Fish Sediment
Exposure Workshop

Deborah A. Edwards for SWMG
ExxonMobil Environmental Services
2800 Decker Drive
Baytown, Texas 77520

TABLE OF CONTENTS **PAGE**

FISH-SEDIMENT EXPOSURE WORKSHOP: GOALS, OUTCOME, PATH FORWARD

Goals and Organization:

On May 30-31, 2018 the USACE ERDC and SWMG jointly sponsored a meeting of government, academic, industry, and consulting experts for the purpose of discussing the assessment of exposure of humans via the consumption of fish contaminated with sediment-related contaminants of concern (COCS). This exposure scenario currently drives the cleanup of most sediment sites and often results in the development of sediment cleanup goals viewed by some as being overly conservative and impractical to achieve. In addition, the effectiveness of sediment COC concentration reduction in reducing concentrations in fish tissue (and thereby reducing risk to human consumers) has been questioned.

Setting cleanup goals that may be more conservative than necessary to achieve acceptable risk targets can be attributed in part to how the uncertainties in evaluating the fish-sediment scenario are addressed. Importantly, use of such conservative cleanup goals often results in controversy and delays in cleanup. Thus, it was felt that reducing uncertainties in the assessment of the fish-sediment exposure scenario, and improving the transparency of its associated risk management decision parameters, would improve the efficiency of sediment remediation. The goal of bringing together experts of varied viewpoints and responsibilities was to optimize collaboration with regard to improving the evaluation and management of the fish-sediment exposure scenario.

The purpose of this workshop was to discuss all aspects of this exposure scenario from movement and accumulation of COCs from groundwater, surface water or sediment into benthic receptors, to accumulation of these COCs into fish, and then finally exposure of humans to these COCs via consumption of impacted fish (See figure 1 which illustrates this exposure scenario). The goals of this workshop were to: (1) agree upon and prioritize areas of uncertainty in evaluating all aspects of this fish-sediment exposure scenario; and (2) to develop potential research projects that could be conducted to reduce these prioritized uncertainties.

Over fifty participants from government (including federal, state and county representatives), industry (SMWG members), academia and environmental consulting firms were invited to participate in the 2-day workshop. The attendee names and the organization they represent can be found in Attachment I. The agenda for this workshop can be found in Attachment II and included six plenary presentations designed to frame the discussion on subdivisions of the fish-sediment exposure scenario. In addition, two expert presenters coordinated the development of each plenary presentation to foster discussion of a diversity of viewpoints. The individual plenary presentations can be found in Attachment III.

The plenary sessions were followed by three breakout sessions. The questions that were addressed in each breakout session can be found in Attachment IV. The participants were divided into five groups of approximately ten participants that individually addressed the breakout questions. The groups were staffed (as much as possible) so that there was equal representation of government, industry, academic and consulting experts. The purpose behind the size and makeup of the breakout groups was to hopefully maximize input from as many participants as possible and foster interaction of participants with varying viewpoints. Following each breakout session, all five groups came back together and provided a summary of the group's input on the breakout questions. The feedback from each group on the breakout questions can be found in Attachment V. Finally, following the feedback from the third and final breakout session, all participants discussed consensus opinions on various topics. These topics included: (1) the workshop format (which was felt to be generally effective); (2) the potential for applying this format to other key environmental issues such as PFAS, for example; and (3) how to take the results of the workshop forward to address the uncertainties identified in the fish-sediment exposure scenario.

The path forward agreed upon at the conclusion of the workshop was divided into four steps. (1) Organize the list of proposed projects developed by the five breakout groups and have all attendees prioritize the top three projects from each of the three breakout sessions. The list of identified projects and results of the prioritization by attendees can be found in Attachment VI. (2) Following the prioritization of the projects a summary of the workshop would be developed and submitted to all participants for comment. This document and attachments are that workshop summary. Once comments are received and resolved, the summary of the workshop would be finalized. (3) Participants in the workshop (and others who would like to participate in the process) would be divided into three focus areas for the purpose of developing detailed scopes of work as well as cost and time estimates for projects given highest priority. Finally, (4) upon completion of scope development for prioritized projects, proposals to fund work would be entertained through SMWG (and potentially other funding organizations).

Plenary Session Highlights (see Attachment IV for full presentations)

I. Plenary Session 1: "Fish Behavior" presented by Karl Gustavson (EPA OSRTI) and David Smith (USACE ERDC)

   i. Starting with the assumption (uncertainty: source of fish exposure) that fish tissue concentrations are related to sediment COC concentrations. However, fish are not stationary. Sediment concentrations are heterogeneous and change over time. So, the challenge (uncertainty related to characterization of sediment concentrations that fish are exposed to) is to determine what sediment concentration results in protective fish tissue concentrations.

   ii. Fish exposure to sediment is not random and varies with species (interspecies) and individuals in population (intraspecies) and with seasons. So that it is unlikely that fish exposure is accurately represented by a SWAC (surface weighted average concentration). Fish exposure is (in any particular water body) influenced by bathymetry and physical features (e.g. habitat). So biological and physical environment can affect fish exposure to impacted sediments.

iii. It would be advantageous to develop data to correlate telemetry (fish residence time) to habitat and hydrodynamics and then relate this to sediment impacts to determine what is driving fish body burdens of COCs. Goal would be to develop a model to determine impacts on fish population both in short and long term.

II. Plenary Session 2: "Fish Natural History and Species Selection" presented by Lisa L. Williams (US Fish and Wildlife Service) and Susan Kane-Driscoll (Exponent)

i. Many factors affect fish exposure and uptake including

ii.

1. Gender (may affect home range and therefore site exposure)
2. Trophic level
3. Food web
4. Habitat and home range (relates to spatial and temporal risk)
5. Lipid content
6. Route of exposure (sediment, water and/or diet)
7. Ongoing and/or historic persistent sources

iii. On top of these complexities there is the question of which fish species to use to represent the uptake into Humans (e.g. fish with small home ranges which might better represent sediment exposure areas vs. fish species that are more often consumed by humans). A literature review regarding the basis of fish species being selected at different sites and pros and cons was suggested. This report would illustrate which uncertainties are selected at each site and how that uncertainty impacts decision making.

iv. Stable Isotope studies were suggested as an alternative or in addition to telemetry studies since fish natural history and prey seem to be generally better understood than are the movements of fish at most sites. Stable Isotope studies have the benefit of being relatively cheap to conduct but do require experts to interpret. In addition to relating fish tissue concentrations to source areas and media (i.e., benthic food web vs surface water), stable isotopes can help resolve issues with regard to reference areas (i.e., differences in trophic level and time integration vs. snapshot evaluation of differences in fish prey)

III. Plenary Session 3: "Bioaccumulation Modeling for Aquatic Food Webs" presented by Trina von Stackelberg (Harvard School of Public Health) and John Connolly (Anchor QEA)

i. The area of bioaccumulation modeling has evolved over the years generally becoming more complex.

ii. The best model to use for a specific site is the simplest model that "adequately" predicts the bioaccumulation of COCs from sediment, surface water and/or diet into fish.

iii. A further consideration is whether steady state or time variable results are needed.

iv. Challenges to selecting a model are how the 4 major carbon "sinks" or compartments are addressed those being:
   1. Water column particulate organic matter
   2. Near bottom water column particulate organic matter
   3. Recently deposited particulate organic matter
   4. Sub surface sediment organic matter

v. Uncertainties exist regarding the movement between these sinks, the relative responses of each compartment to remediation, and the depth limit of significant exposure (bioturbation, propwash, etc.).

vi. Exposure is driven by biota movement.

vii. Additional challenges are uptake, storage and transformation of compounds like PFAS and DDT.

viii. Lack of site-specific data to address movement, transformation, update etc. lead to optimization of bioaccumulation models to fit monitoring data but no global understanding of mechanisms; which then often leads to remediation that is ineffective or less than effective at reducing fish tissue concentrations. Models are often blamed for this situation, but models are only as good as the data that go into them.

ix. Bioaccumulation in aquatic mammals and wildlife is more complicated than fish (less information).

x. Needs to improve models:
   1. Better measurements of benthic feeding guilds
   2. Stable Isotope to characterize movement between four sinks above
   3. Establish exposure depth for benthos

4. Use random walk models to account for fish movement
5. Fate & transport data on ionized compounds
6. Guidelines for selection of "fit for purpose" model

IV. Plenary session 4:" Fish Consumption Rates and Data Collection" presented by Russell Keenan (Integral) and Debra Williston (King County DNRP)

i. Uncertainties exist around the following:
   1. Who is eating fish/shellfish (general populations vs. subgroups)
   2. Which species are they eating (resident or anadromous at which trophic levels)
   3. What body parts and how is fish prepared
   4. How much fish and how often
   5. Are all fish from site, or also background or outside sources (e.g. Supermarket)

ii. This information is important not only for cleanup but also for risk management (before and after cleanup)

iii. The less site-specific the information is the more uncertain and usually conservative the estimate

iv. The shorter time frame that consumption study covers the more uncertain

v. Would distributions across each consuming population give better estimates

vi. Impact of species selection: are the species consumed the same ones being monitored (often not)

vii. Heritage rates and Suppression: can they be accurately estimated? Will current fishery or habitat support higher consumption rates?

viii. What is the best survey method to determine consumption rates? They all have some bias

ix. Ideal studies hard to conduct (e.g. long term, representative participation, culturally neutral etc.)

x. Should we determine sustainable consumption rates for use in cleanup goal development

xi. Data gaps:
   1. Data on angler for longer than one year
   2. Mobility (do people really fish same river for lifetime?)
   3. Age and life circumstance influence over how much fishing/consumption
   4. Up to date studies (monitor river before and after cleanup…validate suppression, habitat improvements/availability of fish etc.)
   5. Possible area for public/private partnership to address uncertainty
      a. Develop guidelines for studies
      b. Smartphone apps for survey vehicle/ improve recall
      c. Camera studies for frequency and location of fishing

V. Plenary session 5: "Exposure and Data Analysis: Issues and Considerations associated with characterizing and Quantifying human Exposure to contaminants in Fish" presented by Gary Buchanan (NJDEP) and Paul Anderson (Arcadis)

i. What are representative exposure concentrations in fish (point estimates or distributions)

ii. Variability and uncertainty in human exposure

iii. Individual fish measurements vs. composites

iv. Species to collect
   1. Based on human exposure or contaminant distribution
   2. Small vs. large home range
   3. Resident vs. migratory
   4. Trophic level

v. Size of fish sampled (legal limit??)

vi. Tissue
   1. Fillet
   2. Skin on/off
   3. Whole body
   4. Organs
   5. Cooked vs. raw –weight based rate
   6. Cooking method: balance loss of COC vs. moisture

vii. Background vs. site concentrations

viii. Fraction consumed from site

ix. Can fishery support consumption rate used

x. Duration of human exposure (census data on mobility)

xi. Bioavailability vs. bioavailability in toxicity studies

xii. Deterministic vs. Probabilistic methods

xiii. Risk/ Benefit of fish consumption (heart disease reduction usually greater than incremental cancer increase)

xiv. Subpopulations: should subpopulations be separated from general populations (children, subsistence, cultural); should distributions of each population be used?

xv. Population vs. individual risk (acceptable incremental increase in risk)

xvi. Absolute population risk
   1. Percentage exposed
   2. Percentage of background mortality
   3. Comparative cost of life saved
   4. Linking distribution percentiles with allowable risk benchmark

xvii. Path forward: compile information from successful remediations
   1. Sediment contaminant reduction
   2. Fish tissue reduction
   3. Model ability to predict

xviii. Site-specific guidelines for sites or a watershed approach

xix. Consider that background levels of COCs like PCBs decreasing

xx. Recontamination

xxi. Fish advisories need to be linked to sediment remediation target

xxii. Distinguish risk management from exposure assessment

VI. Plenary session 6: "Risk Management and Remedy Decision-Making" presented by Marc Greenberg (US EPA Superfund HQ) and Ralph Stahl (DuPont)

i. Managing uncertainty is a key challenge

ii. Reaching unlimited human fish consumption is a goal

   1. Can this goal be achieved is question?

iii. Are we relying too heavily on models that have not been adequately calibrated? What if we can't calibrate them?

iv. Should we be doing more monitoring during remedial action?

   1. Baseline is critical

v. What is an acceptable time frame for recovery?

   1. Should we be doing more interim RODs, early action or adaptive management (how is adaptive management defined?)

   2. Should there be interim targets for fish

vi. Risk assessment is basis for requiring action

   1. Exposure assumptions
   2. Background risks
   3. Unlimited human consumption
   4. How will risk reduction be measured

vii. Risk management decisions involve legal, risk, social, feasibility, political and cost/benefit evaluations

   1. Research and adaptive management/monitoring are seen as ways to improve the process (reduces uncertainty and speeds up environmental cleanup)

   2. Collaboration of industry, government and academia has proven to be the best way to effectively address sediment uncertainty

Breakout Session Highlights (see attachments IV, V and VI):

The questions asked at each breakout session were essentially the same and are shown below.

a. What are the most consequential uncertainties with regard to: (1) fish biology and bioaccumulation modeling; (2) fish consumption and exposure; and (3) risk management and decision making?

b. What are the best or most promising opportunities for improving the evaluation: (1) of fish biology/behavior or bioaccumulation modeling; (2) of human exposure assessment; and (3) of the correlation of fish tissue concentrations to sediment concentrations?

c. What studies are the most important to advance the practice of: (1) fish biology and bioaccumulation modeling; (2) fish consumption exposure assessment; and (3) risk management practice related to fish-sediment correlations?

Highlights from Breakout session I: Fish Biology-Bioaccumulation

The five breakout groups developed 5 projects which were seen as most important to potentially improve the assessment of impacts to fish from sediment, surface water or trophic bioaccumulation. These projects are listed in attachment VI along with the type of activity each project represents and a relative cost and schedule estimate. The potential projects were ranked as follows:

(1) Fish Exposure Handbook and Workgroup
(2) Post audit-retrospective for model validation
(3) Tie: Stable Isotope review and Food web characterization guidance
(4) Fish Telemetry and behavior modeling
(5) Tie: Passive Sampling for bioaccumulation modeling and Improve understanding of PFAS bioaccumulation

The charge of the Fish Biology and Bioaccumulation workgroup will be to validate the project rankings above, develop detailed workscopes, cost estimates and schedules for the top 2/3 projects and advise on potential funding mechanisms.

Highlights from Breakout session II: Exposure and Consumption

The five breakout groups developed a total of 8 projects to improve assessment of human exposure to fish. These projects are also listed in attachment VI and characterized as to type of activity and relative cost and time to complete. The potential projects were ranked as follows:

(1) Fish consumption exposure guidance
(2) Fish tissue concentration as metric for remedy monitoring

(3) Meta-analysis on fish consumption and human contaminant levels
(4) Fish consumption survey guidance for NCI data analysis method
(5) Evaluation of sustainability of fish consumption rates
(6) Lifetime fish consumption cohort study
(7) Tie: Evaluate change in fish consumption following remediation and advisory relaxation; and Reasonably foreseeable future use

The charge of the Exposure and Consumption workgroup will be to validate project rankings above, develop detailed workscopes, cost estimates and schedules for the top 2/3 projects and advise on potential funding mechanisms.

Highlights of Breakout Session III: Risk Management

The five breakout groups developed a total of 8 projects to improve risk management regarding this exposure scenario. These projects are also listed in attachment VI and characterized by activity type and relative cost and time estimates. The potential projects were ranked as follows:

(1) Form an Adaptive management workgroup (Completed by SMWG)
(2) Incentivize early action with monitoring and legal credit
(3) Decision analysis framework to support uncertainty analysis in remedy and cost
(4) Policy on acceptable risk targets and percentiles for population groups
(5) Risk management case studies/ lessons learned
(6) Encourage comprehensive pre and post remedy monitoring and Risk communication resources for fish-sediment issues
(7) Develop Superfund analog to USACE standard of "least costly environmentally acceptable alternative"
(8) Additional resources for EPA RPMS

The charge of Risk Management workgroup will be to validate rankings above, develop detailed workscopes, cost estimates and schedules for the top 2/3 projects and advise on potential funding mechanisms.

Summary and Conclusions:

On May 30-31, 2018 the USACE and SMWG cosponsored a workshop of experts on assessing the exposure of humans from consumption of contaminated fish which is the exposure scenario that drives cleanup at most contaminated sediments sites. Figure 1 illustrates the complexity of this exposure scenario as contaminants move from water and sediment into benthic receptors, then into fish and finally into humans who consume the contaminated fish. The plenary presentations documented numerous uncertainties that together can make evaluation of this exposure scenario highly uncertain and can lead to very conservative sediment cleanup goals if conservative assumptions are used to address the numerous uncertainties. As this exposure scenario drives cleanups that can take decades and potentially cost billions of dollars; reducing the uncertainty in the assessment and management of this exposure scenario warrants additional research.

At the workshop experts from government (at several levels), academia, consulting firms and industry collaboratively discussed the uncertainty in evaluating this exposure scenario and developed and ranked projects with the potential to improve the assessment and management of human exposure to fish contaminated by COCs in sediments and hopefully, thereby, lead to more effective sediment remediation.

The next step in this process is for each of the three subgroups to validate the project rankings developed by the May 2018 workshop and to develop detailed workscopes, cost estimates and schedules for the two or three projects of highest priority. Finally, the workgroups will provide advice to SMWG on potential funding mechanisms for the projects. SMWG intends to select some of these projects to fund directly but will also seek alternative funding sources for other projects.

With regard to participation in the workgroups: these groups will be open to participation from any party not just the workshop attendees. The Workshop attendees felt that the collaborative nature of the workshop was a model that should be encouraged to address other environmental topics going forward including, for example, PFAS.

Attachment 1

Workshop Attendee List

FISH EXPOSURE WORK SHOP ATTENDEE LIST

First Name	Last Name	Organization	Email Address
US Army ERDC /US Navy (7)			
Todd	Bridges	US Army, ERDC	todd.s.bridges@usace.army.mil
Phil	Gidley	US Army, ERDC	Philip.t.gidley@usace.army.mil
Gui	Lotufo	US Army, ERDC	Guilherme.lotufo@usace.army.mil
David	Moore	US Army, ERDC	David.w.moore@usace.army.mil
Carlos	Ruiz	US Army, ERDC	Carlos.e.ruiz@usace.army.mil
Paul	Schroeder	US Army, ERDC	Paul.r.schroeder@usace.army.mil
Dave	Smith	US Army, ERDC	David.l.smith@usace.army.mil
Regulatory/Resource (12)			
John	Cargill	DNREC	john.cargill@state.de.us
Jeff	Stern	King County, WA	Jeff.stern@kingcounty.gov
Debra	Williston	King County, WA	debra.williston@kingcounty.gov
Gary	Buchanan	NJDEP	gary.buchanan@dep.state.nj.us
Jim	Meador	NOAA	james.meador@noaa.gov
Sarah	Greenfield	Oregon DEQ	Greenfield.Sarah@DEQ.state.or.us
Larry	Burkhard	USEPA, EERL, Duluth	burkhard.lawrence@epa.gov
Marc	Greenberg	USEPA, ERT	greenberg.marc@epa.gov
Karl	Gustavson	USEPA, OSRTI	gustavson.karl@epa.gov
Doug	Tomchuk (R2)	USEPA, R2, CSTAG	tomchuk.doug@epa.gov
Lisa	Williams	USF&W	Lisa_Williams@fws.gov
Jeff	Steevens	USGS (Columbia)	jsteevens@usgs.gov
Academic (2)			
Trina	von Stackelberg	HSPH & NEK Assoc.	kvon@hsph.harvard.edu
Barry	Kelly	Simon Fraser University	bc_kelly@sfu.ca
Consulting (13)			
Betsy	Ruffle	AECOM	betsy.ruffle@aecom.com
John	Connolly	Anchor-QEA	jconnolly@anchorqea.com
Paul	Anderson	Arcadis	paul.anderson@arcadis-us.com
Eric	Blischke	CDMSmith	blischkee@cdmsmith.com
Barrie	Selcoe	CH2M	Barrie.Selcoe@ch2m.com
Steven	Peterson	ERM	Steven.Peterson@erm.com
Susan	Kane Driscoll	Exponent	sdriscoll@exponent.com
Laura	McWilliams	Haley Aldrich	lmcwilliams@haleyaldrich.com
Russ	Keenan	Integral	rkeenan@integral-corp.com
John	Wolfe	LimnoTech	jwolfe@limno.com
Rick	Fox	O'Brien & Gere	rick.fox@obg.com
Miranda	Henning	Ramboll	mhenning@ramboll.com
John	Toll	Windward	johnt@windwardenv.com
SMWG/Industry (11)			
Tim	Hassett	Ashland	tdhassett@ashland.com
Stephanie	Barczyk	Chevron	sbarczyk@chevron.com
Will	Gala	Chevron	wgala@chevron.com
Steve	Brown	Dow	stevenbrown@dow.com
Jack	Zabik	Dow	JMZabik@dow.com
Tim	Bingman	DuPont	Timothy.S.Bingman-2@dupont.com
Ralph	Stahl	DuPont	Ralph.G.Stahl-jr@usa.dupont.com

FISH EXPOSURE WORK SHOP ATTENDEE LIST

First Name	Last Name	Organization	Email Address
Deb	Edwards	ExxonMobil	Deborah.a.edwards@exxonmobil.com
Paul	Montney	Georgia-Pacific	pamontne@gapac.com
Bob	Wyatt	Northwest Natural	rjw@nwnatural.com
Steve	Nadeau	SMWG	snadeau@honigman.com

26615096.1

Attachment 2

Agenda

(5/24/18)

Fish-Sediment Exposure Workshop Agenda

May 30-31, 2018

U.S. Army Engineer Research and Development Center, Environmental Laboratory

Waterways Experiment Station

3909 Halls Ferry Rd.

Vicksburg, Mississippi

Purpose: The workshop will explore issues related to the assessment of fish exposure to contaminated sediment (and humans through fish) and implications for site clean-up. Discussions will focus on technical areas where further study is warranted to reduce uncertainty and identifying approaches and actions that should be taken to improve overall risk-based decision-making and support national consistency. A workshop outcome goal will be to develop a consensus list of key issues and candidate actions to be taken to improve overall understanding and decision-making related to the sediment-fish exposure pathway.

