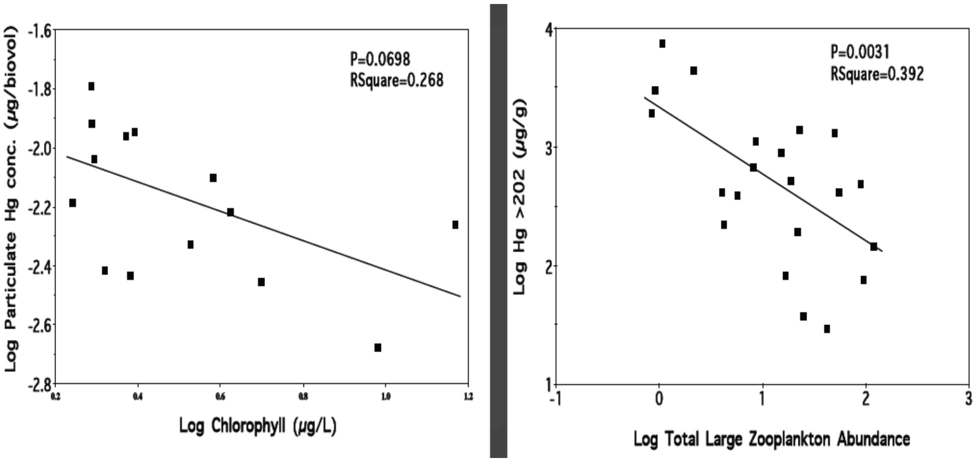


- Trace metal clean technique
- Plankton metal and taxonomy samples (45-202 and >202 μm)
- pH, TN, TP, DO, Cond., DOC, Chlorophyll
- Calculated variables (BMF, Food web structure)

Metal Analysis: Dartmouth Trace Element Analysis Core

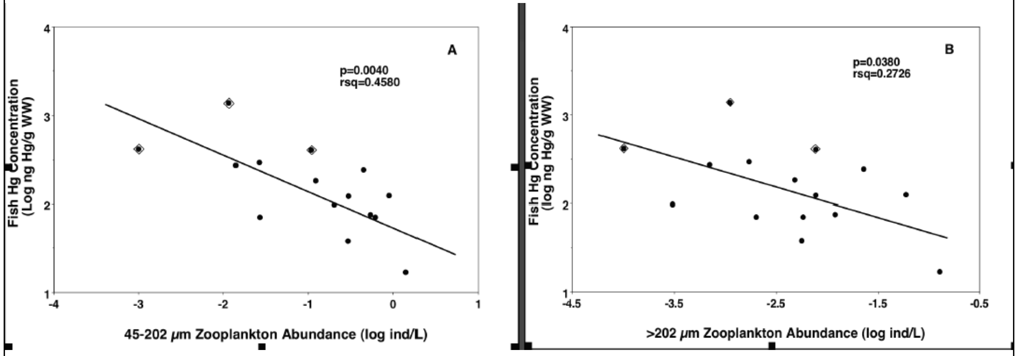
- Acid digestions
- High resolution ICP-MS (Trace Metal Lab Facility)
- Hg analysis via cold/vapor ICP-MS

Biomass Dilution: Phytoplankton and Zooplankton Densities Decrease Hg Bioaccumulation



