Risk-Based Management of Contaminated Sediment

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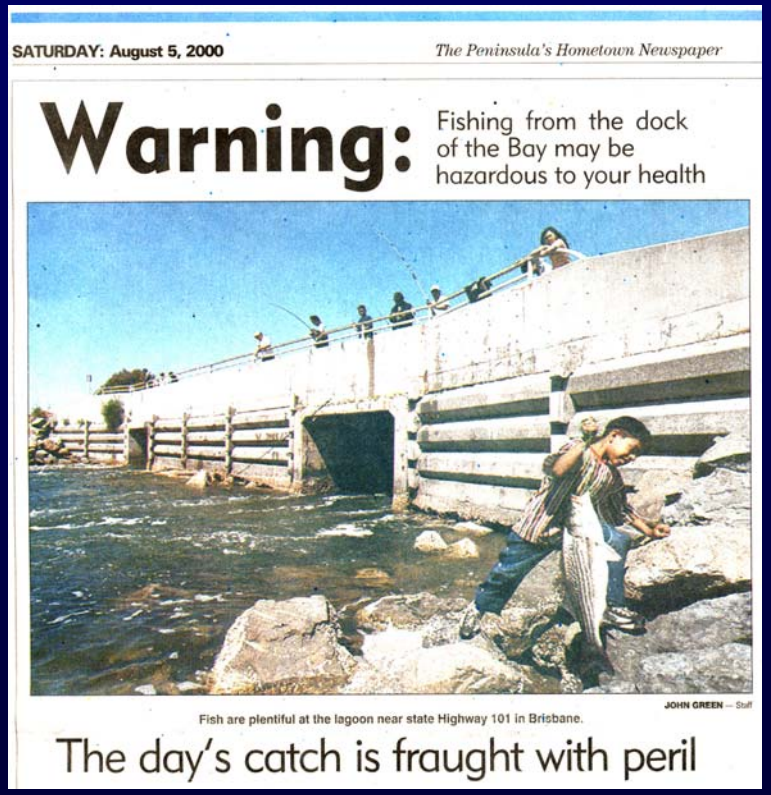
Contaminated Sediment Topics

- Sediments matter
- ERDC activities
- Risk Analysis
  - Risk Assessment
    - Exposure processes
    - Effects processes
  - Risk Management
    - Comparing remedies and making decisions
  - Risk Communication
    - Mental modeling

Scope of the Sediment "Problem"

- EPA 1997 sediment survey report concludes 1.2 billion yd^3 surficial sediment "pose potential risks"
- Cleanup programs
  - ~350 sediment sites in Superfund
    - ~ 30 megasites (> $50M)
- TMDL program includes numerous sediment issues
- Navigation dredging



SATURDAY: August 5, 2000 — *The Peninsula's Hometown Newspaper*

Warning: Fishing from the dock of the Bay may be hazardous to your health

Fish are plentiful at the lagoon near state Highway 101 in Brisbane. JOHN GREEN — Staff

The day's catch is fraught with peril

What is a “risk-based” decision?

- Three principles of risk-based decision making
  - Adverse conditions are driven by site-specific conditions and processes
  - Uncertainties can be reduced, but not eliminated
  - Risks are managed, not eliminated

T. S. Bridges, S. E. Apitz, L. Evison, K. Keckler, M. Logan, S. Nadeau, R. J. Wenning. 2006. Risk-based decision making to manage contaminated sediments. *Integrated Environmental Assessment and Management* 2:51-58.

Dredging Operations Environmental Research (DOER)

Focus Areas

- Operations Technologies
  - Mr. Tim Welp
- Environmental Resource Protection
  - Dr. Doug Clarke
- Dredged Material Management
  - Dr. Joe Gailani
- Risk
  - Dr. Todd Bridges

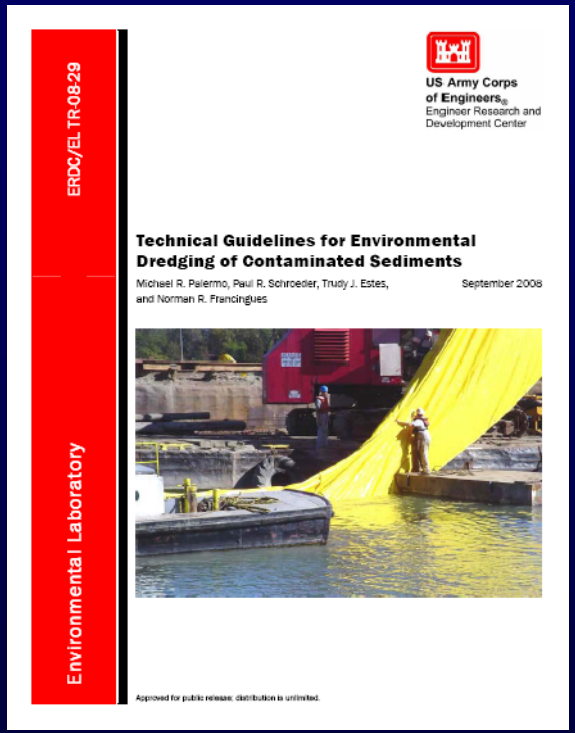
www.wes.army.mil/el/dots/doer

Risk-Related DOER Projects

- Exposure assessment methods and approaches
  - Assessing and Managing Contaminant Losses During Dredging
  - Effects of Bioturbation on Contaminant Transport and Availability
  - Simulating Contaminant Release, Transport, and Fate from Dredging Operations
  - Improved Contaminant Bioaccumulation and Exposure Modeling
  - Development of Sediment Bioaccumulation tests Using the Amphipod *Leptocheirus plumulosus*
- Effects assessment procedures and tools
  - Use of Surrogate Devices for Assessing the Bioavailability and Toxicity of Organic Compounds in Dredged Material
  - Miniaturizing Toxicity Tests for Cost and Time Optimization
- Risk management in the dredging program
  - Review and Assessment of Sediment Treatment Technologies
  - Verification/Comparison of Cap Effectiveness Models

ERDC Support to EPA and Others

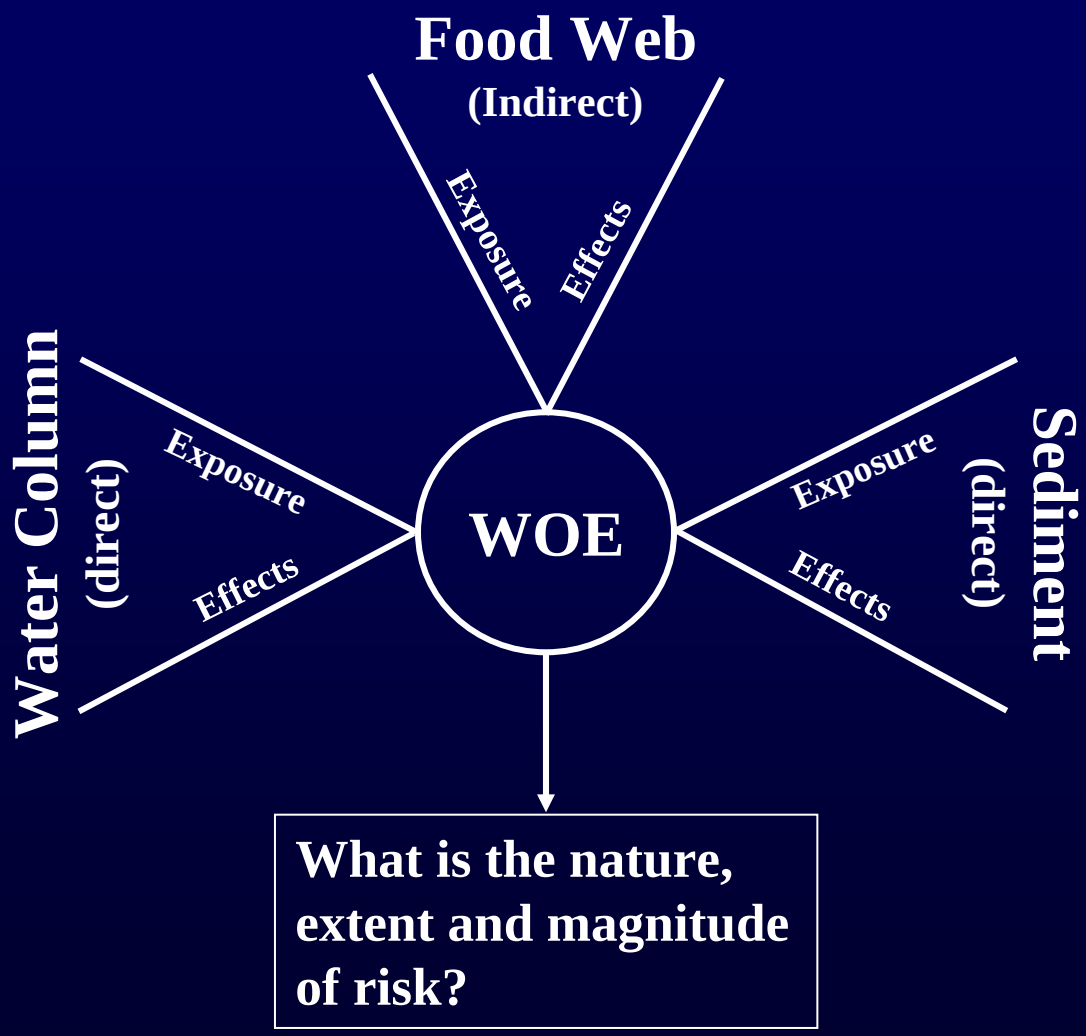
- R&D support to OSRTI
  - Technical Guidelines
    - Environmental Dredging
    - Update for capping
  - Research projects
    - Recreational prop wash
    - Cap amendment injection
    - Physical stability of mixed-grain caps
  - Training
- Support to EPA Regions
  - Through Superfund Sediment Resource Center
  - Through IAG with Regions



Sites where ERDC has provided Support

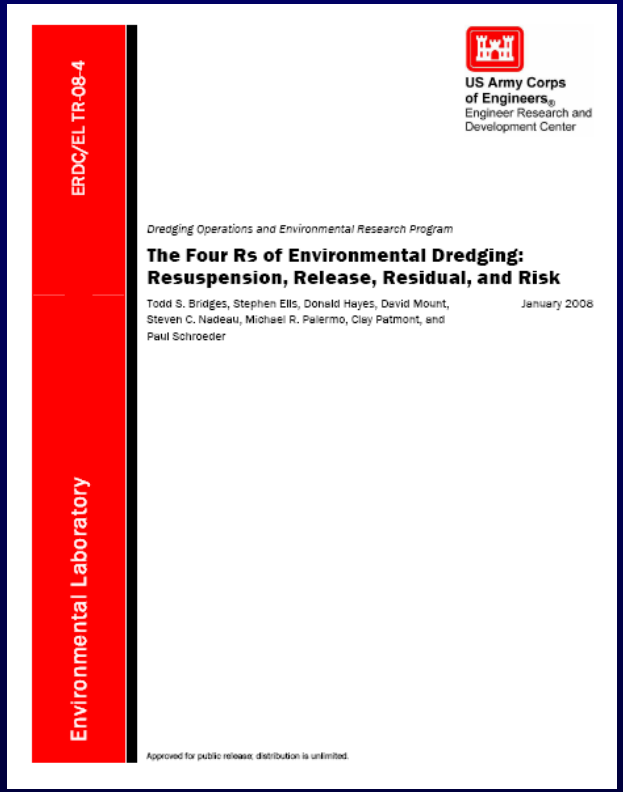
- Hudson River, NY
- Grasse River, NY
- Passaic, River, NY
- New Bedford Harbor, MA
- Housatonic River, MA
- Fox, River, WI
- Upper Columbia River, WA
- Duwamish River, WA
- Portland Harbor, OR
- Palos Verdes Shelf, CA
- United Heckathorn, CA
- Hunters Point, CA
- Many Others

