Assessing and Managing Exposure at Relevant Spatial and Temporal Scales

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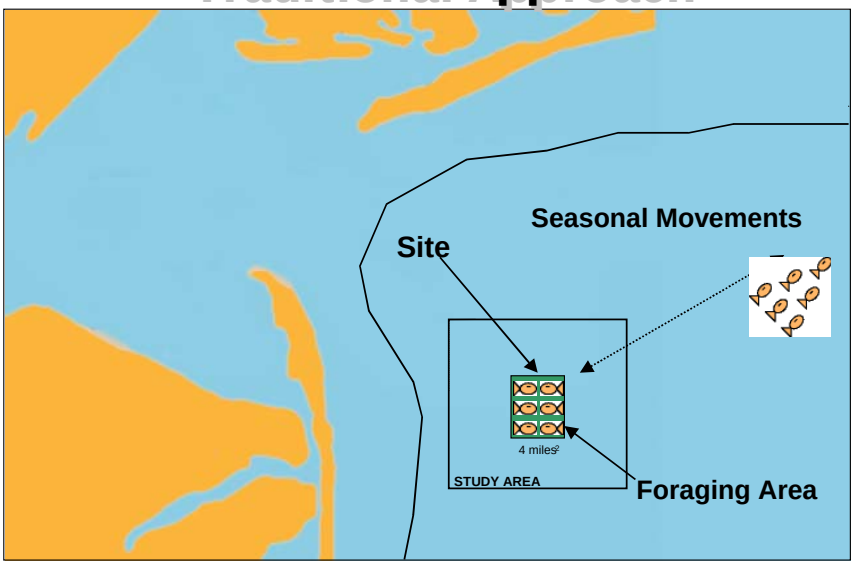
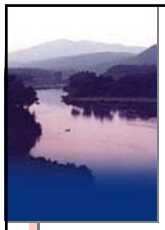
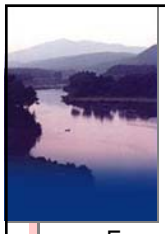
Issue of Scale in RA: Traditional Approach





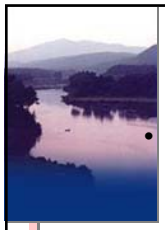
Why Do We Need To Consider Spatial and Temporal Scales in Risk Assessment?

- Nature of the sites
  - **Heterogeneous site contamination**
  - **Spatial and temporal variability in the source term**
  - **Behavior of ecological receptors**
- Benefits: Realistic and site-specific assessment
  - **Better problem formulation and assessment**
  - **Reduced cost of remediation**
- Regulatory Framework
  - **RAGS – Probabilistic Risk Assessment Guidance (EPA, 2001)**
  - **State**
  - **ASTM E47.02 Draft Standard**



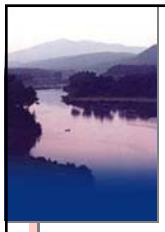
EPA 2001 Guidance for Probabilistic Risk Assessment

- Exposure Units (EU)
  - **Goal – define concentration term assuming long-term exposures**
  - **Geographical area in which receptor is randomly exposed to a contaminated medium**
  - **Multiple exposure units may be defined**
  - **Problem – non-random exposures (i.e. habitat preferences)**
- Non-random exposures
  - **Model spatial relationship between the contaminant and receptor**
  - **Divide EU into smaller subunits**
  - **Use information on attractiveness of subunits for receptors**
- Uncertainty and Variability in Concentration Term
  - **Conservative point estimates**
  - **2D Monte-Carlo to address spatial and temporal variability**



Overview

- Why commonly used Exposure Unit Approach does not Work (Linkov)
  - **Example – Risk assessment for contaminated lake**
  - **Ecological Risk Characterization based on exposure unit approach**
- Spatially explicit Modeling Approach (von Stackelberg)
  - **Dealing with spatial and temporal scales at large and small sites**
  - **Parameters and methods in modeling**
- Case Study – Hypothetical Open Water Disposal Facility; PCBs contamination (von Stackelberg)
  - **Illustrates how advanced risk assessment results in more realistic risk estimates**
- Software tools for Spatially Explicit Risk Assessment (Linkov)
  - **Dealing with spatial and temporal scales**
  - **Habitat Suitability index**



