Sediment Quality Assessments

The Sediment Environment

- Sediments are primarily composed of particulate mineral matter and organic matter in various stages of decomposition, size-sorted in relation to type of overlying water and velocity of water movement
- Sediments are major sites of biogeochemical nutrient recycling; bacterial populations and metabolic activity in surficial sediments are typically much larger than in overlying water; conditions are frequently anoxic

The Sediment Environment

- Benthic fauna are extremely diverse (nearly every animal phylum represented) and display great heterogeneity in distribution, feeding modes, growth, and reproduction

- Benthic fauna are a major source of prey for higher trophic level consumers; density and community structure vary by substrata, season, changes in ecosystem

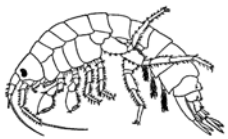
The Sediment Environment

SEDIMENT

Sediment Particles

Interstitial Water

Home to benthic organisms



Interstitial water, often referred to as pore water, is the water between sediment particles

Sediment Contamination

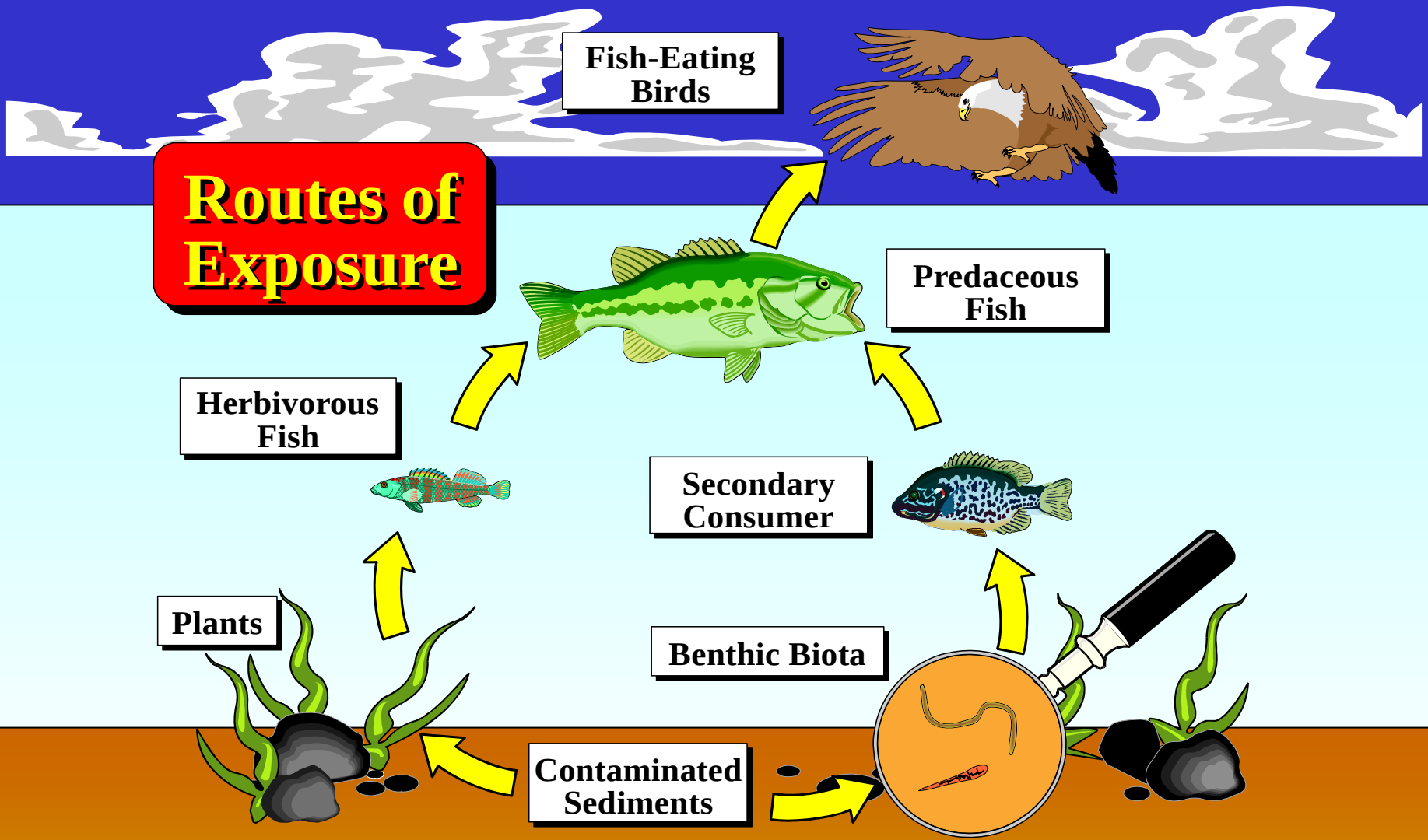
- Accumulation of Metals and Hydrophobic Organic Compounds (e.g., PCBs, PAHs, Metals, DDT, Pesticides)
- Lethal/Sublethal Effects to Resident Benthic Organisms
- Community Structure Alteration/Loss of Species/Loss of Function
- Bioaccumulation/Food Chain Transfer to Consumers

