Components of Estuarine and Marine Ecological Risk Assessment

Denise M. Klimas
Donald A. MacDonald
Assessment and Restoration Division
Office of Response and Restoration

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

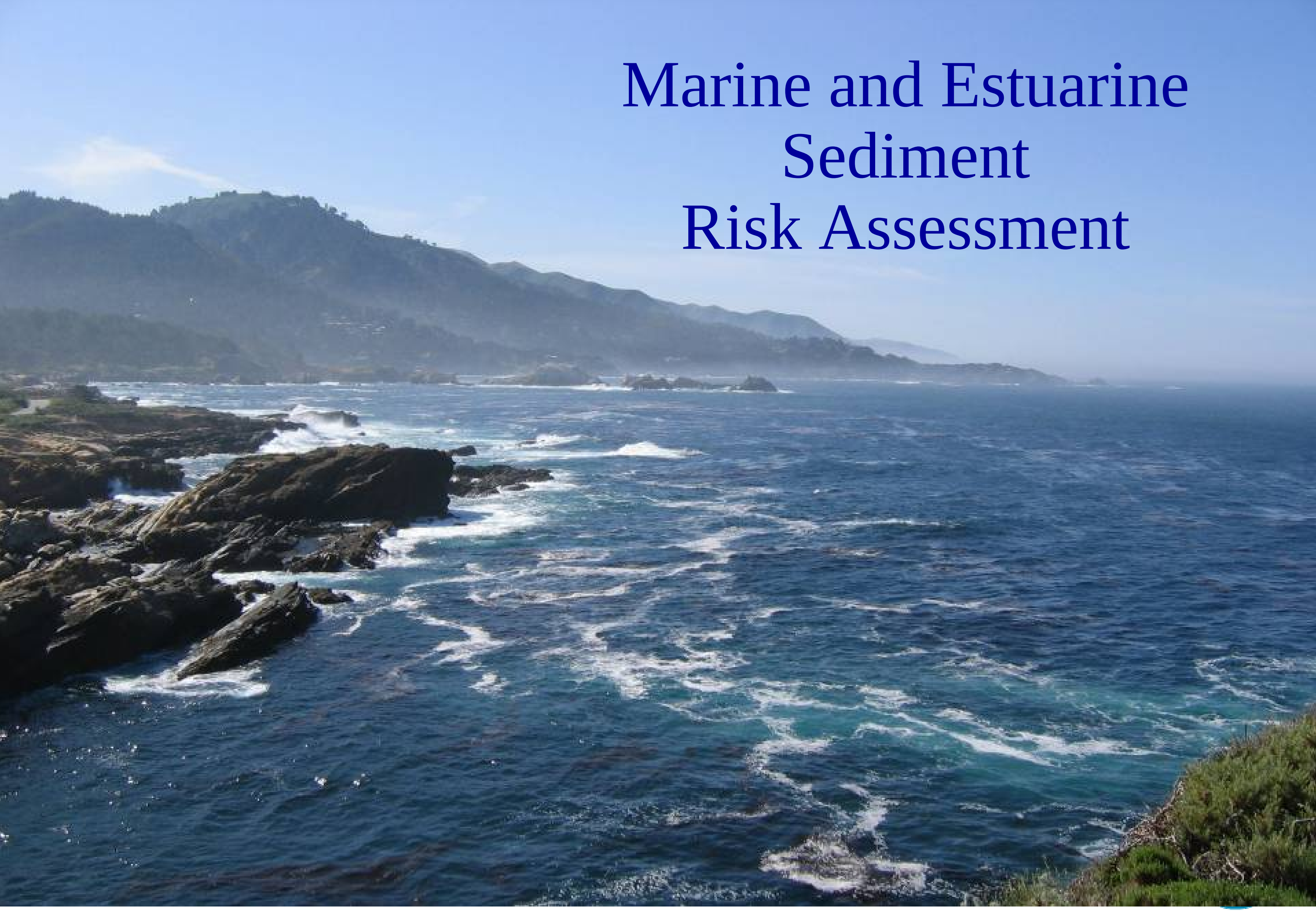
- 2001- MOU between DTSC and NOAA to Protect and Restore Coastal Resources
- NOAA provides technical support to DTSC project managers in OMF and Site Mitigation
- NOAA acts as a technical liaison and co-trustees with other federal, state, and local response agencies during field investigations, remedial 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