Lines and Weight of Evidence in Sediment Assessment

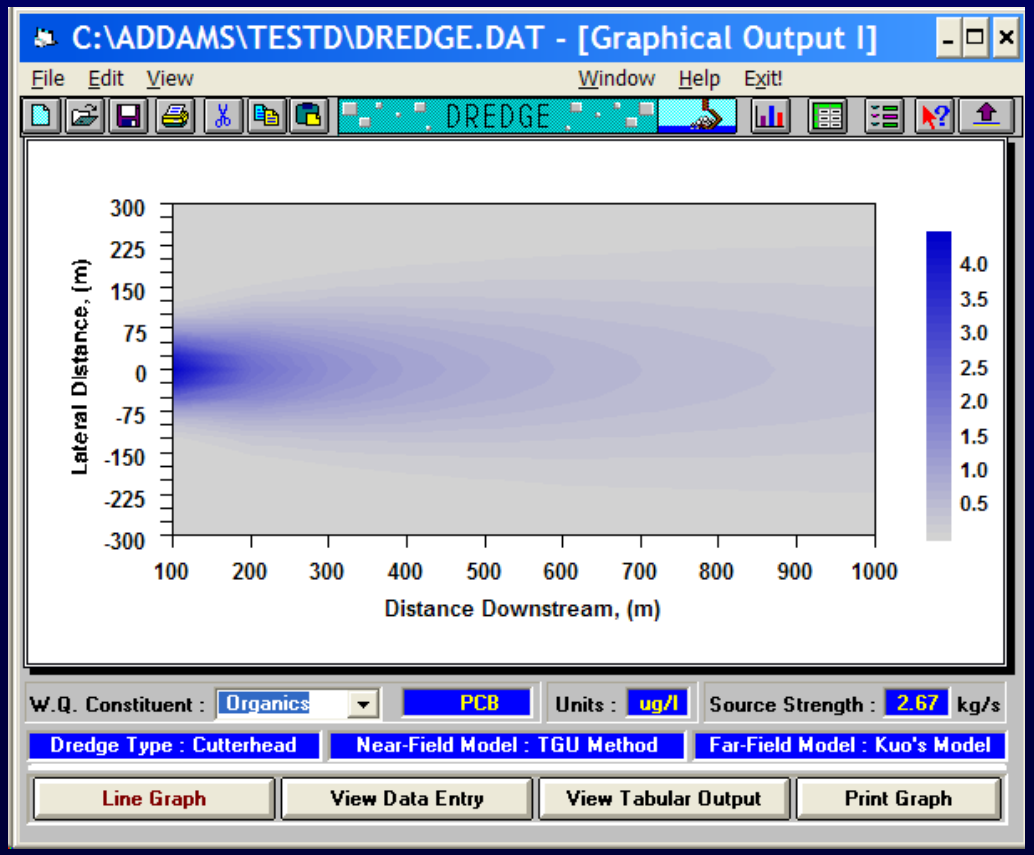


ERDC Sediment Exposure Models

- Sediment transport processes- erosion, transport, deposition
  - PTM - Particle Tracking Model
- Mixing Models for Water Quality and Toxicity Evaluations
  - DREDGE - continuous resuspension
  - CDFATE / CORMIX - continuous discharge
  - STFATE - discrete discharges
- Releases from Bedded Sediment and Residuals
  - RECOVERY
  - CAP