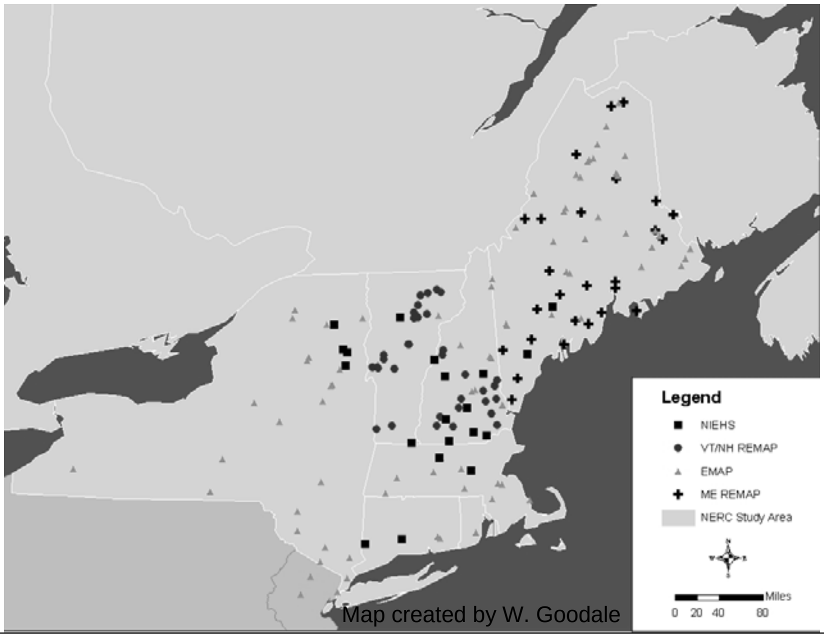
Chen and Folt 2005

Biomass Dilution:
Higher Zooplankton Density Relates to Lower Hg in Fish



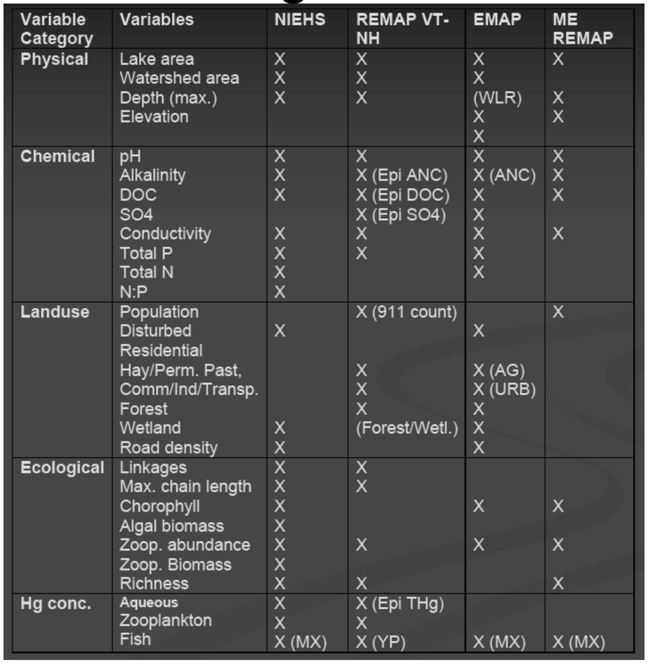
Chen and Folt 2005

Comparison of Multi-Lake Datasets from the NE US



Map created by W. Goodale

Predictors of Hg Bioaccumulation

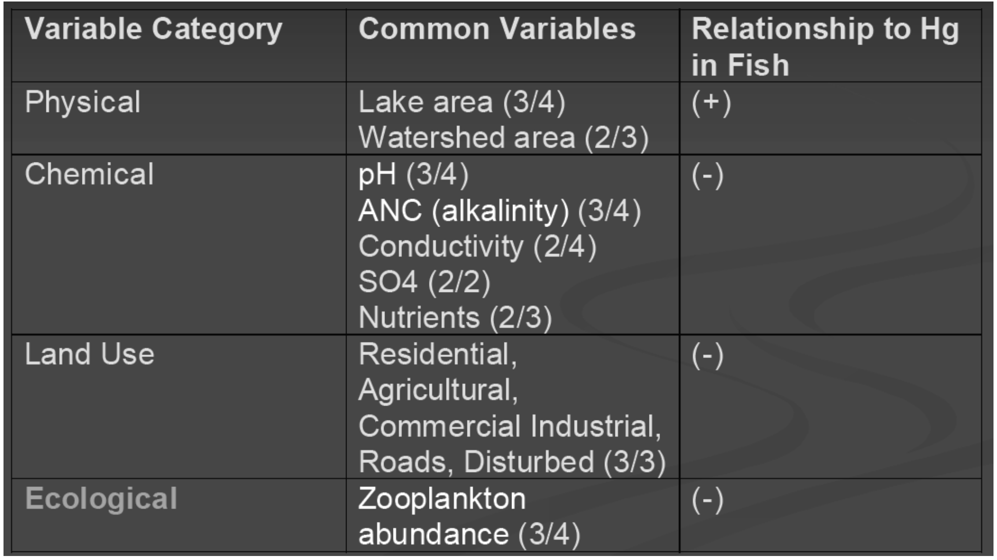


Variable Category	Variables	NIEHS	REMAP VT-NH	EMAP	ME REMAP
Physical	Lake area	X	X	X	X
	Watershed area	X	X	X	
	Depth (max.)	X	X	(WLR)	X
	Elevation			X	X
				X	
Chemical	pH	X	X	X	X
	Alkalinity	X	X (Epi ANC)	X (ANC)	X
	DOC	X	X (Epi DOC)	X	X
	SO4		X (Epi SO4)	X	
	Conductivity	X	X	X	X
	Total P	X	X	X	
	Total N	X		X	
	N:P	X			
Landuse	Population		X (911 count)		X
	Disturbed	X		X	
	Residential				
	Hay/Perm. Past,		X	X (AG)	
	Comm/Ind/Transp.		X	X (URB)	
	Forest		X	X	
	Wetland	X	(Forest/Wetl.)	X	
	Road density	X		X	
Ecological	Linkages	X	X		
	Max. chain length	X	X		
	Chorophyll	X		X	X
	Algal biomass	X			
	Zoop. abundance	X	X	X	X
	Zoop. Biomass	X			
	Richness	X	X		X
Hg conc.	Aqueous	X	X (Epi THg)		
	Zooplankton	X	X		
	Fish	X (MX)	X (YP)	X (MX)	X (MX)