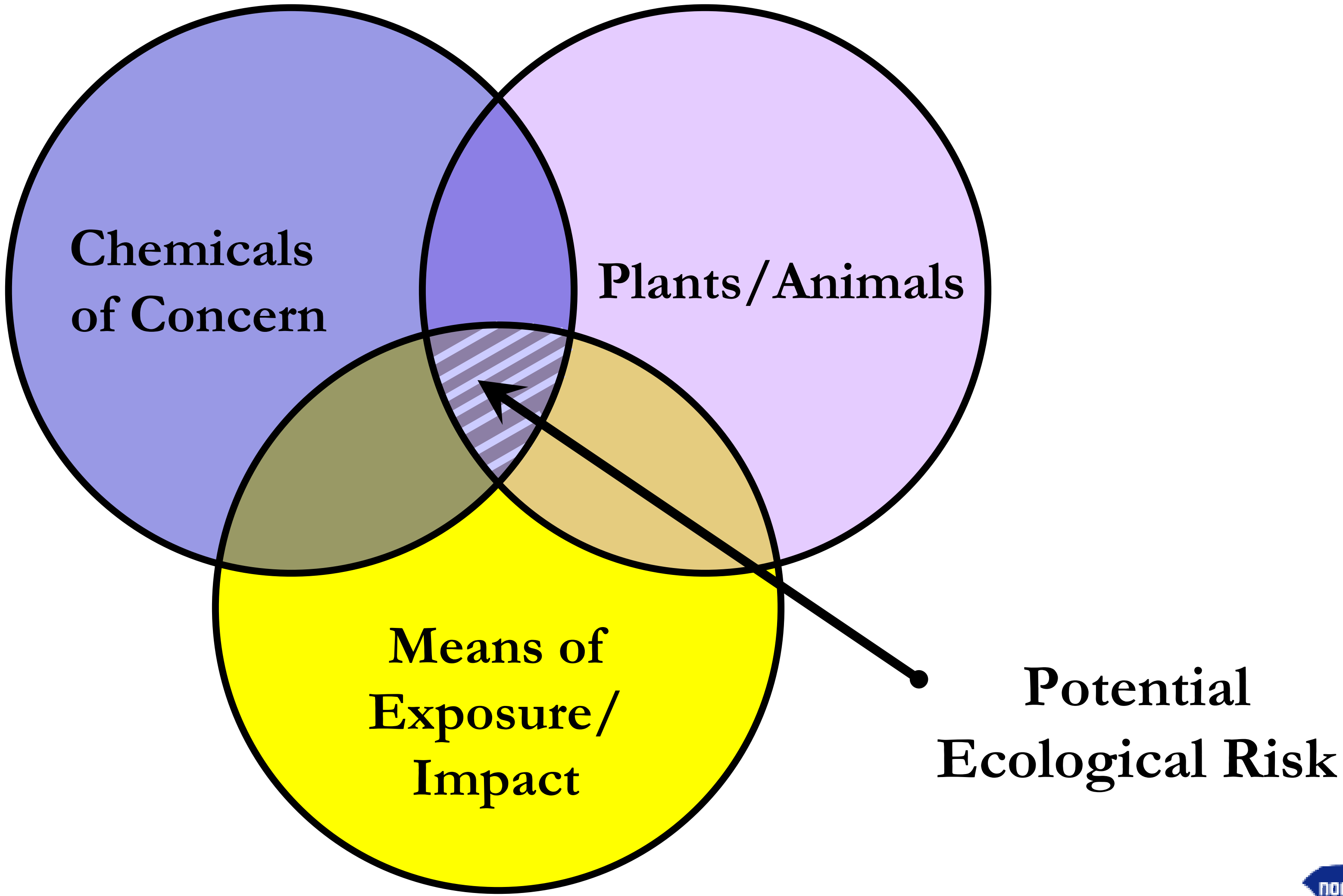
How can a Sediment Ecological Risk Assessment differ from a Terrestrial ERA?