Sources of Sediment Contaminants

- Existing and historical point source discharges
  - Industrial discharge
  - Sewage treatment
- Atmospheric deposition of contaminants
  - Fuel combustion
  - Waste incineration

Sources of Sediment Contaminants

- Nonpoint source runoff
  - Harvested croplands (agricultural runoff)
  - Landfills, toxic waste storage and disposal sites
  - Urban stormwater
  - Inactive and abandoned mining sites


Routes of Exposure
Fish-Eating Birds
Predaceous Fish
Herbivorous Fish
Secondary Consumer
Plants
Benthic Biota
Contaminated Sediments

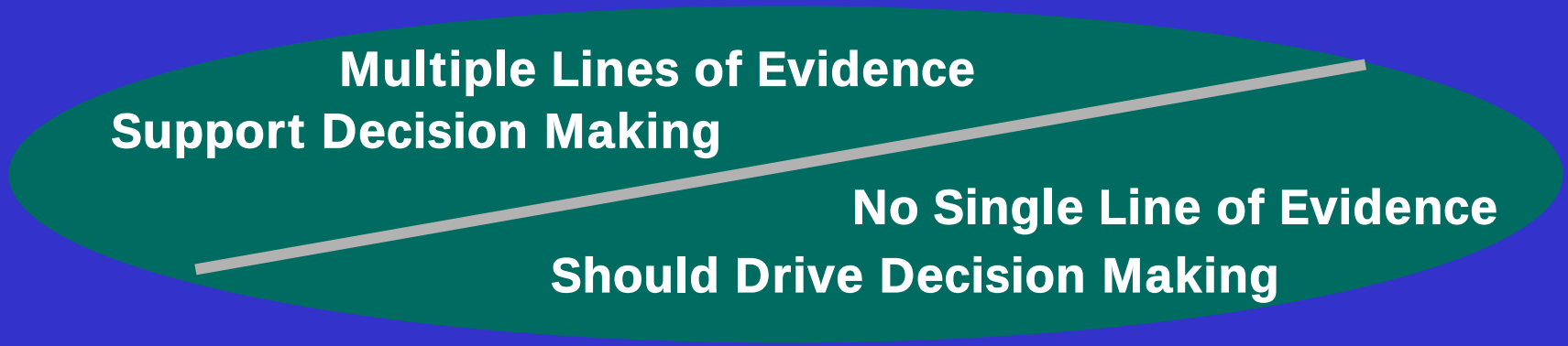
Costs of Contamination

- Damage to aquatic ecosystems
- Fish disease
- Lost fisheries resources
- Lost recreation value
- Health impacts if consumption warnings are not issued or heeded
- Harbor impacts
- Lost beneficial uses (e.g., habitat restoration)