Use of Exposure Units Approach in Eco RA

- **Problem: Contaminated Lake (PCBs)**
- **Affected ecological receptors**
- **Remedial Alternatives:**
  - No action;
  - Comprehensive Dredging;
  - Hot spot dredging.
- **Exposure units approach – overly conservative**

Site Background

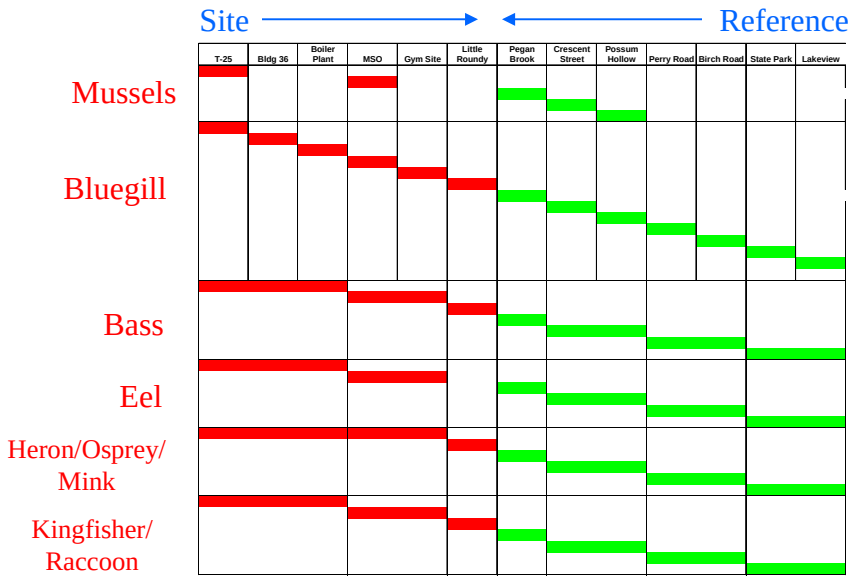
1000 feet

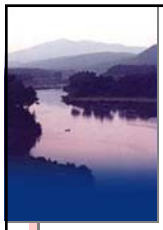
Assessment End Points

- **Invertebrates**
- **Fish**
  - Largemouth Bass
  - Bluegill
  - American Eel
- **Birds**
  - Great blue heron
  - Belted kingfisher
  - Osprey
- **Mammals**
  - Raccoon
  - Mink

Are the COC concentrations in sediments high enough to cause acute or chronic health effects in exposed

Summary of Exposure Units for Ecological Receptor





Site Use by Eco Receptors

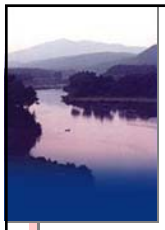
	Worst-Case	Intermediate (Adjacent Off-Site Percent Below)	Best-Case/Most Likely
Mink	100	33 67	6.4
Raccoon	100	50 50	4.2
Great Blue Heron	100	33 67	1.4
Belted Kingfisher	100	50 50	0.55
Osprey	100	33 67	0.11

Used in Deterministic RA

Which assumption should be used in realistic RA?