Chen et al. 2005

Common Variables

Spearman Rank Correlation, $P<0.05$

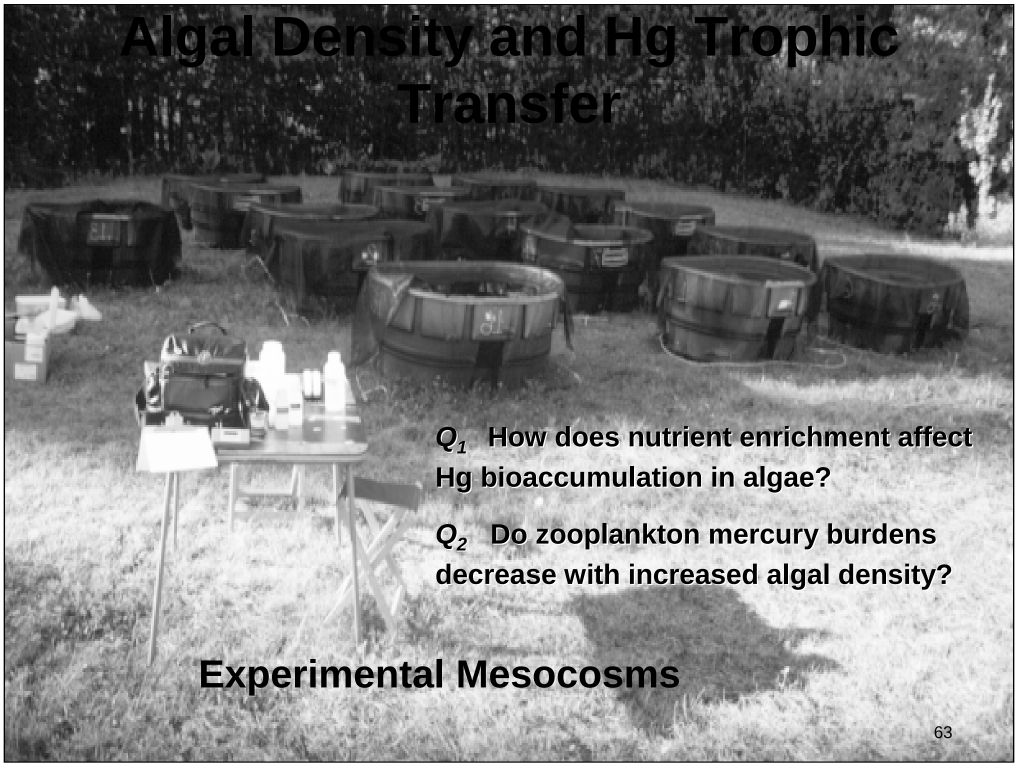


Variable Category	Common Variables	Relationship to Hg in Fish
Physical	Lake area (3/4) Watershed area (2/3)	(+)
Chemical	pH (3/4) ANC (alkalinity) (3/4) Conductivity (2/4) SO4 (2/2) Nutrients (2/3)	(-)
Land Use	Residential, Agricultural, Commercial Industrial, Roads, Disturbed (3/3)	(-)
Ecological	Zooplankton abundance (3/4)	(-)

Bonferroni Adjustment

Chen et al. 2005

2. Experimental Approach in Mesocosms to Investigate Biomass Dilution and Trophic Transfer



Algal Density and Hg Trophic Transfer

Q_1 How does nutrient enrichment affect Hg bioaccumulation in algae?

Q_2 Do zooplankton mercury burdens decrease with increased algal density?

Experimental Mesocosms

Experimental Design

- Two tanks at each nutrient level
- N and P ($\mu g \bullet L^{-1}$) all at 30:1 atomic ratio
- Stable isotopes of Hg (**$CH_3{}^{200}Hg^+$, $^{201}Hg^{2+}$**)
- Hg bioaccumulation in algae and zooplankton (daphnia)

100.4 : 7.4
oligotrophic
1x

201 : 14.8
mesotrophic
2x

302.6 : 22.3
mesotrophic
3x

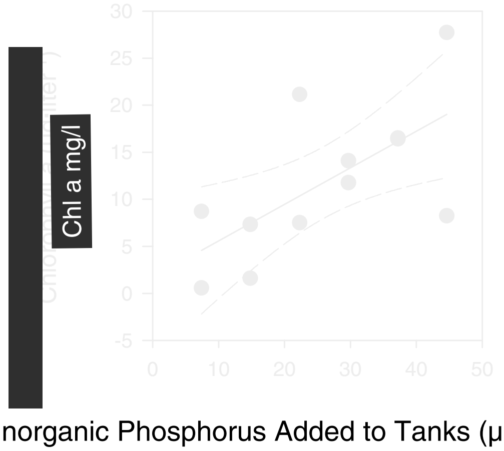
403.5 : 29.7
mesotrophic
4x

504.4 : 37.2
eutrophic
5x

605.3 : 44.6
eutrophic
6x

Pickhardt et al. 2002

Added N:P Increased Algal Biomass



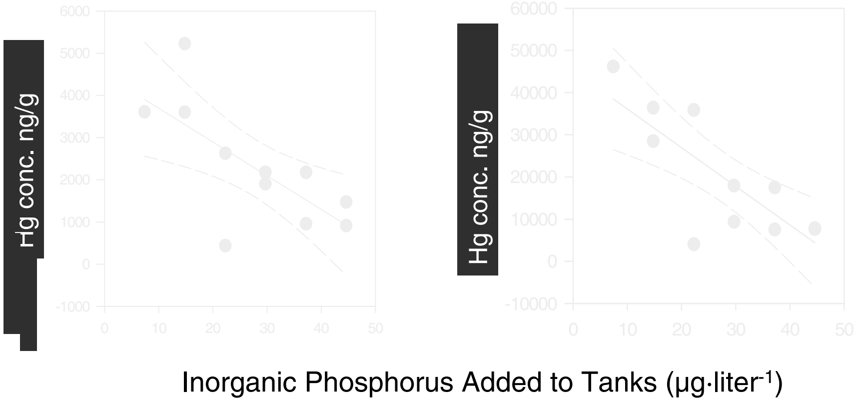
[redacted]

