Components of Estuarine and Marine Ecological Risk Assessment

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DTSC Ecological Risk Assessment Workshops • July – August 2007
OUTLINE for Sediment ERA presentation

- NOAA’s Role at DTSC
- Sediment characteristics
- Components of a Sediment ERA
  - Conceptual site models
  - Tools for evaluation
  - Weight of evidence-risk characterization
- Sediment Quality Guidelines
- Query Manager mapping tools
NOAA’s Role

- 2001- MOU between DTSC and NOAA to Protect and Restore Coastal Resources
- NOAA provides technical support to DTSC project managers in OMF and Site Mitigation
- NOAA acts as a technical liaison and co-trustees with other federal, state, and local response agencies during field investigations, remedial planning, and the design and implementation of mitigation strategies
- NOAA exercises trusteeship at both DoD and industrial sites
When do Natural Resource Trustees get involved in a site?

“When there is an injury to, destruction of, loss of, or threat to natural resources as a result of a release of a hazardous substance or a discharge of oil.”

NCP Section 300.600
Marine and Estuarine Sediment Risk Assessment
Why do we care about contamination in Sediments?

- Sediments act as “sinks” for contamination
- Benthic communities, which form the basis of the aquatic food chain, can be eliminated or tainted by sediment contamination
- Persistent organic contaminants in sediments can accumulate through the food web into higher trophic level organisms, including humans
- Contaminants in sediments can easily spread beyond the point of origin through physical or biological means
- Contaminated sediments can lead to an economic impact on local and regional communities
How can a Sediment Ecological Risk Assessment differ from a Terrestrial ERA?

- Contaminated sediments may occur in a wide variety of aquatic environments: wetlands, harbors, estuaries, rivers, lakes, etc.
- Aquatic environments are often large, complex and diverse with multiple sources, multiple contaminants, and multiple uses.
- Contaminants may be transported long distances from their sources by tides, currents, floods, and seasonal influxes.
- Selecting a reference area, and separating background concentrations from site-specific sources can be difficult.
How can a Sediment Ecological Risk Assessment differ from a Terrestrial ERA?

- Sampling and remediation of sediments can be technically challenging
- Evaluating the multiple communities and trophic levels associated with contaminated sediments can be very complex: communities may vary over smaller distances
- Remediation of sediments can destroy sensitive habitats and have a long-term impact on receptors which rely on those habitats
Physical/Chemical Parameters of Sediments

- Temperature
- Salinity
- Sediment Grain Size
- Total Organic Carbon
- pH
- Eh (Electrode Potential)
- Total Solids/Moisture Content
- Total Sulfide
- Acid Volatile Sulfides
Assessing the Risk at a Marine Sediment Site
Potential Ecological Risk

Chemicals of Concern

Plants/Animals

Means of Exposure/Impact

Potential Ecological Risk
Conducting a Sediment ERA--Contaminants

- Identify contaminants, sources, and pathways to aquatic environment
  - Site history
  - Consider releases to surface water
    - Direct or via Groundwater
  - Consider releases from groundwater to sediments
  - Consider releases from the atmosphere/wind driven particulates or volatilization
Basic Sediment-Based Marine Food Chain

**Quaternary Predators**
Very Large Fish – Cetaceans – Humans

**Tertiary Predators**
Birds – Large Fish – Pinnipeds – Cetaceans – Sea Otters – Humans

**Secondary Predators**
Birds – Medium Fish – Pinnipeds – Cetaceans – Sea Otters – Humans

**Primary Predators**
Birds – Shrimp – Crabs – Small Fish – Pinnipeds – Cetaceans – Sea Otters – Humans

**Invertebrate Infauna & Epifauna**
Worms – Amphipods – Mollusks – Sea Urchins – Humans

**Plants – Algae – Bacteria – Detritus**
Generalized Aquatic Food Web

**Consumers**
- Carnivores
  - Piscivorous and Benthic Fish
- Omnivores
  - Vertebrate Omnivores (including filter feeders)
  - Invertebrate Omnivores benthic, free (pelagic) (including filter feeders)
- Herbivores
  - Vertebrate Herbivores (including filter feeders)
  - Invertebrate Herbivores scrapers, grazers, filter feeders (including zooplankton)