- 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


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

↑

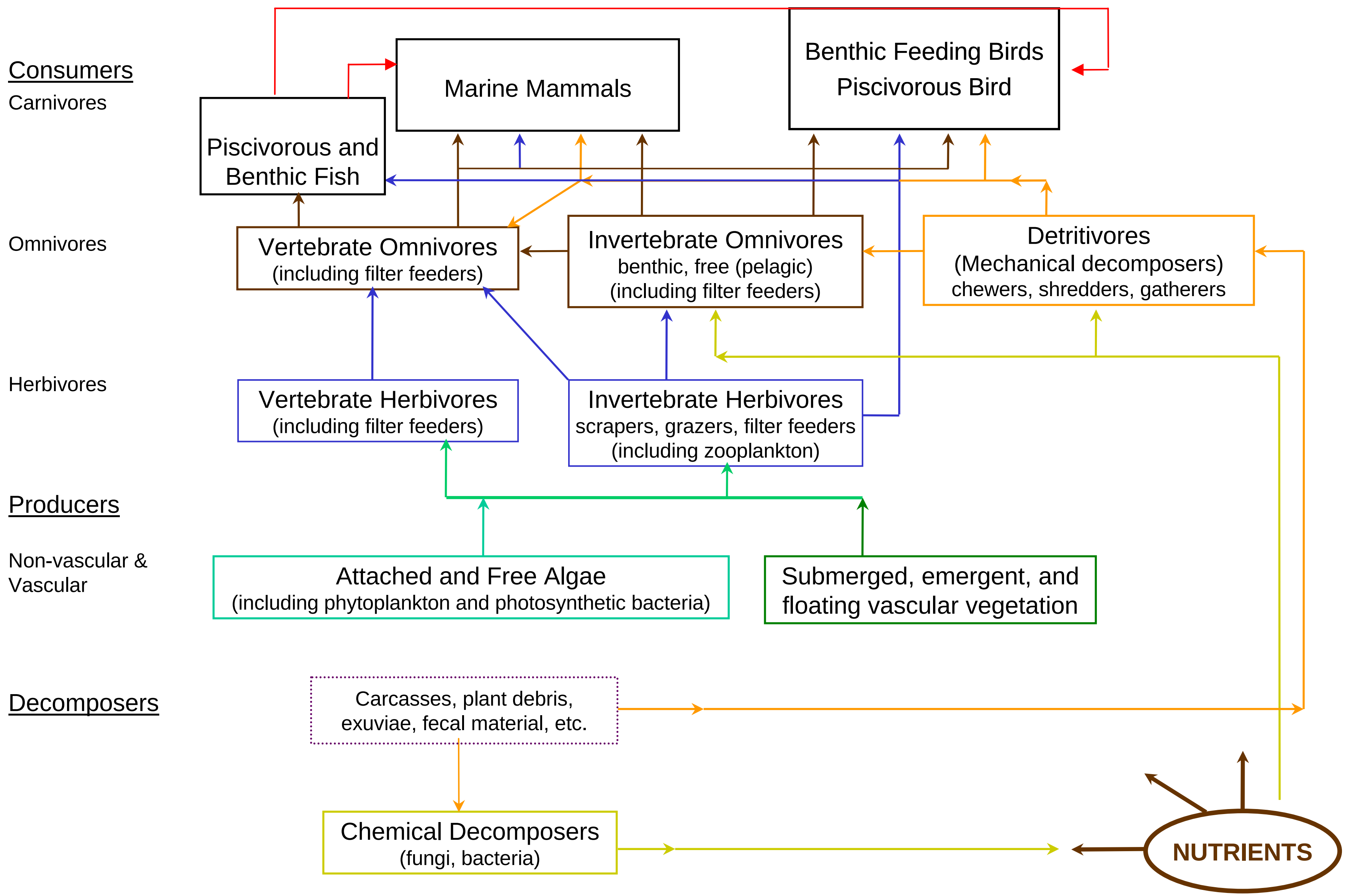
Invertebrate Infauna & Epifauna

Worms – Amphipods – Mollusks – Sea Urchins – Humans

↑

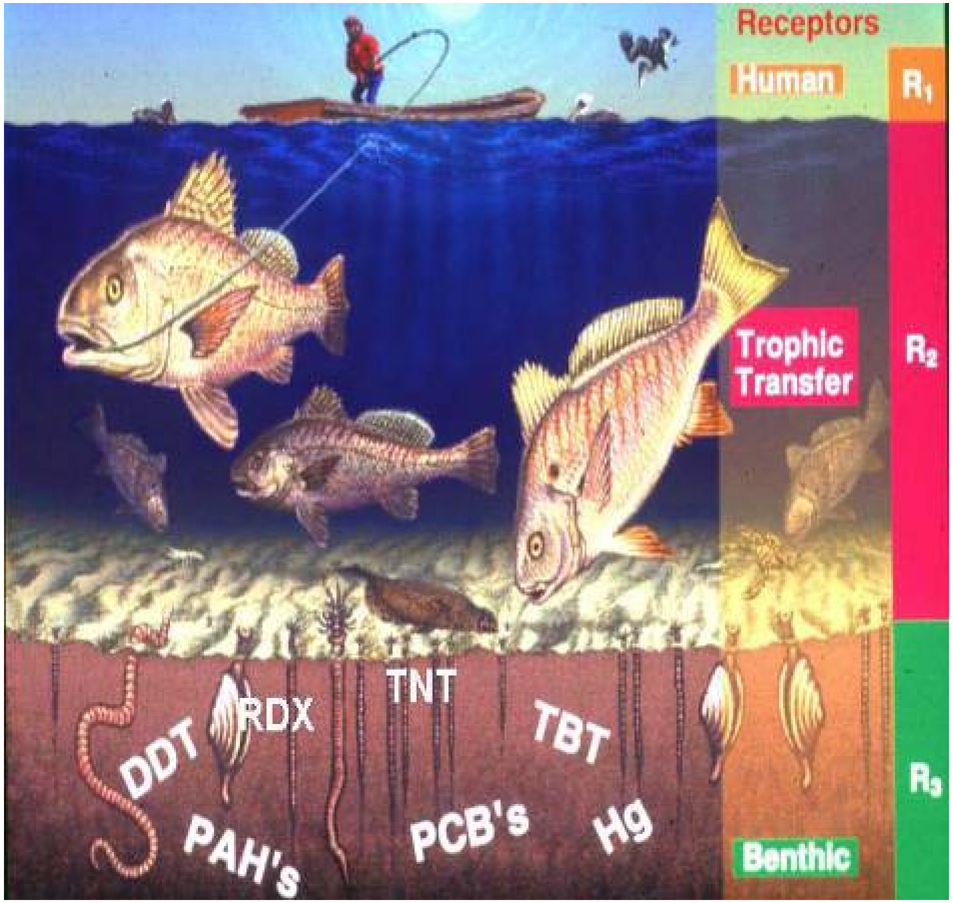
Plants – Algae – Bacteria – Detritus