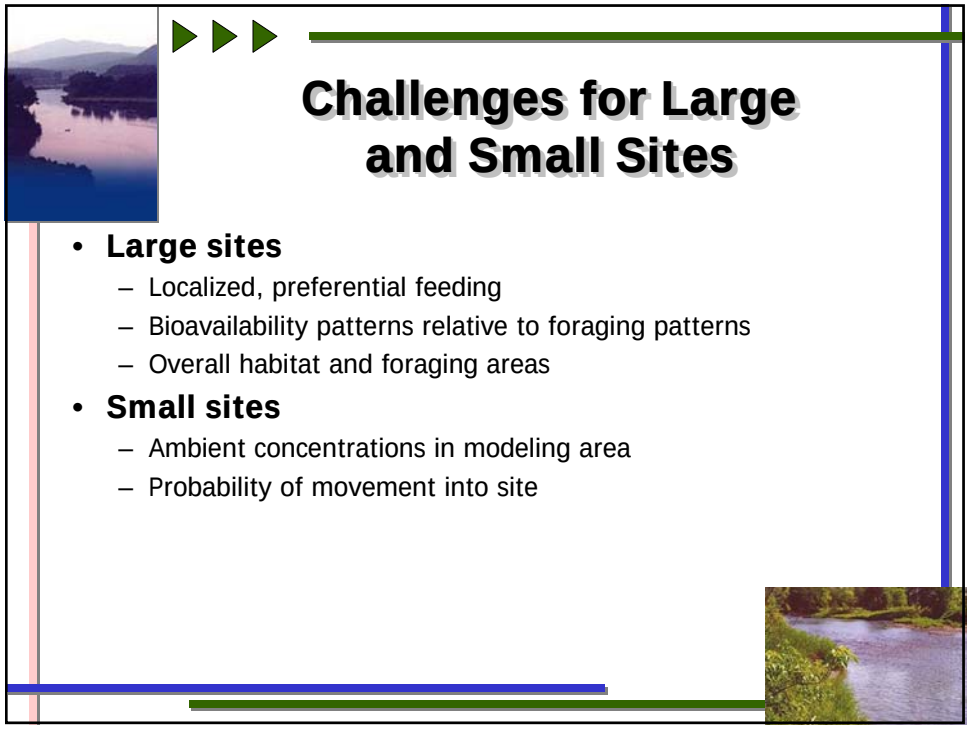
Parameters and Methods in Spatial Models

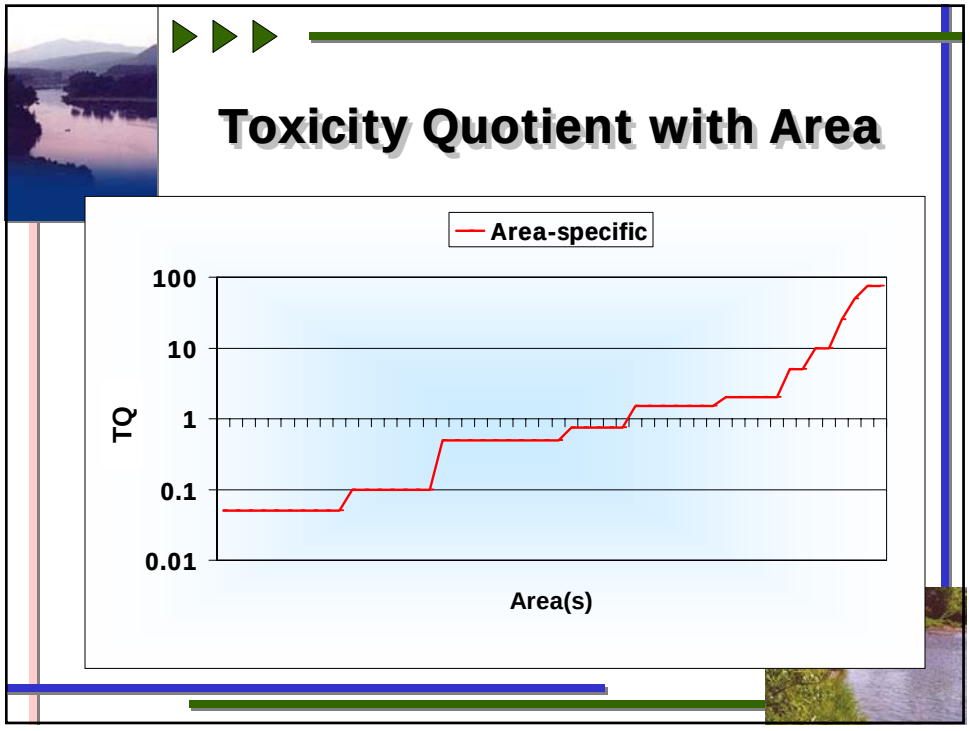
- **Habitat size**
  - biological definition (tagging studies)
  - management definition (size of site)
- **Foraging area and migration pattern**
  - literature review
- **Facility characteristics**
  - size and shape
  - attraction factor
- **Simple to complex**
  - Site use factor
  - Define a few parameters
  - Probabilistic