AGENDA

Day 1: Wednesday, May 30, 2018

7:30 am	**Breakfast (Catered In)**
8:00 am	Welcome and Overview (Todd Bridges/ERDC, Steve Nadeau/SMWG)
8:30 am	Plenary 1 – Fish Behavior Modeling (*Dave Smith/ERDC, Karl Gustavson/EPA*)
9:00 am	Plenary 2 – Fish Natural History and Species Selection (*Susan Kane-Driscoll/Exponent, Lisa Williams/USFWS*)
9:30 am	Plenary 3 – Bioaccumulation Modeling (*Trina von Stackelberg/HSPH, John Connolly/Anchor QEA*)
10:15 am	**Coffee Break (15 minutes)**
10:30 am	Plenary 4 – Fish Consumption Rates and Data Collection *(Debra Williston/King County, Russ Keenan/Integral)*
11:00 am	Plenary 5 – Exposure and Data Analysis *(Paul Anderson/Arcadis, Gary Buchanan/NJDEP)*
11:30 am	Plenary 6 – Risk Management and Remedy Decision-Making *(Marc Greenberg/EPA, Ralph Stahl/Dupont)*
12:00 pm	**Lunch (Catered In)**
1:00 pm	Orientation for Breakout Groups
1:30 pm	Breakout Groups #1
3:00 pm	**Coffee Break (15 minutes)**
4:00 pm	Rejoin - Summary of Day 1 Breakout Groups (Facilitators)
5:00 pm	Adjourn Day 1
5:00 pm	Optional tour of a couple of ERDC's labs (5 minute walk)
6:00 pm	**Reception**

Day 2: Thursday, May 31, 2018

7:30 am	**Breakfast (Catered In)**
8:00 am	Orientation and Day 2 Focus (Todd and Steve)
9:00 am	Breakout Groups #2
10:15 am	**Coffee Break (15 minutes)**
11:30 am	Rejoin - Summary of Day 2 Morning Breakout Groups (Facilitators)
12:00 pm	**Lunch (Catered In)**
1:00 pm	Breakout Groups #3
2:45 pm	**Coffee Break (15 minutes)**
3:00 pm	Rejoin - Summary of Day 2 Afternoon Breakout Groups (Facilitators)
3:30 pm	Summary of Key Themes, Consensus, Action Items
5:00 pm	Workshop Adjourn
6:00 pm	**Dinner - Optional gathering for those interested in breaking bread together (TBD)**
	(NOTE: expenses for this particular dinner will be borne by everyone individually for this event)

ATTACHMENT 3

Plenary Presentations

Plenary 1 – Fish Behavior

Karl Gustavson – EPA OSRTI
David Smith – USACE ERDC

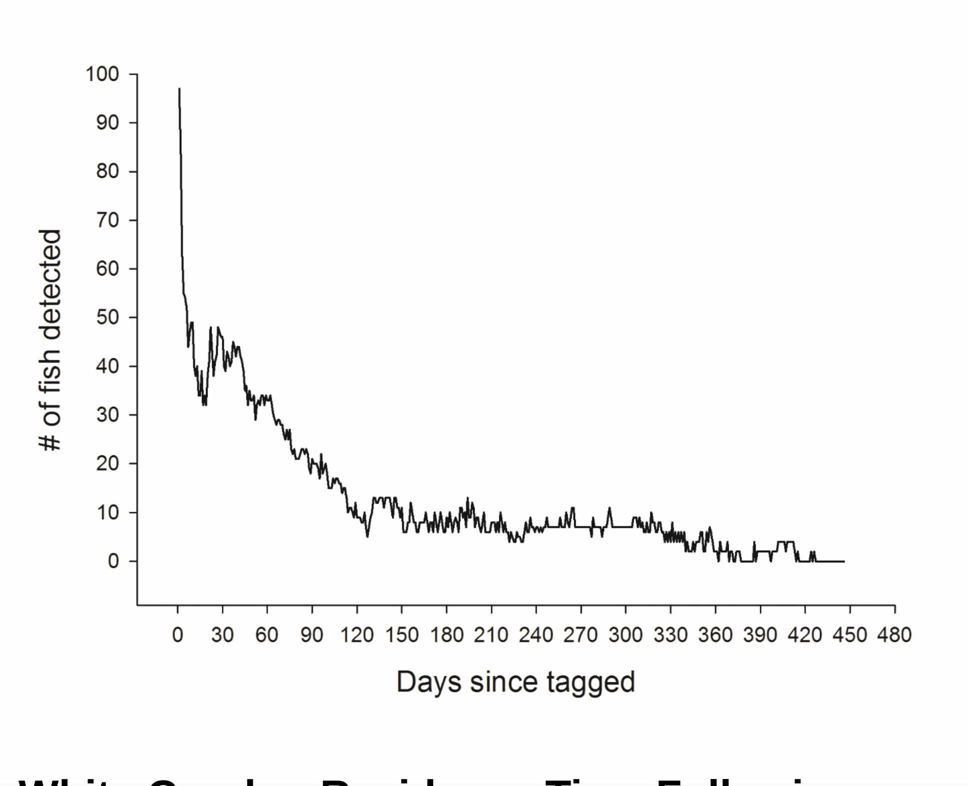
Overview

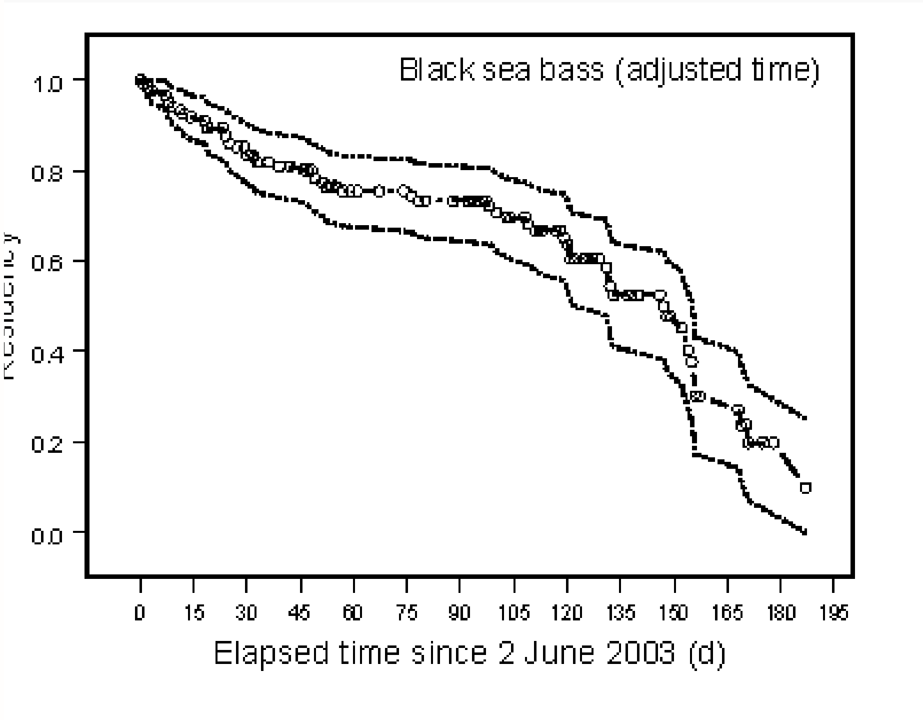
- Fish Matter
- Fish Move
- Exposures Change
- Establishing a sediment concentration that corresponds to a “protective” fish tissue concentration is a challenge

Fish Matter

- Human health risk at sites with PCB-contaminated sediments primarily stems from consumption of fish tissue.
- Assumption that fish tissue contaminants derive from sediment contaminants.
- So, sediment remediation is conducted to decrease fish tissue contaminants.

Fish Move





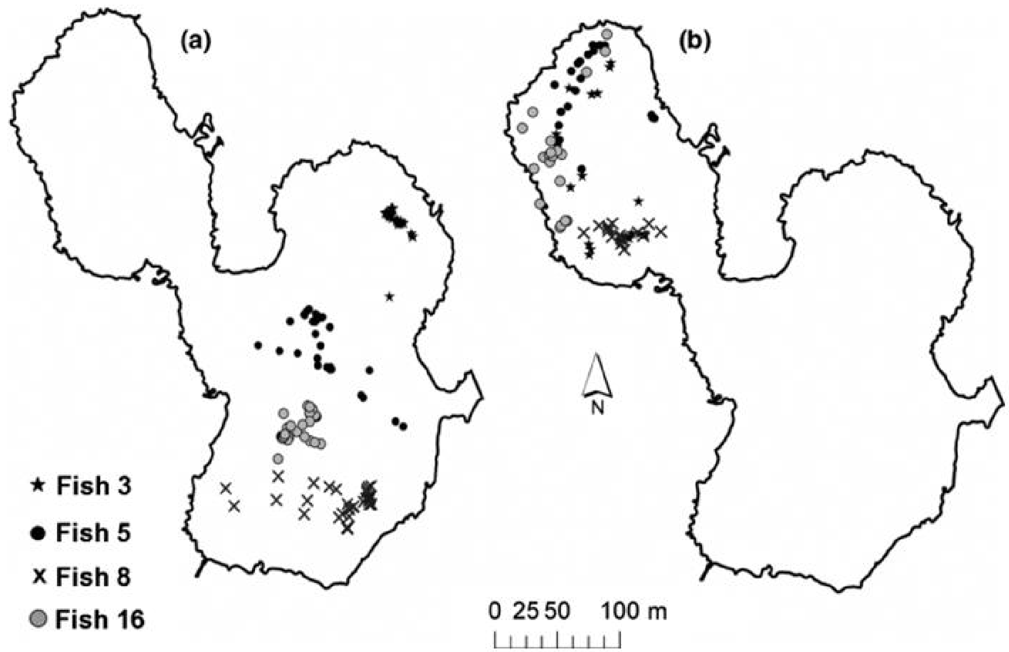
White Croaker Residence Time Following Tagging. Palos Verde Shelf. Pacific Ocean. (EPA Region 9; study conducted by Lowe and Wolfe, CSULB)

Black Sea Bass Residency Following Tagging. HARS. NJ, Atlantic Ocean. (Fabrizio et al. Northeast Fisheries Science Center)

Fish Move

- Fish exposure areas:
  - -vary between species
  - -among individuals
  - -between seasons

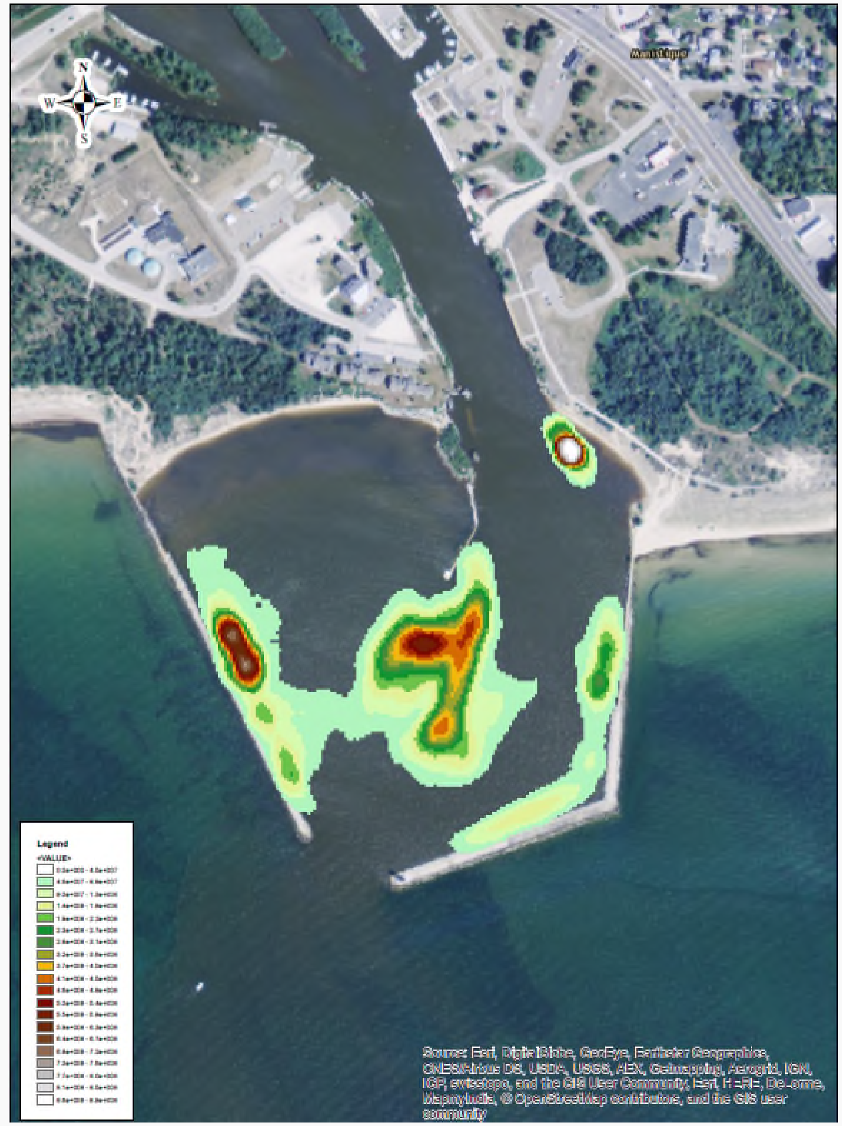
Seasonal Movements (winter vs spring)



Hasler et al. 2007. Ecology of Freshwater Fish. 16: 417–424

Fish Move

- Fish behavior is not random
- Unlikely to be represented by a “SWAC”
- Areas of focus readily discernible
- Apparent connection between bathymetry and physical features



Exposures Change

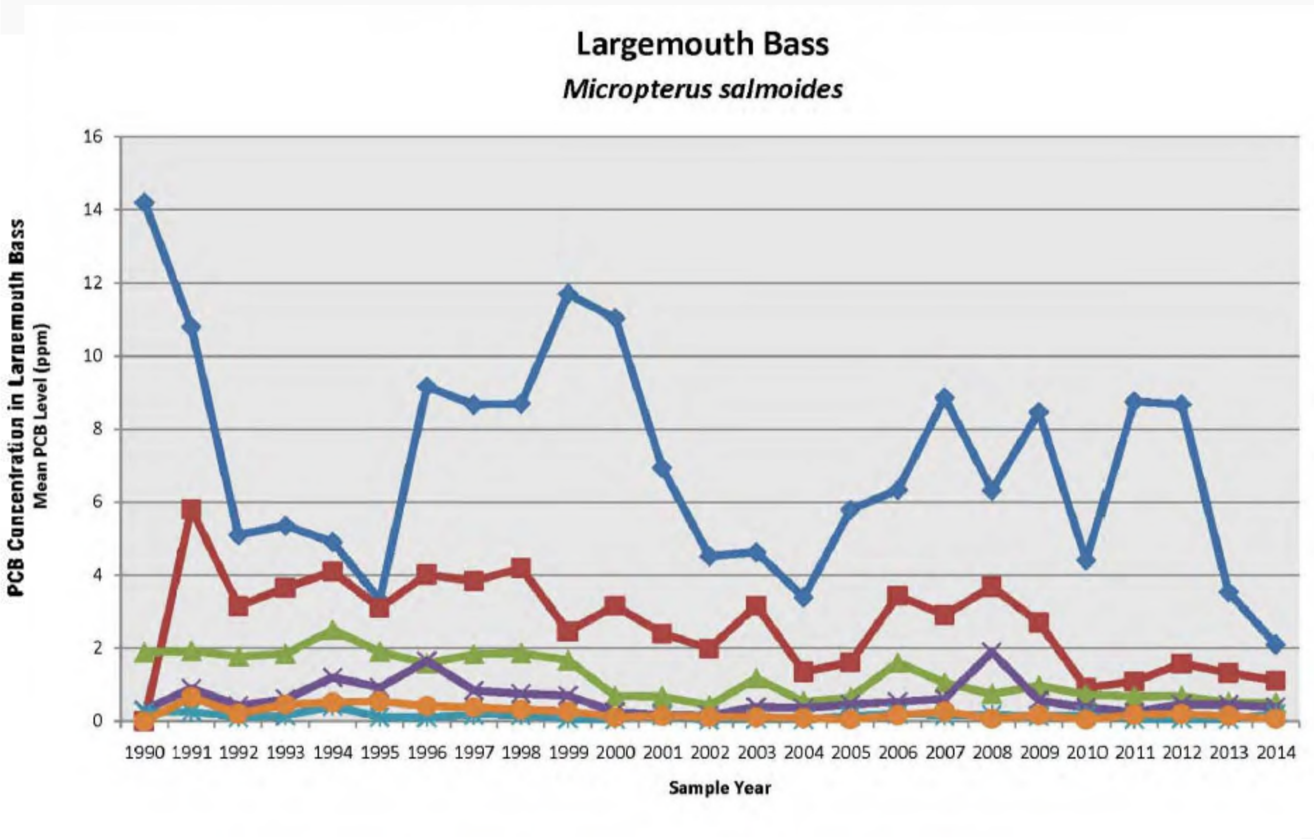
Biology

- location
- life cycle
- seasonal feeding
- size-dependent diet
- available prey

Environment

- temperature
- watershed inputs
- sediment erosion/deposition
- releases

Establishing the Sediment to Fish Relationship is Challenging



Source: Record of Decision and Long-term monitoring data: Lake Hartwell Site, EPA Region 4. Craig Zeller, RPM.

Opportunities

- What’s driving body burden, where?
- Studies to define fish residency and location
- Management approaches: simple or complex?

Fish Natural History and Species Selection

Lisa L. Williams
U.S. Fish and Wildlife Service*

Susan Kane Driscoll
Exponent Inc.

Sediment-Fish-Human Exposure Workshop
Vicksburg, MS

May 2018

*The findings and conclusions in this presentation are those of the author and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

Outline

- Overview of Factors that Affect Fish Exposure and Uptake
- Case Study: Influence of Gender on Movement/Migration and Exposure
- Case Study: Influence of Trophic Level on Biomagnification
- Case Study: Influence of Food Web on Potential Exposure

Fish-Related Factors Influencing Exposure and Uptake

- Species feeding strategy and diet
- Trophic level
- Life history
- Daily and seasonal behaviors
- Habitat and home range
- Bioenergetics
- Metabolic capacity
- Lipid content

- Interaction of fish with contaminants at source area and within site
- Interaction of fish outside of site boundary with contaminants from source area and site (resuspension, transport, prey movements)
- Degree of accumulation

Contaminant-Related Factors Influencing Fish Exposure and Uptake

- Persistence relative to releases
  - Ongoing source, low persistence à chronic exposure
  - Historical release, high persistence à chronic exposure
- Fate (e.g., solubility, sorption)
  - Determine fish exposure route(s) of greatest concern: sediment, water, diet

Considerations in Selecting Species

What is the question?!

- Site contribution?
- Current risk?
- Spatial and temporal variation in risk?
- Being able to model future risk?
- Trend in exposure?

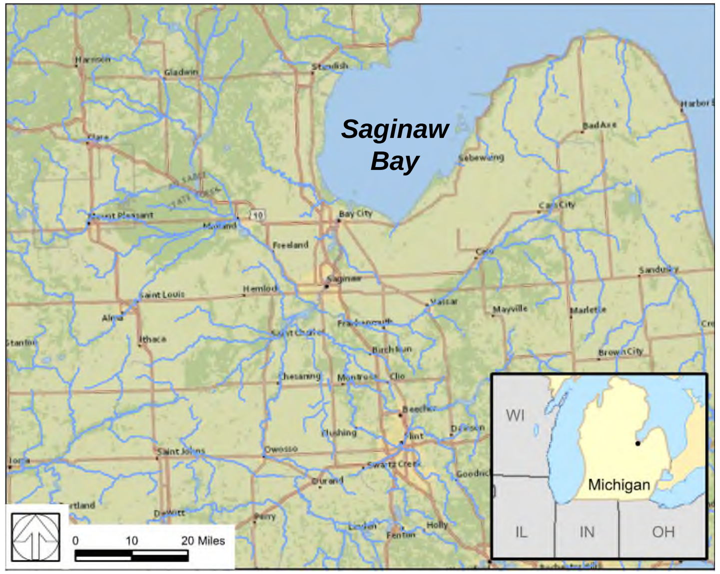
Interactions between fish and human factors:

- Importance of fish species to subsistence, recreational, commercial fish consumption
- Fish tissues consumed, e.g., skin-on or skin-off fillets, whole or nearly whole
- Seasonality of fishing effort with fish lifecycle and body burdens

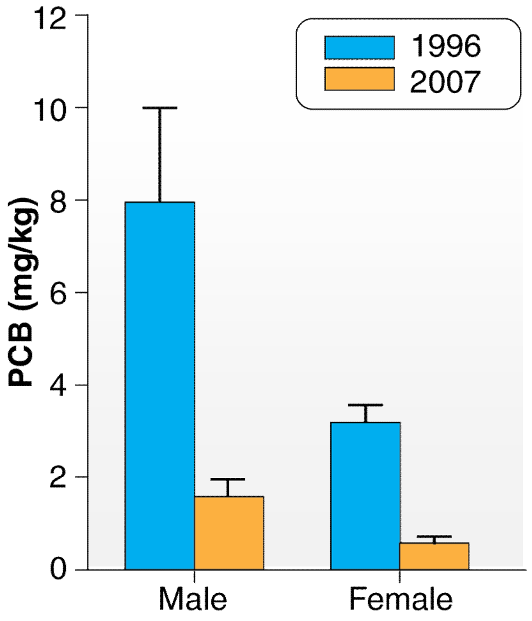
Example Species Selections

- Small home range, year-round resident fish species or YOY
  - High site relationship but perhaps less human consumption
  - May be especially important for investigating a continuing point source, e.g., WWTP
  - May be useful in investigating gradients within large sites and extending offsite
- Benthic fish species with home range size relevant to site area
  - Close relationship with sediment if that is the driver for fish exposure
  - May be important for subsistence consumption
- Piscivorous species with significant human consumption
  - May represent greatest risk for a chemical that biomagnifies
- Species with historical data available
  - Could compare with data from dated sediment core samples
- Species with known toxicokinetic parameters to develop or validate models

Influence of Sex on Home Range and Exposure: Saginaw Bay Walleye



Location of Saginaw River and Saginaw Bay in Michigan on Lake Huron



Concentrations of PCBs 2.5 times higher in males than females.

Mean (95% CI) whole-fish PCB concentrations for Saginaw Bay adult walleyes by sex and year. 1996 = Before dredging of Saginaw River in 2000–2001. 2007 = After dredging.

(Madenjian et al. 1998, 2009.)