Generalized Aquatic Food Web

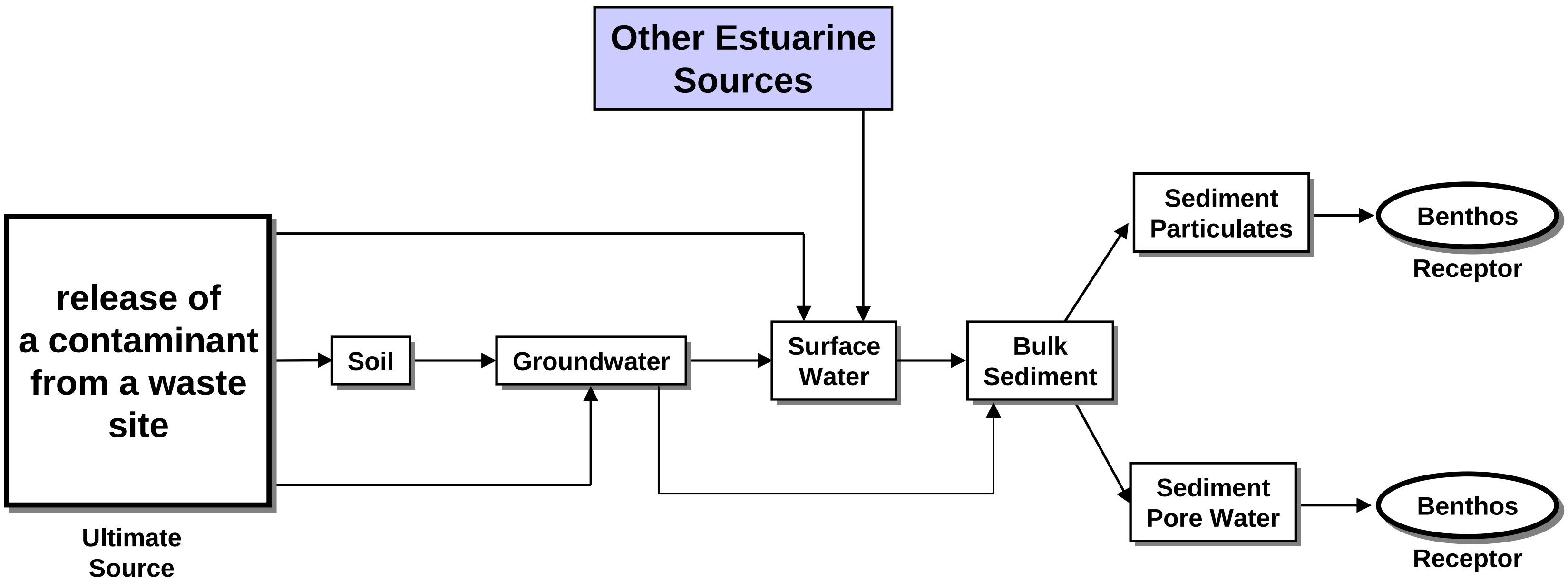


Conducting a Sediment ERA--Receptors

- 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



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



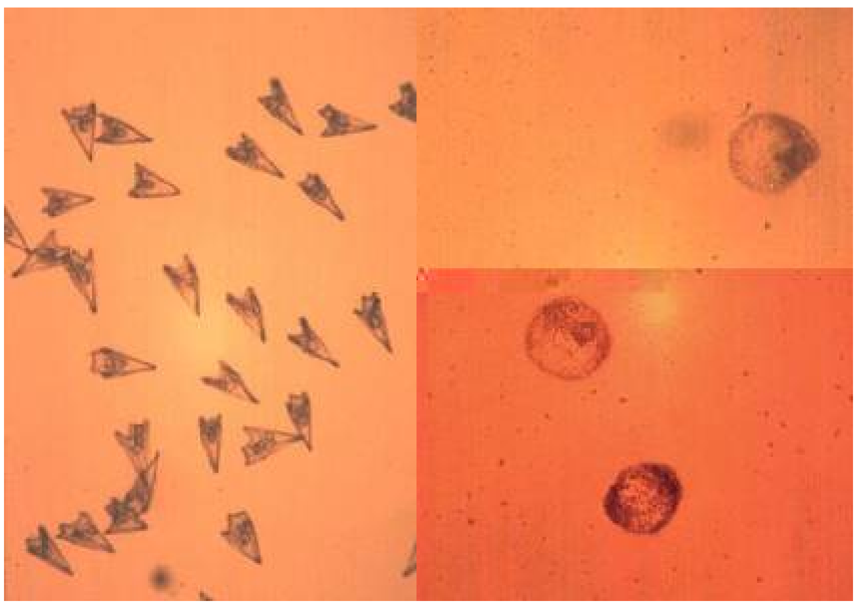

Laboratory Studies

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