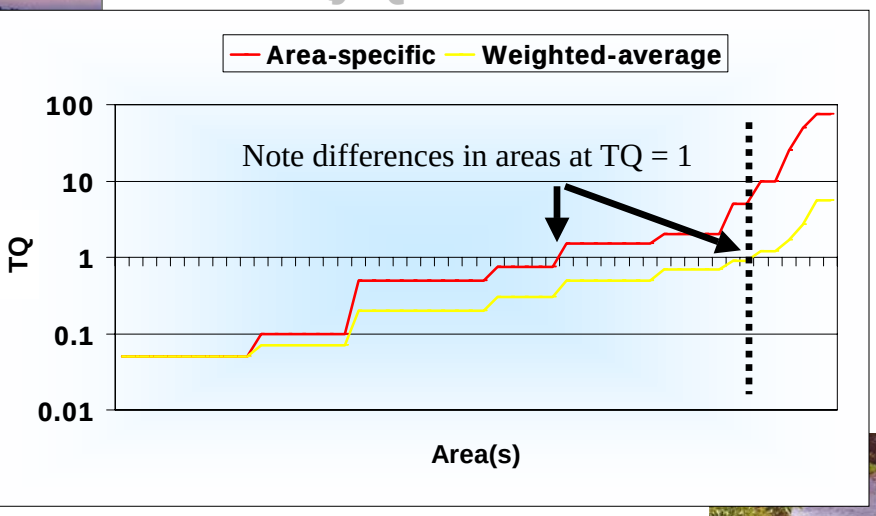
Calibration and Validation Challenges

- **More realistic exposure estimates**
  - Calibration parameters?
  - Predicted versus observed: model parameterization?
  - Adjustments within the range of data impact predicted risks by an order of magnitude
  - Data requirements
  - Data gaps
  - Parameter interactions

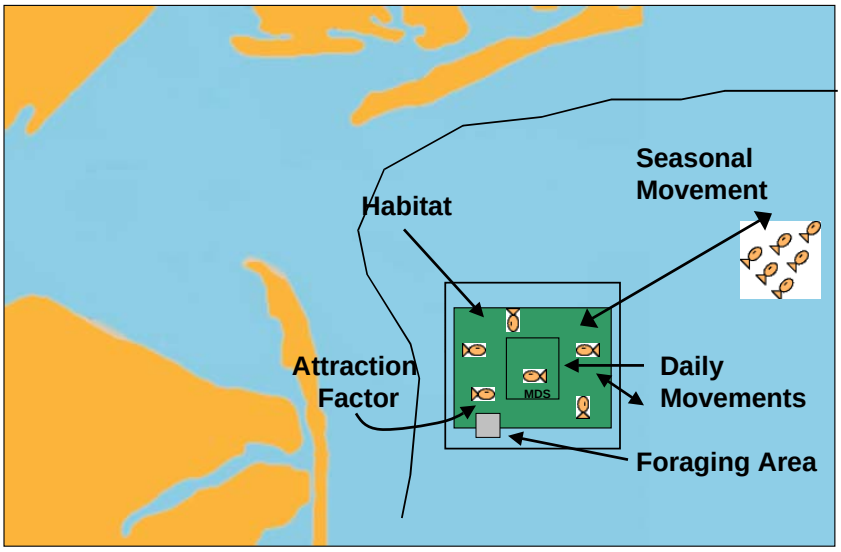

Challenges for Large and Small Sites
• Large sites
– Localized, preferential feeding
– Bioavailability patterns relative to foraging patterns
– Overall habitat and foraging areas
• Small sites
– Ambient concentrations in modeling area
– Probability of movement into site

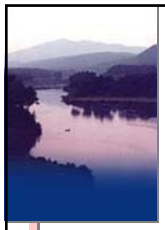

Toxicity Quotient with Area
Area-specific
100
10
1
0.1
0.01
TQ
Area(s)