Chl. *a* = 0.39(µg P) + 1.69

n =12, R^2 = 0.431, $P < 0.021$

Pickhardt et al. 2002

Strong Algal ‘Dilution’ of Hg at 24 hours



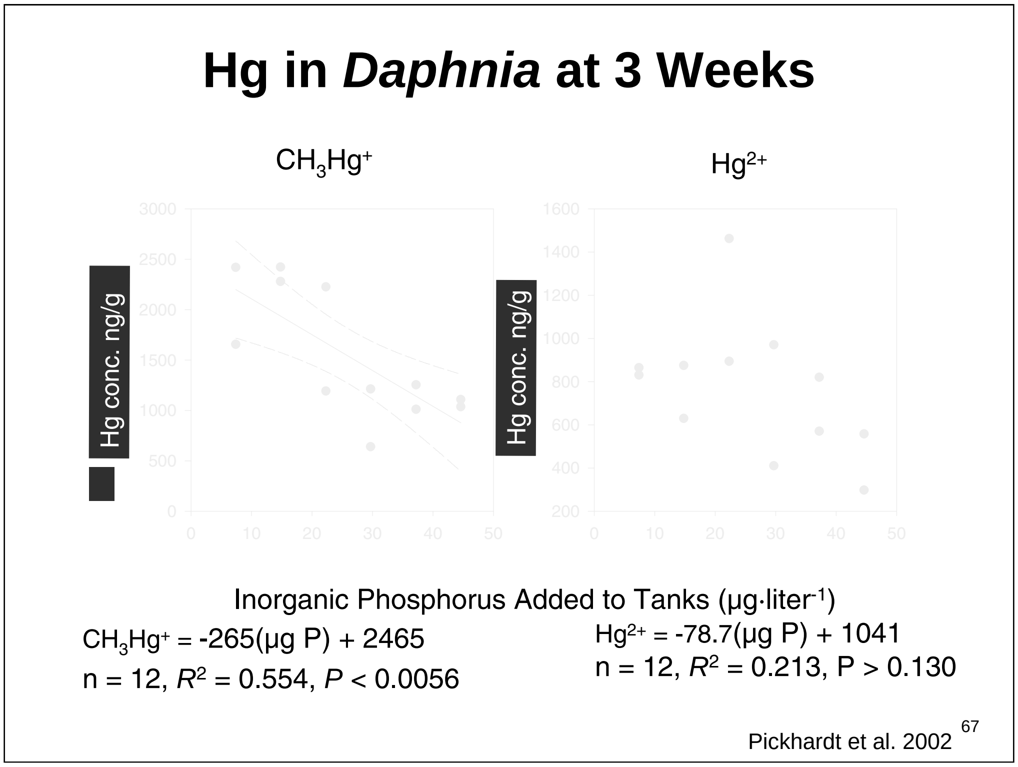
CH_3Hg^+

Hg^{2+}

CH_3Hg^+ = -80.14(µg P) + 4502
n = 11, $R^2 = 0.499$, $P < 0.016$

Hg^{2+} = -917(µg P) + 45290,
n =11, $R^2 = 0.623$, $P < 0.004$

Pickhardt et al. 2002



Hg in *Daphnia* at 3 Weeks

Inorganic Phosphorus Added to Tanks ($\mu g \cdot liter^{-1}$)