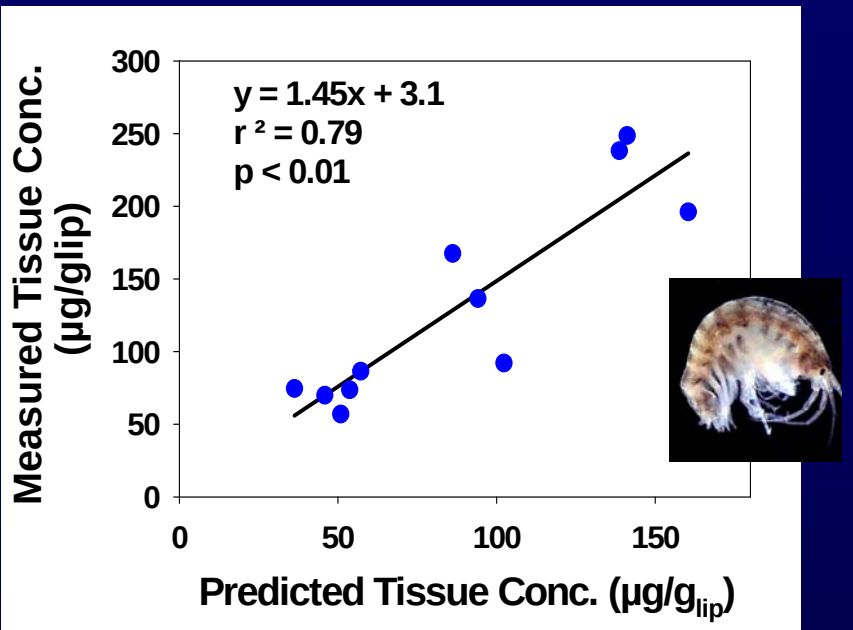


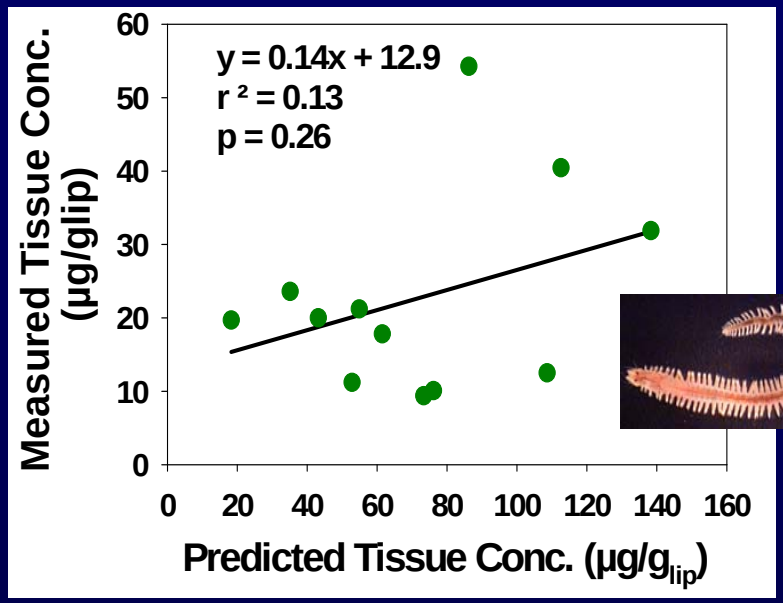
DREDGE

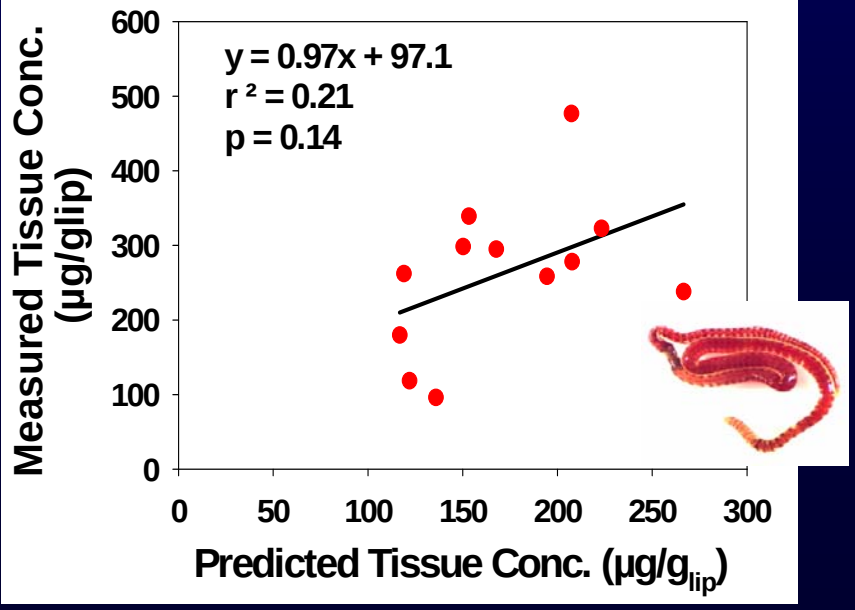


Prediction of Sediment Resuspension and Contaminant Release by Dredging

SPME-predicted vs Measured Tissue Conc.: SumPCBs



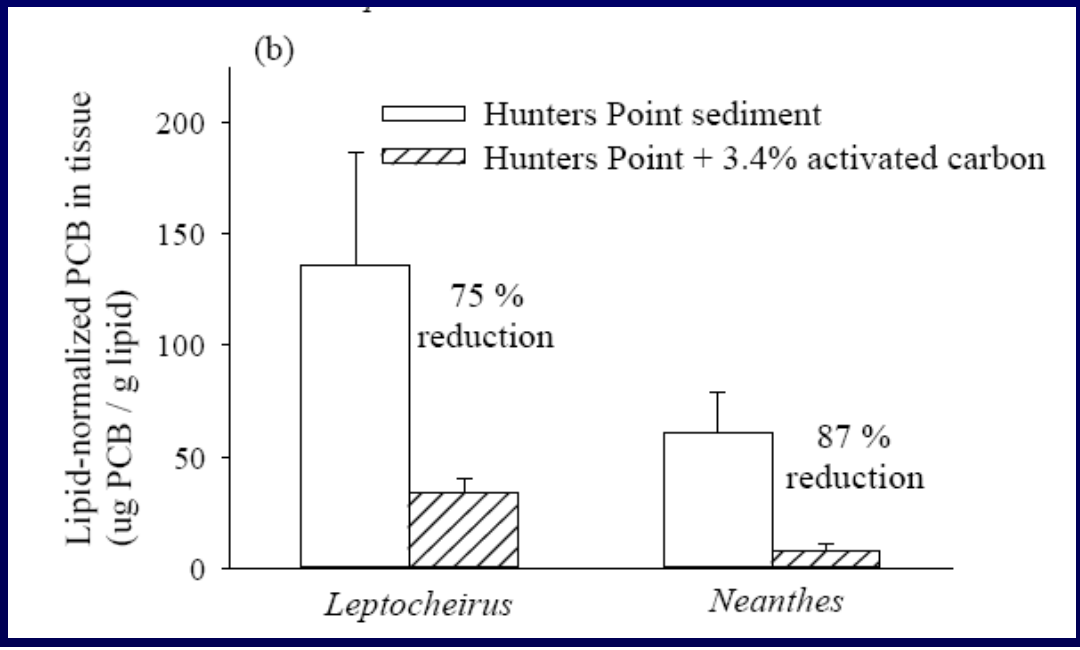


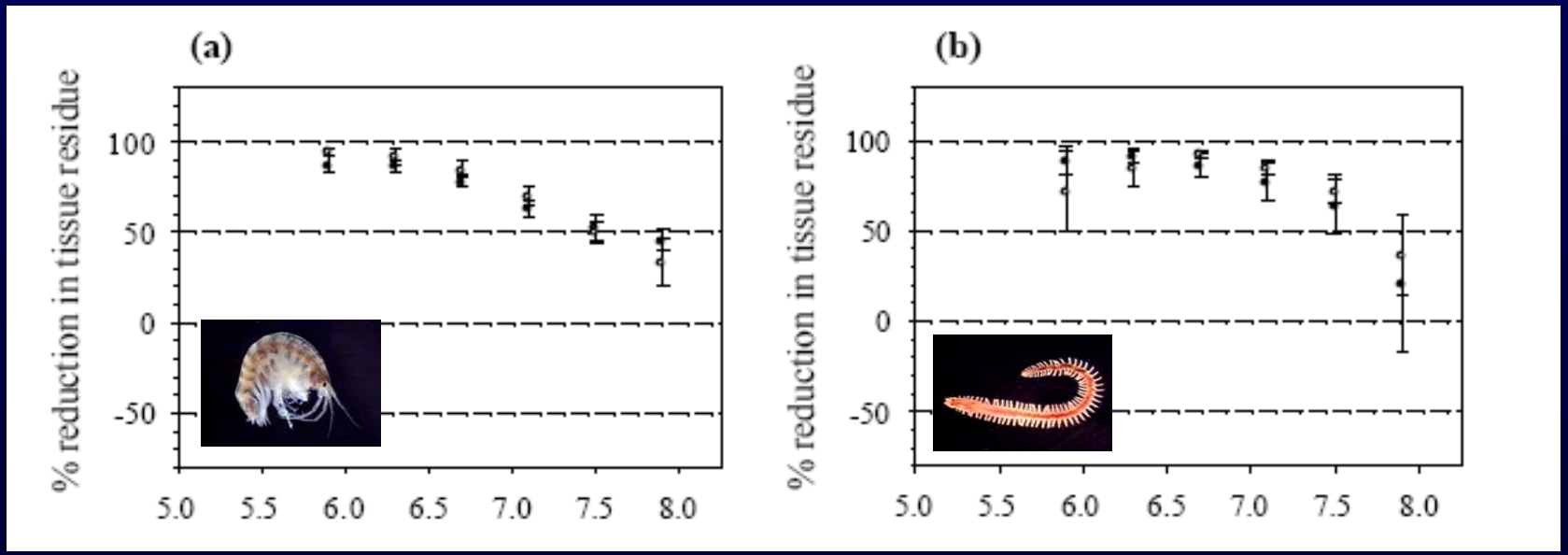


Major species-specific differences.

- Great correlation for *Leptocheirus.*
- Good correlation for *Lumbriculus* when all congener data was used (not shown).
- Poor correlations for *Neanthes*

Measuring the effect of activated carbon on PCB bioavailability and bioaccumulation





R. N. Millward, T. S. Bridges, U. Ghosh, R. J. R. Zimmerman ,G. Luthy,. 2005. Addition of activated carbon to reduce PCB bioaccumulation by a polychaete (*Neanthes arenaceodentata*) and an amphipod (*Leptocheirus plumulosus*). *Environmental Science and Technology* 39:2880-2887.

TrophicTrace

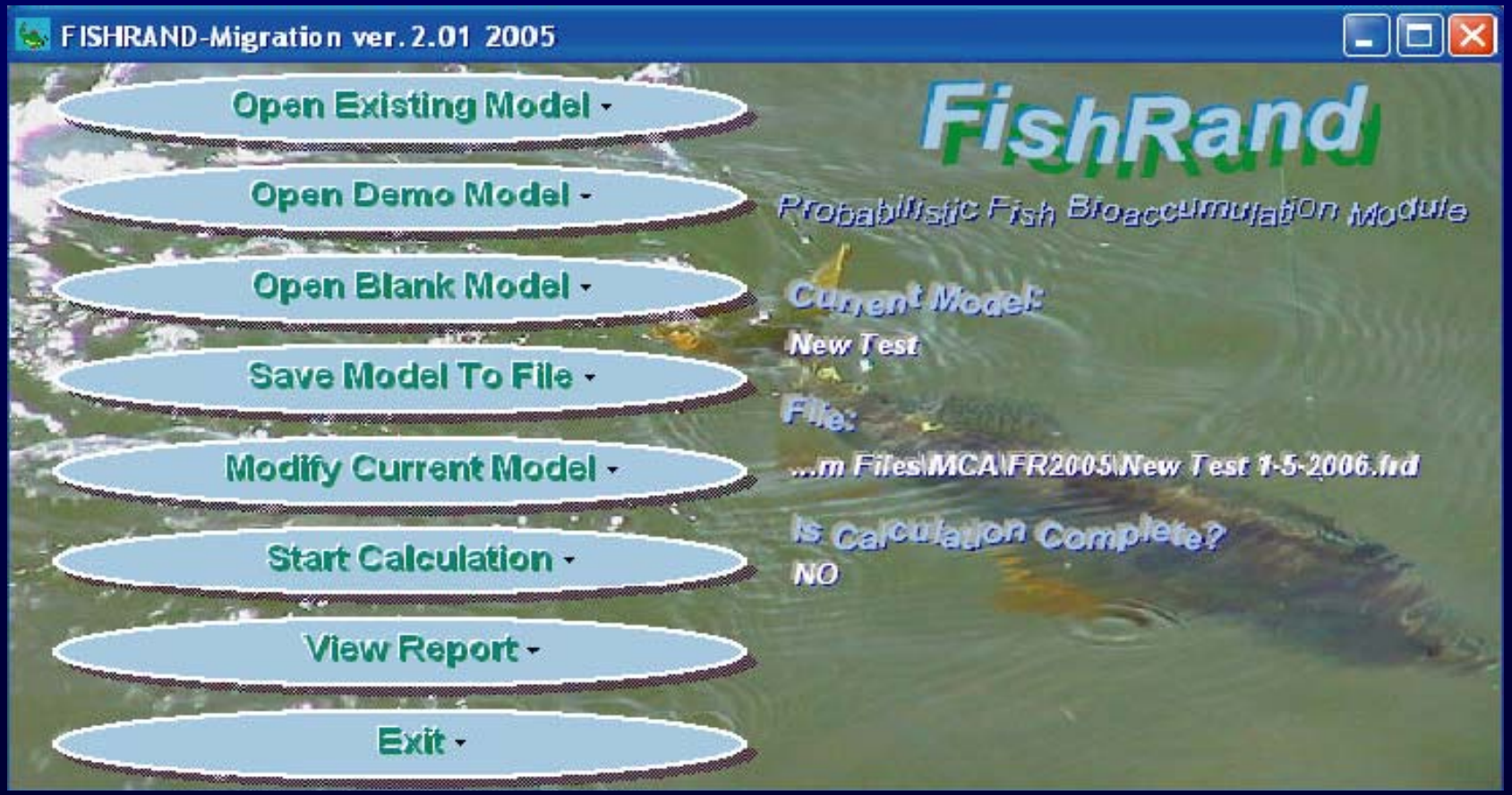
- Steady-state bioaccumulation model based on Gobas (1993 and 1995) for organics
- Includes means to calculate HH and Eco risks

- Designed as flexible tool that can be customized for region/site-specific use
- Downloadable at: http://el.erdc.usace.army.mil/trophictrace/index.html

Spatial/Temporal Scales

- Contaminant concentration varies over space/time at sites
- Animals spend variable amounts of time in or around sites
- Often necessary to incorporate spatial and temporal variation in exposure modeling

FISHRAND-Migration



FISHRAND-Migration Model Structure

Spatial Submodel

- Habitat size
- Fish abundance
- Foraging area
- Size of the site
- Sediment concentrations
- Water concentrations

Output: Time-varying (monthly) sediment and water concentrations to which fish are exposed

Bioaccumulation Submodel

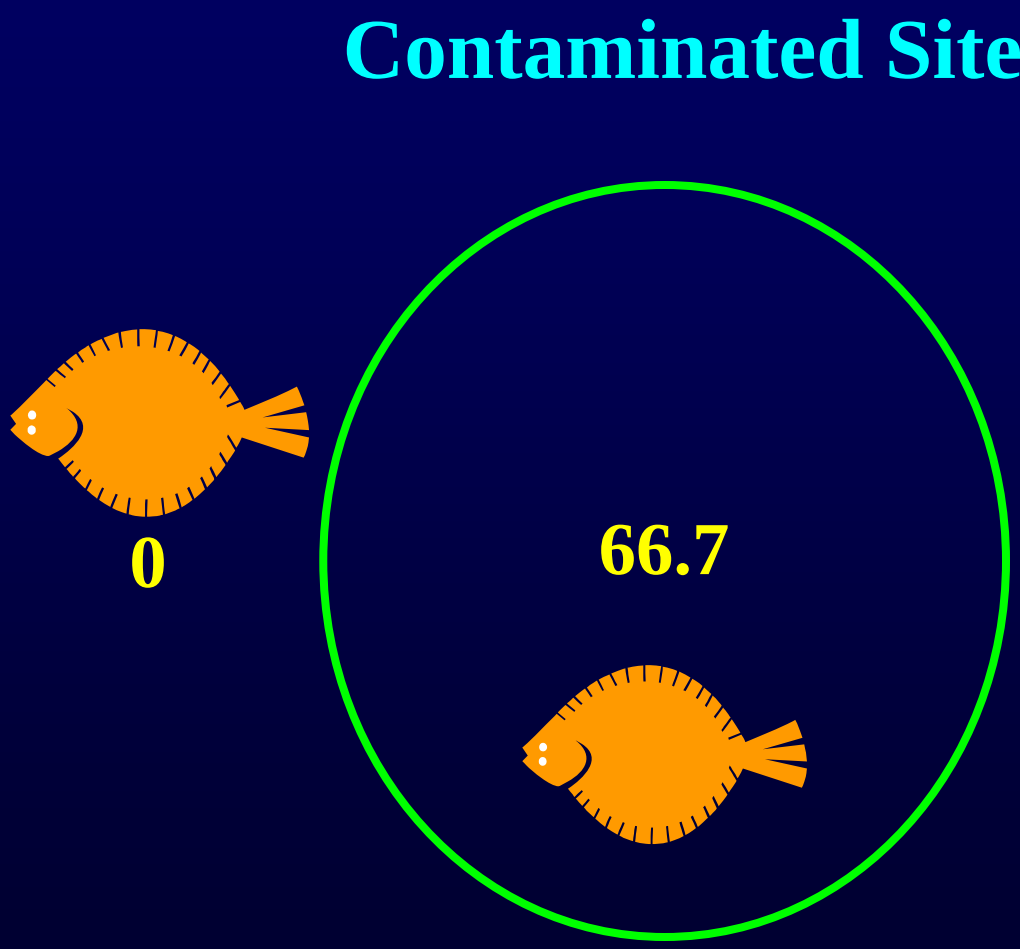
- Lipid content
- Body weight
- Food web characteristics
- Physical-chemical properties of contaminant