Influence of Gender on Home Range and Exposure: Saginaw Bay Walleye

Differences between males and females hypothesized due to:

- Loss of PCBs by females after spawning
- Greater growth efficiency in females leading to growth dilution
- Males spend more time in contaminated areas

Influence of Gender on Home Range and Exposure: Saginaw Bay Walleye

Differences between males and females hypothesized due to:

- Loss of PCBs by females after spawning
  - Sharp gender-specific decrease in PCB concentrations after spawning in some species (i.e., northern pike) due to PCB concentration in ovaries 100x higher than the whole body
  - Historical data for walleye reported small differences in PCB concentrations in ovaries and somatic tissue, indicating spawning had little effect on gender differences

Influence of Gender on Home Range and Exposure: Saginaw Bay Walleye

Differences between males and females hypothesized due to:

- Faster growth and greater growth dilution in females
  - Bioenergetic modelling indicated only minor gender differences (<15%) in growth efficiency

Influence of Gender on Home Range and Exposure: Saginaw Bay Walleye

Differences between males and females hypothesized due to:

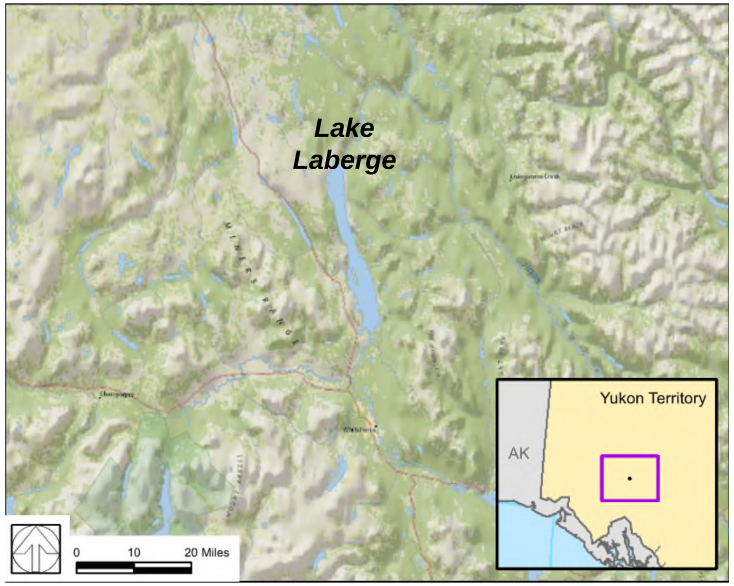
- Males spend more time in contaminated areas
  - Mark-recapture study of 50,000 walleye indicated that males spend more time in more contaminated Saginaw River
    - 34% of recaptured females were in Saginaw River
    - 61% of recaptured males were in Saginaw River

Gender Differences in Exposure: Management Implications

- A potential confounding effect for site assessment (i.e., site versus reference) and monitoring for long-term trends (i.e., MNR, post-remediation)
- Cost saving by switching to gender-stratified sampling (e.g., 2 females and 5 males), which is as accurate and precise as random sampling of 20 individuals
- Recommend monitoring for gender differences

Exponent®
Engineering and Scientific Consulting

Influence of Trophic Level on Biomagnification: Lake Laberge



Location of Lake Laberge in the Yukon Territory, Canada

- High levels of organochlorines in burbot and lake trout in Lake Laberge in comparison to other nearby lakes (i.e., ppm levels of DDT, PCBs, and toxaphene)
- Health advisory and closure of the commercial, sport, and native subsistence fisheries 1990–1991

This Week
22 July 1995
Toxins ruin Arctic catch
By Fred Pearce

Influence of Trophic Level on Biomagnification: Lake Laberge

Elevated concentrations of organochlorines in fish in Lake Laberge hypothesized due to:

- Surreptitious dumping
- Treatment with piscicides (i.e., toxaphene) to remove certain fish species
- Agricultural pesticides

Biomagnification through the food chain

Influence of Trophic Level on Biomagnification: Lake Laberge

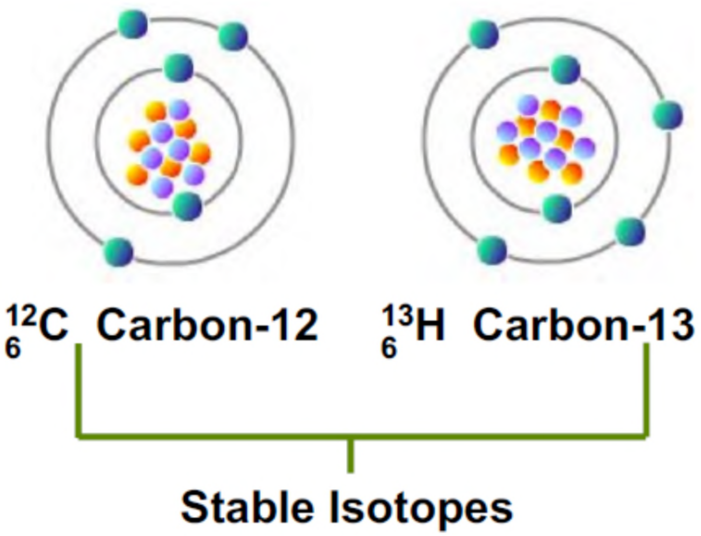
Elevated concentrations of organochlorines in fish in Lake Laberge hypothesized due to:

- Surreptitious dumping
- Treatment with piscicides (i.e., toxaphene) to remove certain fish species
- Agricultural pesticides

Concentrations in water and sediment of Lake Laberge comparable to other arctic lakes

Hypotheses related to elevated inputs from local point sources dismissed

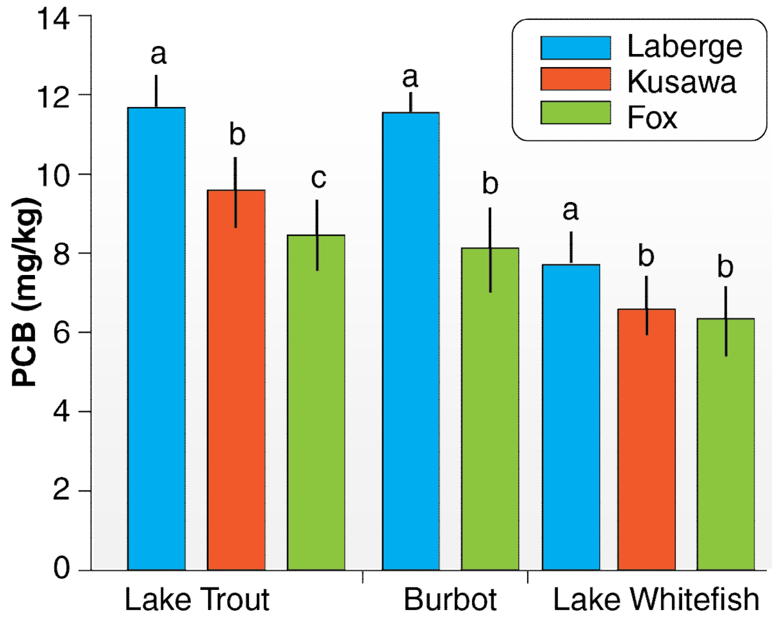
Use of Stable Isotopes in Ecotoxicology



From Krabbenhoft 2017

- Stable isotopes are atoms of the same element (e.g., carbon, nitrogen, sulfur) that have different masses
- Natural differences in isotope ratios exist among food sources
- Ratios of isotopes of carbon in consumers are similar to those in their diet
- Ratios of isotopes of nitrogen in consumers are higher than in their diet

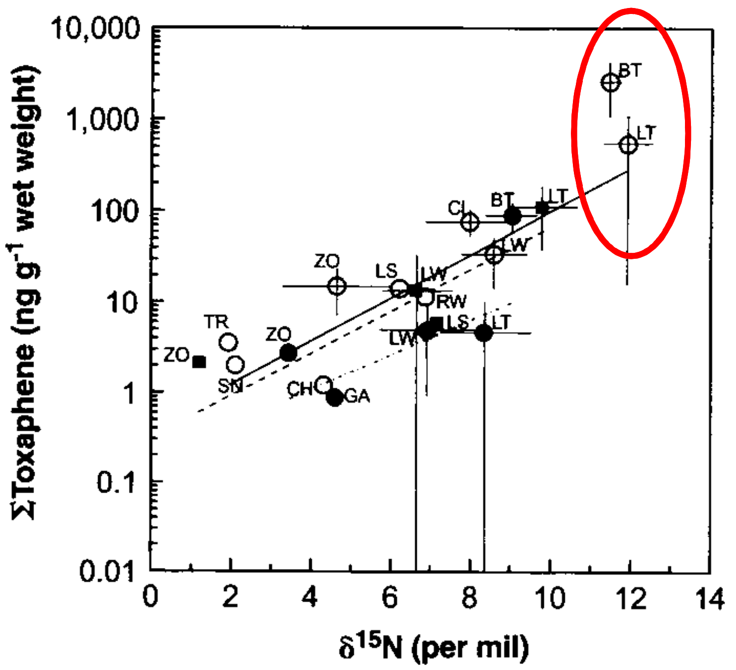
Influence of Trophic Level on Biomagnification: Lake Laberge



Mean (± SD) δN15 in fish from Laberge, Fox, and Kusawa lakes (Kidd et al. 1995).

- Ratio of stable isotopes of nitrogen (N^{15}/N^{14}), which increases from predator to prey, used to examine trophic structure of several lakes
- Higher δN15 indicates fish are feeding at higher trophic level in Lake Laberge than in other lakes

Influence of Trophic Level on Biomagnification: Lake Laberge



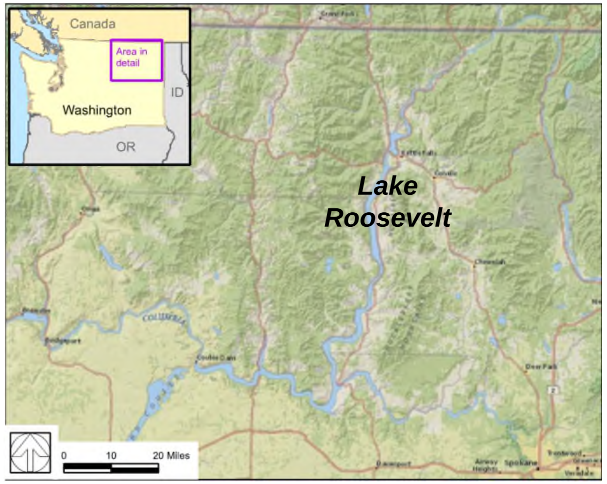
- Higher δN15 in burbot (BT) and lake trout (LT) in Lake Laberge indicates that these species feed at a higher trophic level in Lake Laberge than in other lakes
- Result confirmed with gut contents

Mean (± SD) δN15 versus toxaphene for invertebrates, burbot (BT) and lake trout (LT) from Lake Laberge (open symbols, solid line), and Fox and Kusawa (solid symbols, dashed lines)

Influence of Trophic Level on Exposure: Management Implications

- Trophic level can have a profound influence on fish tissue concentrations
  - Differences among species and even within a single species among habitats
- A potential confounding effect for site assessment (i.e., site vs reference) and monitoring for long-term trends (i.e., MNR, post-remediation)
- Important to consider and account for trophic level as a potential influence on fish tissue concentrations
- Stable isotopes a useful approach for characterizing trophic level among species and habitats

Potential Influence of Food Web: Lake Roosevelt, WA



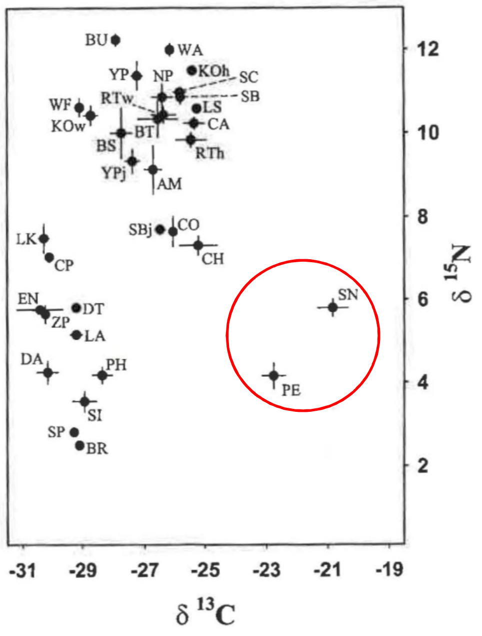
Lake Roosevelt, Washington, USA

Investigated the importance of alterative food sources to fish:
- **Pelagic:** Open-water phytoplankton
- **Benthic:** Nearshore attached periphyton

- Lake Roosevelt undergoes extreme annual drawdown, which eliminates benthic primary production
- Some fish species present in the lake are typically classified as obligate benthivores
- Available data on stomach contents, taken during period of peak benthic productivity did indicate a benthic diet
- But are these species actually functioning solely as benthivores, with potential for exposure from contaminated sediment?

Exponent®
Engineering and Scientific Consulting

Potential Influence of Food Web: Lake Roosevelt, WA



Mean (SE) stable isotope ratios for carbon (δC^{13}, ‰) and nitrogen (δN^{15}, ‰) for the food web components of Lake Roosevelt (Black et al. 2003) (PE = benthic periphyton; PH = pelagic phytoplankton; SN = snail)

- Benthic carbon entering the food web can be distinguished from pelagic carbon in this system by periphyton's significant enrichment in δC13 over phytoplankton.
- Relative trophic status of an organism can be detected by a 3–4‰ increase in δN15 between prey and predator.
- Striking lack of exclusively benthic consumers
  - Snails appear to be the only exclusive benthic consumers
- All other taxa, especially higher trophic level organisms, appear to obtain most of their food from pelagic sources (e.g., 68–100% for fish)

Potential Influence of Food Web: Management Implications

- Managers should be aware of the impact water level fluctuation can have on aquatic food webs
- Stable isotopes can be used to provide a line of evidence for the extent to which fish are exposed to benthic food webs
- If overlying water is not in equilibrium with sediment, this type of analysis could be used as a line of evidence to support diminished exposure of food web to contaminated sediment
- Stable isotope analysis can be used to support development of models to predict fish tissue concentrations

Use Stable Isotopes in EcoToxicology

- Advantage of Stable Isotope (SI) over traditional dietary analyses (e.g., gut contents):
  - SI is relatively inexpensive (US$10–30 per sample)
  - SI provides a time-integrated measure of assimilated food rather than a snapshot of recently ingested items
- Disadvantages/Uncertainties of SI analyses:
  - Need expert input to address uncertainties
  - For example, SI ratios at the base of the food web (e.g., primary producers) can vary due to input of nutrients from exogenous sources (i.e., sewage, agricultural input), which can confound interpretation of trophic level differences among and within systems.

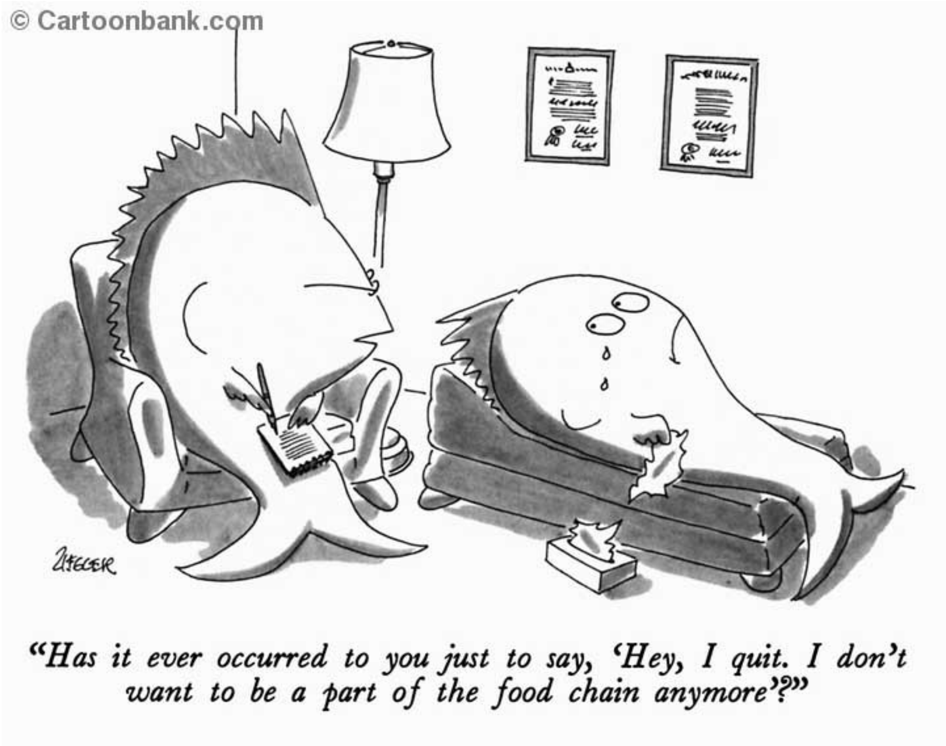
Hoffman, J.C. 2016. Tracing the origins, migrations, and other movements of fishes using stable isotopes. In ***An Introduction to Fish Migration.*** CRC Press.
Jardine et al. 2006. Applications, considerations, and sources of uncertainty when using stable isotope analysis in ecotoxicology. ***Environ. Sci. Technol. 40: 7501–7511.***

Opportunities for Progress

- Fish natural history and prey items are typically better understood than movement/migration
  - Tagging, acoustic monitoring, other techniques from Plenary #1
- Need for improved understanding of the spatial and temporal variability in factors that influence site-specific bioaccumulation
  - Movement and migration (Saginaw Bay example)
  - Trophic structure (Lake Laberge example)
  - Food web structure (Lake Roosevelt example)
- Species selection is often question-specific and site-specific
  - Is there a need for a literature review of fish species selected for different purposes and situations?

Bioaccumulation Modeling for Aquatic Food Webs

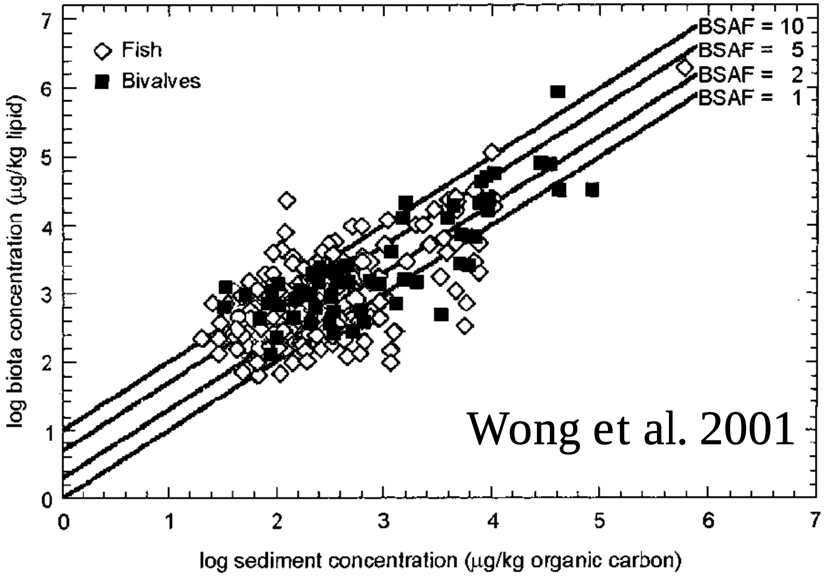
Trina von Stackelberg & John Connolly



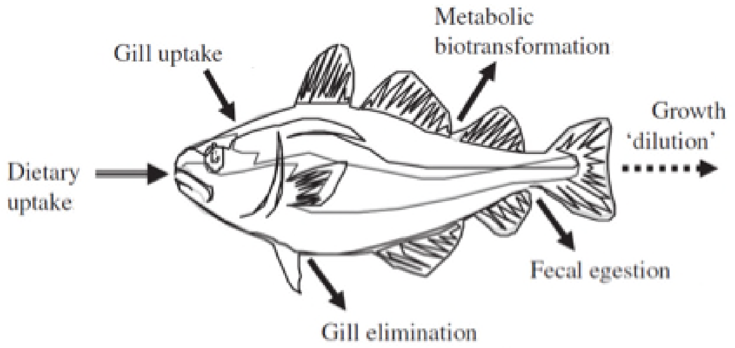
"Has it ever occurred to you just to say, 'Hey, I quit. I don't want to be a part of the food chain anymore'?"

Mathematical Model?

- The best model is the simplest model that is still complex enough to help us understand the system and *solve problems* (Velton 2009)
- The *problem* is how will concentrations in fish change as environmental exposure concentrations change?
- Broadly, there are two classes of models:
  - Simple statistical models of the form: fish = a(water) + b(sediment)
  - Mechanistic food web models that are steady-state or time variable



Wong et al. 2001

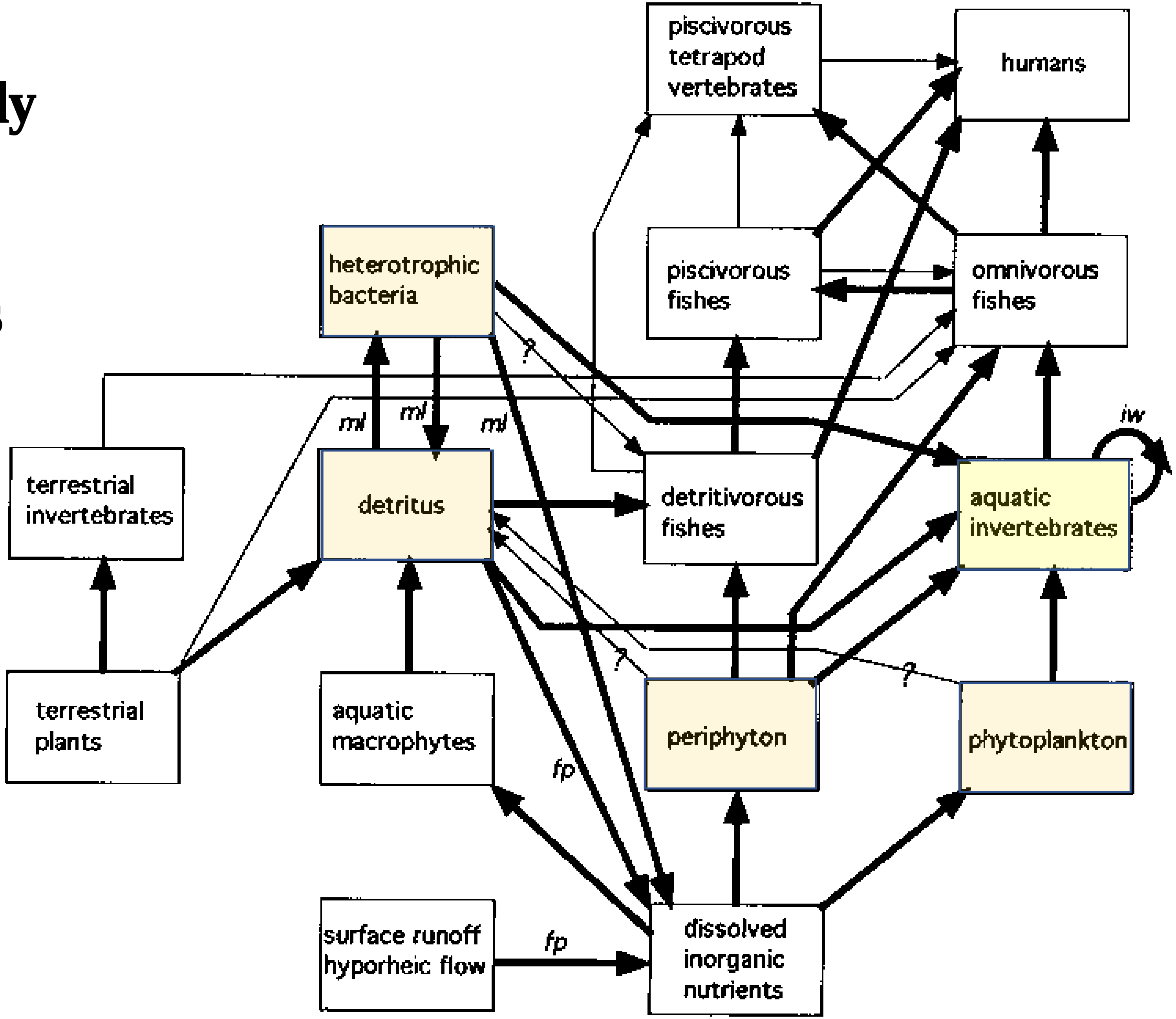


Food Webs are Inherently Complex

How much complexity is required to answer the question?

How do we decide?

How to best constrain required inputs?



History of Contemporary Aquatic FW Models

- Began by integrating pollutant biokinetics in bioenergetics modeling
- Advanced through a series of applications

1977: Norstrom et al.

Single species, age-dependent, steady-state model integrating pollutant biokinetics with bioenergetics modeling

1984: Thomann & Connolly

Linear food chain steady state

1985: Connolly & Tonelli

Time variable, Food web with benthic & pelagic links & fish migration

1991: Connolly

PCB homologs & migration

Probabilistic and spatially-explicit exposure modeling

2002: von Stackelberg et al.

Enhanced equations for pollutant biokinetic mechanisms

2004: Arnot & Gobas

More on spatially-explicit exposure

2016: von Stackelberg et al.

Challenges: Characterizing Connection to the Various Carbon Sources

- Four major classes of carbon sources to the food web:
  - Water column particulate organic matter
  - Near-bottom water column particulate organic matter
  - Recently deposited particulate organic matter
  - Sub-sediment surface particulate organic matter
- Needed, but uncertain, are
  - Importance of the pathways to energy flow
  - Relationships among contaminant concentrations for these sources of organic matter
  - Relative responses of these sources to various remedial options
  - The relevant depth of subsurface exposure and mechanisms (e.g., bioturbation, propwash)

Challenges: Spatial and Temporal Dimension of Exposure Driven By:

- Biota movement
  - Variation within a population and across species
- Seasonal variations in activity (e.g., over wintering activity; migratory behavior)
- Bioaccumulation model is often held responsible for shortcomings in understanding of fate and transport
- Variation of contaminant levels in the water column and on the various carbon sources
  - Effect of varying flows, seasonal primary production, etc.