Toxicity Quotient with Area



Case Study – Hypothetical Open Water Disposal Facility

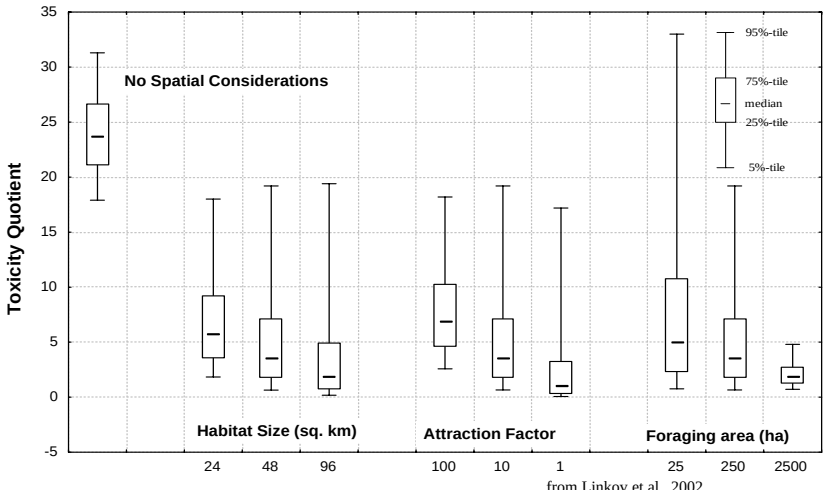




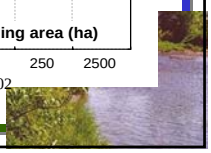
Spatially Explicit Modeling

- **Goal**
  - To incorporate uncertainty and variability from the spatial and temporal characteristics of organisms into estimated risks
- **Issues that Arise in Spatial Modeling**
  - Scale
    - Bioavailability
    - Animal movement
    - Watershed processes
  - Which parameters contribute most to uncertainty and variability?
  - How do spatial and temporal factors influence predicted risks?
  - When is a *Site Use Factor* appropriate and how to quantitatively estimate it?

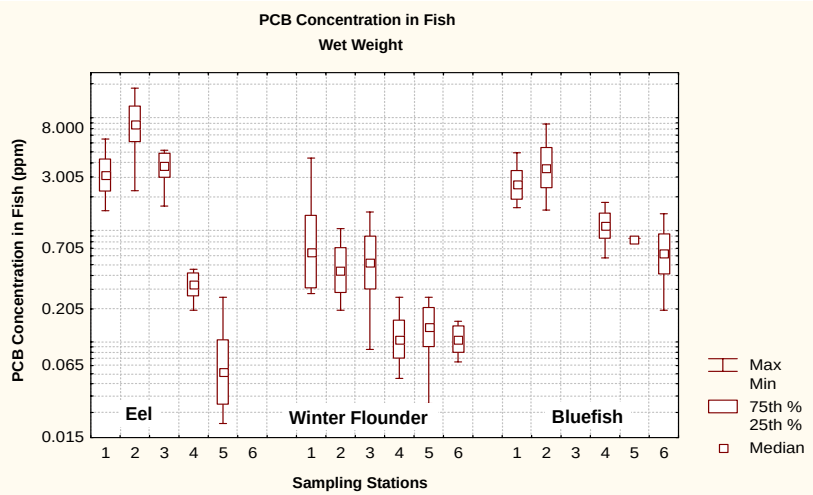
Spatially Explicit Risk Characterization



from Linkov et al., 2002



Evidence from Data



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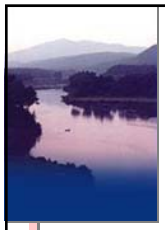
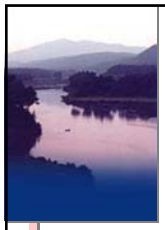


Case Study Summary

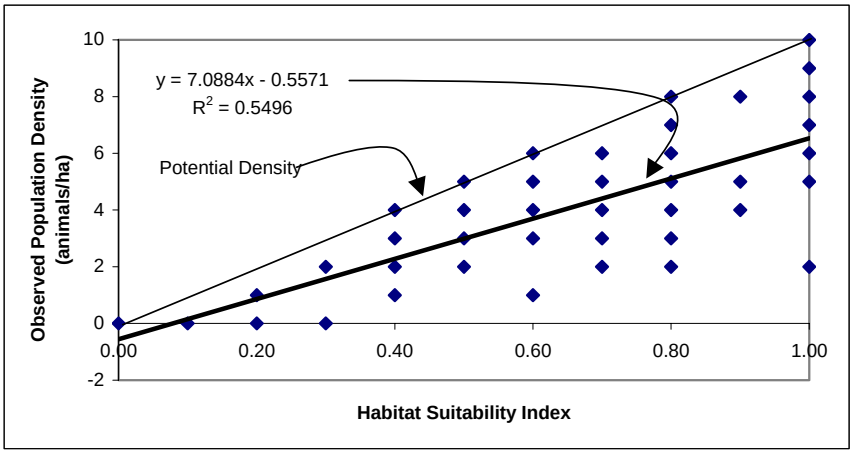
- **Current modeling approach taken to derive site-specific values may be conservative**
- **Spatial and temporal considerations can be incorporated into risk model**
  - **habitat size**
  - **migration pattern**
  - **foraging area**
- **Incorporating spatial considerations typically reduces risks relative to no inclusion**
- **Calibration and validation challenges**