Sediment Quality Assessment Applications

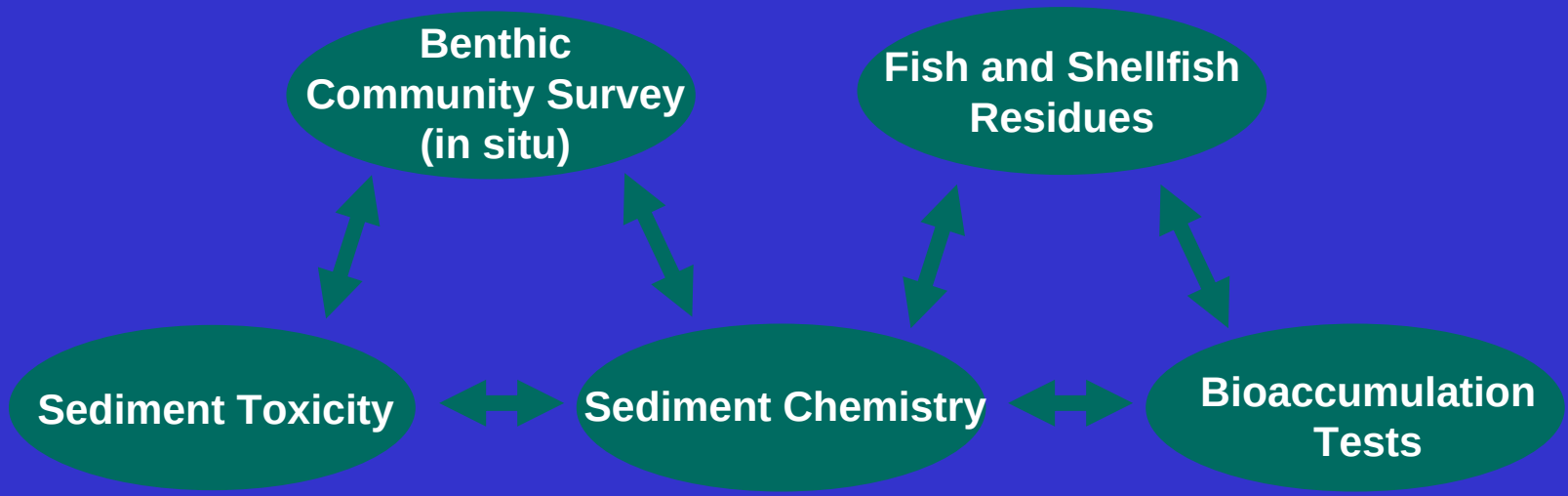
- State Water Quality Standards
  - Interpreting narrative or general criteria
  - State of Washington - Numeric Sediment Criteria
- Dredged Material Assessment and Management

Weight of Evidence Approach



- Some lines of evidence (measurement endpoints) can be "weighted", or valued, more highly than others
- A tiered approach calls for increasingly complex evaluations only as needed to quantify and reduce uncertainties associated with risk estimates
- Weight of evidence required should be proportional to the weight of the decision

Sediment Quality "Triads"



Risk to Benthic Organisms

Risk to Human and Wildlife Consumers

(Other lines of evidence include biomarkers, histopathological analyses, and microcosm/mesocosm studies)

Triad Chart of Conclusions for Benthic Organisms

Situation	Elevated Chemical Levels	Toxicity	Community Alteration	Possible Conclusions
1	+	+	+	Strong evidence of contaminant-induced degradation
2	-	-	-	Strong evidence of no contaminant-induced degradation
3	+	-	-	Contaminants not bioavailable, or present at nontoxic levels
4	-	+	-	Unmeasured chemicals or conditions exist, with potential to cause degradation
5	-	-	+	Alteration is not due to toxic chemicals
6	+	+	-	Toxic chemicals are stressing system, but not enough to not modify the community
7	-	+	+	Unmeasured chemicals causing degradation
8	+	-	+	Chemicals not bioavailable and alteration not caused by toxic chemicals, or tests not sensitive