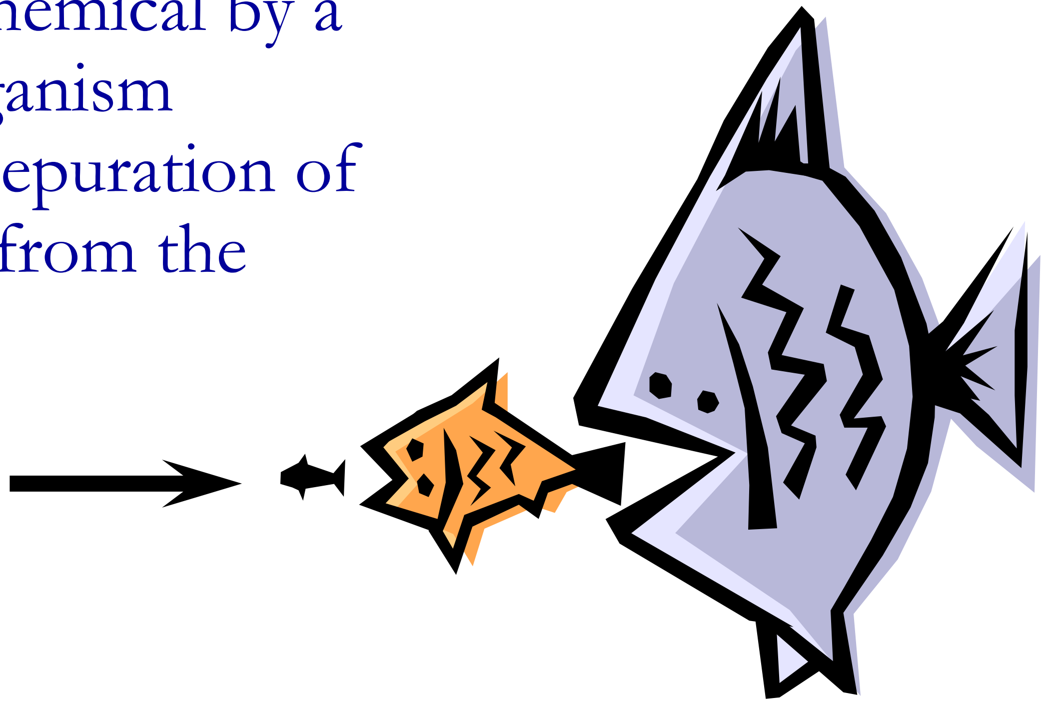
- Provides quantifiable information about the potential for bioeffects at a site
- Indirect indicator of bioavailability of contaminants
- Controlled conditions of exposure (minimizes natural variability)
- Not dependent on presence of an *in-situ* population
- Quick and relatively inexpensive