Challenges: Uptake, Loss and Storage of Ionized or Biotransformed Chemicals

- e.g., PFAS (such as Perfluorooctane sulfonic acid-PFOS; PFOA; PFAS generally)
  - At levels triggering consumption advisories, but biokinetics poorly understood
  - Doesn't follow Log K_{ow}-based lipid partitioning behavior
    - Protein binding
    - Phospholipids
- e.g., DDT and its metabolites
  - Biotransformation depends on route of uptake and tissue distribution

Challenges: Non-unique Calibration Space

- These individual challenges culminate in a poorly constrained biological system
- Compensating factors result in local optimization – but not one global solution
- Model is defined by assumptions rather than “revealing” importance of sediment versus water pathways

Challenges: Bioaccumulation by Aquatic Mammals and Wildlife

- Connection to the aquatic food web complicated by uncertainties in foraging behavior and diet composition
- Biokinetics differ from aquatic species
  - Gill versus lung
  - Growth limitations
  - Lactation as a loss mechanism

Areas of agreement (among the presenters, and to the extent useful within the technical community)

- Structure of the process equations
- Ranges of model parameters for lipophilic chemicals

Areas of disagreement (among the presenters, and to the extent useful within the technical community)

- What is the simplest model that is still complex enough to help us understand the system and *solve problems*?
- Need to account for species age structure and temporal variations in biology and exposure
- Use of BSAF
- Appropriateness of lipid normalization for lipophilic chemicals
  - Degree to which excretion is the major concentration sink
- Factors driving uncertainty in model results

Needs for Making Progress

- Better measurements of the feeding guilds of the benthic community
- Use of stable isotopes to characterize energy flow from the four carbon sources through the food web
- How to establish exposure depths for benthos
- Use of random walk models to account for fish movement
- Laboratory studies of the uptake, loss and storage of ionized chemicals
- Fit-for-purpose model selection

Plenary Session 4
Fish Consumption Rates and Data Collection

Russell E. Keenan (Integral Consulting Inc.) and Debra Williston (King County DNRP)

SMWG/Army Corps Workshop - Fish Sediment Exposure Workshop

May 30-31, 2018

integral consulting inc.

King County

Why Is It Important to Understand Fish Consumption Rates for Contaminated Sediment Sites?

- Greatest risk to human health from contaminated sediment site is typically from eating "resident" fish and shellfish
- Because of this, HHRA/RI/FS process will need to learn more about the following for a contaminated site:
  - Who is fishing and eating fish and shellfish from site?
  - What species are being caught?
  - What parts are being consumed: fillet, whole body, organ tissue (e.g., crab hepatopancreas)?
  - How much fish/shellfish is being consumed?

Uses of Fish Consumption Rates at Contaminated Sediment Sites

- Characterizing human health site-specific risks
- Establishing fish consumption exposure scenario clean-up goals (e.g., RAOs, PRGs)
- Assisting in chemical-specific fish advisories by State Health Departments

Photo credit: ECOSS

EPA Hierarchy for Selecting Fish Consumption Rates[1]

1. Local survey data for waterways of interest
2. Regional data (similar geography/population groups)
3. Data from national surveys
4. EPA's default rates based on USDA short-term recall data

[1]Additional Resource: EPA. 2014. ***Estimated Fish Consumption Rates for the U.S. Population and Selected Subpopulations (NHANES 2003-2010).*** Final Report. April. EPA-820-R-14-002.

Assessing Fish Consumption: Critical Questions for Risk Assessors

- Who consumes?
  - General population, anglers, tribes?
  - Is the catch shared with family members?
- What sources?
  - Statewide, regional, waterway or reach-specific?
  - Large or small waterways?
  - Multiple or single waterway?
- Which species?
  - Anadromous vs. resident?
  - Freshwater, marine, or estuarine?
  - Trophic level?
- How much (meal size)?
- How often (frequency)?
- What duration (annual or perennial)?
- How are fish/shellfish prepared and which parts are eaten?

Who Consumes?

- Recreational anglers
- Tribal population
- High fish and shellfish consuming populations (e.g., Asian-Pacific Islanders)
- Other considerations:
  - Is the catch shared with family and friends?
  - What is the distribution of consumption rates across the consuming population?
  - How variable is the rate of fish consumption from year to year?
  - Are there cultural/ethnic considerations concerning fish/shellfish in diet?
  - Is fish consumed by members of Environmental Justice communities?

The "who" affects consumption rates
and exposure frequency decisions for site.

Fish Consumption Rate Approaches—Freshwater vs. Marine Waterbodies

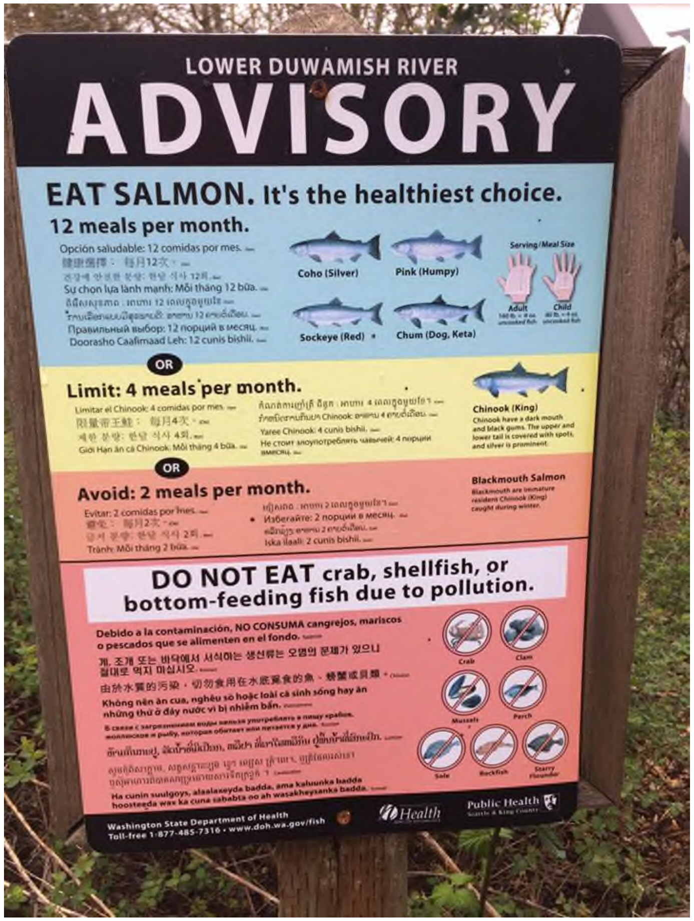
- Lakes and streams
  - —Rate likely based on few fish species
  - —Often angler targeted species
  - —Rate often lower than estuarine/marine waterbodies
- Estuarine and marine waterbodies
  - —Rate likely focused on multiple species including fish and shellfish
  - —Multiple fisher populations may be fishing at different rates

Impact of Species Selection

- Anadromous species may be large portion of total fish consumption
  - Seasonal availability
  - Less affected by local contaminated sediment
  - Increasingly prevalent with restoration of degraded habitat and fish passages
- Monitoring at sediment sites is typically focused on resident species
  - Sometimes less desirable species for consumption
  - Highest contaminant levels
- Are species consumed the same ones being monitored for site management?

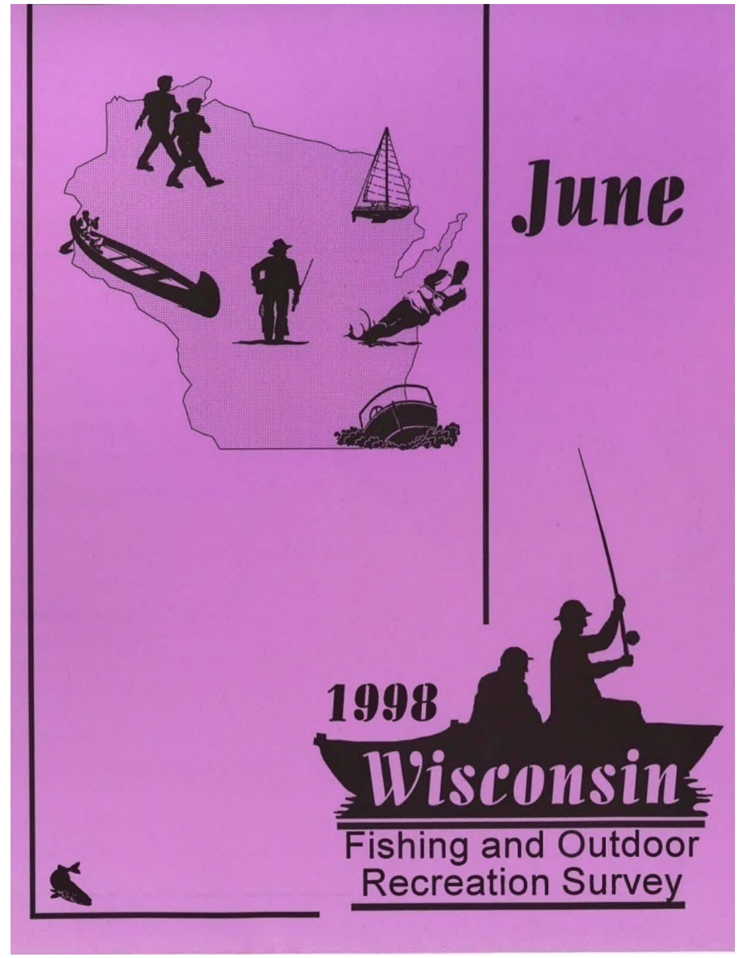
Consideration of Advisories/Suppression; Heritage Rates

- Current fish advisories for site?
- How does the advisory affect current vs. potential future consumption rates?
- Can we quantify suppression due to advisory if occurring?
- Should the risk assessment consider heritage rates?
  - — Would habitat support these rates?
  - — Fishing pressures differ



Options for Consumption Rate Survey Methods

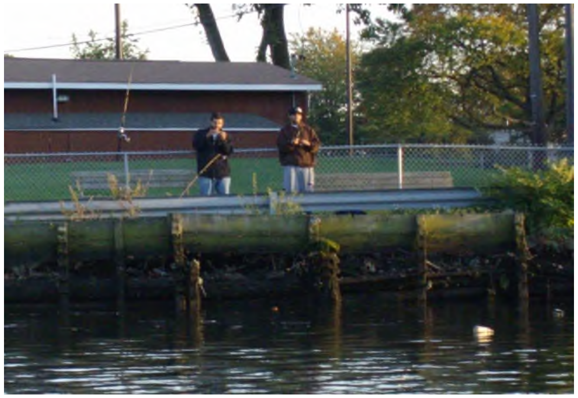
- Types of Surveys
  - Creel/intercept surveys
  - Recall mail surveys
  - Recall telephone surveys
  - Diary studies
  - Dietary recall studies
- Short-term vs. long-term data
- Availability of full data sets and survey instruments facilitate interpretation and use of existing surveys



Example—Creel/Intercept Surveys

Counts and interviews of anglers on site

- **Provides waterway-specific information**
  - — Fish/shellfish species and sizes caught
  - — Site-specific consumption rates
  - — Identifies angler demographics
- **Minimizes recall bias**
- **Avidity bias requires correction**
- **Seasonal variability must be addressed**
- **Behavioral models developed to address consumption suppression in highly contaminated waterways**



Consumption Rate Survey Considerations

- Survey period
  - Cover all seasons, times of day; geographical location of site affects this
- Use consistent survey questionnaire and pilot test survey
- Offer incentives to participate
- Who should conduct survey:
  - Members of ethnic community, University students, public health officials or outreach staff?
  - Need training for those conducting survey
- Identification of fish/shellfish consumed; not all fishers have same names for same fish/shellfish depending on ethnic background
- Translation considerations for both oral vs. written surveys
- Careful of community fatigue if too many “asks” for information

Consumption Surveys—Other Benefits

- Data collection efforts can be useful for outreach to fisher community if fish consumption advisories are needed until contaminated sediment cleanup is complete or if limited consumption remains after cleanup.
- If members of community help with surveys or outreach efforts, it is a way to empower locally affected community and get them involved in cleanup process.

Fishery Productivity and Sustainable Consumption Rates

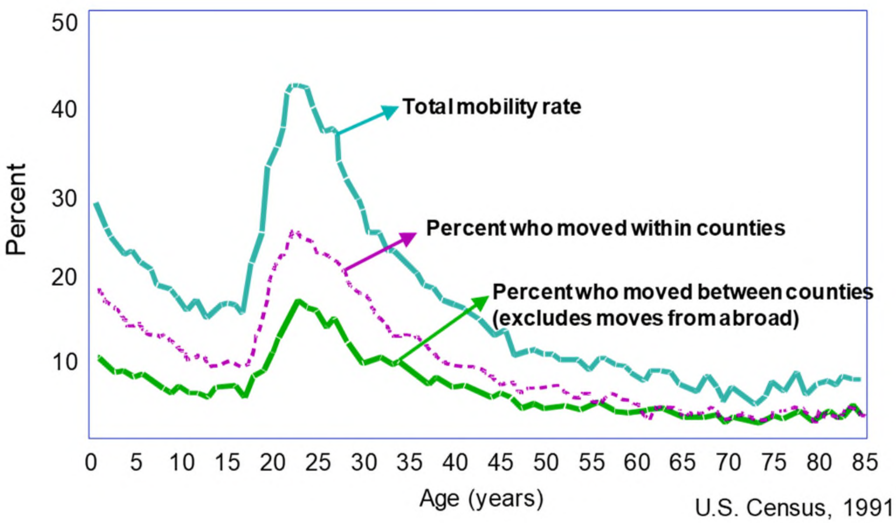
- Can fishery productivity be considered?
- Can site sustain fish consumption rates used for site assessment?
- What are best ways to evaluate these questions for freshwater vs. estuarine/marine waterbodies?

Consumption Rates and Cleanup Decisions

- What if consumption rates result in unobtainable cleanup levels for site?
- If risk-based cleanup levels are below sediment background levels, then site cleanup defaults to background.
  - How to communicate to affected community?
  - Will fish advisories still be required?
  - What fish consumption rate at acceptable risk levels will be obtainable after cleanup?
- Will the cleanup offer a significantly different timeframe than natural attenuation?
- Risk communication issue:
  - Cleanup maybe more effective for some contaminants or consumption levels.

Information Gaps and Future Work

- Little data on angler consumption > 1 year
- Individual behavior varies with age (e.g., mobility)
- Age and life circumstances undoubtedly affect angling activity
- Human behavior will continue to be hard to predict over the long term for a site
- Well-designed studies needed!



Possible Areas of Government/Private Joint Research to Address or Reduce Uncertainties in Fish Consumption Rate Process

- Guidelines or standards for fish consumption study approaches to help site-specific studies
- Development of smartphone app as another method to survey fishing community
- Others identified through this workshop

Plenary 5: Exposure and Data Analysis

Issues and considerations associated with characterizing and quantifying human exposure to contaminants in fish

Gary Buchanan and Paul Anderson

Topics Covered

- Estimating representative exposure concentrations in fish
- Developing exposure factors (point estimates or distributions)
- Issues associated with characterizing variability and uncertainty in human exposure
- Current issues in exposure/risk assessment
- Areas of Potential Disagreement
- Opportunities and Challenges

Estimating representative exposure concentrations in fish

- Individual samples versus composites
- Which species to collect
  - Based on consumption information vs expected chemical loading
  - Small vs. large home range
  - Resident vs migratory species
  - Trophic level
- Small vs large individuals
  - Average legal-sized fish

Estimating representative exposure concentrations in fish [cont.]

- Tissue type
  - Fillet
    - Skin on
    - Skin off
  - Whole body
  - Specific organs
- Contaminant-specific issues
- Distinguishing background from site concentrations

Developing exposure factors (point estimates or distributions)

- Fish consumption rate – covered in Plenary 4
  - can the affected area support the assumed fish consumption rate
  - cooked vs raw weight based consumption rates
- Species consumed
- Tissue type consumed
- Fraction consumed from affected area
- Cooking method effects and use
  - chemical-specific
  - cooking method-specific
  - balance of loss of chemical vs loss of mass/moisture

Developing exposure factors (point estimates or distributions) [cont.]

- Duration of exposure
  - 30 years (CERCLA upper bound default assumption)
  - lifetime (Clean Water Act default assumption)
  - site-specific (census tract-based)
- Bodyweight
- Bioavailability (relative to bioavailability in data used to derive toxicity benchmark)
  - chemical specific

Issues associated with characterizing variability and uncertainty in human exposure

- Uncertainty and variability can be addressed by deterministic or Probabilistic Risk Assessment (PRA) methods
  - Low, mid and upper bound deterministic estimates (though focus is usually on upper bound)
  - Distributions from PRA with focus on different percentiles

Current issues in exposure/risk assessment (1)

- Risk/benefits of fish consumption
  - Cancer, heart disease, listing of other endpoints
  - Mortality (reductions in coronary heart disease mortality almost always outweigh increased cancer risk, even assuming estimated cancers are all fatal)
  - Other endpoints (how to weigh changes in quality of life associated with non-mortality endpoints (e.g., IQ, nutrition)
- Background exposures
  - from fish consumption
  - from all sources
  - cancer (incremental) vs non-cancer endpoints

Current issues in exposure/risk assessment (2)

- Consideration of subpopulations
  - Separate assessments of general population and subpopulations
    - High-risk: children, pregnant women and women of childbearing age
    - Subsistence
    - Cultures with high consumption of fish
  - Incorporate subpopulations in distribution of risk for whole population?
- Population versus individual risk
  - Need arithmetic average individual risk to estimate population risk; can’t use upper bound/upper percentile individual risks
  - What are acceptable population risk thresholds?
    - Absolute number of deaths?
    - Percentage of exposed population?
    - Percentage of background mortality?
    - Comparative cost of life (or life year) saved?

Areas of Potential Disagreement

- Background concentrations
- Species of fish
- Fraction consumed from affected area
- Cooking method effects/use
- Risk vs. Benefit
- Selection of population(s) to evaluate (general, angler, subsistence)
- Population vs. individual risk
- Interpretation of PRA results (e.g., linking percentiles with allowable risk benchmarks)

Opportunities

- Compilation of information from successful remediation projects
  - Sediment contaminant reduction
  - Fish contaminant reduction
  - Successful model predictions
- Size-specific guidelines for sites (e.g., small, medium, large)
- Background contaminant levels are decreasing (e.g., PCBs)

Challenges

- Long time frames to see success
- Recontamination
- Linking fish consumption advisories and sediment remediation targets
- Distinguishing risk management from exposure assessment (e.g., population to be assessed)

Plenary 6: Risk Management and Remedy Decision-Making

Marc S. Greenberg, Ph.D.
U.S. EPA – Superfund HQ
Environmental Response Team
greenberg.marc@epa.gov

Ralph G. Stahl, Jr., Ph.D., D.A.B.T
DuPont Company
Corporate Remediation Group
Ralph.G.Stahl_Jr@dupont.com

Where it all comes together

- In risk management the investigations should be tied together and relied upon to make a decision on cleanup
- A major challenge we're focused on is managing uncertainty

Sediment Site = ↑ Uncertainty =

↓ Strength in Predicted Project Outcomes

↑ Time and Expense Needed to Reduce Uncertainty

↓ Site Progess

How can we manage varied project risk tolerances?

The risk assessment got us here

- What are the exposure assumptions?
- What are the background risks?
- Do we expect to reach a point where unlimited human consumption of fish would be possible?
- How will risk reduction be determined for the site (e.g., site wide, sections, impoundments)?

Selecting the Remedy

- **Type of decision**
  - ROD?
  - Interim ROD?
  - Early action?
- **Are we relying too heavily on modeling to select final remedies?**
- **What recovery time scale was ultimately selected as acceptable?**
- **How were “risks of remedy” considered?**
- **Adaptive management – what this may mean can depend on who defines it**

Evaluating the Remedy

- **What are acceptable timeframes to demonstrate recovery and achievement of RAOs?**
- **What will constitute your baseline data set?**
- **Will there be any monitoring during the remedial action itself?**
- **Fish monitoring**
  - What % change or rate of decline is expected?
  - Should interim fish tissue targets be developed?