CH_3Hg^+ = -265(μg P) + 2465

n = 12, $R^2 = 0.554$, $P < 0.0056$

Hg^{2+} = -78.7(μg P) + 1041

n = 12, $R^2 = 0.213$, P > 0.130

Pickhardt et al. 2002

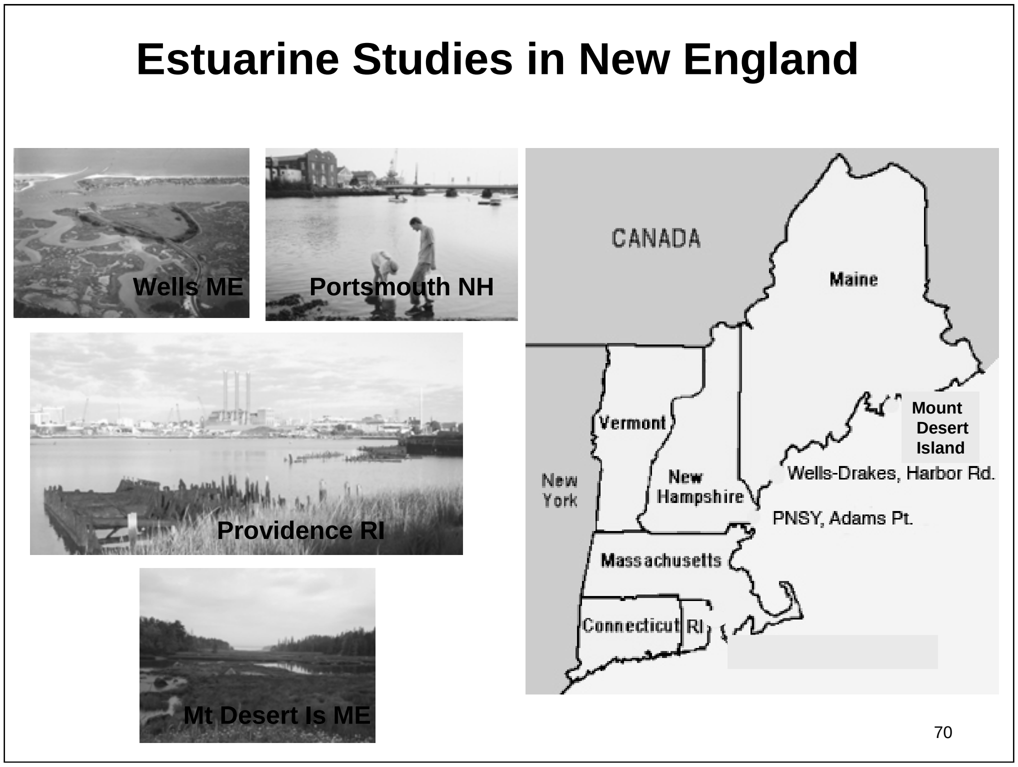
3. A Field Approach in Coastal Marsh Ecosystems to Investigate Feeding Pathways of Trophic Transfer

Bioadvection of Contaminants via the Trophic Nekton Relay

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

— 2003-4

Illustration by W. Scavone



Estuarine Studies in New England

Sampling in the Field

Biotic Samples:

Primary consumers: Snails, Mussels

Secondary consumers: Killifish, Green Crabs

Metal Analysis

-whole organisms freeze dried & homogenized

-Hg speciation by isotope dilution purge and trap GC-ICPMS at Dartmouth

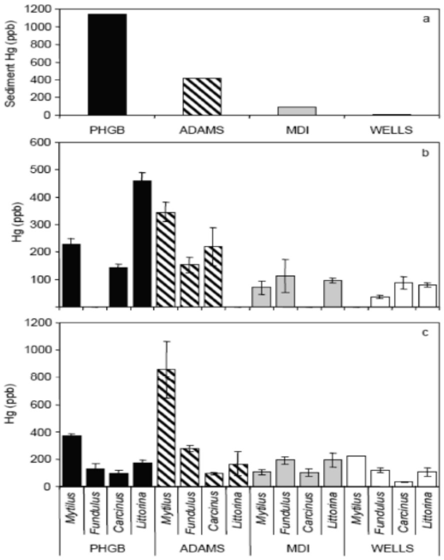
Isotope Analysis

-separate set of samples collected in field simultaneously

-whole organisms freeze dried and homogenized

δ^{13}C, δ^{15}N

Variation in Sediments vs. Biota (2003-4)