Types of Assessments

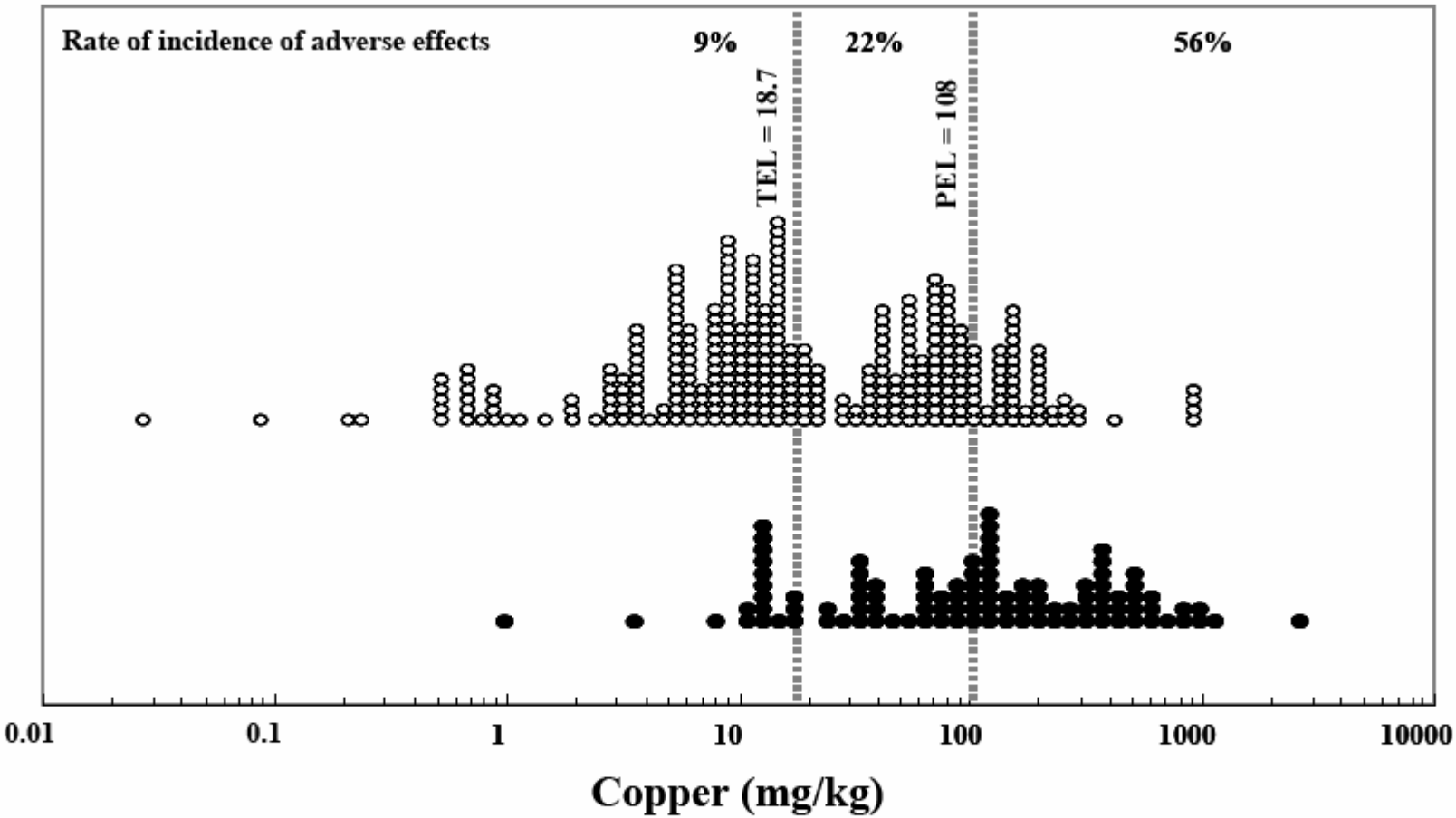
- Sediment Chemistry
  - Empirical Relationships with Observed Adverse Effects
  - Measures of Bioavailable Fraction (Equilibrium Partitioning)
- Sediment Toxicity
  - Survival, Growth, Reproduction

Types of Assessments

- Benthic Community
  - Measures and Indices of Abundance and Diversity
  - Presence of Indicator Species
- Bioaccumulation
  - Laboratory Tests and Food Chain Models
  - Tissue Residue Analysis

Sediment Quality Guidelines (SQGs)

- Empirically Derived [e.g., NOAA's Effect Range Medium/Effect Range Low (ERM/ERL)]
  - Rely on paired field sediment chemistry with field or laboratory effects data
  - Based on frequency distributions and statistical procedures
  - Implicitly account for all chemicals present, but do not establish cause and effect



Source: Adapted from CCME 1999.

Figure 1 **Distribution of copper concentrations in marine and estuarine sediments associated with adverse biological effects (●) and no adverse biological effects (o)**