Risk Management at Sediment Sites

Ralph G. Stahl, Jr., Ph.D., D.A.B.T

DuPont Company

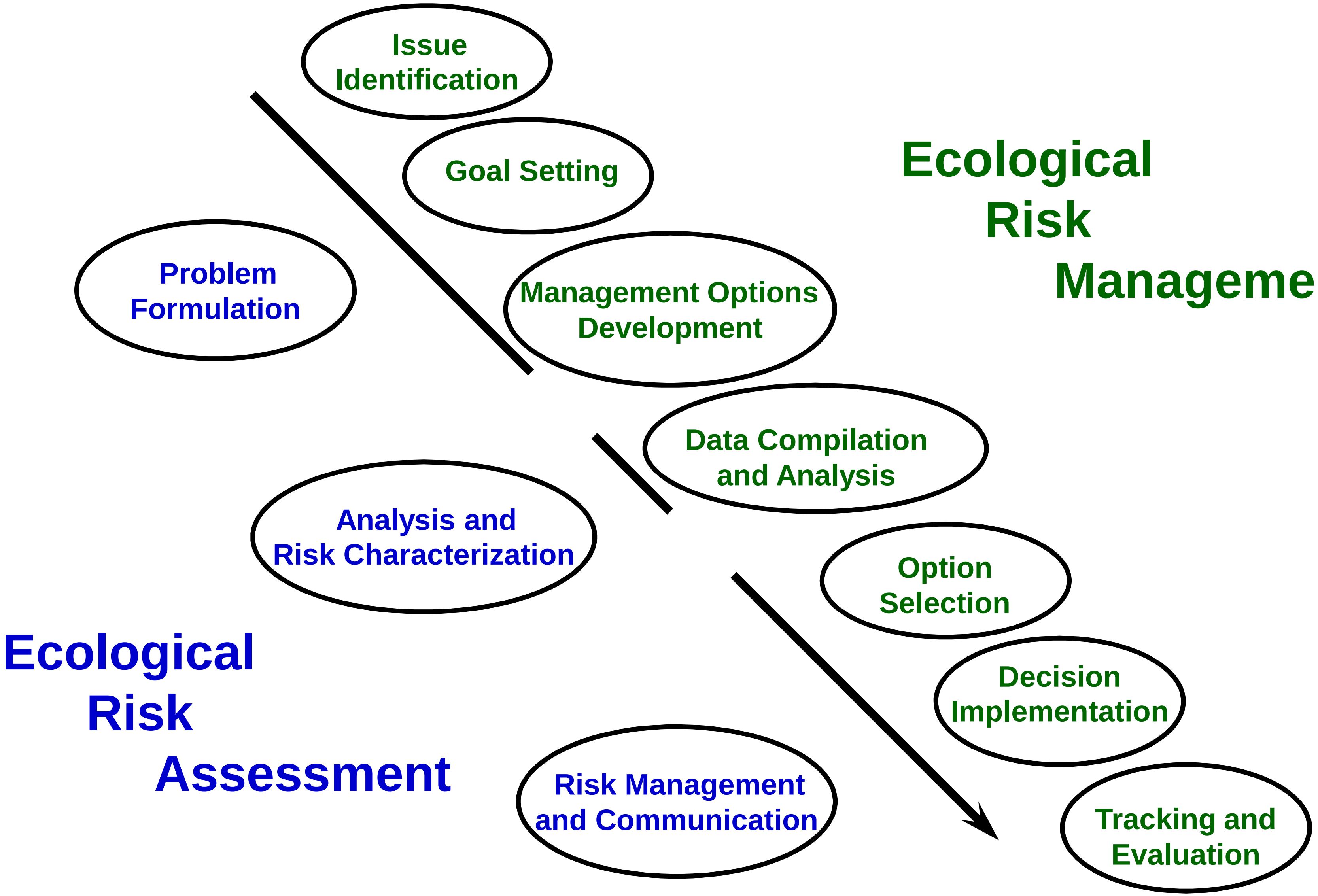
Vicksburg, MS

May 30, 2018

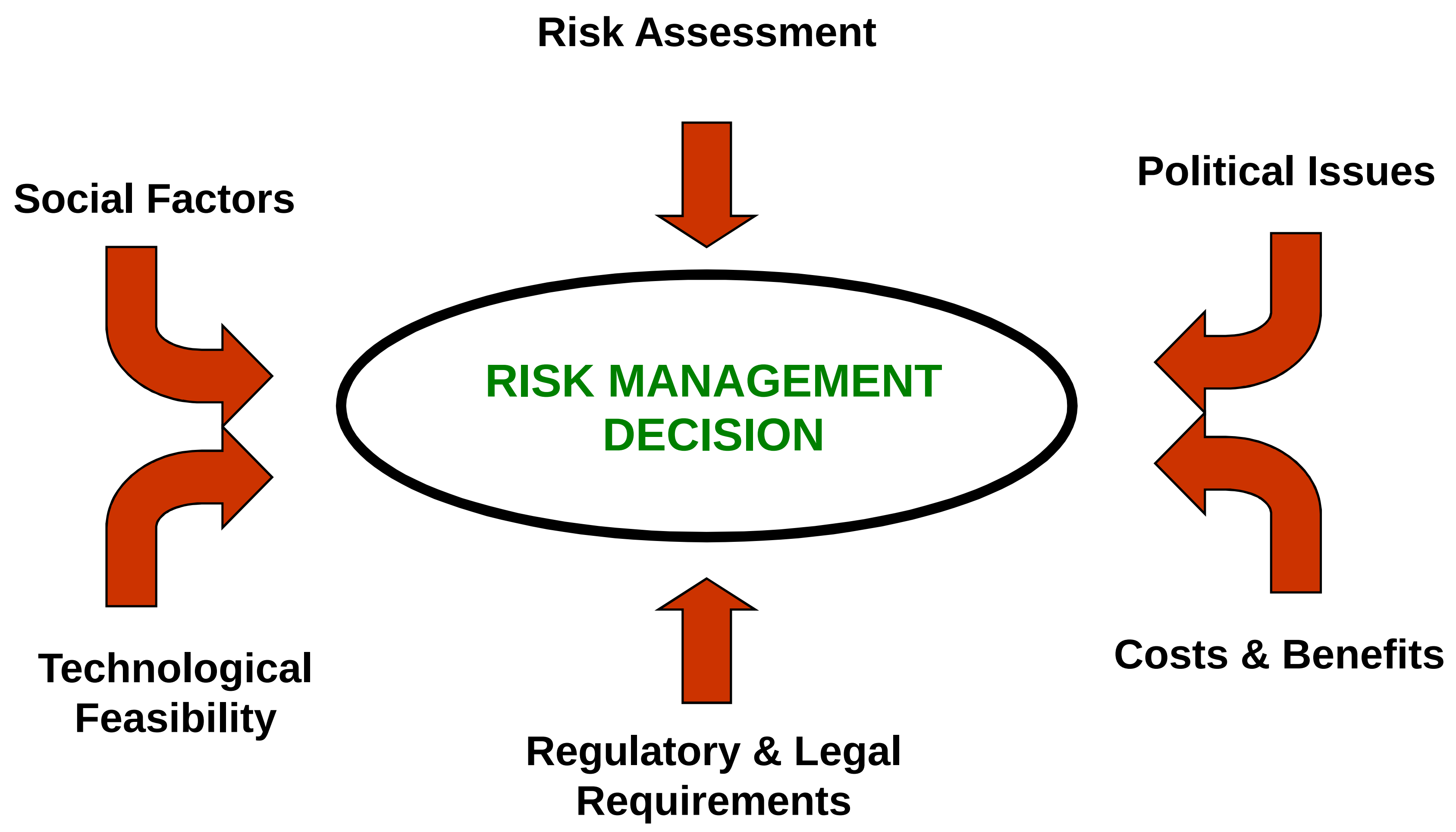
Topics

- Risk Management
- Challenges
- Opportunities

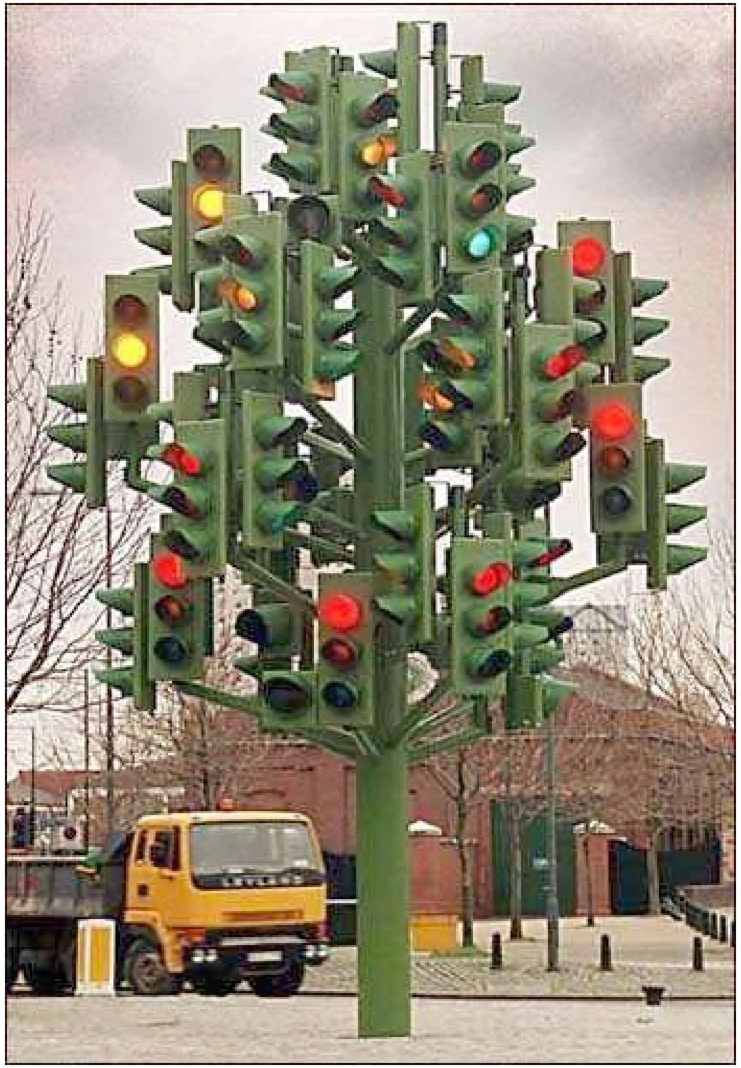
Relationship of the Ecological Risk Management Framework (Pittinger et al. 1998; Stahl et al. 2000) to the Ecological Risk Assessment Framework (U.S. EPA 1998)



INPUTS TO THE RISK MANAGEMENT DECISION



Risk Management – How it Really Works



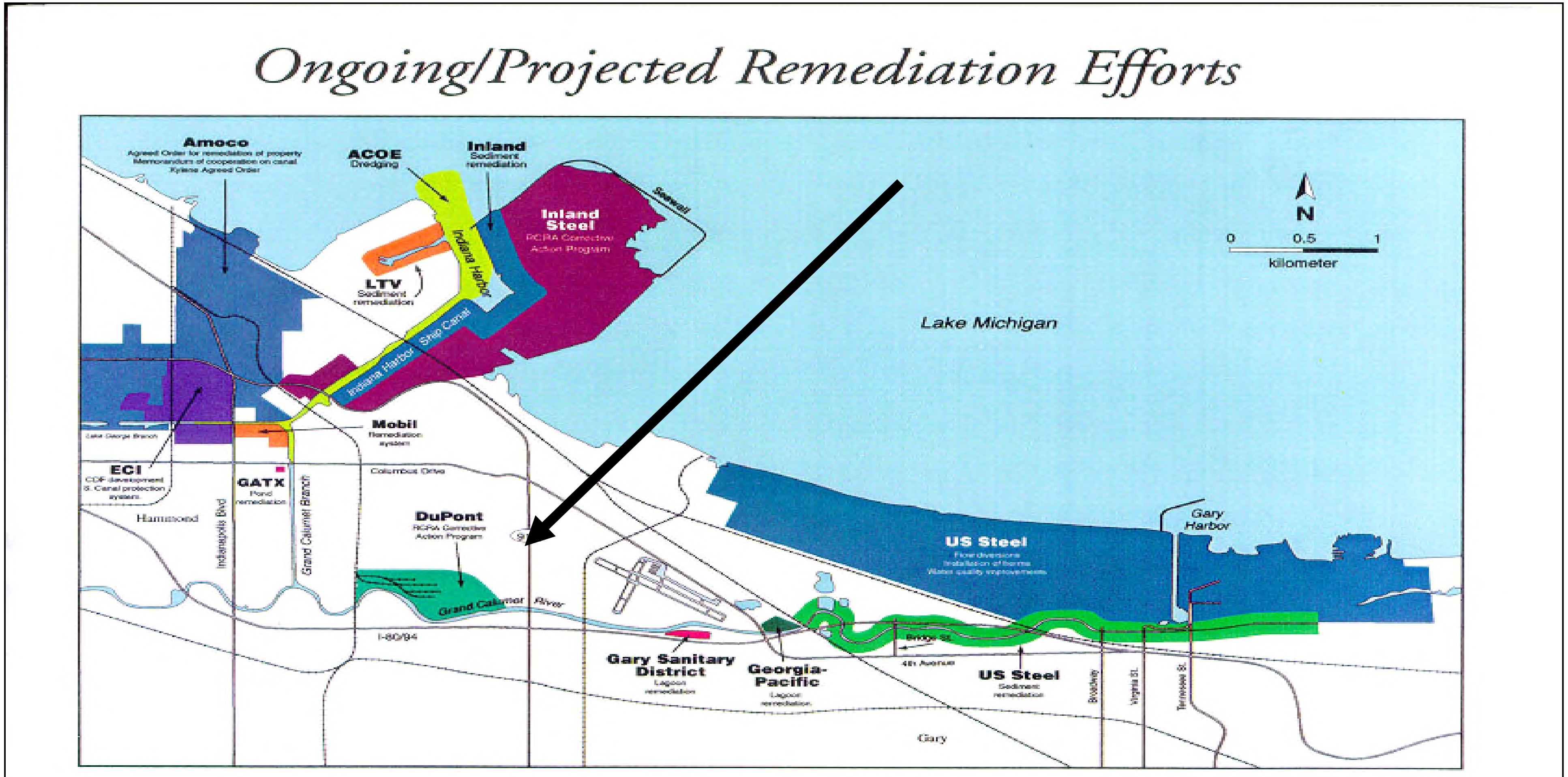
Challenges – 1. My Laundry List

- Types of Contaminants
  - Mercury, Dioxins, PCBs, PAHs, Pharms, Carcinogens, Radiological, Nano
- Location of Sites
  - Urban, Industrial, Freshwater, Estuarine, Marine
- Using the Risk Assessment (HHRA and ERA)
  - Who or what are we trying to protect (and at what level)?
    - Receptors (“real”; hypothetical; etc.)
  - How (and What, When) to measure / monitor for success
    - Mass removal; reduced loading; biological; construction
    - How long do we continue to measure / monitor post-remediation?
  - Default assumptions
    - How much fish do we really eat?

Challenges – 2. Yes, This is a Real Sediment Sample. What do you do after you dig it up? Who caused this mess anyway?

Guess the Origin of this Sediment Sample.

Challenges – 3. Source Attribution and Assignment of Costs



Multiparty Sites Only Add to the Challenges

Challenges – 4. Who Makes the RM Decision?

- EPA – Do This !
  - Evaluate risks to human health & environment
  - Specify a remedy
  - Implement
  - Reduce risks
  - Monitor

- "Trustees" – Do This!
  - Evaluate natural resource injury
  - Estimate lost services
  - Estimate damages
  - Fund restoration
  - Pay the claim
  - Monitor

Opportunities – 1.

- **Our Tool Box Hasn't Changed Much**
  - Dig it up
  - Cover it up
  - Add Something
  - Blame our ancestors
  - Bring in the lawyers
  - Wait and Watch
  - Do all of the Above, and Hope for the Best
- **Re-Examine our Risk-based Goals / Targets**
- **Adaptive Management**

Opportunities – 2. Continue to Fill Research Gaps

14 **Sediment Quality Guidelines**

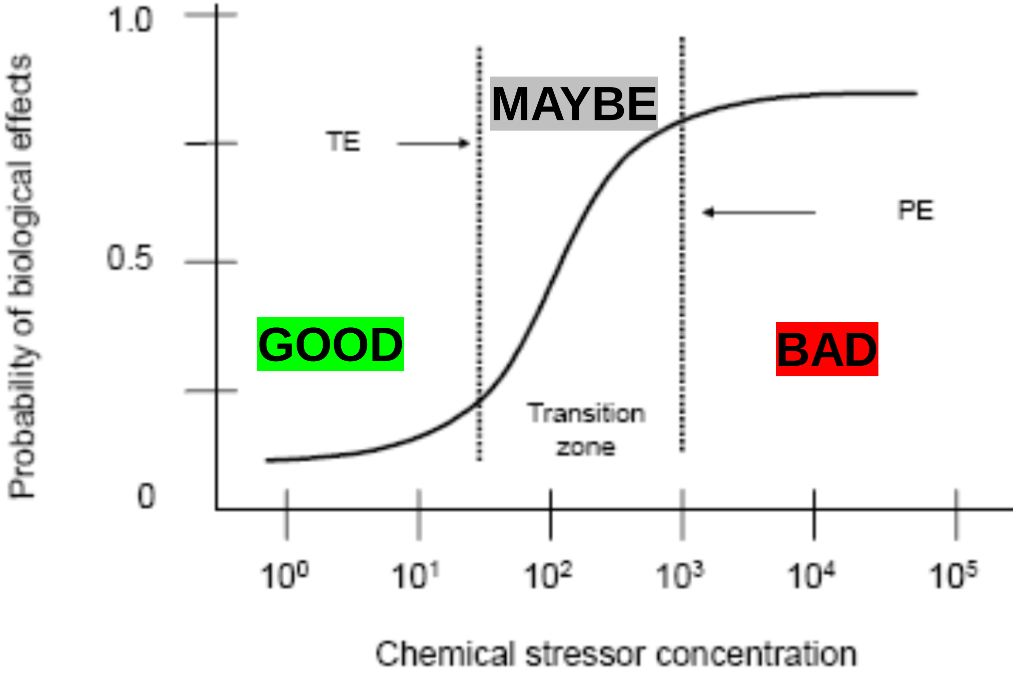


Figure 2 A generalized concentration–response model describing the TE and PE guidelines along a gradient of increasing probabilities of adverse biological effects for a single sediment-bound contaminant.

Environmental Pollution 210 (2016) 76–84

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

ELSEVIER

Identification of threshold body burdens of metals for the protection of the aquatic ecological status using two benthic invertebrates

Lieven Bervoets*, Maarten De Jonge, Ronny Blust

Department of Biology, Systemic Physiological and Ecotoxicological Research Group, University of Antwerp, Groenenborgerlaan 171, 2020 Antwerp, Belgium

Opportunities – 3. Adaptive (Risk) Management

Integrated Environmental Assessment and Management — Volume 2, Number 1 — pp. 92–98
92

From Optimization to Adaptation: Shifting Paradigms in Environmental Management and Their Application to Remedial Decisions

Igor Linkov,† F Kyle Satterstrom,† Gregory A Kiker,‡ Todd S Bridges,§ Sally L Benjamin,|| and David A Belluck#*

†Cambridge Environmental, 58 Charles Street, Cambridge, Massachusetts 02141, USA
‡Agricultural and Biological Engineering Department, University of Florida, PO Box 110570, Gainesville, Florida 32611-0570, USA
§US Army Corps of Engineers Center for Contaminated Sediments, Engineer Research and Development Center, Waterways Experiment Station, EP-R, 3909 Halls Ferry Road, Vicksburg, Mississippi 39180
||Farm Service Agency, US Department of Agriculture, 1400 Independence Avenue SW, Washington DC 20250
#US Federal Highway Administration/U.S. Department of Transportation, 400 7th Street SW, Washington DC 20590

(Received 9 June 2005; Accepted 14 June 2005)

Conservation Biology

Essay

Judging adaptive management practices of U.S. agencies

Robert L. Fischman[*] and J.B. Ruhl†

[*]Maurer School of Law, Indiana University, 211 S. Indiana Avenue, Bloomington, IN 47405, U.S.A., email rfischma@indiana.edu
†Vanderbilt University Law School Nashville, TN 37203, U.S.A.

Conservation Biology, Volume 30, No. 2, 268–275

DOI: 10.1111/cobi.12616

AM Example – South River, Virginia.

Applying a Watershed-Level, Risk-Based Approach to Addressing Legacy Mercury Contamination in the South River, Virginia: Planning and Problem Formulation

Ralph G. Stahl Jr. [a] , Donald Kain [b] , Paul Bugas [c] , Nancy R. Grosso [a] , Annette Guiseppi-Elie [d] & Michael R. Liberati [a]

[a] DuPont Company , Wilmington , DE , USA

[b] Virginia Department of Environmental Quality , Harrisonburg , VA , USA

[c] Virginia Department of Game and Inland Fisheries , Verona , VA , USA

[d] DuPont Company , Charlotte , NC , USA

Accepted author version posted online: 20 Sep 2013.Published online: 25 Nov 2013.

Human and Ecological Risk Assessment 20(2), 316-345, 2014

Goal:

Reduce or Eliminate the Fish Consumption Advisory on the South River, VA.

south river SCIENCE TEAM

Opportunities – 4. What Happened to the RTDF - Sediment Action Team ? A great framework for government / industry / academia interactions.

Integrated Environmental Assessment and Management — Volume 1, Number 1—pp.2–8

Assessing and Managing Contaminated Sediments: Part I, Developing an Effective Investigation and Risk Evaluation Strategy

Sabine E. Apitz,† John W. Davis,‡ Ken Finkelstein,§ David W. Hohreiter,‖ Robert Hoke,# Richard H. Jensen,†† Joe Jersak,‡‡ Victoria J. Kirtay,§§ E. Erin Mack,†† Victor S. Magar,‖‖ David Moore,## Danny Reible,††† and Ralph G. Stahl, Jr.††*

Questions and Discussion

Attachment 4

Breakout Session

Fish-Sediment Workshop Break-Out Session Thought Starter Questions (05 25 18)

Break-Out Session 1: Fish Biology and Bioaccumulation Modeling

1. What are the most consequential uncertainties in site assessments that are related to fish biology or behavior?
2. What are the best or most promising opportunities for incorporating fish biology and behavior to improve site assessments?
3. What are the best or most promising opportunities for improving the application of bioaccumulation modeling to inform risk assessments?
4. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance practice on the use of fish biology and behavior in assessments?
5. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance practice on bioaccumulation modeling?

Break-Out Session 2: Exposure and Consumption

1. What are the most consequential uncertainties in site risks assessments that are related to fish consumption and exposure?
2. What are the best or most promising opportunities for improving practice related to exposure assessment?
3. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance exposure assessment practice?

Break-Out Session 3: Risk Management

1. What are the most consequential uncertainties related to fish-sediment for risk management and decision making?
2. What are the best or most promising opportunities for addressing or managing uncertainties in fish-sediment processes related to remedy selection and long-term site management?
3. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance risk management practice related to fish-sediment processes?
    a. cleanup??

Attachment 5

Breakout Session Feedback

Attachment 5

Breakout 1: Fish Biology-Bioaccumulation

Group I: (ppt)

1. Development and use "tags" i.e. stable isotopes, chemical fingerprints, other technologies
2. More investment/use of 1) observe, 2) act, 3) observe
    - Monitored remediation pilots
    - Before-After-Control-Impact
    - 5-yr reviews, when done right
3. More collaborative co-development of products and models across sectors and organizations (private, government, academia)
    - Formation of a Fish Exposures Work Group
    - Develop a "Fish Exposures Factors" handbook and guidance

Group II (flip chart)

1. Characterize base and trophic levels of food web
    - Chemistry, biology, stable isotope
        i. Site-specific study
        ii. Research study
2. Fish telemetry in concert with hydrodynamics to better inform spatial explicit component of bioaccumulation models; would inform foraging vs. home range and factors that affect behavior (e.g. gender, season, etc.)
3. Post audit at a range of sites
    - Effectiveness of bioaccumulation model
4. Better mechanistic understanding of PFAS (ionized compounds)
    - Lab study

Group III (Word Doc)

1. Develop a fish exposure factors handbook (similar to the wildlife exposure factors handbook
    a. Multi-stakeholder collaboration
- Literature synthesis designed for Site Assessors, Risk Assessors, Remedial Decision Makers, etc.
    - History synopsis
    - Life stages
    - Diet
    - Habitat constraints
- Provide guidance as to what type of habitat or physical characteristics certain species prefer as a function of time of year, life stage, gender:
    - Temperature
    - Salinity
    - Water depth
    - Substrate type
    - Hydrodynamic characteristics (flow)
- Uses
    - Inform Sampling and Analysis Plans, Monitoring Programs
    - Conceptual Site Model Development
    - Food Web and Bioaccumulation Model Inputs
    - Move toward residency-weighted sediment exposure (rather than SWAC)

2. Review Paper on State of Science Regarding Use of Stable Isotopes (Carbon, Nitrogen, Sulfur) to Characterize the Food Web
    - Multi-stakeholder collaboration, including regulatory community
    - Objective:
        - Explore Pros and Cons for this application
        - Identify Best Practices
    - Pitfalls – sampling bias, analysis, interpretation
    - Other complementary lines of evidence are required (e.g., fish gut content)
    - Which isotopes and ratios are applicable to which uses
    - Interpretation
        - Inform trophic structure and relationships
        - Improve the bioaccumulation models
        - Inform post-remediation monitoring
    - Example SOP for study design, sample collection, and data analysis (Appendix)

3. Retrospective Analysis of Sediment Remediation with Fish Monitoring Studies (similar to Patmont et al)
    - Multi-stakeholder collaboration, including regulatory community
    - Objective:
        - Examine relationship between remediation metrics (e.g. change in sediment concentration) and fish tissue concentration
        - Re-examine which variables matter under various conditions (which monitoring endpoints are most predictive?)
        - Lessons learned from failures as well as successes
        - Re-calibrate expectations
    - Assemble case studies with post-remedial validation monitoring
    - Include a range of sites, including smaller (perhaps state led) Sites
    - Target sites with data over 10 years or more
    - Include studies from non-remediated sites (collected for other purposes)
    - Look at spatial scales – how much of the home range was remediated?
    - Provide recommendations for future monitoring studies

Group IV (worksheets)

1. Gather data on relative time spent in contaminated areas for exposure assessments
2. Share information – learn from one another; if data is collected or available, work to compile it
3. Passive sampling standardization and incorporation into bio accumulation models

Group V (word doc)

1. Fish Tracking before and after the remedy
2. Develop protocols for stable isotope methods, C:N Ratios
3. Examine sites where remediation has occurred and conduct monitoring to determine if fish tissue concentrations track the predictions from the modeling

Group 1 - Breakout 1

Todd Bridges (facilitator)
John Toll (note taker)
Karl Gustavson
Jeff Stern
Will Gala
Steve Nadeau
Jack Zabik
Barry Kelly
Gui Lotufo
Barrie Selcoe

Session 1: Fish Biology & Bioaccumulation Modeling

1. What are the most consequential uncertainties in site assessments that are related to fish biology or behavior?
    a. Site versus other area influences on tissue concentrations
    b. Fish movement
    c. Is it important at all (if decisions will always be based on worst case assumptions)?
    d. Spatial distribution of contamination versus fish
    e. Pelagic versus benthic prey contributions
    f. Why do cohort fish have drastically different tissue concentrations?
    g. Prey selection/dietary preferences
    h. Depuration processes and rates
    i. How does habitat use vary over time (stray rates, seasonality)
    j. Are the assumptions about partitioning in the organism that are built into the model we're using appropriate for the target species?
    k. Uncertainty about the management questions that the model is being built to help answer.
    l. Benthic ecology
2. What are the best or most promising opportunities for incorporating biology and behavior to improve site assessments?
    a. Get consensus on the decision variable (e.g., assumption about what fish people are going to eat)
    b. Promulgated guidance (driven by empirical data) on realistic assumptions about biology and behavior, with a database
    c. Tracking and mark-recapture studies
    d. Stable isotopes
    e. Overlap between habitat and contamination, understanding fish movements
    f. Guidance for selecting the right species to model, good modeling practices, exposure factors handbook for fish
    g. Find a way to link fish sampling and tracking
    h. Fish productivity versus consumption rate
3. What are the best or more promising opportunities for improving the application of bioaccumulation modeling to inform risk assessment?
    a. Studies on metals accumulation in fish
    b. eDNA to better characterize what fish are eating

c. Site-specific model verification studies
d. Start the long-term monitoring at the start of the RI
e. Habitat enhancements or other strategies to decouple food web from contamination
f. Contamination depuration rates
g. Use of passive samplers to better estimate freely dissolved concentrations
h. Sensitivity analysis to identify and focus on key uncertainties
i. Mesocosm studies/experimental approach
j. Use hydrodynamics to understand where the small fish will be

4. (rolled 5 into 4) What are the most important studies (e.g., literature based, laboratory, field) that could be performed to advance practice on the use of fish biology and behavior in assessments?
    a. Pilot to define the compartments driving fish tissue concentrations
    b. Use migrating fish as an opportunity to study kinetics
    c. Investment in review/synthesis papers across many sites
    d. Better monitoring efforts
        i. Pilots – so more frequent monitoring
        ii. Before & after sediment, water and fish
        iii. Multiple treatments (e.g., adaptive management)
    e. Site-specific studies of residency
    f. Fish exposure work group
    g. Modeling studies to inform watershed-scale restoration strategies
        i. Will hot spots matter?
    h. Literature review for producing exposure factors (beyond fishbase open source database)
    i. Particulate-bound contaminant uptake across gills, especially for carp
    j. Start the long-term monitoring early. Get good, consistent data over time.