**Producers**
- Non-vascular & Vascular
  - Attached and Free Algae (including phytoplankton and photosynthetic bacteria)
  - Submerged, emergent, and floating vascular vegetation

**Detritivores** (Mechanical decomposers)
- chewers, shredders, gatherers

**Decomposers**
- Chemical Decomposers (fungi, bacteria)
  - Carcasses, plant debris, exuviae, fecal material, etc.
  - Nutrients

**NUTRIENTS**
Conducting a Sediment ERA--Receptors

- Identify receptors potentially impacted by the release
  - Benthic organisms via sediment, porewater/gw
  - Fish and epibenthic organisms via surface water, sediment, and contaminated prey
  - Marine mammals via contaminated prey
  - Aquatic-dependent birds via sediments and contaminated prey
Simple Conceptual Model

release of a contaminant from a waste site

Ultimate Source

Other Estuarine Sources

Soil → Groundwater → Surface Water → Bulk Sediment

Sediment Particulates → Benthos Receptor

Sediment Pore Water → Benthos Receptor
Evaluating Exposure and Effects
Once Sediment Data are Available…

Identify the potential chemical action of contaminants as they relate to exposure of receptors at the site.

Can exposure to the contaminant result in:

- Toxicity
  - Acute
  - Chronic
- Bioaccumulation/Biomagnification
  - Food web
How to Estimate Potential Impacts to Receptors

**Toxicity** from exposure to metals, pesticides, PAHs and PCB contamination

**For Sediments:**
- Use Sediment Screening Guidelines (ER-L, etc)
- Conduct appropriate toxicity tests with site sediment

**For Surface and Pore water:**
- Use Ambient Water Quality Criteria/California Toxics Rule values
- Conduct appropriate toxicity tests with site water
How to Estimate Potential Impacts to Receptors

**Bioaccumulation** from exposure to certain metals, pesticides, dioxins and PCB contamination

For Sediments:
- Conduct appropriate accumulation tests with site sediment
- Collect resident organisms for tissue residue analysis
- Can use literature-based accumulation factors for food web

For Surface and Pore water:
- Use partitioning factors, literature-based factors
- Collect resident organisms for tissue residue analysis
Bioaccumulative Contaminants in Sediment

- Metals
  - Cd, Cu, Hg, Ni, Pb, Se, Tributyltin, Zn Pesticides and PCBs
- PAHs in benthos
- Dioxins and dibenzofurans
Exposure and Effects: What Receptors and Functions Do We Care About?
Generic Assessment Endpoints

- **Protection/maintenance of an animal/plant population:**
  Refers to the ability of a population of the species of concern to survive, grow and reproduce.

- **Protection/maintenance of a biotic community:**
  Refers to the ability of all species in the community to survive, grow and reproduce maintaining the proper balance of species.

- **Protection/maintenance of an endangered species:**
  Refers to the ability of every individual of the endangered species of concern to survive, grow and reproduce.
Candidate Assessment Endpoints for Aquatic ERAs

- Survival and growth of aquatic plants
- Survival and growth of aquatic invertebrates
- Survival, growth and reproduction of fish
- Survival, growth and reproduction of aquatic-dependent mammals
- Survival, growth and reproduction of aquatic-dependent birds
Laboratory Studies
Types of Laboratory Studies

- **Toxicity testing**
  - Survival → amphipods (*Eohaustorius sp*)
  - Growth → worms (*Neanthes sp*)
  - Reproduction → echinoderms (*Dendraster sp*)

- **Bioaccumulation studies**
  - Tissue residues and growth → bivalves, fish
Toxicity Test Organisms
Advantages of Toxicity Tests

- Provides quantifiable information about the potential for bioeffects at a site
- Indirect indicator of bioavailability of contaminants
- Controlled conditions of exposure (minimizes natural variability)
- Not dependent on presence of an *in-situ* population
- Quick and relatively inexpensive
Disadvantages of Toxicity Tests