Sediment conc.
varies by 200X

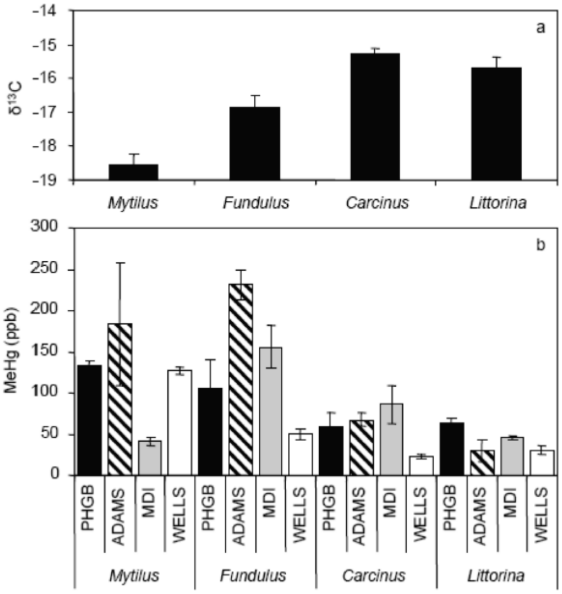
Four Species:
Mussels
Killifish
Green crab
Snail

Biotic conc.
vary by 2-4X

Concentrations (ug/g DW) of THg in: a) sediments and b) four focal species collected in 2003 (not all four species collected at all sites) and c) 2004.

Chen et al. 2009

Relationship of Feeding Pathway and MeHg



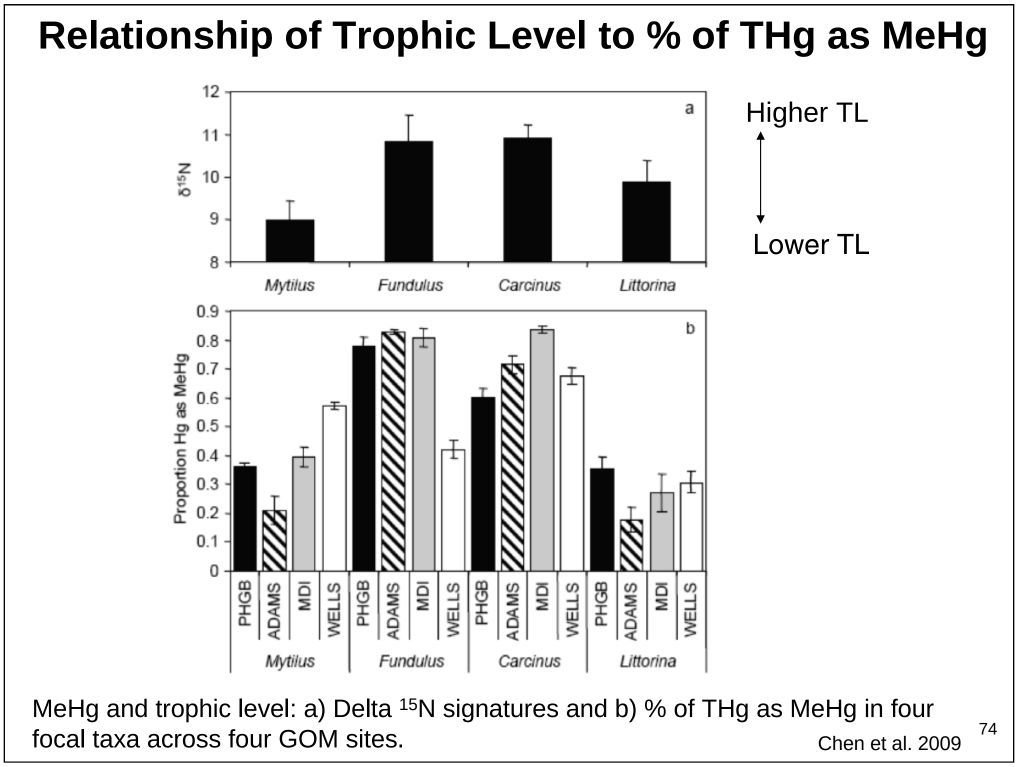
Benthic

↓

Pelagic

MeHg and Food source: a) Delta ^{13}C signatures and b) MeHg concentrations (ug/g DW) in four focal taxa across four GOM sites.