Top 3

1. Observe early and often
2. Stable isotopes, fingerprints, other tags (guidance)
3. Fish exposure work group
    a. Fish exposure factors guidance or handbook and database

Foster more collaborative co-development of products and models etc.

Group 2 - Breakout 1

Betsy Ruffle (Facilitator)
Susan Kane Driscoll (Note taker)

What are the most consequential uncertainties in site assessments that are related to fish biology or behavior?

David Moore (DM): Default to literature on food web and prey items = major area of uncertainty. Fish often don't feed on what lit says they feed on. Feed opportunistically. Example: Lakes in Sierras in CA. Some areas with low Hg and high fish conc, and vice versa. DM thinks it is due to food web and what they eat.

J Meador (JM): Most lit studies say juvenile chinook don't feed on benthos, but they do.

Trina von Stackelberg (TVS): Recommendation is to better characterize base of food web.

R Stahl (RS): Did a lot of work on the South River, gut contents. Couldn't figure out where fish got dose because water concentrations were very low. Prey items changed over time. Grasshoppers early in the year, small fish later. Found that different areas of the river had higher/lower methylation and demethylation rates, which went right up the food chain from periphyton to insects to fish and birds.

Debra Williston (DW): Major area of uncertainty is amount of movement in and out of site, and even within your site.

DM: Studies on Palos Verdes shelf. Studies show 2 populations: one spends most of time on shelf, one spends most time in Harbor.

BR: How do you account for differences in EPCs

Doug Tomchuk (DT): Similar issue at Hudson: Have a resident population and a migratory population.

Bob Wyatt (BW): How do you pick which fish species to monitor? Should you do fidelity studies before you start the RI? Many sites driven by HH PCB risk.

DT: BCSA did 7 years of yearly baseline monitoring which is very helpful as part of site assessment. Hudson has 20 years of data. Of course, still issues and uncertainties.

TVS: Models have a series of questions. What is most important for human consumers? What species is most tied to sediment? What can you catch?

BW: Sometimes need to consult locals to understand where fish can be caught?

DW: May need 2 species: one for monitoring of response, another for health advisories.

DM: Don't spend enough time formulating the problems/questions. If it is a big enough site, spend some time

BR: Lots of time spent on site chemistry. Not as much as time spent on biological considerations, such as fish movement & behavior that affects bioaccumulation.

DT: Lots of uncertainties don't make a difference.

TVS: Hudson did not set sediment numbers. RAOs based on fish tissue concentrations.

BW: How do you understand the boundary conditions? How do you understand contributions from e.g., areal deposition vs legacy contaminants

DT: Maybe do a stable isotope characterization of food web before even doing chemistry?

BR: Need information on temporal changes in food webs?

DM: Can envision a site where benthic community structure is very different in a contaminated area. Lots of filter feeders, fewer deposit feeders. So fish get an exposure more related to surface water than subsurface sediment.

BR: Calibrating model can be challenged by available data – need consider sediment exposure depth (Passaic sed samples from 0-15 cm but majority of exposure to top few cm).

BW: Often times we get 3 years into a RI and don't know what to do with the data.

BW: Need for an agreement on what we are using as a basis for comparison for evaluating the need for a remediation and the results of remediation. Important to discuss and define the role of reference/background in site assessment.

What are the most promising opportunities for incorporating fish biology and behavior to improve site assessment?

BR: Better characterization of base of the food web; stable isotopes

DM: What are the sites where you want information on fish biology? Sites where fish are elevated. LA white croaker example. Conc across wide area is similar, but want to know what % of body burden is driven by the site. Not a good use of $

RS: For South River, stable isotopes showed that even if you could cut off 80% of concentration in lower trophic level, you will not be able to lower fish tissue concentration to acceptable levels.

What are the best or most promising opportunities for improving the application of bioaccumulation modeling to inform risk assessments?

TVS: Question#3: **Need for more post-remedy validation/auditing**. Doing it now for the Hudson.

DT: Also need to have an accurate exposure estimate.

TVS: Agreed. The bioaccumulation model is often the focus of scrutiny, but the exposure estimate is equally important.

TVS: The primary reason to develop bioaccum model is to compare scenarios. So lots of uncertainty will be similar among scenarios. Different standard of performance based on comparison of remediation scenarios. Could not establish a unique sediment concentration, rather combinations of sediment and water concentrations that can produce a particular fish concentration.

RS: Eventually you need to make a decision. Employ adaptive management.

BW: Spatial issues. Interested in perspectives related to SWAC vs. point-by-point. **How do you decide on how to address the exposure point concentration?**

DM: EPA developed a tool based on variability and sediment chemistry. EPA developed a tool that tells you how many samples you need to collect to ID a hotspot. Is there similar guidance for site characterization?

TVS: Approaches are available. Fish Rand uses Theisen polygons, could also use grids. Fish are randomly placed on grids. Need to include GIS experts, with fish biology experts.

DT: What is the predictive capacity of bioaccum models and how does it relate to management needs. For example, TVS said a predictive ability within a factor of 2 is very good, but is that acceptable for management needs?

PA: If management decision is that we want every fish to be below a certain concentration vs. want the mean of fish tissue concentration to be below

RS: Cost is important too.

BW: Example. Point source with gradient away from site. Seemingly a simple decision to remediate. But actually a % of what is in the fish comes from elsewhere. But if regulators and other stakeholders are skeptical, is the information useful?

DM: Post-remedy monitoring to characterize pattern changes. For example, you improve the benthic community and so enhance food chain transfer. Use results for field-based to verify/monitor inputs to models.

Group 3 - Breakout 1

1. Most consequential uncertainties in site assessments:

    - Understanding the primary vs. secondary routes of exposure to fish. Different for different species and different sites. Can apply to site vs. background. Water vs. sediment. Highly variable between Sites. More than we realize. Water-sediment interface has a fluff layer.

    - Understand fish movement. Into and out of Site. Different portions of Site.

    - Why are fish congregating in one area rather than another area? Food, protection, reproduction. But understanding this would help us focus the remediation.

    - Degree to which the fish being sampled are linked to the sediment. What is the trophic structure? If a certain prey species lives in a fixed location it may get more contamination. Pisciverous fish will integrate over various smaller ranges.

    - Identify metrics that are appropriate for monitoring. Repeat some measurements over time (certain species). Can also measure stable isotopes to see if prey is changing.

    - We overestimate our ability to predict. The fish at the top of the food chain have the most uncertainty = we have the least ability to predict what will happen. Perhaps we could monitor something lower on the food chain. Or even pore water.

2. What are the most promising opportunities for incorporating fish biology or behavior to improve site assessments?

    - Find the intersection between the high contaminant concentrations and where the fish spend their time. If we had certain characteristics that a particular species of fish favors, we could focus where the fish are more likely to hand out. Move toward residency-weighted exposure.

    - Validate using fish telemetry and tagging studies.

    - The isotope data is quite promising. But need guidance on interpretation. We had an example that was very useful. Other case studies are very messy. Need to make certain the data is collected consistently. Maybe we could propose a research project.

3. What are the best opportunities for improving application of bioaccumulation modeling to inform risk assessments?

    - Literature review of TRVs; compile wildlife effects levels. Could we develop sediment screening levels protective of wildlife? That would be hard because it is so site specific. Don't want it to be used as clean-up numbers. Might we be able to come up with a fish tissue concentrations? Even that depends so much on quality of the data and the site-specific food web.

- Need to find the dietary concentration for a given receptor.

4. What are the most important studies that could be performed to advance the practice of the use of fish biology and behavior in fish assessments?

    - Compile available literature (and provide guidance on) on fish monitoring to understand behavior. For each species (Walleye, Sturgeon, Salmon, Pike, etc…). Where do they hang out at what time of year? Provide guidance as to what type of habitat physical characteristics they prefer:
        - Temperature
        - Salinity
        - Water depth
        - Substrate type
        - Hydrodynamic characteristics (flow)

    - There are books out there, but could we recast the fish biology text book to create a fish exposures handbook.

5. What are the most important studies that could be performed to advance practice on bioaccumulation studies?

    - Understand relationship between fish and pore water concentrations. We are missing the driver. Often models don't work because they don't have the correct drivers. we could monitor pore water as an endpoint. Would need to improve the pore water collection techniques. Pore water does a good job of predicting what we see in clams. The problem is how to translate to organisms that have a larger home range, or have another loading source. If you could accurately measure the pore water concentrations would that help? Not really.

    - Better understand the relationship between concentrations in young of year (snapshot in time and smaller home ranges) to the concentrations in larger fish which are consumed. Get a relationship between young of year that you can actually catch and measure, and the ones that you really care about. – could we piggy-back that onto an ongoing study such as the fish surveys in Canada.

    - Field studies on the depth of the biological active zone. Literature review to see if there are any general guidelines? Or is it Site-specific? Inappropriate to assume 15 cm.

    - Could we apply modeling retrospectively to various sites and compare success of simple vs. complex models?

Fish Tissue Database

- There is likely a lot of data. Not every data set will meet all of the ideal criteria. But there should be enough information out there to put together a set of empirical models. Someone could set up a publicly-available database, and then future studies upload the data. If we set up a database with pre-defined fields (e.g., gender, length, weight, date, lat, long, water temp, etc.) then people may prompted to collect all those types of data.

Could the EPA's Fish advisory database meet these needs (Sharon Frey)

Develop a Fish Exposure Factors Handbook (similar to the Wildlife Exposure Factors Handbook)

- Multi-stakeholder collaboration
- This is a literature synthesis designed for Site Assessors, Risk Assessors, Remedial Decision Makers, etc.
    - History synopsis
    - Life stages
    - Diet
    - Habitat constraints
- Provide guidance as to what type of habitat or physical characteristics certain species prefer as a function of time of year, life stage, gender:
    - Temperature
    - Salinity
    - Water depth
    - Substrate type
    - Hydrodynamic characteristics (flow)
- Uses
    - Inform Sampling and Analysis Plans, Monitoring Programs
    - Conceptual Site Model Development
    - Food Web and Bioaccumulation Model Inputs

Move toward residency-weighted sediment exposure (rather than SWAC)

Review Paper on State of Science Regarding Use of Stable Isotopes (Carbon, Nitrogen, Sulfur) to Characterize the Food Web

- Multi-stakeholder collaboration, including regulatory community
- Objective:
  - Explore Pros and Cons for this application
  - Identify Best Practices
- Pitfalls – sampling bias, analysis, interpretation
- Other complementary lines of evidence are required (e.g., fish gut content)
- Which isotopes and ratios are applicable to which uses
- Interpretation
  - Inform trophic structure and relationships
  - Improve the bioaccumulation models
  - Inform post-remediation monitoring
- Example SOP for study design, sample collection, and data analysis (Appendix)

Retrospective Analysis of Sediment Remediation with Fish Monitoring Studies (similar to Patmont et al)

- Multi-stakeholder collaboration, including regulatory community
- Objective:
  - Examine relationship between remediation metrics (e.g. change in sediment concentration) and fish tissue concentration
  - Re-examine which variables matter under various conditions (which monitoring endpoints are most predictive?)
  - Lessons learned from failures as well as successes
  - Re-calibrate expectations
- Assemble case studies with post-remedial validation monitoring
- Include a range of sites, including smaller (perhaps state led) Sites
- Target sites with data over 10 years or more
- Include studies from non-remediated sites (collected for other purposes)
- Look at spatial scales – how much of the home range was remediated?

Provide recommendations for future monitoring studies

Group 5 - Breakout 1

Members: Eric Blischke, Jeff Steevens, Marc Greenberg, Paul Schroeder, Phil Gidley, John Connolly, Paul Montney, John Wolfe, Deb Edwards

Can we improve bioaccumulation modeling? What are the main opportunities?

1. Site fidelity and fish movement. Understanding fish movement is very important. However, we don't know much about this for different species.
    - § What are the key parameters?
    - § Will the remedy change the behavior? Do foraging behaviors and site fidelity change associated with the remedy? Have you cleaned it up better than the other areas within the foraging region?
    - § Over a large spatial scale to show changes are occurring and where the fish are located.
    - § Could fish movement be used to inform remediation strategy? If fish are not hanging out at a hot spot then remediation of that site will not affect a change. They may also avoid that area because of contamination?
    - § What do we know about fish behavior and effects of organics? Does not affect benthos and so does not affect the feeding behavior.
    - § Can we create fish habitat to reduce exposure? Such as aquatic plants, fish sticks, etc.
    - § Can we create a weighted SWAC for fish behavior? Following up on Trina's spatially explicit model we can create determine site exposure.
    - § Project: [fish tracking before and after the remedy] Fish tracking before and after, spatially and with depth. Conduct additional telemetry studies to develop probabilistic approaches. Needs to be for different types of sites. Capture information about pelagic and benthic fish, sex, etc

2. Species specific traits-foraging. Dealing with different sediment we have different guilds that interact with the sediment.
    - § How do you partition that out? Even if you have a benthic fish feeding on benthic invertebrates; fish are opportunistic. More focused on understanding the community.
    - § Can we focus on invertebrates to better understand the different species traits? Is there a way to guide the modeling? Can we apply terminology from ecology to classify invertebrate traits that are relevant and use methods to quantify these traits? See: Schmera, D.; Podani, J.; Heino, J.; Erős, T.; Poff, N. L., A proposed unified terminology of species traits in stream ecology. *Freshwater Science* **2015,** *34*, (3), 823-830.
    - § There is a lot to learn from stable isotope applications.
    - § Project: [develop protocols for stable isotope methods, C:N ratios] Carbon identifies source and nitrogen shows how far it goes up into the food web. Start at the base of the food web and go up the food web.

3. How does the bioaccumulation change with the remedy? What is the duration?
    - § There are places where we have done this work. For example Gras River where this type of information was collected. Passaic where information on settling of material on top of the cap. There are field sites where we can get this type of information.
    - § Often looking at multiple species.

- § Will the remedy change the behavior? Do foraging behaviors and site fidelity change associated with the remedy? Have you cleaned it up better than the other areas within the foraging region?

4. Lipids. Are there improved methods for characterizing the different lipids in invertebrates or fish?
   - § How do we understand and forecast trends in lipid levels?
   - § Focus studies on bioenergetics and fish lipids. Capture some of the existing information (literature review) that has already been done. See text by Orr and Rand on fish physiology.
   - § Are the lipid trends seasonal or cyclic or are there evolutionary trends in a system?
   - § To what extent are different temperature regimes affecting fish?
   - § Methods for determining lipids may be important for some species such as bass. However, it may not be important for fast growing fish like pumpkinseed.
   - § What other variables matter for wet weight fish tissue concentration? Look at other factors other than lipid. Consider age, species, size, gender… Consider a multivariate approach.

5. Project: Examine sites where remediation has occurred and conduct monitoring to determine if fish tissue concentrations track the predictions from the modeling. Can be minimalist monitoring, but could be more monitoring to track fish on a site. So the scientific community would learn from monitoring.

   Project outcome 1: How do we target remediation?

   - § What are the science opportunities for incorporating restoration goals with reducing exposure associated with clean up goals (NRDA/CERCLA)?
   - § Can we get more bang for our buck by more strategic thinking about a site versus just focusing on hot spots?
   - § We still need to think about hot spots. If we leave behind a hot spot, then it has a potential for affecting other surrounding areas after change. Conduct additional telemetry studies to develop probabilistic approaches.
   - § Needs to be for different types of sites.

   Project outcome 2: Develop a monitoring framework for multiple sites. Each site has some base level of monitoring where there is some consistency. System conditions are different.

Hudson or Passaic. Exposure depth is a big issue that comes up for invertebrates. Is it the top 12 cm? Applies to caps and recontamination layers; combined/averaged may be averaged but organisms may only be interacting with the surface. Getting species specific post remedy data.

Breakout 2: Exposure & Consumption

Group V (ppt)

1. Lifetime Cohort Study
   Problem
   - Do not have lifetime data on individual fish consumption.
   - We may not know the fish consumption and therefore conservative assumptions are often used

   Solution
   - Develop population data sets (cohorts) by following a group of individuals throughout their lifetime.
   - Similar concept as the Michigan Panel Study on Income Dynamics (could tie into this study), Framingham Heart Study, Fels Growth Study
   - This is a long term study

   Application
   - Provides a pattern of consumption over their life, could scale based on this study.
   - Confirm that metrics from site specific study and cohort study are consistent.
2. Updated Consumption Surveys and Technical Doc/Guidance
   Problem
   - We do not have agreed upon consistent set of protocols; current protocols may not be accepted by regulatory agencies
   - Some studies are dated
   - Current studies may not be deemed acceptable by key stakeholders

   Solution
   - Develop updated studies based on agreed upon protocols
   - Involves all stakeholders in design
   - Data should support calculation of central tendency and distribution
   - Specifics include species specific information, frequency, and spatial components
   - Short term project

   Application
   - Standardized protocols (guidance or technical document) that will yield a statistically robust consumption distribution
3. Linking take with the sustainability of the fishery and Technical Doc/Guidance
   Problem
   - Can the assumed consumption rate be sustained by the local fishery?

   Solution
   - Consumption rate should be linked to spatial data where fish are and are being caught
   - Use fisheries biology to estimate sustainable take (right size the consumption rate/bounding)
   - Short term activity

   Application
   - This information could be used in the development of fish consumption rates and revised as part of long-term monitoring
   - Technical report and/or guidance

Group IV (worksheets)

1. Understand how fisheries advisories are developed in a jurisdiction & matching site risk reduction to the same process.
2. Bring in social scientists to communicate risk of fish consumption and what's achievable
3. Decouple fish tissue concentration as a metric with remediation success at a site, especially in areas with multiple sources. (Alternative- biopneumetics?)