Disadvantages of Toxicity Tests

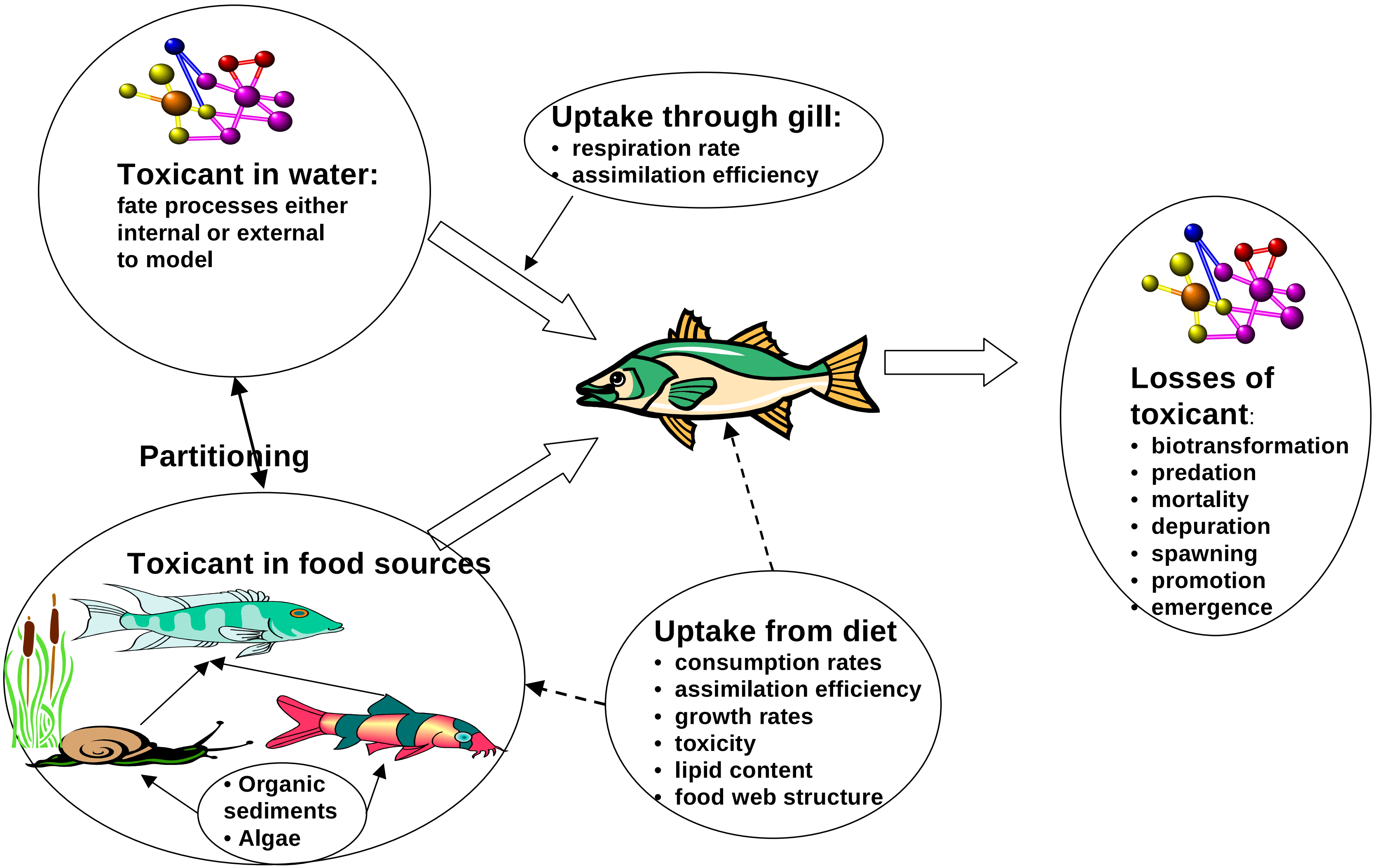
- Not designed to mimic natural exposure, so may be difficult to relate directly to actual responses at a site
- Test tells whether or not media is toxic not what is causing toxicity
- Not appropriate for contaminants that cause subtle effects over long periods, or for those where the major concern lies 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