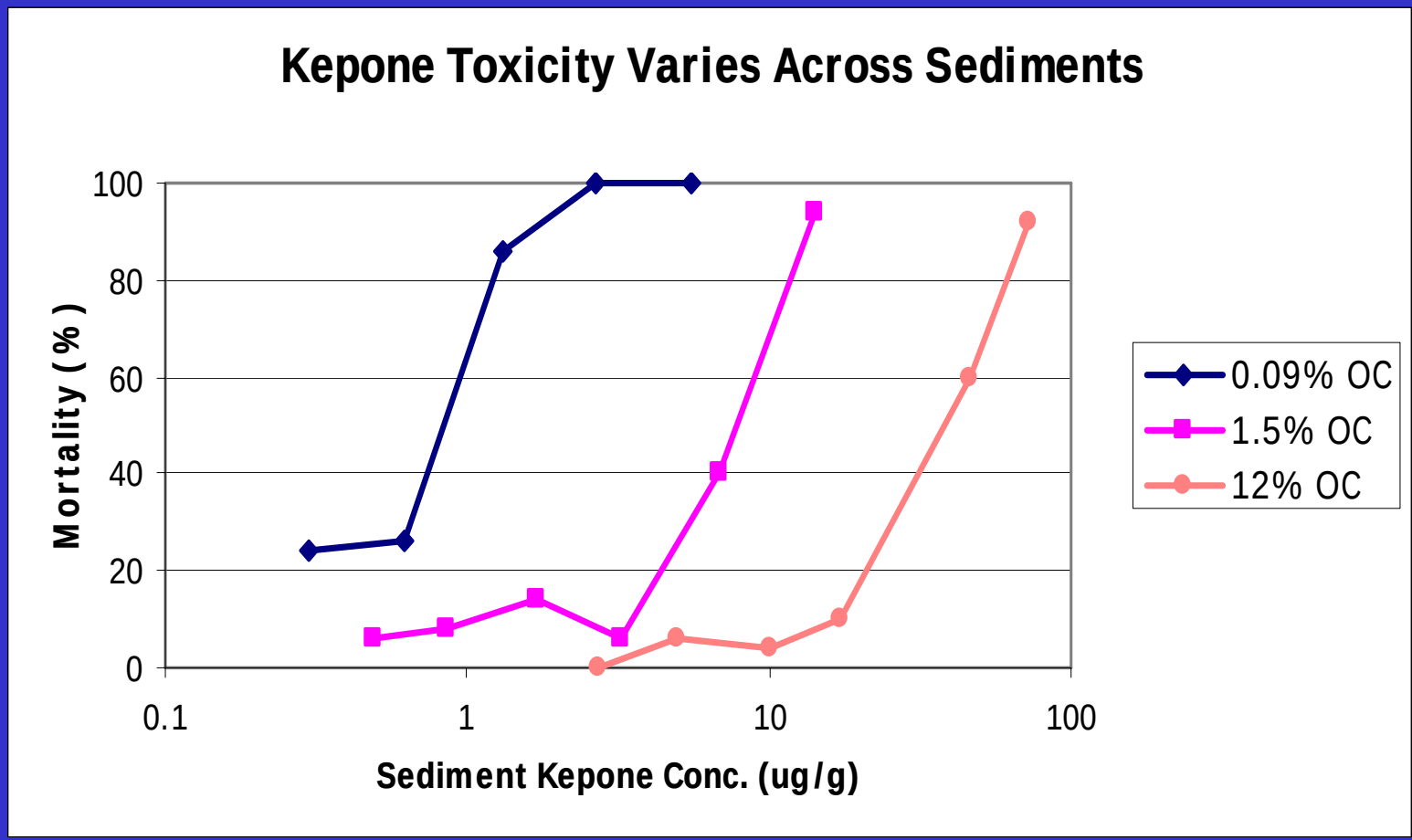
Sediment Quality Guidelines (SQGs)

- Theoretically Derived (e.g., EPA's equilibrium partitioning based numbers)
  - Rely on physical/chemical properties of sediment and chemicals
  - Based on laboratory studies of chemical interactions and effects
  - Reflect causality, but do not account for unmeasured chemicals