Output: Time-varying (monthly) predicted fish tissue concentrations

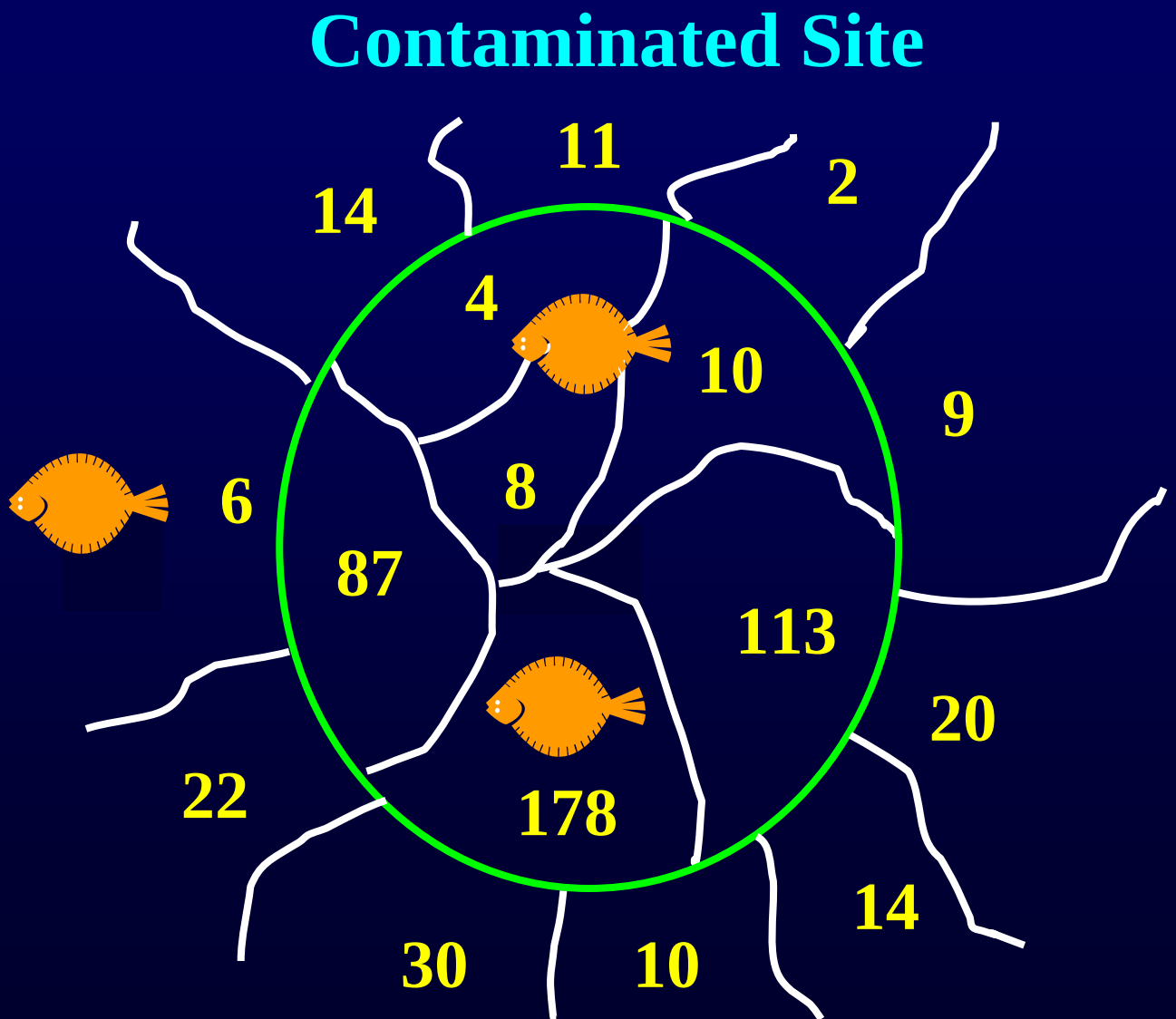
Risk Submodel

- Human exposure parameters
- Body weight
- Fish ingestion rate
- exposure duration
- toxicity estimates

Modeling Exposure in Spatially Heterogeneous Environments

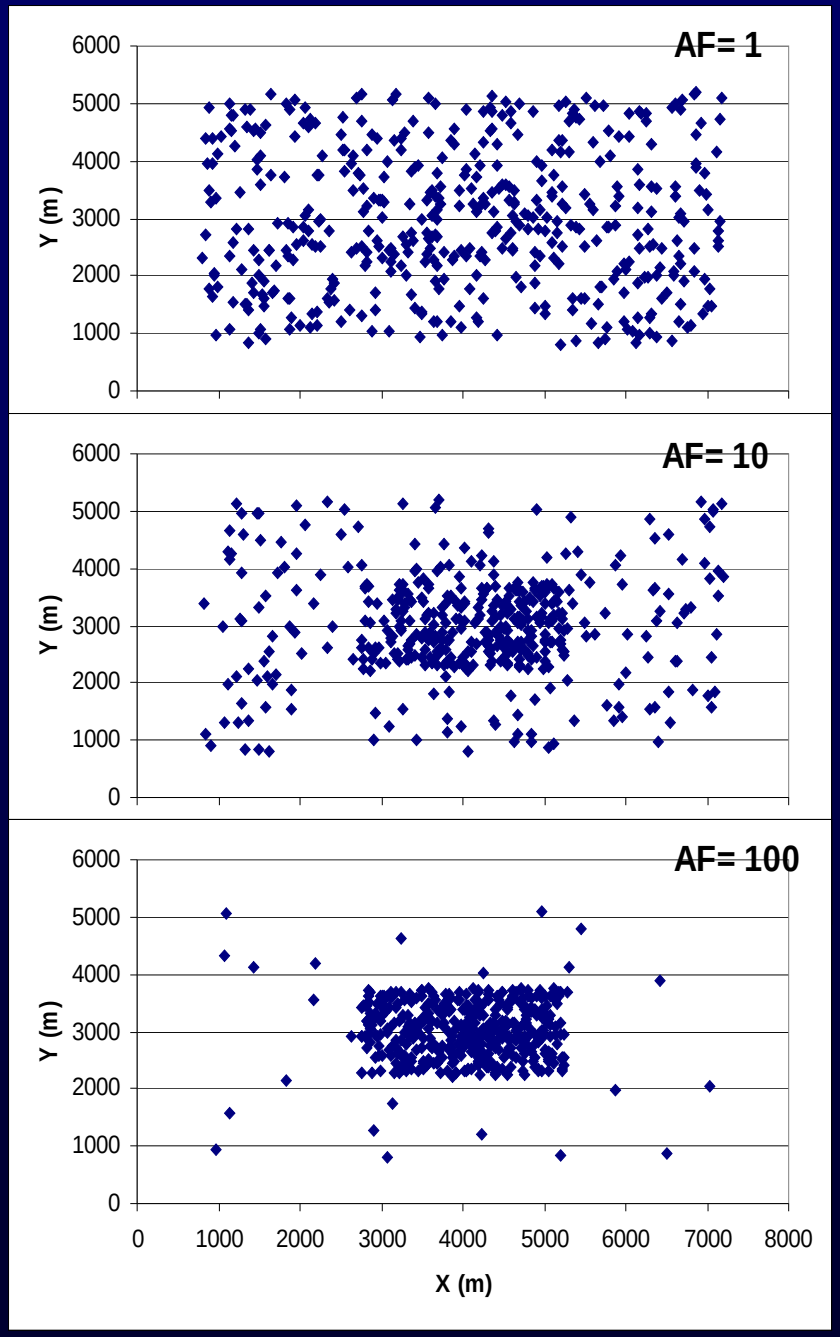


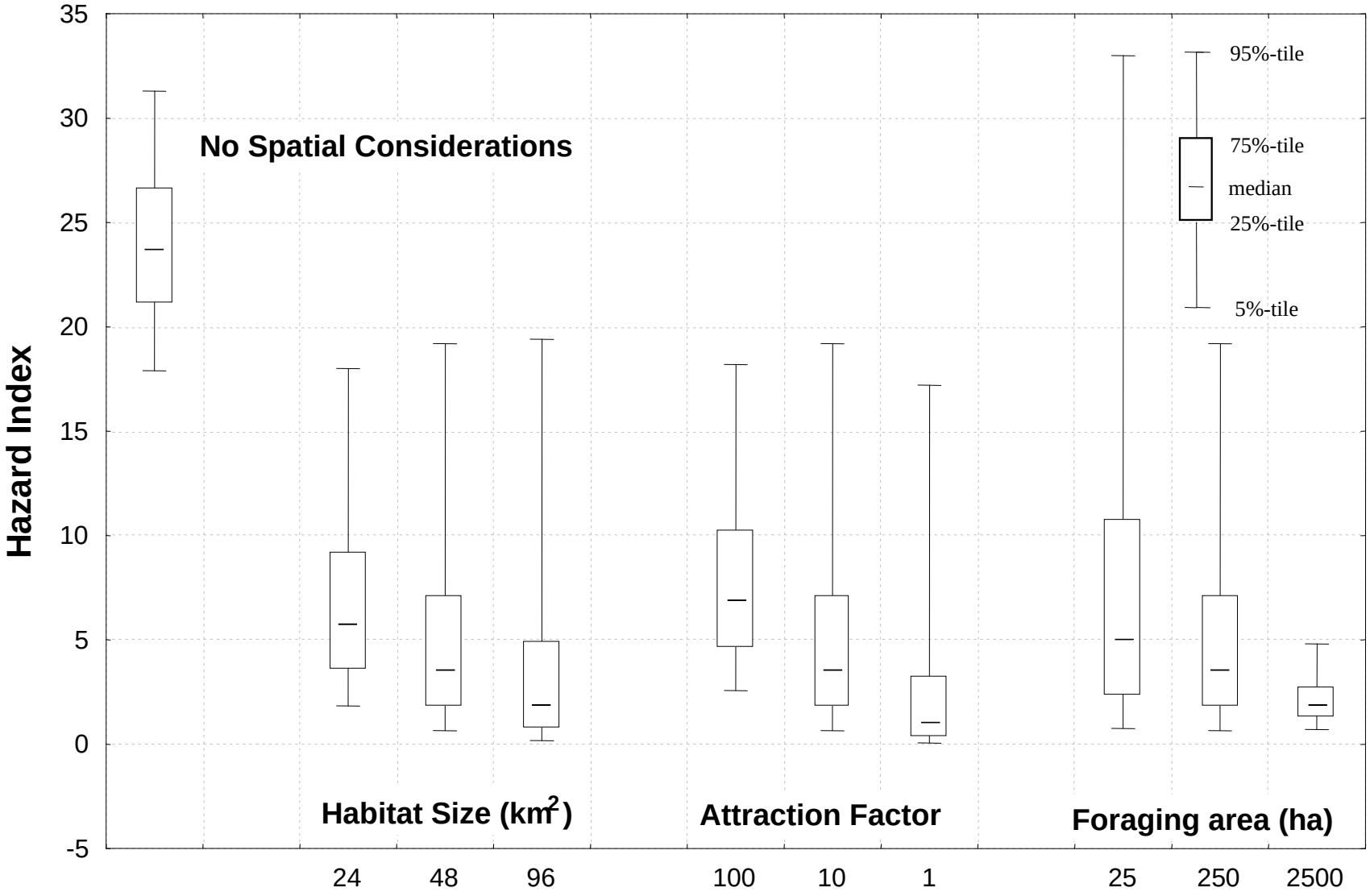
Modeling Exposure in Spatially Heterogeneous Environments



Spatial Issues in Exposure Assessment

- Disposal sites are relatively small (3.75 km^2)
- Fish mobility varies among species
  - Many recreational and commercial species range over large areas
- Do disposal sites attract fish?
  - How will this affect exposure?