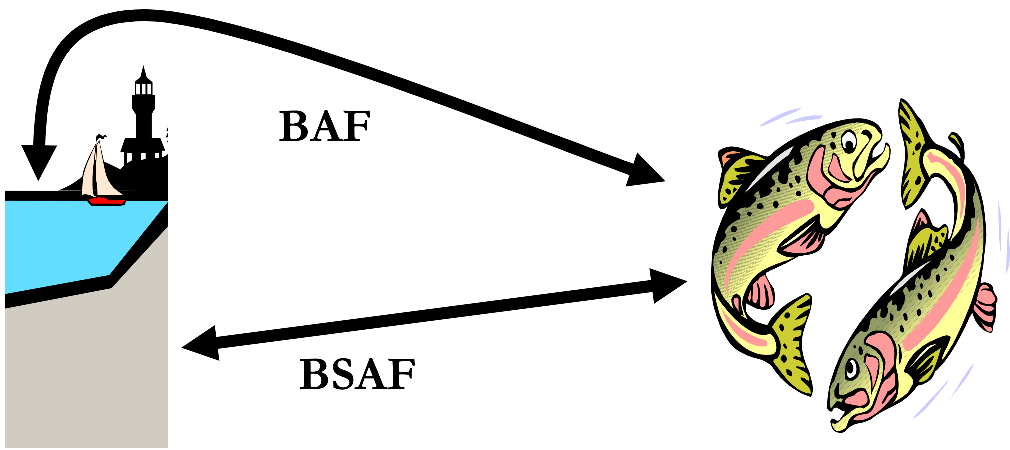


Bioaccumulation



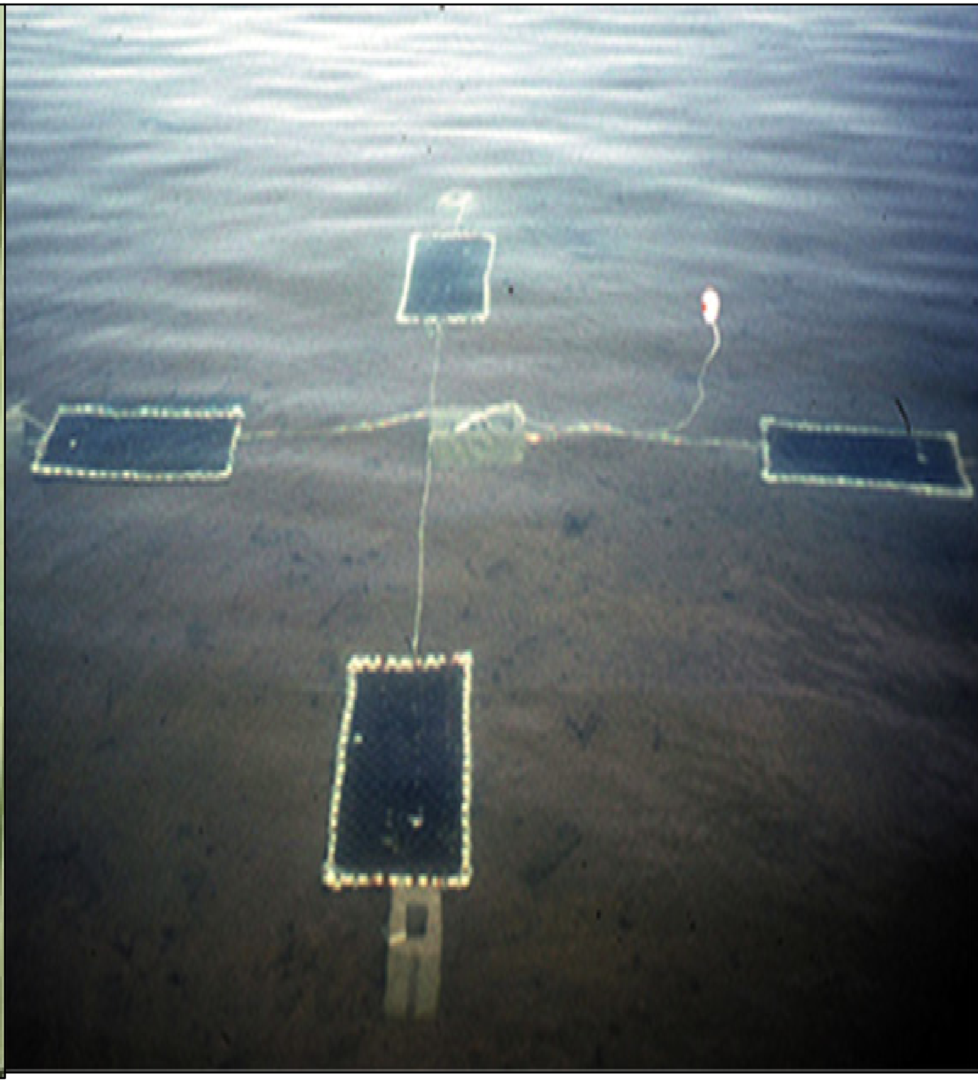
Bioaccumulation Factor (BAF)
Biota-Sediment Accumulation Factor (BSAF)