Chen et al. 2009



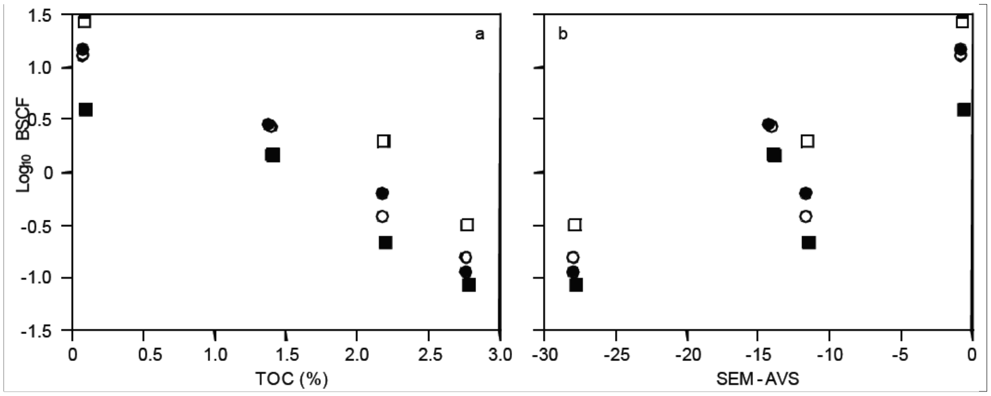
Relationship of Trophic Level to % of THg as MeHg

MeHg and trophic level: a) Delta ^{15}N signatures and b) % of THg as MeHg in four focal taxa across four GOM sites.

Chen et al. 2009

Relationship of Sediment Carbon to Bioaccumulation of Hg

BSCF = Benthic-sediment concentration factor = Hg in organism/Hg in sediment



Relationship of biotic-sediment concentration factors (BSCF) across sites and four focal taxa to: a) TOC and b) SEM-AVS. Symbols: (open square) *Mytilus*, (solid square) *Carcinus,* (open circle) *Littorina*, (solid circle) *Fundulus.*

Chen et al. 2009

Overall Conclusions

- Metal fate in aquatic food webs is determined by a number of ecological processes:

  Trophic Transfer

  Biomagnification.

  Biomass dilution

  Feeding Pathway

- These processes are present across lake and estuarine systems

Acknowledgments

Illustration by W. Scavone

Dartmouth Collaborators:
Carol Folt, Brian Jackson, Vivien Taylor, Jason Williams, Deenie Bugge, Darren Ward

Other Collaborators:
Paul Pickhardt, Lakeland College
Neil Kamman, VT DEC
Michele Dionne, Wells NERR
Dave Evers, Biodiversity Research Institute
Brandon Mayes, Long Trail Brewery

Supported by: National Institute of Environmental Health Sciences (NIEHS) as part of a Superfund Research Program at Dartmouth College (NIH Grant Number P42 ESO7373); Hubbard Brook Research Foundation Science Links Program; NH Sea Grant Program; Strategic Environmental Research and Development Program (SERDP).

Resources & Feedback

- To view a complete list of resources for this seminar, please visit the **Additional Resources**
- Please complete the **Feedback Form** to help ensure events like this are offered in the future

U.S. EPA Technical Support Project Engineering Forum
Green Remediation: Opening the Door to Field Use Session C (Green Remediation Tools and Examples)
Seminar Feedback Form

We would like to receive any feedback you might have that would make this service more valuable.
Please take the time to fill out this form before leaving the site.

First Name: Jean
Last Name: Balent
Daytime Phone Number: 703-603-9924
Email Address: balent.jean@epa.gov
☐ Please send a copy of my feedback confirmation as a record of my participation to this address
Date of Seminar:
○ December 15, 2009
Delivery Media

Need confirmation of your participation today?

Fill out the feedback form and check box for confirmation email.