Equilibrium Partitioning Sediment Quality Guidelines

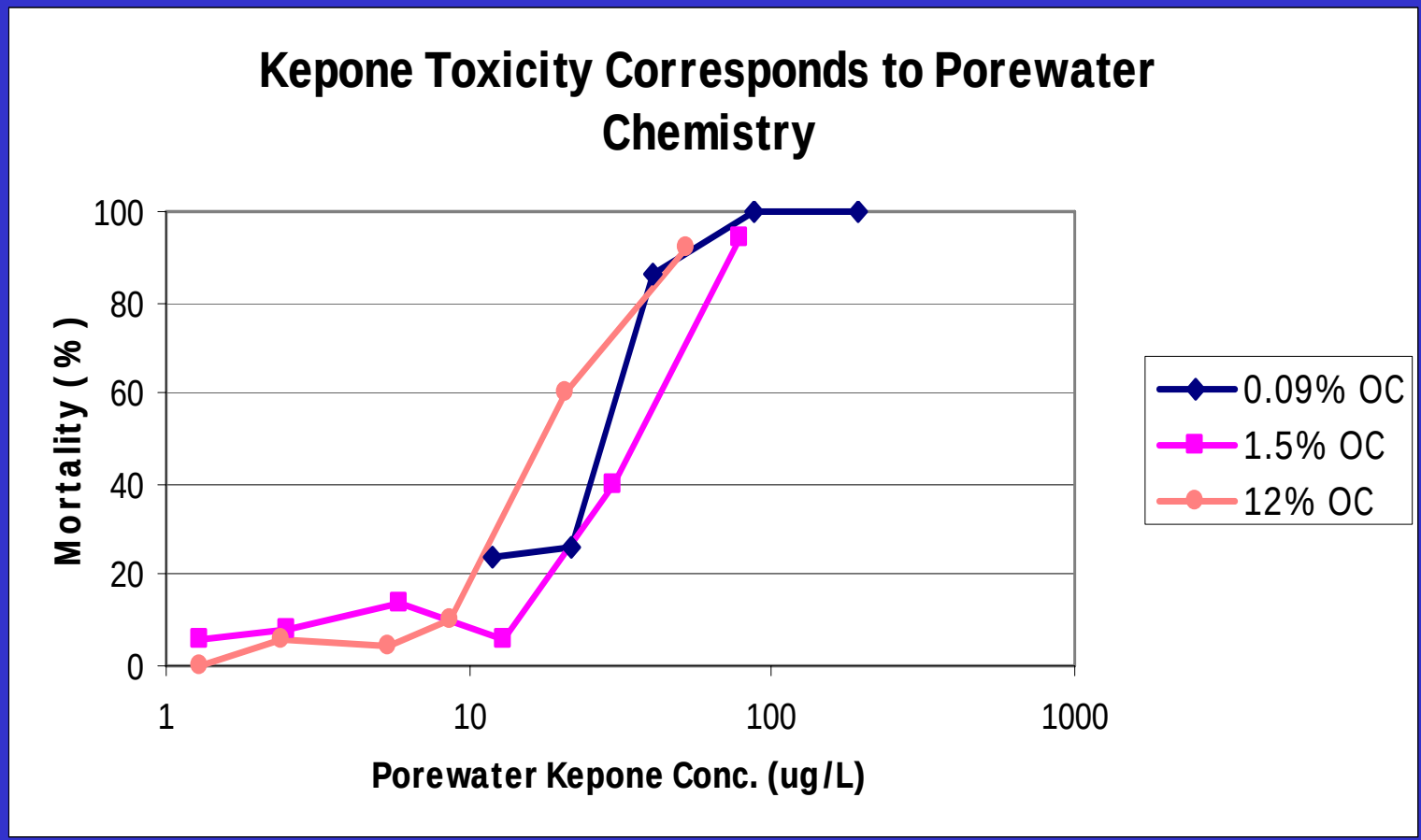
- Equilibrium Partitioning (EqP) is a conceptual approach for predicting the bioavailability of sediment-associated chemicals and, therefore, their toxicity. EqP was developed in response to the observation that the toxicity of chemicals in sediment is affected by the physical/chemical characteristics of the sediment. In other words, two different sediments with the same total toxicant concentration may not have the same toxicity to benthic organisms.

Bioavailability of Sediment Contaminants



Midge Exposed to Kepone (Adams et al., 1985)

Bioavailability of Sediment Contaminants



Midge Exposed to Kepone (Adams et al., 1985)

Guideline Calculation

$$ESG_{OC}^{*} = FCV \times K_{OC}$$

ESG_{OC} Chemical concentration in sediment protective of benthic organisms from direct toxicity normalized to organic carbon (☞g /g_{OC})

K_{OC} Organic Carbon-normalized partition coefficient; a measure of a chemical's differential solubility between the organic carbon and the interstitial water (L/kg)

FCV Final Chronic Value of the chemical of interest from the aquatic life WQC (☞g/L)

* - Name subject to change

Role of Sediment Toxicity Tests

- Provide direct measure of whole sediment, elutriate, or porewater bioaccumulation and toxic effects for a variety of benthic dwelling test organisms
- Account for bioavailability and contaminant interactions
- Can be standardized for multi-program, multi-region use
- May not adequately represent range of species to assess or protect