Software Tools

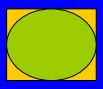
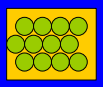
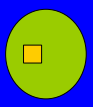
- **Tools Incorporating Attraction factor**
  - Cons: overly simplistic, poor predictive capacity, limited verification
  - Pros: Simple to use
- **Tools Incorporating Habitat Suitability Index**
  - reflect best professional judgment of a panel of experts
  - developed by fitting population density data to landscape components
  - explanatory, correlative, or surrogate variables identified
  - models constructed using simple algebraic and graphic expressions
    - Cons: Limited verification
    - Pros: Can be done quickly, Provides reasonable qualitative estimate of habitat quality

Habitat Suitability Index



Adapted from presentation by A. Farmer, Wildlife Habitat Modeling: How far has it come and how much farther can it go? ASTM Symposium on *Landscape Ecology and Wildlife Habitat Evaluation: Critical Information for Ecological Risk Assessment, Land-Use Management Activities, and Biodiversity Enhancement Practices*, 7-9 April 2003, Kansas City, MO. (Kapustka, 2004)

When Do We Need to Consider Spatial Scales

spatial relationship	habitat heterogeneous contamination homogeneous	habitat heterogeneous contamination heterogeneous	habitat homogeneous contamination heterogeneous	habitat homogeneous contamination homogeneous
Type 1 	1) Exposure to organisms is function of site mean contamination level. HSI weighting is not required.	2) Exposure to organism is not a function of site mean contamination level. HSI weighting is necessary.	3) Exposure to organism is function of site mean contamination level. HSI weighting is not required.	4) Exposure to organisms is function of site mean contamination level. HSI weighting is not required.
Type 2 	5) All individuals equally exposed. HSI weighting is not required.	6) All individuals not equally exposed. HSI weighting required to estimate exposure frequencies in population.	7) All individuals not equally exposed. HSI weighting required to estimate frequencies of exposure among population.	8) All individual equally exposed. HSI weighting is not required.
Type 3 	9) Exposure to organisms function of site contamination and relative habitat quality. HSI weighting necessary to estimate exposure frequency to individual.	10) Exposure to organisms function of site contamination and relative habitat quality. HSI weighting necessary to estimate exposure frequency to individual	11) Exposure to organisms function of contamination. HSI weighting is not required.	12) Exposure function of contamination. HSI weighting is not required.

After L. Kapustka, ASTM standards

Conclusions

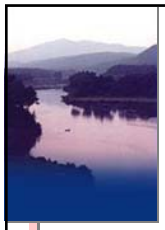
Spatially Explicit Risk Assessment

State-of-the-art approach for modeling

Cons and Pros

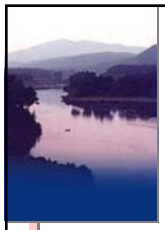
- **EXPENSIVE Analysis**
- **computational intensity**
- **necessity for qualified project staff**
- **potential artifacts of methodology**

- **LESS EXPENSIVE solutions**
- **realistic representation of receptor populations**
- **specific to site/receptors**
- **can be probabilistic and temporally explicit**



The Way Forward

- Spatially and temporally explicit Eco RA can be used to reduce uncertainty in exposure estimates and to optimize selection of remedial alternatives
- Even though it results in more realistic exposure estimates, the overall uncertainty associated with specific sediment management alternatives may be high
- **Why Decision Analysis:**
  - Environmental evaluations and decisions are growing more complex
  - Uncertainty is increasing
- **Why Adaptive Management:**
  - Inherent inability to optimize environmental policy given the uncertainties in modeling and characterization



Bibliography

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