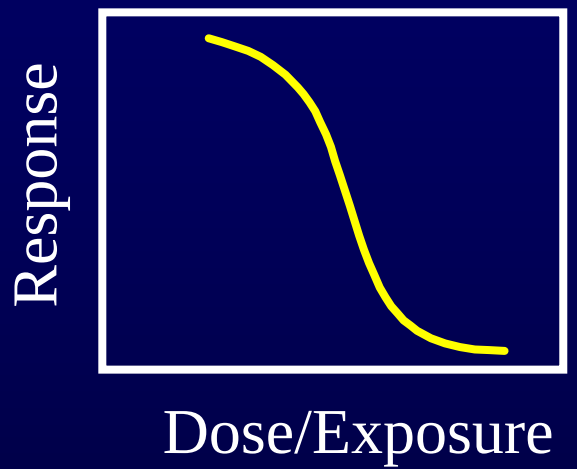




Linkov, I., D. Burmistrov, J. Cura, T.S. Bridges. 2002. Risk-Based Management of Contaminated Sediments: Consideration of Spatial and Temporal Patterns in Exposure Modeling. *Environmental Science and Technology* 36:238-246.

Acute vs. Chronic Toxicity

- Acute toxicity
  - Short-term exposure (hrs-days)
  - Adults
  - Lethality endpoint
  - Higher levels of contamination
- Chronic toxicity
  - Longer-term exposure (days-weeks)
  - Early life stages
  - Sublethal endpoints (growth, reproduction)
  - Lower levels of contamination

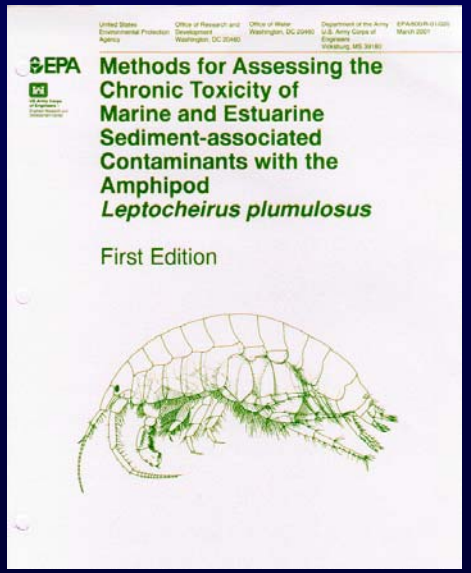


Neanthes Chronic Toxicity Test

Test Parameter	Condition
Age/size	Emergent juveniles (<7 d)
Test duration	28 d
Salinity	20 - 35 ‰
Exposure chamber	250-ml glass beaker
Animals/beaker	1
Reps/treatment	10
Feeding	2 mg TetraMarin & 1 mg alfalfa 2x weekly
Endpoints	Survival, growth (mg/day)
Test acceptability	>80% control survival

Leptocheirus Chronic Toxicity Test

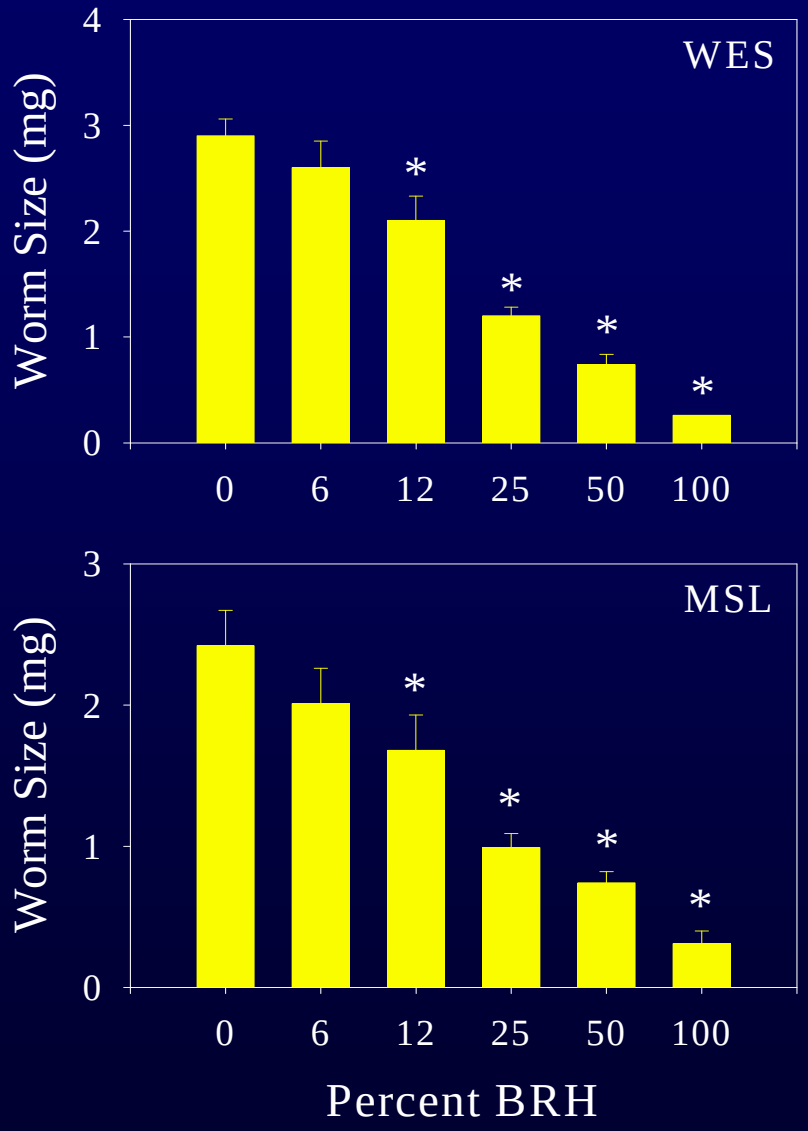
Test Parameter	Condition
Age/size	250-600 µm (1-2 wks)
Test Duration	28 d
Salinity	5-20 ‰
Exposure chamber	1-L glass beaker
Animals/beaker	20
Reps/treatment	5
Feeding	1.0 mg Tetramin/animal - 3x weekly (MWF)- first 2weeks; 2.0 mg/animal thereafter.
Endpoints	Survival, growth, reproduction
Test acceptability	>80% control survival, repro. in all reps
Guidance manual:	www.epa.gov/waterscience/cs/leptofact.html



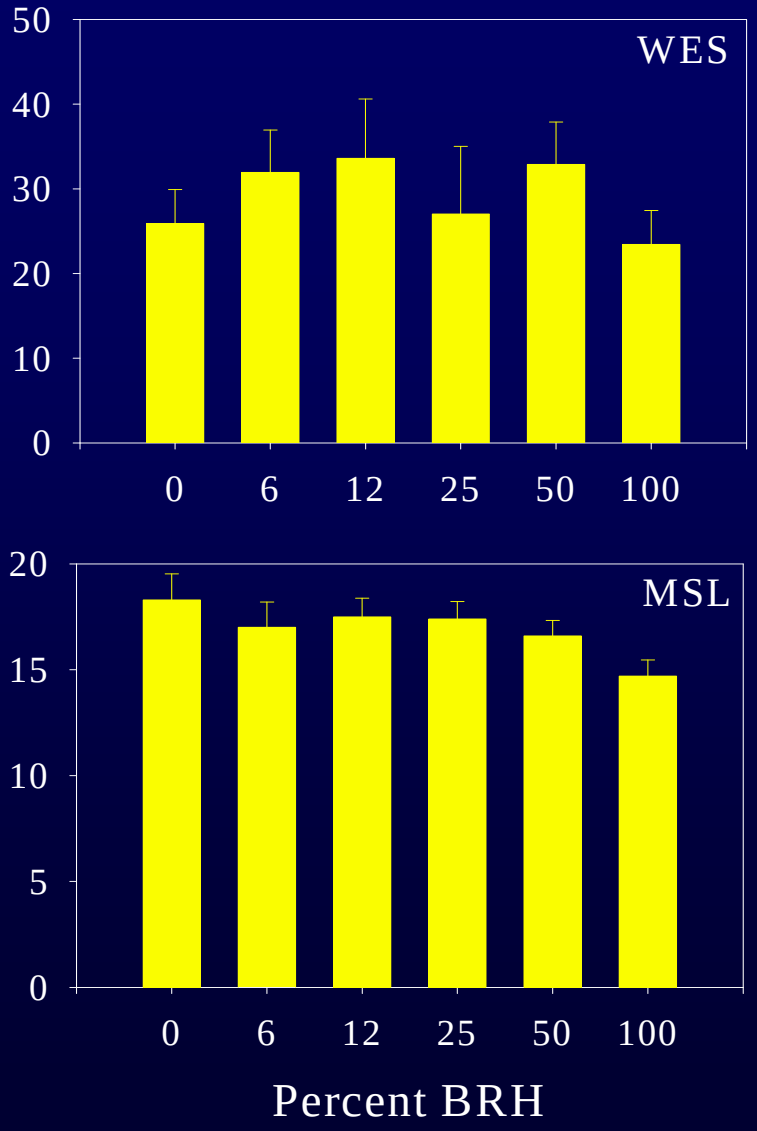
Leptocheirus
Comparison of Acute and Chronic Tests

	10		28-d	
Compound	LC_{50}	LOEC	LC_{50}	LOEC
DANT	55.9	81	67.2	81
DDT	2.0	1.9	2.1	1.9
PCB-29	177.2	240	145.6	120
Lead	4.72	8	5.43	2
Fluoranthene	75.0	55.0	70.3	15.9