- Not designed to mimic natural exposure, so may be difficult to relate directly to actual responses at a site.
- Test tells whether or not media is toxic not what is causing toxicity.
- Not appropriate for contaminants that cause subtle effects over long periods, or for those where the major concern lies in their potential to biomagnify.
- May observe toxicity in unexpected places (i.e., “clean” sites) due to unknown or unquantified factors.
Bioaccumulation

The net result when the uptake of a chemical by a biological organism exceeds the depuration of the chemical from the organism.
Bioaccumulation

Toxicant in water:
- fate processes either internal or external to model

Uptake through gill:
- respiration rate
- assimilation efficiency

Uptake from diet:
- consumption rates
- assimilation efficiency
- growth rates
- toxicity
- lipid content
- food web structure

Losses of toxicant:
- biotransformation
- predation
- mortality
- depuration
- spawning
- promotion
- emergence

Partitioning

Toxicant in food sources
- Organic sediments
- Algae
Bioaccumulation Factor (BAF)
Biota-Sediment Accumulation Factor (BSAF)

BAF = [Organism] / [Media]

BSAF = [Organism] / [Sediment]
[ug/kg of lipid] / [ug/kg of organic carbon]
Field Deployment of Clam Bioaccumulation Study
Advantages of Bioaccumulation Studies

- Direct measure of bioavailability
- Integrates contamination levels over time
- Concentrates chemicals from water allowing easier and less expensive analyses
- Potential for determining health risks
- Use information to calculate uptake through the foodweb (dose to predator)
Disadvantages of Bioaccumulation Studies

- Due to bioregulation or metabolism of some contaminants, body burdens are not related to levels found in the environmental
- Relationship between body burdens and bioeffects uncertain
- Difficult to associate contamination in mobile species to the contaminated site
- Uptake of one contaminant may be inhibited by the presence of other contaminants-antagonism
- Rates of biological processes may be reduced by contamination, thus reducing rates of bioaccumulation
Biota Sampling
Benthic Community Analysis
Deploying Remotes camera and bottom image taken with camera (NASSCO).
Community Measures

- Taxa Richness
- Percent Contribution of Dominant Taxa
- Abundance
- Community Similarity Indices:
  - Benthic Response Index (BRI)
  - Relative Benthic Index (RBI)
Community Studies

Pros

- Measures actual *in-situ* biological responses to contaminants
- Demonstrate effects on indigenous organisms
- Integrates temporal exposure

Cons

- High natural variability
- Requires experienced expert investigators
- May not be appropriate for contaminants whose major concern lies in their potential to bioaccumulate
Data Interpretation
Summary of Information

- **Presence of Contaminants**
  - Chemical Analysis: Sediment chemistry, Water chemistry
- **Bioavailability of Contaminants**
  - Bioaccumulation: Tissue chemistry, Lipid bag deployment
- **Bioeffects**
  - Toxicity Tests: Amphipod mortality, Daphnia reproduction, Neanthes growth
  - Community Studies: Species richness, Species ratios, Community composition
Uncertainty: Common Extrapolations

- Between taxa
- Between responses
- From laboratory to field
- Between geographic areas
- Between spatial scales
- From data collected over a short time frame to longer-term effects
Weight of Evidence---Triad Approach

- Chemistry results
  - Exceeds benchmarks—yes or no
- Results of toxicity testing
  - Can include bioaccumulation testing
- Community Structure Indices
# Weight of Evidence Table Example

<table>
<thead>
<tr>
<th>Loc Test</th>
<th>Chemistry</th>
<th>Toxicity testing</th>
<th>Benthic Community</th>
<th>Bioaccm testing</th>
<th>Score</th>
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<td>_</td>
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</tbody>
</table>
WOE Approach: Advantages & Disadvantages

- **Advantages:**
  - Document exposures and effects spatially & temporally, using qualitative & quantitative analyses
  - Evaluate exposure & effects relationships in multiple compartments in both the lab & field

- **Disadvantages:**
  - Cannot provide predictive capability (i.e., correlation is not causality)
  - Cannot predict clean-up levels
  - Individual LOE are quantitative; WOE approach may be subject to using only qualitative BPJ
Questions?