Role of Sediment Toxicity Tests

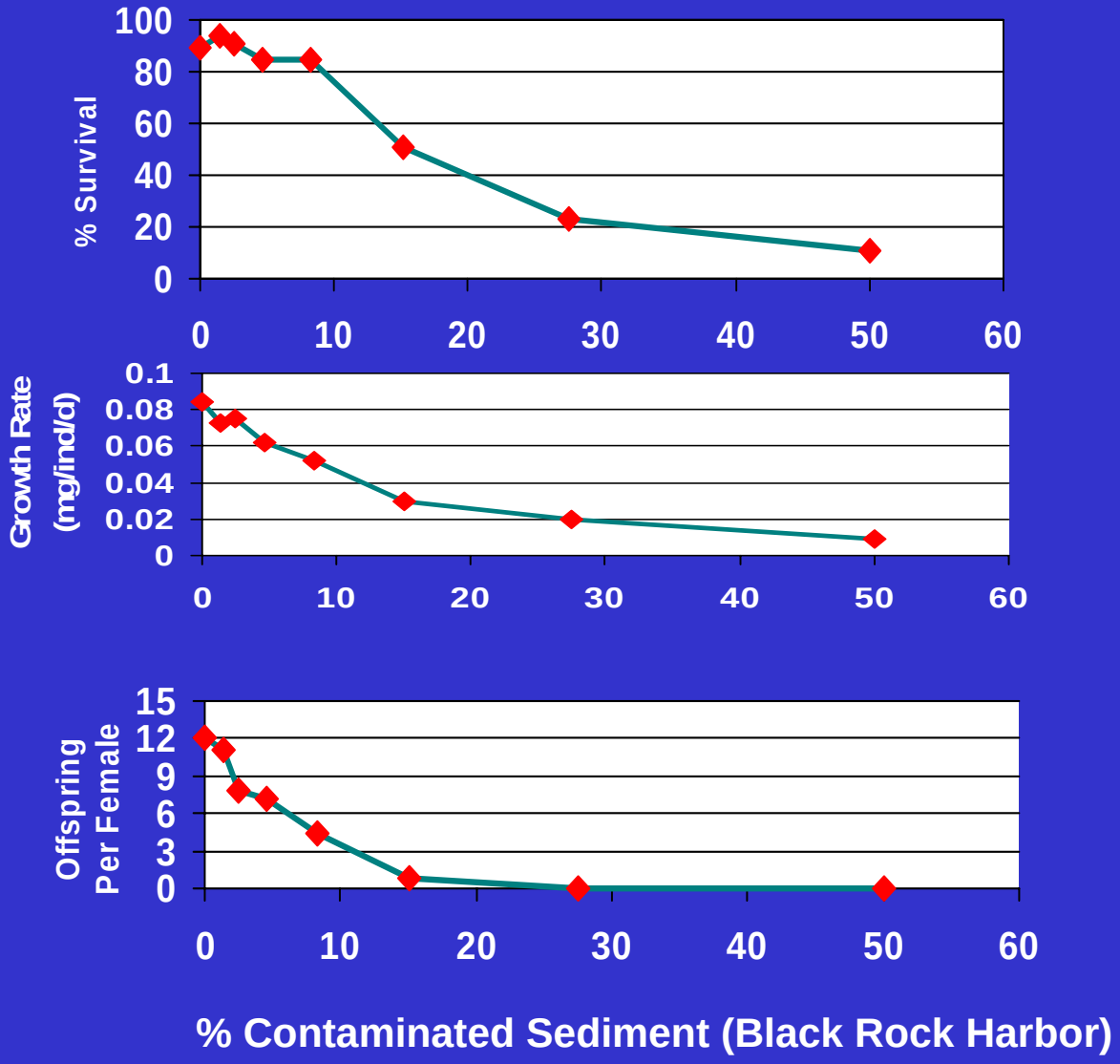
- Cannot differentiate among potential contaminant or natural geochemical causes or among routes of exposure
  - Sediment Toxicity Identification Evaluation (TIE) methods currently under development
- Test species sensitivity to contaminant(s) varies
- May alter natural bioavailability through sample collection, handling, and storage
- Can be applied *in situ*

Sediment Toxicity Analysis

Relative sensitivity: water 10-d LC50s (☞g/L; ASTM E1706)

Chemical	*Hyalella azteca*	*Chironomus tentans*	*Lumbriculus variegatus*
Copper	35	54	35
Zinc	73	1125	2984
Nickel	2.8	NT	158
Cadmium	780	NT	12160
Lead	<16	NT	794
p,p'-DDT	0.07	1.23	NT
p,p'-DDD	0.17	0.18	NT
p,p'-DDE	1.39	3.0	>3.3
Dieldrin	7.6	1.1	NT
Chlorpyrifos	0.086	0.07	NT

Chronic Toxicity Test for *Leptocheirus plumulosus*



- All 3 endpoints exhibit dose/ response
- Rank-order of sensitivity is Reproduction > Growth > Survival
- Concentration-survival curves for 28-d and 10-d exposures are the same (not depicted on this slide)

Benthic Invertebrate Community Assessment

- Bioassessments: an evaluation of the biological condition of a waterbody using surveys of the structure and function of the community of resident biota of the waterbody
- Advantages:
  - Allows you to directly measure resource intended to protect
  - Reflects all physical and biological stressors and their cumulative impacts

Benthic Invertebrate Community Assessment

- Why use Benthic Macroinvertebrates?
  - Limited mobility - indicators of local conditions
  - Responsive to stress
  - Primary food source for fish and shellfish
  - Abundant and relatively easy to sample
- Disadvantages include:
  - Index development and calibration requires commitment of resources