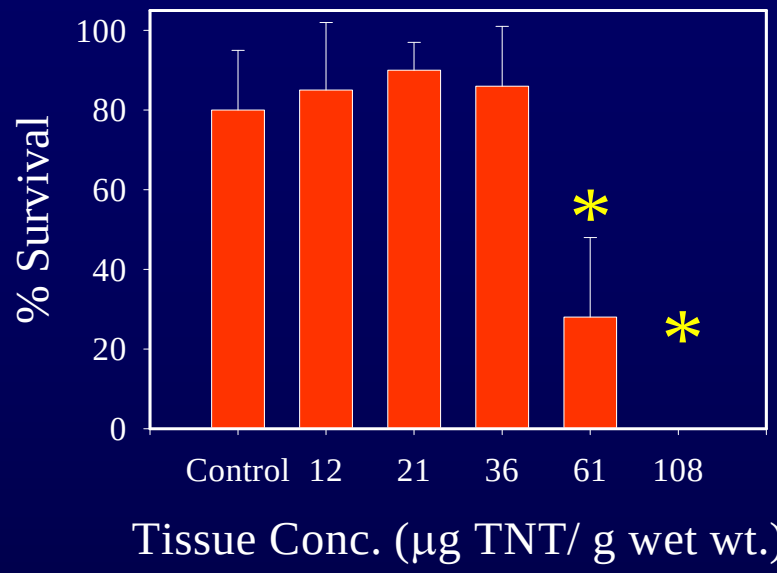
WES *Neanthes* Protocol



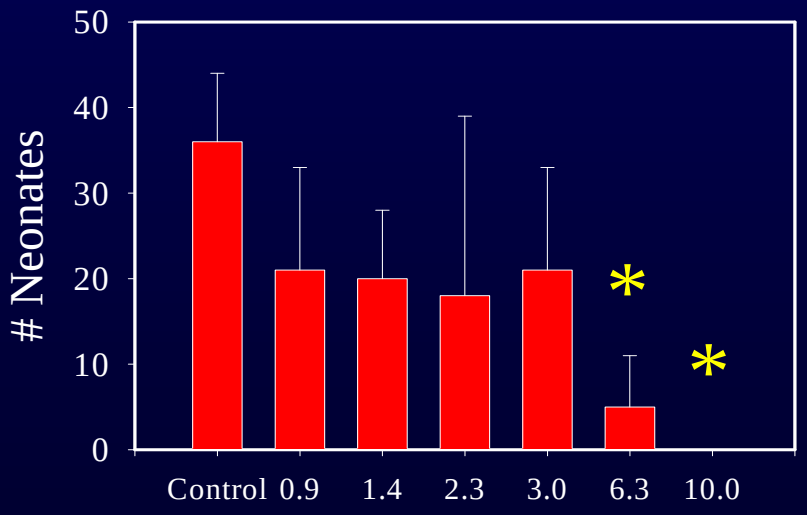
PSDDA *Neanthes* Protocol



TNT Toxicity to *N. arenaceodentata*



TNT Toxicity to *L. plumulosus*



Green et al., 1999 ET&C 18: 1783-1790

Environmental Residue-Effects Database (ERED)

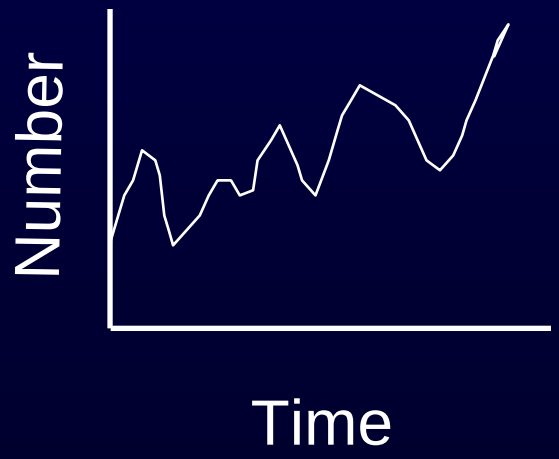
- Database went online 1997
  - Data last updated in Nov. 2008
- Broad data coverage
  - 13,981 distinct observations
  - Summarizing 2180 studies
  - 404 contaminants, 446 species
- Database easily accessed via the internet
  - http://el.erdc.usace.army.mil/ered/index.html
- Results of queries viewed in tabular and graphic form
- Data are downloadable