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

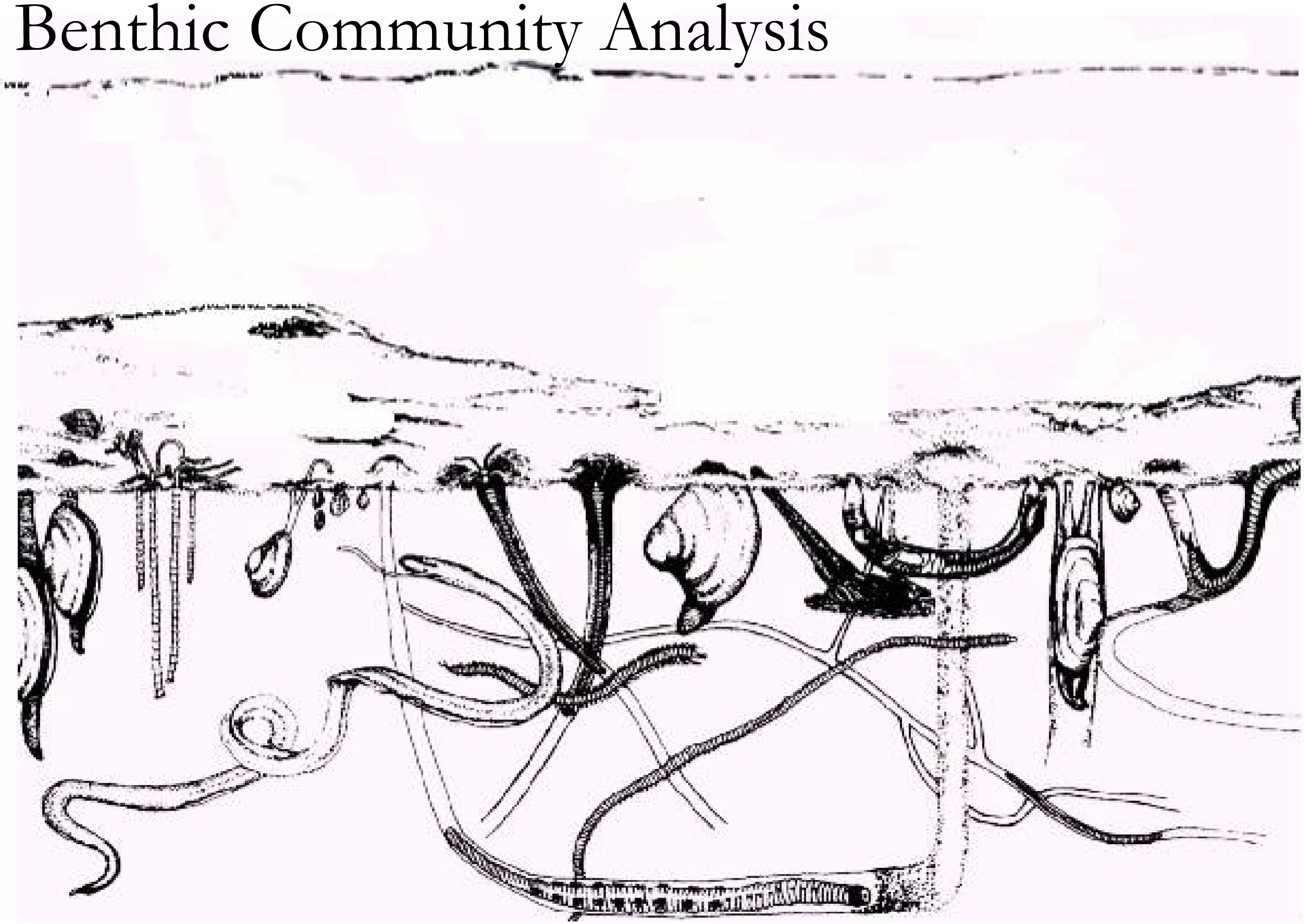
- Direct measure of bioavailability
- Integrates contamination levels over time
- Concentrates chemicals from water allowing easier and less expensive analyses
- Potential for determining health risks
- Use information to calculate uptake through the foodweb (dose to predator)

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




Ponar


Eckman grab

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 CONTAINANTS → **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

Loc / Test	Chemistry	Toxicity testing	Benthic Community	Bioaccm testing	Score
Loc 1	+	+	+	+	High
Loc 2	+	+	_	+	High
Loc 3	_	+	+	_	Potential
Loc 4	+	_	+	_	Potential
Loc 5	_	_	_	_	Low

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?