Group III (word doc)

1. Follow-on Paper building on SMWG Background White Paper (sediment, water, fish tissue concentrations)
    - Multi-stakeholder collaboration, including regulatory community
    - Objective:
        - How do you calculate Regional Background in Urban Areas where multiple Sites impact exposure?
    - Is a watershed approach appropriate and in what circumstances?
    - Acknowledge "background" is a range of conditions
    - "Background" is a moving target, how do you identify a clean-up goal?
    - How to account for cumulative risk from multiple sites as well as background
2. Working group to better define and describe issue of reasonable foreseeable use and exposure
    - Multi-stakeholder collaboration, including regulatory community
    - Objective:
    - Provide guidance on how to account for future changes in site and exposure conditions as a result of
        - Active remedies
        - Natural recovery
        - Habitat
        - Human use/demographic changes
        - Climate change
    - Difference between "Reasonable" future use vs. Aspirations (Recognition that we will not reach a pristine condition)
    - Use of Regional Trend Lines in predicting incremental benefit of a given action, for example:
        - Ecosystem services
        - Human recreation and fish consumption
3. Perform meta-analysis on relationship between contaminant levels in people and fish consumption
    - Multi-stakeholder collaboration, including regulatory community
    - Objective:
        - Provide repository of information to better define actual exposure resulting from fish consumption
        - Evaluate relationships between fish consumption and biomonitoring endpoints (e.g., blood levels, hair, etc.)
    - NHANES database as a starting point
    - Focus on PCBs and Mercury, PFAS (limited data availability?)
    - Identify Potential Data Gaps, examples might include:
        - Synergistic effects with occupational exposure
        - Adequate coverage of subpopulations
    - Interpretation
        - Validate current default uptake assumptions
        - Improve human exposure models

- Inform establishment of fish consumption advisories
- Integrate into risk interpretation
- Compare to laboratory studies of exposure uptake relationships in other species

Group II (ppt)

1. Guidance on probabilistic methods including how to represent/include high-consuming populations
2. Guidance on site-specific fish consumption surveys to gather data to be analyzed using NCI method to derive usual FCRs for current consumption
3. Guidance on data needed to understand site-related fish consumption versus outside of site
    a. Species and site fidelity
    b. "angler site fidelity" (fraction ingested)
4. Guidance on characterizing background risks
    a. Background/regional conditions
    b. Storebought/restaurant

Group I (flip chart)

1. Develop a guide "fish consumption/exposure handbook"
    - Co-developed – ITRC?
    - Guide for surveys practice, data analysis, exposure calculations, case studies background, site-specific vs non-site specific approaches, including guidance conservation (more accessible and usable)
2. Verification of high exposure groups
    - Blood, disuse data
    - Follow-up survey, correction for bias
    - National epi survey – NIH outcomes
    - Legacy studies of outcomes for highly exposed groups
    - Review/synthesis paper

Tech solutions - Apps for survey data, crowd sourcing, social media data

Group 1 - Breakout 2

Todd Bridges (facilitator)
John Toll (note taker)
Karl Gustavson
Jeff Stern
Will Gala
Steve Nadeau
Jack Zabik
Barry Kelly
Gui Lotufo
Barrie Selcoe

Session 2: Exposure and Consumption of Fish

1. What are the most consequential uncertainties in site risk assessments that are related to fish consumption and exposure?

a. Guidance on good survey and fish sampling study design. Good practice standards.
b. Compounded conservative assumptions
c. Reliance on hypothetical exposure scenarios/consumption rates for future consumers
d. Use of the site by the fish
e. RfD and SF were discussed
f. Fish tissue concentrations
g. Apportionment of intake across species and waterbodies
h. Projecting future consumption rates
i. How will the exposed population be defined (exposure duration, size of population)
j. Relationship between the size of the exposed population and the sustainable consumption rate
k. Risk of remedy
l. Will public health management strategies be admissible in the RI/FS (e.g., a fish exchange facility and program)

2. What are the best or most promising opportunities for improving practice related to exposure assessment?
    a. Guidance on survey techniques, their strengths and weaknesses, survey design, and statistical interpretation of survey data. When to use which techniques
    b. Case studies of good practice
    c. Guidance for risk managers on the use of conservative assumptions
    d. Human exposure factors handbook for the fish consumption scenario
        i. How to generate a site consumption rate if you're not going to do a site-specific study
    e. Verification of high exposure cohort
    f. Verification of higher exposure in the targeted subpopulation than in the broader population (e.g., with blood data)
    g. Define/quantify the likely risk (P50)
    h. Move to a source control approach, rather than a risk-based approach
3. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance exposure assessment practice?
    a. Run research through NIH, not EPA:
        i. Possibly reinstate a National Human Adipose Tissue Survey, at least long enough to verify that blood and adipose tissue COC concentration are strongly correlated.
        ii. Long-term fish consumption surveys on a large scale, across the US.
        iii. Epidemiology (outcomes of high fish consuming individuals and populations)
    b. Compilation of best practices and studies of human fish consumption
    c. More comprehensive studies to reduce uncertainty about fish tissue COC concentrations
    d. Human biomarkers for quantifying exposure/identifying high exposure
    e. Establish multi-organization/sector human exposure assessment work group

Top 3

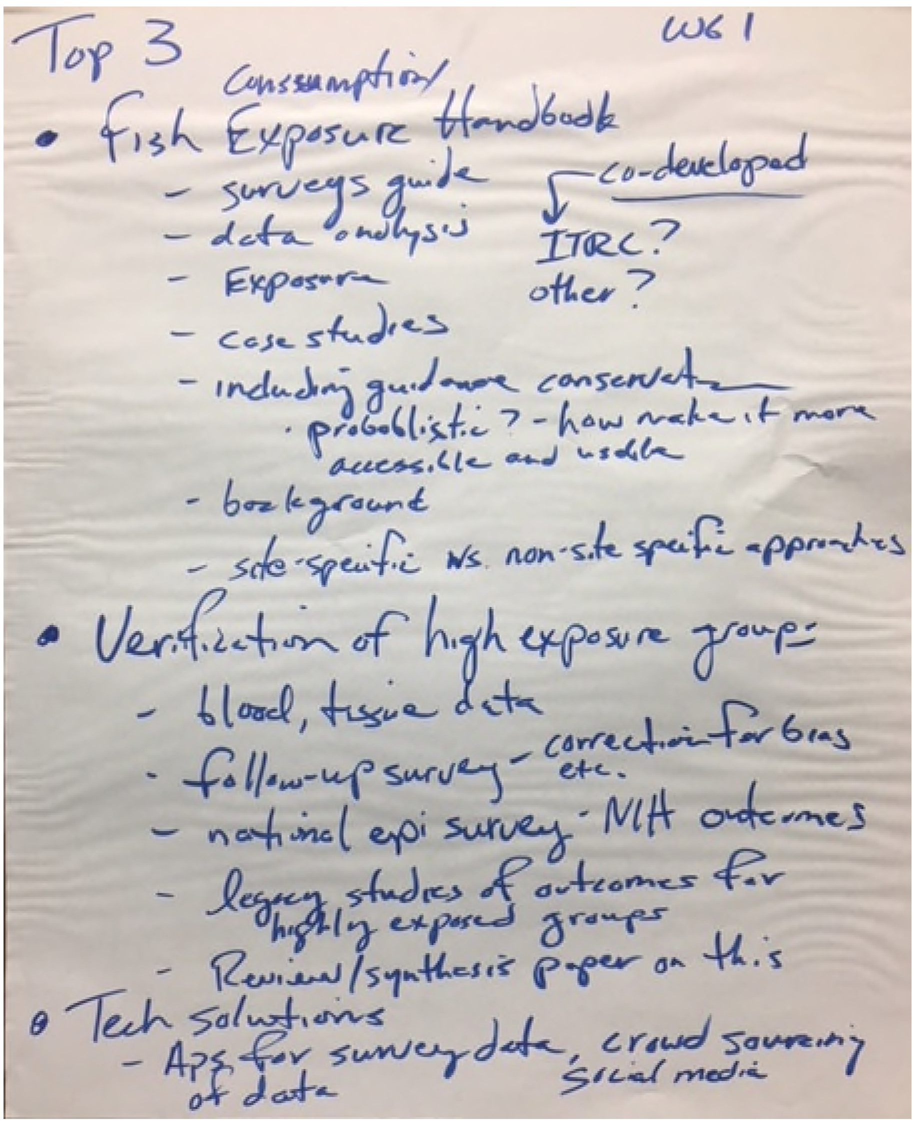
1. Verification of high exposure cohort
    a. Using human tissue data
    b. Outcome data
        i. NIH studies of public health risks and benefits of fish consumption

ii. Mine (e.g.) Michigan, Inuit population studies

c. Survey validation techniques

2. Guidance document series, and different paradigm for inclusive guidance development
    a. Guidance on survey techniques, their strengths and weaknesses, survey design, and statistical interpretation of survey data. When to use which techniques
    b. Case studies of good practice
    c. Guidance for risk managers on the use of conservative assumptions (site-specific and non-site-specific approaches)
    d. Human exposure factors handbook for the fish consumption scenario
    e. Dust off the probabilistic HHRA guidance for Superfund sites
    f. Establishing background concentrations
3. Technological solutions
    a. Apps for collecting survey data

Crowd sourcing of data/social media exploitation



Group 2 - Breakout 2

Notes for SMWG Breakout Session 2 – Exposure Assessment

(Group 2 – Betsy Ruffle facilitator)

What are consequential uncertainties in exposure assumptions

1) Derivation of reasonable FCRs reflective of current and reasonable sustainable possible future consumption.
    a. Sustainability (how much fish biomass consumption is supportable by the affected portion of the water body
2) Would there be more consumption if not contaminated (suppression)
3) What is source of chemical causing the exposure
4) Fraction of fish from site versus from elsewhere (lack of rational way to derive)
    a. Angler site fidelity
5) Species targeted by anglers for consumption versus species used for monitoring
    a. Representative species
6) Inconsistency in assumptions across sites
7) Evaluation of highly exposed populations
8) Lack of population risk
9) Highly uncertain pathways may not need to be quantified (e.g., nursing infant) until the quantification can be realistic/representative
    a. Probabilistic instead of deterministic approach to capture uncertainty and conservatism in the analysis
10) Impact of advisories on FCR
    a. Suppression
11) Tissue concentrations – current (this is likely one of the least uncertain fish consumption exposure assumptions)
    a. Analytical methods (representativeness) change over time
    b. Exposure variability – species, tissue type (whole body vs. fillet, skin on or skin off), cooking loss
12) Future tissue concentrations
    a. Modeled
13) Toxicity factors have large uncertainty factors
    a. Uncertainty and conservatism not accounted for or well represented

Methods/Opportunities

1) Use of drones/technology for characterizing fishing pressure, angling behaviors
2) Increased use or PRA
3) Better understanding of degree of uncertainty in risk estimates
4) Evaluate background risk to put site risk in perspective
    a. Site vs. off-site
    b. Store-bought fish, fish from other water bodies
5) Separate exposure assessment from risk management
    a. Risk managers should not limit assumptions used in the risk assessment
    b. Risk assessments should not have a predetermined/preferred risk outcome and drive a particular remedy decision

6) Availability on EPA 2014 data on regional FCRs for US population

Big ideas

1) Guidance on probabilistic methods including how to represent/include high-consuming populations
2) Guidance on site-specific fish consumption surveys to gather data to be analyzed using NCI method to derive usual FCRs for current consumption
3) Guidance on data needed to understand site-related fish consumption versus outside of site
    a. Species and site fidelity
    b. "angler site fidelity" (fraction ingested)
4) Guidance on characterizing background risks
    a. background/regional conditions
    b. tore-bought/ restaurant

Group 2: Exposure Assessment BIG Ideas

1. Guidance on probabilistic methods including how to represent/include high-consuming populations
2. Guidance on site-specific fish consumption surveys to gather data to be analyzed using NCI method to derive usual FCRs for current consumption
3. Guidance on data needed to understand site-related fish consumption versus outside of site
   - Species and site fidelity
   - "angler site fidelity" (fraction ingested)
4. Guidance on characterizing background risks
   - Background/regional conditions
   - Storebought/restaurant

Group 3 - Breakout 2

6. Most consequential uncertainties in site assessments related to fish consumption and exposure:

- Risk assessments make conservative assumptions that lead to a fish consumption rate that is not sustainable on the water body. No mechanism to include this consideration. Needs to be a check. Need something that we can show the regulators.

- The "realistic" scenarios are forced to be put in the uncertainty section.

- Anything that deviates from the default assumptions goes in uncertainties

- What are people actually eating from the Site? What is the effect of fish advisories?

- Studies (at least in New York) are 20 years old. Not site specific. DEP did a study in the 90s which is what is currently used. There was a 2008 study, but not approved by the EPA.

- There are lots of illegal fisherpeople that you never see. Never counted. Little information on what they are doing. Are they eating the fish, or using them as bait? They don't want to be caught. But if they're catching food species, they're either eating them or selling them.

- Different immigrant populations turn over every couple of years. Hard to reach out to them. Hard to explain risk.

- Nevertheless, people do what they always did. Need to recognize that. People on islands will eat the fish even if they know that the military did lots of testing there

- Maybe we could establish a regional approach to establish what is being eaten on a non-contaminated water body (that would be the future conditions). But it's hard to find that water body in urban areas.

- Must recognize that sites are not isolated. If it was only 1 site, might not be a problem. But the combination of exposure from all sites is a problem.

- Newtown Creek has a set of 4 "reference" sites with a span of land use and CSO inputs. Maybe could be used as an example for other areas. But the use of this information is not optimal, because everything has so be moved to the uncertainty section. HH Baseline Risk Assessment not allowed to consider these various considerations.

- If you calculate a risk-based level that is lower than background. Best case scenario is to achieve background. Need an "off-ramp" to stop worrying about the details. If regional background is best we can do. Need to focus effort on establishment of regional background. How do you define the region?

- Need better guidance on characterization of background. But don't want to mask cumulative risk. Site could contribute to regional background. If regional background is unacceptable, it is due in part to the background. Maybe could make a watershed-scale background.

7. What are the most promising opportunities for improving practice related to fish exposure?

   - Establish better ways to assess consumption other than creel surveys. Cameras? Other technology?

   - Better biometric data for fish consumers? We make a lot of assumptions. Could we test blood concentrations? Ground truth the models? Support TRVs.

   - Anecdotal statements that fish consumption is not related to PCB concentrations in blood.

   - There is a New York study that found high Mercury in Asian populations, but they were eating imported fish from asian markets.

- Has anyone looked at the 2014 guidance on human risk assessments? Provides a useful bounding estimate. Provides total consumption (including supermarket, and canned fish) broken out by demographic, etc. Provides useful perspective.

- Use probabilistic approaches in addition to determinate approaches. Some regions don't allow PRA. In region 2, it needs to be in the original work plan. RPMs aren't comfortable, because don't get enough training. Need to invest in EPA training. Big burden on an individual person. If they don't understand, they can't defend it. Seems like just a black box.

- Use PRA to provide risk manager with percentiles and absolute numbers of people in angling families in the impacted population and subpopulations relative to various risk thresholds.

8. What are the most important studies to advance exposure assessments?

- Come up with a study that gets at what fish are consumed at what rates by what population.

- We have the technology to accurately estimate consumption, but it's hard to predict what is going to be consumption in the future. How do you predict attractiveness?

- On ecological side, how do you predict future area use factors for ecological receptors?

- How much incremental improvement do we get over natural recovery? How do we incorporate improvements in attractiveness which changes use. Need to compare proposed action to projected "natural" rate of recovery. When it is done, they look solely at reduction in concentrations, not the broader benefits.

- Use peer to peer trained survey methods

- Paired lab and field studies to improve exposure assessment. Design a field study that combines in-situ pore water with lab evaluation of GI bioavailability. Improve on historical studies using pigs or monkeys. Analytical techniques have improved.

- Set of studies regarding bioavailability/bioaccessibility of metals. We do this in detail for invertebrates. Can we do the same thing for human receptors? Reference doses typically based on feeding studies to rodents, but they are feeding

- For mercury, based on epidemiology studies from Faroe Island (is it Mercury, PCBs, or PFAS?) If we could sort that out we could target the correct driving contaminant for remediation.

- Note that EPA is reviewing mercury.

Set of studies regarding bioavailability/bioaccessibility of metals. Mercury, Copper, Vanadium, ionizable compounds such as PFAS

Follow-on Paper building on SMWG Background White Paper

- Multi-stakeholder collaboration, including regulatory community
- Objective:
    - How do you calculate Regional Background in Urban Areas where multiple Sites impact exposure?
- Is a watershed approach appropriate and in what circumstances?
- Acknowledge “background” is a range of conditions
- “Background” is a moving target, how do you identify a clean-up goal?
- How to account for cumulative risk from multiple sites as well as background

Convene a Working Group to Better Define and Describe Issue of reasonable foreseeable use and exposure

- Multi-stakeholder collaboration, including regulatory community
- Objective:
  - Provide guidance on how to account for future changes in site and exposure conditions as a result of
    - Active remedies
    - Natural recovery
    - Habitat
    - Human use/demographic changes
    - Climate change
- Difference between “Reasonable” future use vs. Aspirations (Recognition that we will not reach a pristine condition)
- Use of Regional Trend Lines in predicting incremental benefit of a given action, for example:
    - Ecosystem services

Human recreation and fish consumption

Perform Meta-Analysis on Relationship Between Contaminant Levels in People and Fish Consumption?

- Multi-stakeholder collaboration, including regulatory community
- Objective:
    - Provide repository of information to better define actual exposure resulting from fish consumption
    - Evaluate relationships between fish consumption and biomonitoring endpoints (e.g., blood levels, hair, etc.)
- NHANES database as a starting point
- Focus on PCBs and Mercury, PFAS (limited data availability?)
- Identify Potential Data Gaps, examples might include:
    - Synergistic effects with occupational exposure
    - Adequate coverage of subpopulations
- Interpretation
    - Validate current default uptake assumptions
    - Improve human exposure models
    - Inform establishment of fish consumption advisories
    - Integrate into risk interpretation
    - Compare to laboratory studies of exposure uptake relationships in other species

Review

- Objective:
    - Explore Pros and Cons for this application
    - Identify Best Practices

Retrospective

- Objective:

Group 5 - Breakout 2

What are most consequential uncertainties in site risk assessment that are related to fish consumption and exposure?

- What is the best data to estimate central tendency and distribution?
    - Do not have lifetime data on individuals. Example: economics and panel studies, data sets (cohorts) to follow individuals throughout their life
    - We may not know the fish consumption and therefore conservative assumptions
    - There is a need to update consumption study data
    - There is no agreed upon protocol for conducting consumption studies
    - Are these consumption rates sustainable based on fisheries biology and is the population in the body of water sustainable?
    - Need distribution on rates, concentrations
    - What is the pre versus post consumption? Does it occur and how does it affect risk?
    - Consumption rate should be linked to spatial data where fish are being caught

What are most consequential uncertainties in site risk assessment that are related to fish consumption and exposure?

- What are critical populations? Subsistence fishing population or specific cultural groups?
    - Should focus on people that fish.
    - Could include fishing history as well. Incorporate history provided by individual where possible.
    - What are the potential generation differences in these populations

Other issues/ideas considered

- Fish preparation – skin on skin off filet
    - Cooking loss has a minor impact on uncertainty, as compared to other variables.
    - "To win the uncertainty battle we'll need to win with all of these"
- Health benefits from consuming fish, even if they are contaminated
    - Need to incorporate fish consumption from other sources into background. This is a big issue for
- Develop an App
    - Need to do a study to make sure sub populations are not missed
    - Use existing social media
- Drones and camera study to verify consumption, catch, fishing activity; how could you do this without invasion of privacy?

Project 1: Lifetime Cohort Study

Problem:

- Do not have lifetime data on individual fish consumption.
- We may not know the fish consumption and therefore conservative assumptions are often used

Solution:

- Develop population data sets (cohorts) by following a group of individuals throughout their lifetime.
- Similar concept as the Michigan Panel Study on Income Dynamics (could tie into this study), Framingham Heart Study, Fels Growth Study
- This is a long term study

Application:

- Provides a pattern of consumption over their life, could scale based on this study.
- Confirm that metrics from site specific study and cohort study are consistent.

Project 2: Updated Consumption Surveys

Problem:

- We do not have agreed upon consistent set of protocols; current protocols may not be accepted by regulatory agencies
- Some studies are dated
- Current studies may not be deemed acceptable by key stakeholders

Solution:

- Develop updated studies based on agreed upon protocols
- Involves all stakeholders in design
- Data should support calculation of central tendency and distribution
- Specifics include species specific information, frequency, and spatial components
- Short term project

Application:

- Standardized protocols (guidance or technical document) that will yield a statistically robust consumption distribution

Project 3: Linking take with the sustainability of the fishery

Problem:

- Can the assumed consumption rate be sustained by the local fishery?

Solution:

- Consumption rate should be linked to spatial data where fish are and are being caught
- Use fisheries biology to estimate sustainable take (right size the consumption rate/bounding)
- Short term activity

Application:

- This information could be used in the development of fish consumption rates and revised as part of long-term monitoring
- Technical report and/or guidance

Breakout 3: Risk Management

Group I (flip chart)

1. Incentivize early action w/monitoring to eliminate cause and effect
2. Studies to advance understanding of factors affecting relationship between action and fish concentration.
3. Third party feasibility studies
4. Develop Super Fund analog to Corps "federal standard" – least costly environmentally acceptable alternative

Group II (ppt)

1. Review of RAOs, PRGs, RALs at sites
   - Sediment and fish values (PCBs, pesticides, Hg, TCDD)
   - Post-remedy monitoring data
   - Modeled results for validation with empirical data
2. Incorporate early actions with ongoing remedial site investigation that includes evaluation of effectiveness of early action
   - establish trends and relationships
   - adaptive management
3. National policy linking risk distribution percentiles /metrics with acceptable risk targets
   - (e.g. mean @ 1x10-6, 90th%ile @ 1x10-5, max ≤ 1x10-4)
4. Incentivize early action (legal instrument to get credit as part of the allocation process)

Group III (word doc)

1. Provide additional resources to help EPA RPMS to do their jobs
   - Pilot Test the Use of a Licensed Site Professional at a Superfund Site to expedite cleanup
   - Include a quantitative measure of the success of this "privatization"
   - Decrease case load
   - Engage trustees throughout the process
   - Provide facilitators as needed
   - Increase training, mentoring, and access to experts to help regulators understand complicated scientific/engineering concepts so they are more comfortable implementing them; for example:
     - Probabilistic Risk Assessment
     - Risk Communication
     - Innovative Technologies
2. Encourage thorough pre- as well as post-remediation monitoring
   - Biotic (fish tissue, benthic invertebrates, etc.)
   - Abiotic, Multiple media (sediment, pore water, surface water, etc)
   - Sufficient statistical power to assess change
   - Differentiate Results of Active Remediation from Natural Processes
3. Establish a work group to champion adaptive management as the default approach to cleanup sites
   - Work with CSTAG
   - Encourage interim RODs
   - Non-numeric PRGs with appropriate methods of monitoring success
   - Regulatory "off ramp" to stop spending money refining details that don't inform the remedial decision. Examples:

   - Fine-tuning risk assessment assumptions,
   - Redundant fate and transport modeling
   - Adding target analytes
   - Duplicative site characterization, etc.
4. Encourage the Implementation of Cost-Sharing Opportunities to Speed up the RI/FS/Cleanup Process – Avoid CERCLA
   - Modeled on WRDA and GLNPO private-public partnerships
   - Compile case studies of where it has worked and not worked
   - Remove barriers to access to dispute resolution
   - Provide forum (facilitated discussions) to discuss possibilities and find common ground.
   - Pilot test this model at a Large Scale (watershed based) RI/FS
     - Include private and public funding
     - Quantify if (or how) this approach is more effective than conventional site-based cleanups
     - Candidate sites might include: Delaware River, Hackensack

Group IV (ppt)

1. Risk assessment process and communication of risk to public create unrealistic expectations (translation of what risk reduction is possible); e.g. 10-4 to 10-6 cancer and HI <1; a big part of the issue is the high uncertainty within the process of assessing the connection between contaminants in sediment and fish
   a. Understanding fish behavior in relation to the sediments at the site
   b. Understanding the proportion of residue in fish from site sediments
   c. Understanding the human populations we are trying to protect
2. Contextualizing statements of risk (benzene exposure from drinking water v. pumping gas)
   a. Creating a multi-stakeholder vision for the site early in the process
   b. Watershed and multi-disciplinary projects or project teams to build a wholistic picture of what is happening in the watershed so you can determine the effect from a given project
   c. Utilizing tools to reduce uncertainties in data collection (e.g. stable isotopes, passive samplers) and standardizing methods for data collection for sediments à fish à humans
   d. Utilize adaptive management to create and iterative process to test hypotheses; it is critical to define the framework for the process prior to beginning

3. Review case studies to compile "lessons learned" – were all data generated used to make remedial decisions? Were all data necessary? Were resources spent wisely?
   a. Developing a better understanding of the lower trophic level, base of the food web processes
   b. Review current, linear process (read and understand the goals before following the recipe)

Group V (ppt)

1. Decision Analysis Framework to Support Uncertainty Analysis of Remedy and Costs
   Problem:
   - Where does cost effectiveness weigh in? Cost effectiveness is a modifying factor and should be proportional to overall effectiveness
     - Technical basis how to cost effectively implement risk management option
     - SWAC versus RAL

- What is the cost for a unit of risk reduction
- Source control in an early action…

Solution:

- Develop a technical guidance/decision analysis tools and implementation how uncertainty when evaluating remedial options can better inform considerations of cost effectiveness in remediation decision making
- All of this needs to be done before a ROD

Application:

- Decision analysis tools to encourage remedy decisions within an adaptive management framework; could increase cost effectiveness

2. Communicating and Managing Expectations with Public

Problem:

- Modeling the uncertainty of how fish respond to remediation.
- What are the limitations of the remedy?
- How is this communicated? A range of outcomes based on different alternatives; how to deal with overlapping outcomes.
- How to set expectations? Is this an opportunity to develop interim risk targets?