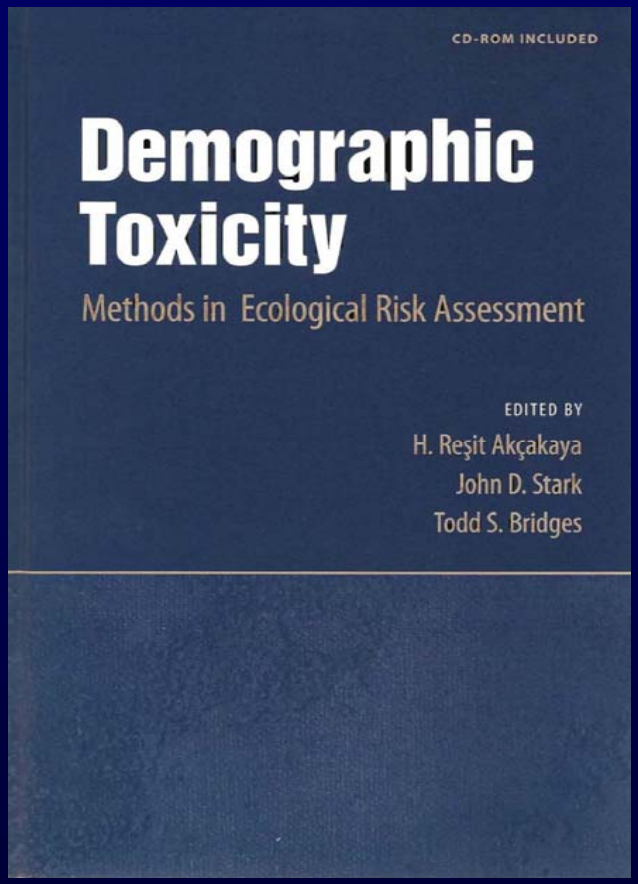
Population Modeling

Individual

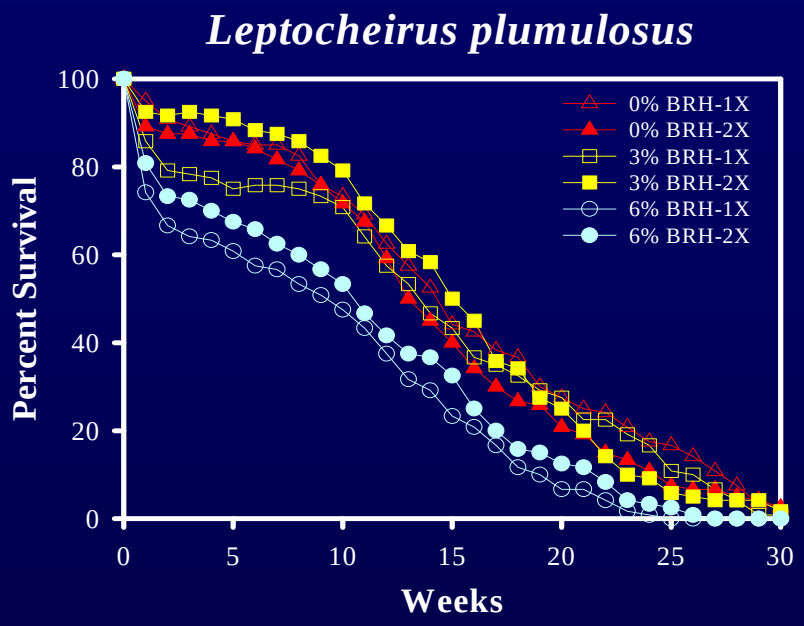
- Survivorship
- Growth
- Reproduction

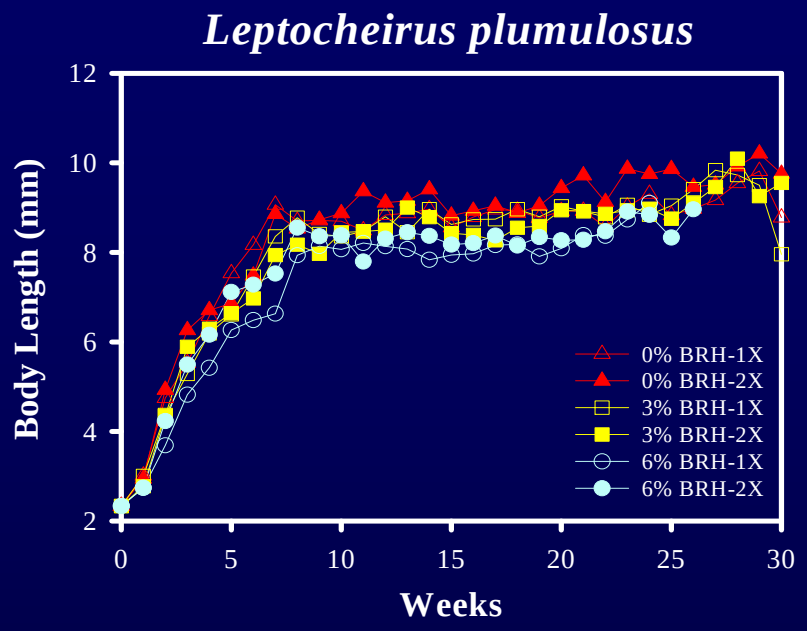
Population

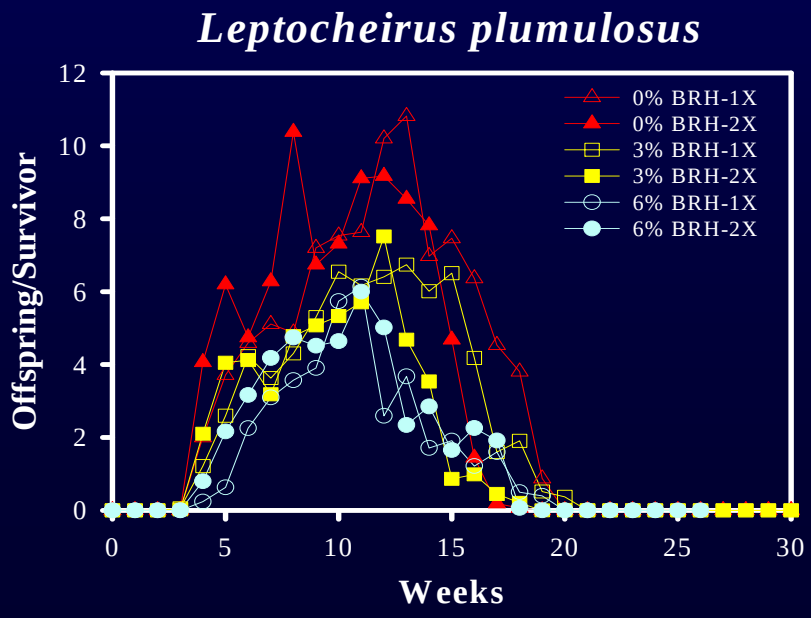




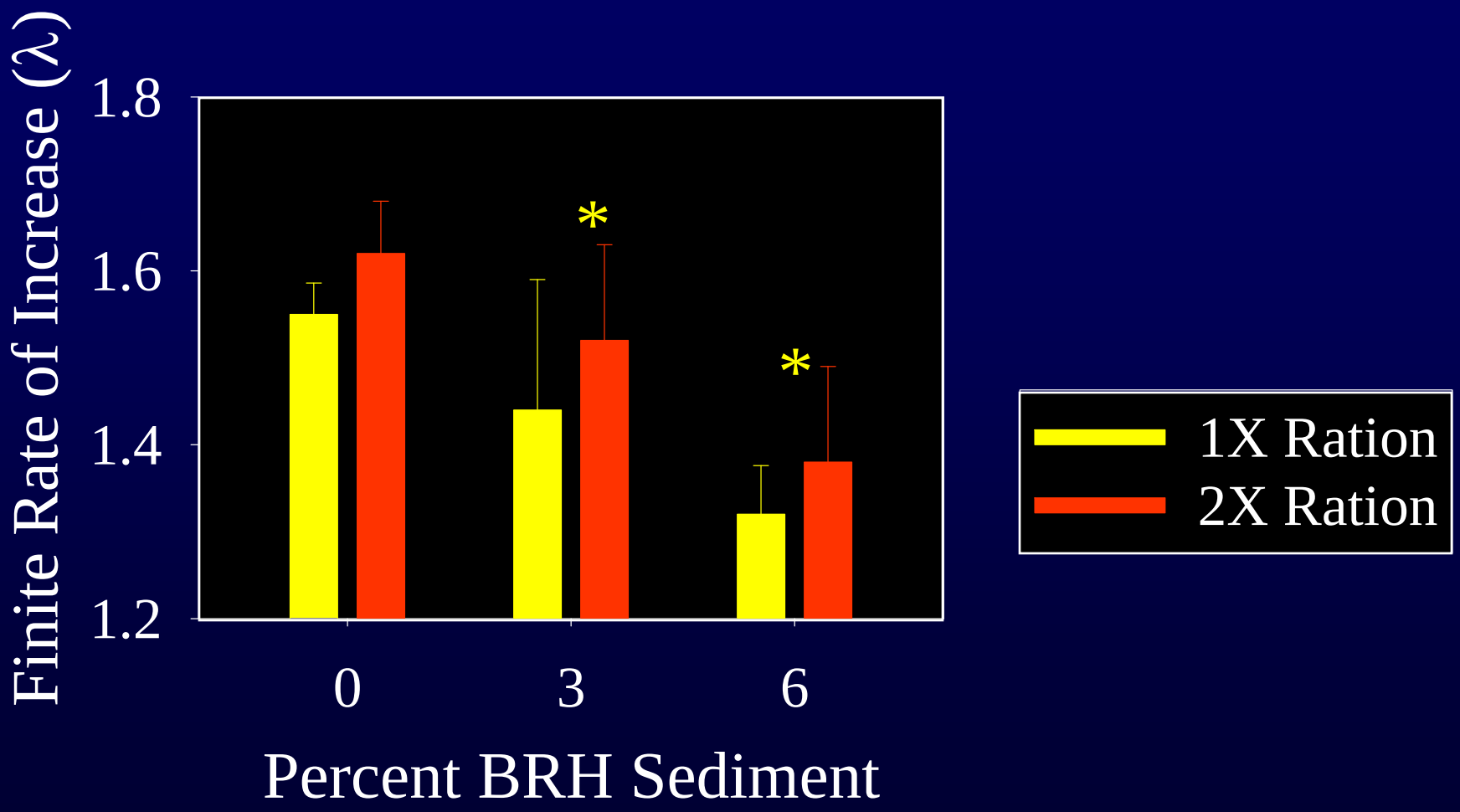
Life-History Response Experiments



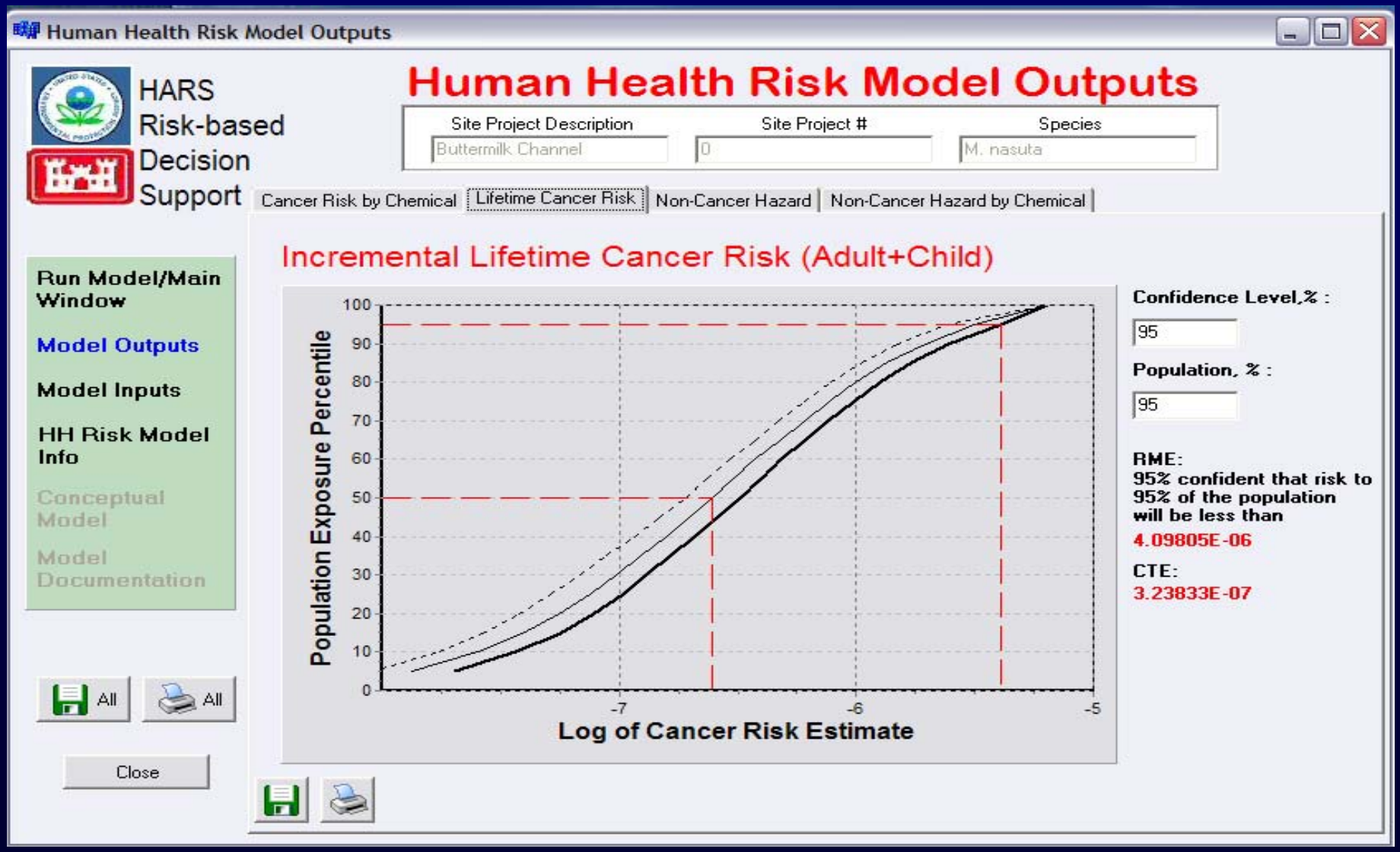




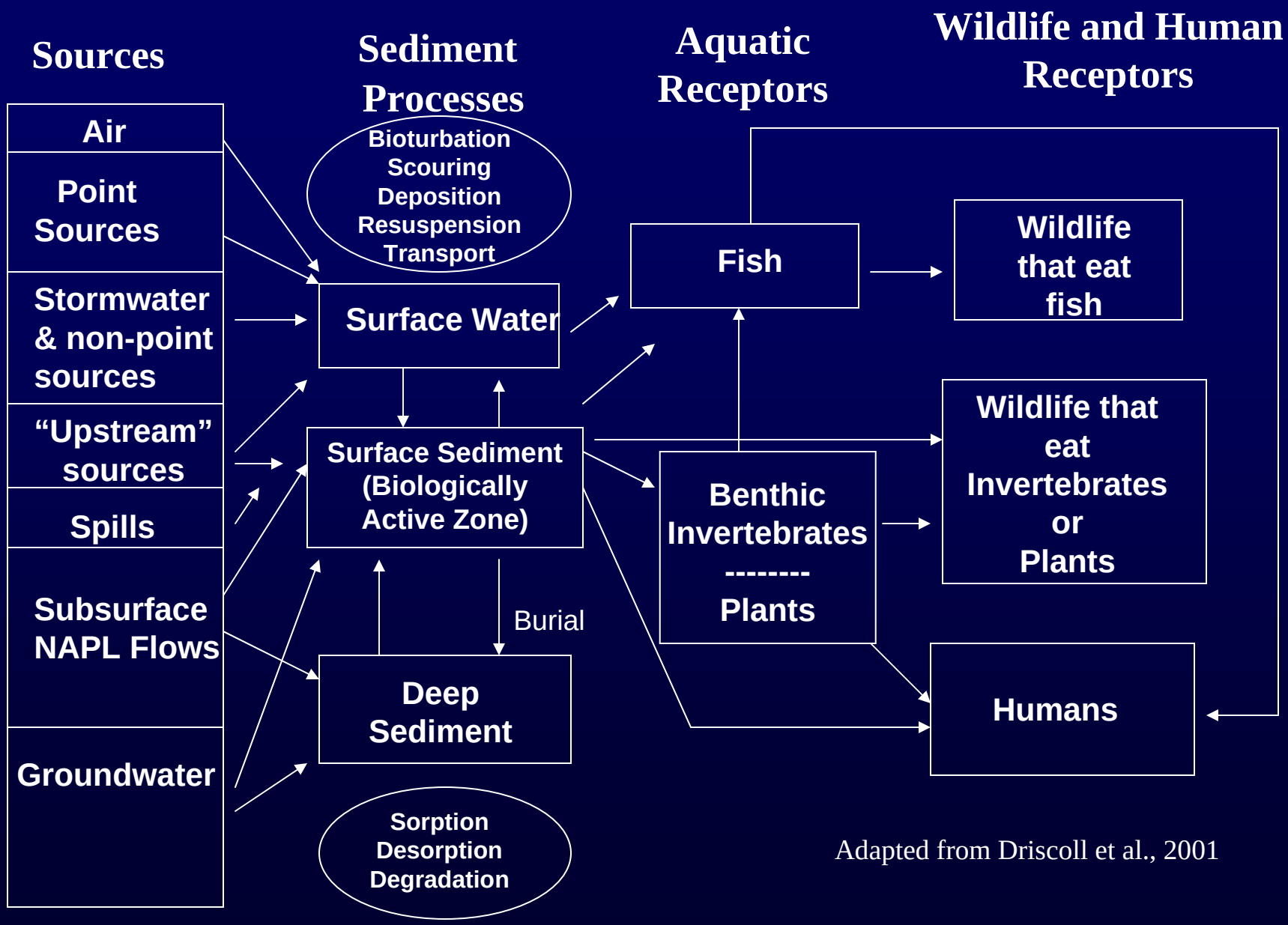
Leptocheirus plumulosus Population-level Effects



Decision Support Software

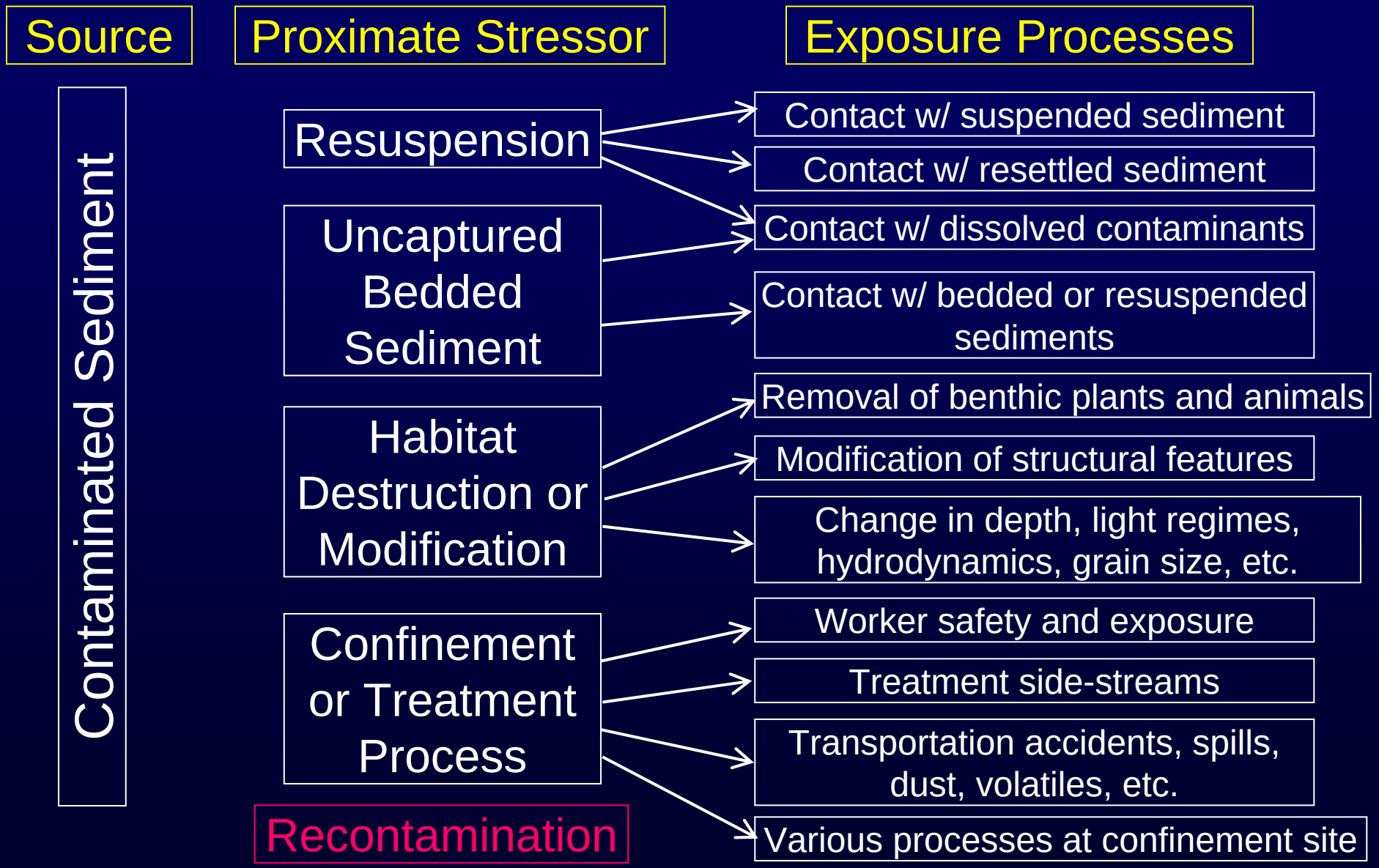


Basic Conceptual Model for Sediment Risk Assessment

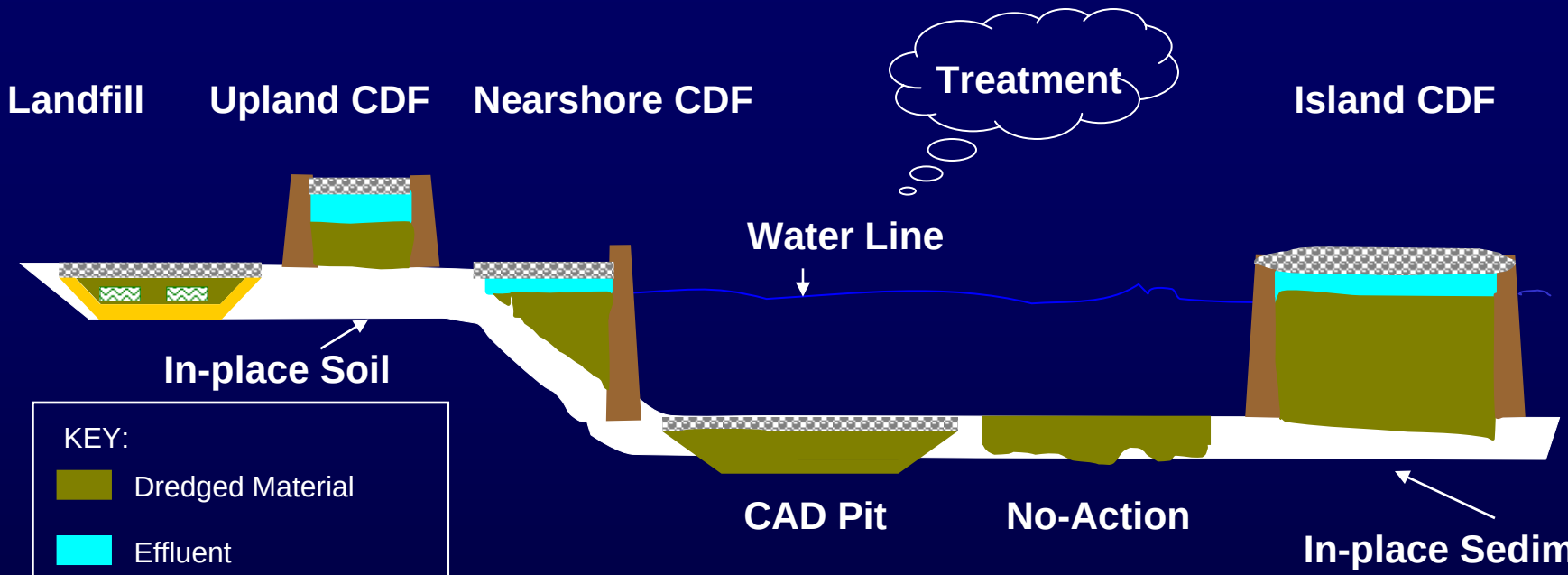


Adapted from Driscoll et al., 2001

Dredging Conceptual Model



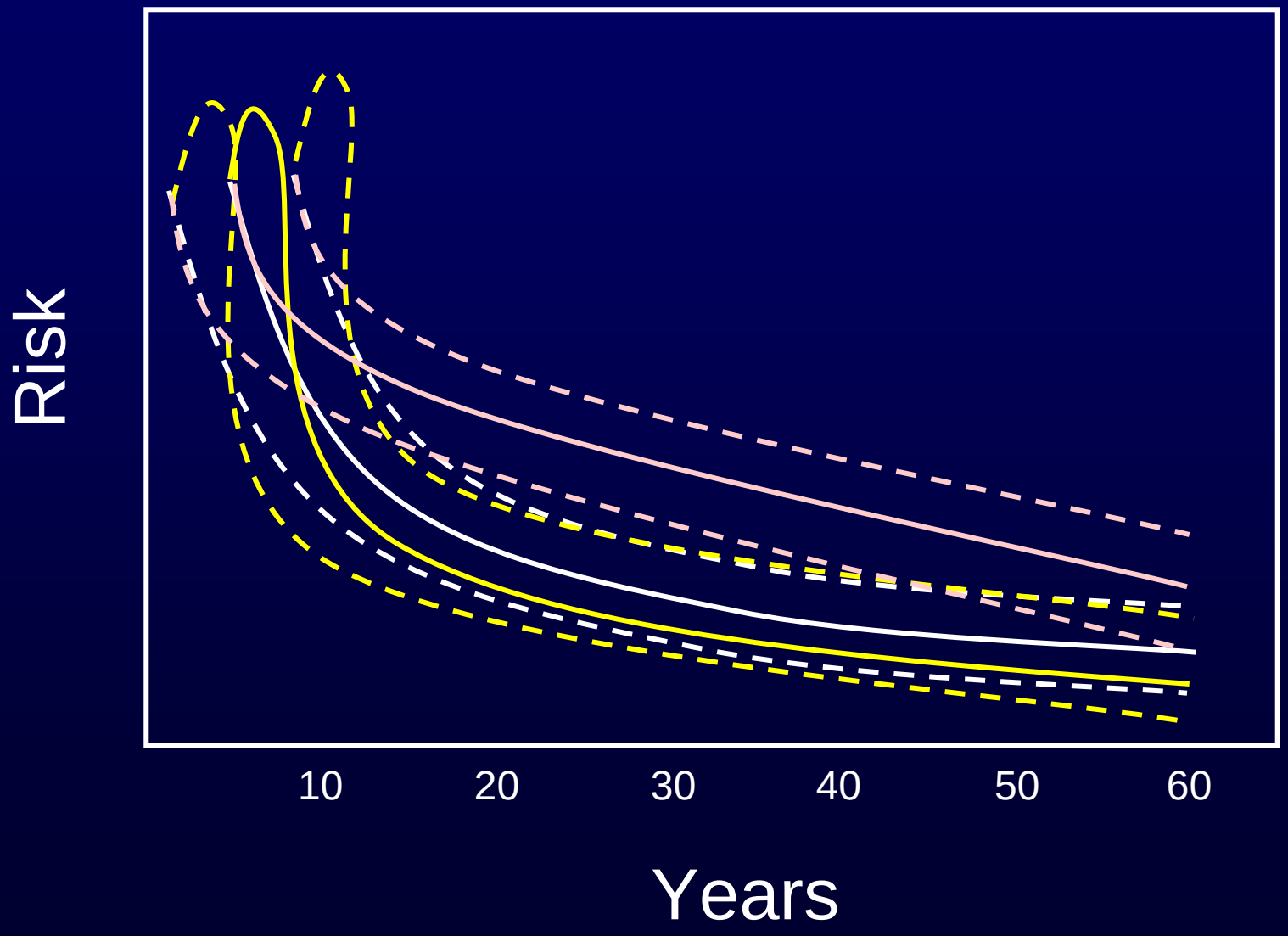
Management Alternatives



Kane Driscoll, S.B., W.T. Wickwire, J.J. Cura, D.J. Vorhees, C.L. Butler, D.W. Moore, T.S. Bridges. 2002. A comparative screening-level ecological and human health risk assessment for dredged material management alternatives in New York/New Jersey Harbor. *International Journal of Human and Ecological Risk Assessment* 8: 603-626.

G. A. Kiker, T. S. Bridges, J. B. Kim. 2008. Integrating Comparative Risk Assessment with Multi-Criteria Decision Analysis to Manage Contaminated Sediments: An Example From New York/New Jersey Harbor. *Human and Ecological Risk Assessment* 14:495-511.

Risk Reduction Comparison



Cognitive aspects of decision-making: Mental Modeling

- Mental models are a complex web of deeply held beliefs that operate below the conscious level
  - MM affect how an individual defines a problem, reacts to issues, learns, and makes decisions
- Currently developing MM for flood risk problem
- Planning to explore use of MM for contaminated sediment problem


The path to risk-based enlightenment passes through what national park?