Solution:

- Guidance for communicating expectations of what the remedy may achieve and over what timeframe
- For example, model uncertainty of how fish respond to remedy and contributions from other sources (the remedy may only go so far)

Application:

- Communicate complex situations/models in a very simple way with public
- All of this needs to be before ROD

Group 1 - Breakout 3

Todd Bridges (facilitator)
John Toll (note taker)
Karl Gustavson
Jeff Stern
Will Gala
Steve Nadeau
Jack Zabik
Barry Kelly
Gui Lotufo
Barrie Selcoe

Session 3: Risk Management

1. What are the most consequential uncertainties related to fish-sediment for risk management and decision-making?
    a. Ultraconservative treatment of consumption rate and EPCs
    b. Failure to apply risk management principles
    c. Uncertainty about remedy effectiveness at reducing risk, relationship between volume and risk reduction

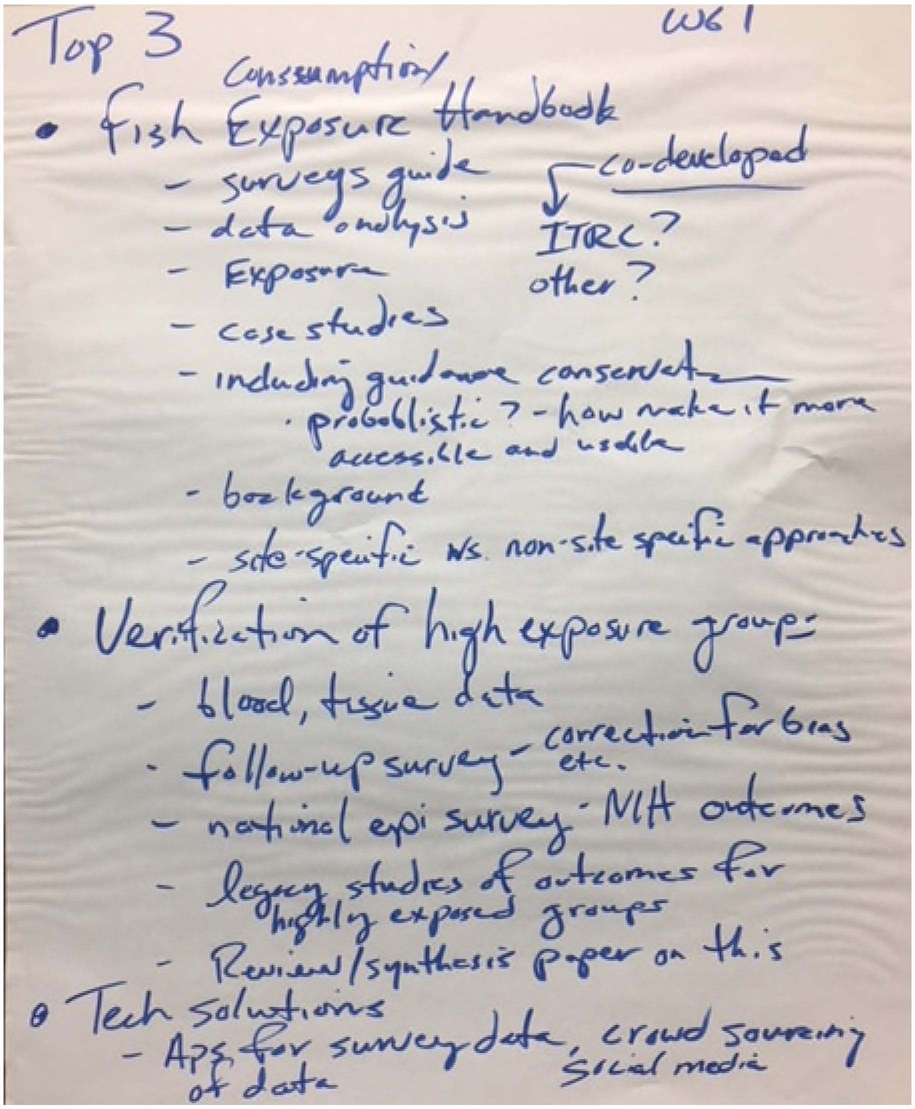
    d. Consequences of failing to explain clearly the uncertain range of consequences of actions.
    e. *Post hoc* acceptability of performance criteria
    f. Lack of connection between implicit/explicit decision-making objectives and metrics
    g. Uncertainty about how to compare risks that should factor into decisions
2. What are the best or most promising opportunities for addressing or managing uncertainties in fish-sediment processes related to remedy selection and long-term site management?
    a. Clear guidance on fish consumption assumptions, accountability for RPMs
    b. Reinforce risk management principles – should require explanation of how applied
    c. Focus evaluation and decision-making on distinguishing alternatives
    d. Incentivize science and data collection by reducing uncertainty factors as you gain more information
    e. Analyze the decision-making difference between most likely and extreme cases
    f. Describe the uncertainty around the toxicity endpoint
    g. Admit the difference between measurement and assessment endpoints
    h. Understand the CSM
    i. Least costly environmentally acceptable option, including risk of remedy
    j. Before/after monitoring
    k. Create incentives for low-cost early action/incentive post-remediation monitoring
    l. Studies describing the actual exposure media and pathways at the base of the food chain
    m. Studies to debunk bad practices (e.g., BSAFs)
    n. Studies to validate models' ability to predict conditions post-remedy and understand prediction errors
    o. More passive sampling for getting relevant water exposure data
3. What are the most important studies (e.g., literature-based, laboratory, field) that could be performed to advance risk management practice related to fish-sediment processes? Cleanup??
    a. Studies to show the use of balancing and modifying criteria (social and decision science)
    b. Clarify the real policy objectives that Superfund is being used to advance
    c. Case study compilation – go back and get data where that would help close the book on case studies
    d. Checklist for applying risk management principles
    e. Evaluate alternative compensatory mitigation measures
        i. Fish swap/exchange
        ii. Compensatory restoration (TX model)
        iii. Redirect human use
    f. Mesocosm studies of fish remediation effectiveness
    g. Retrospective analysis of projects (e.g., Ackerman, Uncertain Search for Environmental Quality)
    h. Decision and communication science research on Superfund
    i. Grand challenge research focused on one watershed/project, e.g., Baltimore Harbor or San Diego Bay

Top 3

1. Facilitate and truly incentivize early actions with monitoring to elucidate cause and effect

2. Studies to advance understanding of factors affecting the relationship between action and fish concentration
    a. Mesocosm and field studies
    b. Case study compilation
3. Develop a Superfund analog to Corps federal standard least costly environmentally acceptable alternative

Third party FS's was an idea that was discussed but not fully fleshed out.



Group 2 - Breakout 3

Notes for SMWG Breakout Session 3 - Risk Management

(Group 2 – Betsy Ruffle facilitator)

Uncertainty

1) Understanding and accounting for effect of non-site (background) sources on fish concentrations
2) Understanding source of fish exposures and which parts of the site (and surroundings) are the most important contributors to exposure
    a. Role of sediment-water-diet components in determining the fish body burden
3) Establishing a link between site sediment concentrations and fish body burden
4) Effectiveness of remedy on reducing fish tissue concentrations

Opportunities

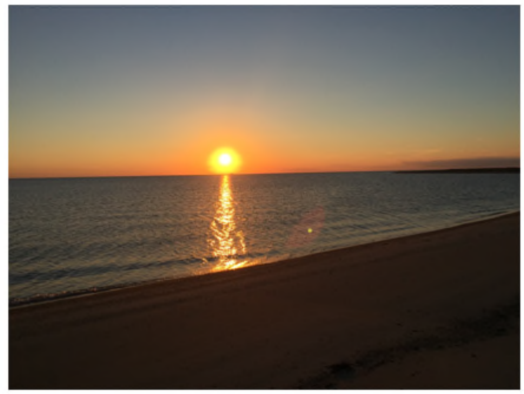
1) Better management of expectations and outcomes at beginning of RI/FS process
    a. On what expectations are we focusing?
        i. Achieving a specific risk threshold
        ii. Achieving a change in the number of meals that can be consumed
        iii. Documenting a reduction in chemical concentration in fish
2) Inconsistency in risk management goals applied across the country
3) Use of distributions to present risk results
    a. discretization can be very informative (risk expressed as number of meals per specific time period (1 per month, one per week, two per week, on per day))
4) During RI/FS, convey key assumptions and uncertainties to risk manager
5) Linking risk percentiles to acceptable risk levels

Study Ideas

1) Review of RAOs, PRGs, RALs at sites
    a. Sediment and fish values (PCBs, pesticides, Hg, TCDD)
        i. Post-remedy monitoring data
        ii. Modeled results for validation with empirical data
2) Incorporate early actions with ongoing remedial site investigation that includes evaluation of effectiveness of early action
    a. establish trends and relationships
    b. adaptive management
3) National policy linking risk distribution percentiles/metrics with acceptable risk targets e.g., mean @ $1x10^{-6}$, 90^{th}%ile @ $1x10^{-5}$, max ≤ $1x10^{-4}$

Group 2: Risk Management: Big Ideas

1. Review of RAOs, PRGs, RALs at sites
   - Sediment and fish values (PCBs, pesticides, Hg, TCDD)
   - Post-remedy monitoring data
   - Modeled results for validation with empirical data
2. Incorporate early actions with ongoing remedial site investigation that includes evaluation of effectiveness of early action
   - establish trends and relationships
   - adaptive management
3. National policy linking risk distribution percentiles/metrics with acceptable risk targets
   - (e.g. mean @ 1x10-6, 90th%ile @ 1x10-5, max ≤ 1x10-4)



Group 3 - Breakout 3

9. Most consequential CHALLENGES in site assessments related to risk management:

   - Decision making in face of uncertainty. All the more advanced analyses go in the uncertainty section, where they are ignored?
   - When do you stop spending money on risk assessments? If you calculate a risk-based level that is lower than background?
   - How do you explain feasibility and technology limitations to the general public?
   - Lack of comfort by regulators regarding a given measurement or technique or analysis, etc. leads to falling back on conservative assumptions and practices.
   - Lack of uniformity from one regulatory body (or regulator) to another
   - Different risk tolerance by different stakeholders
   - We are cleaning up the sediment (not the fish), but the fish are what we are worried about. So how do you set a PRG for sediment?
   - What is the quantitative relationship between contaminant levels in environment and in the fish.
   - How do you fit better check-system (adaptive management) into the process so that people are comfortable making decisions. Not do-or-die. Need ability to make a decision and have the chance to update it.

- Problem of scale. We are not capturing the whole picture. Partly it is because the fish migrate out of the Site. But even without that problem, there are other uncertainties. Remediation will not necessarily produce the result you expect.

- EPA RPMs need better salary and resources to attract better people and retain them so things can move forward.

10. What are the most promising opportunities for improving practice related to risk management?

    - Need guidance that lays out how to establish clean-up goals relating fish to sediment – process for how to develop a sediment PRG that is informed by fish goals (Similar to EPA document on PRGs from pore water). It's going to be site-specific, but laying out a process would be useful.

    - One solution to uncertainty could be elevating the importance of adaptive management for all stakeholders. Adaptive management should become the default. However lots of people are uncomfortable with the idea of not having a ROD. PRPs, trustees, regulators all have to be comfortable.

    - We are moving towards interim RODs. Pre-emptive remediation of something. Community sees something – positive response. EPA can point to progress; however there is a fear that it's a way to get away with doing less. Perceived to short-circuit the system. Although sometimes they are more aggressive in removing source material, and see if we can demonstrate improvements.

    - Maybe PRG could be set based on practical criteria. At Barry's creek they are doing work and looking at proportional reduction in impacts to fish and birds. Look at the endpoints that demonstrate success. Might complete cleanup without every having a numerical PRG.

    - Depends on the receptiveness of regulators. Even if they are contributing money, need to be comfortable.

    - Could PRG be defined as addressing a certain % of the total contaminant mass. Set up a timeline with goals similar to % risk reduction or % concentration and demonstrate success by meeting these goals.

    - Remember CERCLA is supposed to look at cost effectiveness. Need some sort of guidance on cost-benefit analysis. Incorporate risk of the remedy (e.g. destroying habitat). If you look at surface-acre years, much less cost to leave the contaminants there then to destroy the whole thing.

    - If you can talk about number of trees cut down and other human costs (flood protection), then people may be better able to understand the trade-offs.

    - How do we effectively communicate the fish advisories? That's what long-term goals depend on. But those highly-exposed groups ignore them. But all remedies rely on advisories until they are complete.

    - We see remedial actions in the form of removal, not necessarily tied to goals. Note that some of these interim actions are cast as source control.

- Make sure cost benefits analysis includes:
    - Dollars
    - Environmental (Habitat)
    - Recreation, View

11. What are the most important studies related to risk management of fish-sediment processes or cleanups?

- Develop Guidance on what to do when calculated fish consumption rate is not sustainable in the water body.

- How do you even calculate what production/consumption rate is sustainable?

- Use probabilistic approaches in addition to determinate approaches. Provide user-friendly training to EPA?

- Living Document to review successful vs. unsuccessful cleanups and learn what works.
- There are examples where public money is involved and things move forward much more quickly. Could we use the GLNPO example for other areas.

- EPA or USACE could contribute money towards a pilot study and then PRP might be more amenable. Works both ways.

- Attempt a Large Scale (watershed based) RI/FS with private-public funding to see if (or how) this approach is more effective than conventional site-based cleanups.

- Retrospective review of public-private vs. single payer vs. multi-PRP cleanups and see what works best under what circumstances. Demonstrate how dysfunctional the CERCLA process is currently.

- Is there legal jepordy for EPA if they approve a public-payed cleanup that is only 10% as aggressive as what they would require from a private PRP? Note that there is an example of an orphan site where this may have happened. Could be considered arbitrary and capricious – from either side of the fence, but it is hard to win one of these cases. Needs to be a clear violation.

- Require sufficient pre- as well as post-remediation monitoring with sufficient statistical power.

Provide Additional Resources for EPA RPMs to Succeed in Their Jobs;

- Pilot Test the Use of a Licensed Site Professional at a Superfund Site to expedite cleanup
    - Include a quantitative measure of the success of this “privatization”
- Decrease case load
- Engage trustees throughout the process
    - Provide facilitators as needed

- Increase training, mentoring, and access to experts to help regulators understand complicated scientific/engineering concepts so they are more comfortable implementing them; for example:
    - Probabilistic Risk Assessment
    - Risk Communication
    - Innovative Technologies

Encourage thorough pre- as well as post-remediation monitoring

- Biotic (fish tissue, benthic invertebrates, etc.)
- Abiotic, Multiple media (sediment, pore water, surface water, etc)
- Sufficient statistical power to assess change
- Differentiate Results of Active Remediation from Natural Processes

Establish a Work Group to Champion Adaptive Management as the Default Approach to Cleanup Sites

- Work with CSTAG
- Encourage interim RODs
- Non-numeric PRGs with appropriate methods of monitoring success
- Regulatory "off ramp" to stop spending money refining details that don't inform the remedial decision. Examples:
    - Fine-tuning risk assessment assumptions,
    - Redundant fate and transport modeling
    - Adding target analytes
    - Duplicative site characterization, etc.

Encourage the Implementation of Cost-Sharing Opportunities to Speed up the RI/FS/Cleanup Process – Avoid CERCLA

- Modeled on WRDA and GLNPO private-public partnerships
- Compile case studies of where it has worked and not worked
- Remove barriers to access to dispute resolution

- Provide forum (facilitated discussions) to discuss possibilities and find common ground.
- Pilot test this model at a Large Scale (watershed based) RI/FS
  - Include private and public funding
  - Quantify if (or how) this approach is more effective than conventional site-based cleanups

Candidate sites might include: Delaware River, Hackensack

Group 4 - Breakout 3

Big 3 Ideas for Risk Management

1. Risk assessment process and communication of risk to public create unrealistic expectations (translation of what risk reduction is possible); e.g. 10-4 to 10-6 cancer and HI <1; a big part of the issue is the high uncertainty within the process of assessing the connection between contaminants in sediment and fish
   a) Understanding fish behavior in relation to the sediments at the site
   b) Understanding the proportion of residue in fish from site sediments
   c) Understanding the human populations we are trying to protect

2. Contextualizing statements of risk (benzene exposure from drinking water v. pumping gas);
   a) Creating a multi-stakeholder vision for the site early in the process
   b) Watershed and multi-disciplinary projects or project teams to build a wholistic picture of what is happening in the watershed so you can determine the effect from a given project
   c) Utilizing tools to reduce uncertainties in data collection (e.g. stable isotopes, passive samplers) and standardizing methods for data collection for sediments à fish à humans
   d) Utilize adaptive management to create and iterative process to test hypotheses; it is critical to define the framework for the process prior to beginning

3. Review case studies to compile “lessons learned” – were all data generated used to make remedial decisions? Were all data necessary? Were resources spent wisely?
   a) Developing a better understanding of the lower trophic level, base of the food web processes
   b) Review current, linear process (read and understand the goals before following the recipe)

Group 5 - Breakout 3

Project 1: Decision Analysis Framework to Support Uncertainty Analysis of Remedy and Costs

Problem:

- Where does cost effectiveness weigh in? Cost effectiveness is a balancing factor and should be proportional to overall effectiveness
  - Technical basis how to cost effectively implement risk management option
  - SWAC versus RAL
  - What is the cost for a unit of risk reduction
  - Is there a “default” uncertainty bound that modelers could develop for models that are used in decision making?

Solution:

- Develop a technical guidance/decision analysis tools and implementation how uncertainty when evaluating remedial options can better inform considerations of cost effectiveness in remediation decision making
- All of this needs to be done before a ROD

Application:

- Decision analysis tools to encourage remedy decisions within an adaptive management framework; could increase cost effectiveness

Project 2: Communicating and Managing Expectations with Public

Problem:

- Modeling the uncertainty of how fish respond to remediation.
- What are the limitations of the remedy?
- How is this communicated? A range of outcomes based on different alternatives; how to deal with overlapping outcomes.
- How to set expectations? Is this an opportunity to develop interim risk targets?

Solution:

- Guidance for communicating expectations of what the remedy may achieve and over what timeframe
- For example, model uncertainty of how fish respond to remedy and contributions from other sources (the remedy may only go so far)

Application:

- Communicate complex situations/models in a very simple way with public
- All of this needs to be before ROD

Other Considerations

Changing the goal

- A significant change to our CSM (i.e., changes in our understanding of fate and transport, modeling, contributions from other sources, fish consumption) may result in changing the goal
- What opportunities are there to revisit a goal; one that might not be attainable may require a change

Spatial Extent of Remedy

- Remedy goal may exceed the bounds of what the remedy could possibly achieve
- May suggest the goal is unattainable

Uncertainties Related to Risk Management and Decision Making

- Risks of remedy, risks of operation itself versus habitat loss and mitigation requirements
- How to set expectations? Interim risk targets
- Are we protective with institutional controls?
    - Don't enforce institutional controls
    - Restrict access, fencing, security
    - No set guidance for fish advisories
- What will source control look like with a given remedy? What are the expectations; continuous improvement. Remedy might be part of the solution but there are other factors (CSO).
    - Communication to the public as soon as possible so expectations can be managed.
- Frame site risk goals relative to the state averages
- Lack of comfort with risk of "threat"
- Back calculate bioaccumulation to sediment concentrations? Will fish tissue concentrations meet goals as measured in sediment?
- Modeling the uncertainty of how fish respond to remediation. This needs to be communicated to risk managers. A range of outcomes based on different alternatives; how to deal with overlapping outcomes.
    - Problem with application of probabilistic approaches
- Where does cost effectiveness weigh in? Is it a modifying factor? "Cost should be proportional to overall effectiveness"
    - Do we need a framework for this?
    - Technical basis how to cost effectively implement risk management option
    - SWAC versus RAL; isolate all activities in decision-making; can't eliminate politics
    - What is the cost for a unit of risk reduction
    - Source control in an early action…

Uncertainties

- Early action to reduce some level of risk reduction
    - Ending an area and have to come back to an area; how many times do we have to come back? Potential buy out – unconditional release
    - Several of these are enforcement related issues.
    - Perception issues are always getting in way of "sound issues"; have to get to resolution as soon as possible
    - Can we test and recalibrate models using data form early action?
- Once we collect more information, can be based on future models; models should be evaluated based on outcome?
    - Why is model not predicting/matching the measured outcome; an opportunity to learn about model or system?
- Adaptive management: modifying the goal, BG may go down, slope may change; cleanup
- Use passive samplers as a goal as opposed to fish/sediment?
    - Organism interaction with sediment may be different from freely dissolved concentration in water
    - Always uncertainty about what the remedy will achieve and whether it will meet cleanup goals?

Attachment 6

List of Identified Projects

LIST OF IDENTIFIED PROJECTS & PRIORITIZATION		
Work Groups - Fish Biology & Bioaccumulation		
Fish Exposure Handbook & Workgroup (can include food web model guidance)	**Post-audit retrospective for model validation**	**Stable isotopes review**
Total 1 & 2 Votes: 18 **Total All Votes: 22**	**Total 1 & 2 Votes: 9** **Total All Votes: 14**	**Total 1 & 2 Votes: 9** **Total All Votes: 13**
Todd Bridges	Trina von Stackelberg	Miranda Henning
Jim Meador	Deb Edwards	Susan Kane Driscoll
Jack Zabik	Barry Kelly	Gary Buchanan
Sarah Greenfield	Laura McWilliams	John Wolfe
Tim Bingman	John Connolly	Steve Brown
Paul Montney	Paul Schroeder	Phil Gidley
David Moore	Paul Anderson	Lisa Williams
Betsy Ruffle	Ralph Stahl	Steve Peterson
Russ Keenan	Will Gala	David Smith
Bob Wyatt	Gui Lotufo	Jeff Steevens
Eric Blischke	Jeff Stern	Doug Tomchuk
Stephanie Barczyk	John Toll	
Karl Gustavson	Rick Fox	
John Cargill	Larry Burkhardt	
Barrie Selcoe	Mark Greenberg	
Work Groups - Exposure & Fish Consumption		
Fish Consumption Exposure Guidance	**Review on use of fish tissue concentration as metric for remedy monitoring**	**Meta-analysis on fish consumption & human contaminant levels**
Total 1 & 2 Votes: 12 **Total All Votes: 20**	**Total 1 & 2 Votes: 12** **Total All Votes: 16**	**Total 1 & 2 Votes: 7** **Total All Votes: 13**
Steve Brown	Laura McWilliams	Russ Keenan
Todd Bridges	Jim Meador	Barry Kelly
David Moore	John Connolly	John Toll
Ralph Stahl	John Cargill	Miranda Henning
Debra Williston	Eric Blischke	Paul Montney
Philip Gidley	Gui Lotufo	Trina von Stackelberg
Jeff Stern	Karl Gustavson	Jim Meador
Paul Anderson	Rick Fox	Paul Schroeder
Deb Edwards	Sarah Greenfield	John Wolfe
Doug Tomchuk	Jack Zabik	Tim Bingman
Stephanie Barczyk	Will Gala	Betsy Ruffle
Barrie Selcoe	John Wolfe	Gary A. Buchanan
	Mark Greenberg	

Work Groups - Risk Management and Decision-Making		
Form adaptive management workgroup	**Incentivize early action with monitoring and legal credit**	**Decision analysis framework to support uncertainty analysis in remedy and cost**
Total 1 & 2 Votes: 9 **Total All Votes: 19**	**Total 1 & 2 Votes: 9** **Total All Votes: 14**	**Total 1 & 2 Votes: 8** **Total All Votes: 12**
Todd Bridges - 1	Laura McWilliams - 1	David Moore - 1
Ralph Stahl - 1	Tim Bingman - 1	Eric Blischke - 1
Jack Zabik -1	John Cargill - 1	Gui Lotufo - 1
Betsy Ruffle -1	Gary A. Buchanan - 1	
Russ Keenan -1	Will Gala - 1	Deb Edwards - 2
	Stephanie Barczyk - 1	Todd Bridges - 2
Miranda Henning - 2	Jeff Stern - 1	Paul Montney - 2
John Cargill - 2		Steve Brown -2
Eric Blischke - 2	Sarah Greenfield - 2	Paul Schroeder - 2
Jeff Stern - 2	John Wolfe - 2	
		Laura McWilliams - 3
John Connolly - 3	Russ Keenan - 3	Sarah Greenfield - 3
David Moore - 3	Philip Gidley - 3	Betsy Ruffle -3
Tim Bingman - 3	Barry Kelly - 3	Paul Anderson - 3
Paul Montney - 3	Eric Blischke - 3	
John Wolfe - 3		
Gary A. Buchanan - 3	John Toll (did not rank by priority)	
Will Gala - 3		
Gui Lotufo - 3		
Stephanie Barczyk - 3		
John Toll (did not rank by priority)		