Benthic Invertebrate Community Assessment

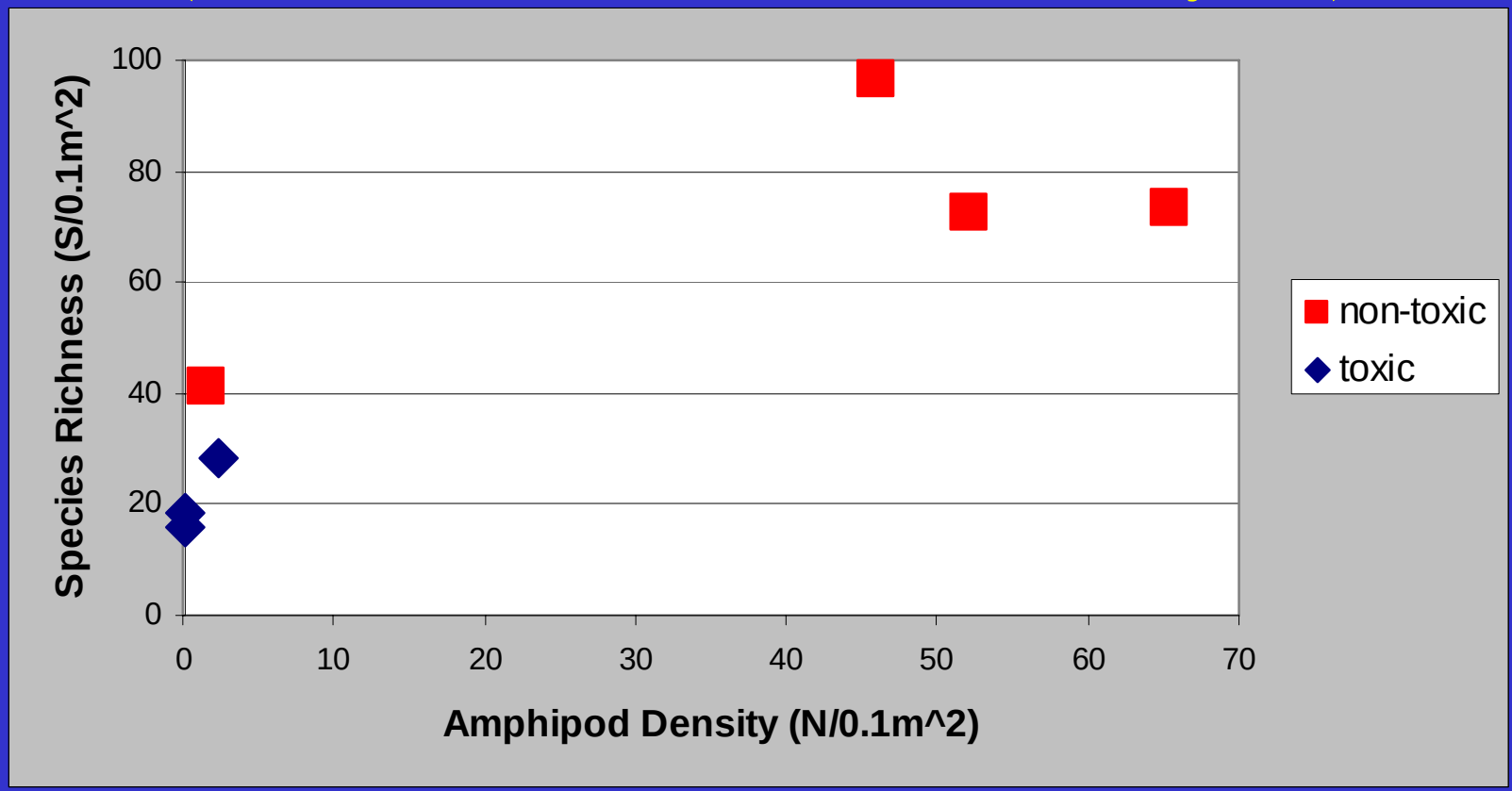
- Symptoms of Degradation include:
  - Fewer native species
  - Fewer intolerant species
  - Greater proportion of exotics
  - Greater incidence of disease and anomalies

Benthic Invertebrate Community Assessment

- Examples of Invertebrate Metrics include:
  - Taxa richness
  - Diversity indexes
  - Total Biomass
  - Total abundance
  - Percent abundance, percent biomass, richness of pollution sensitive taxa

Acute Toxicity, Amphipod Density, and Benthic Species Richness

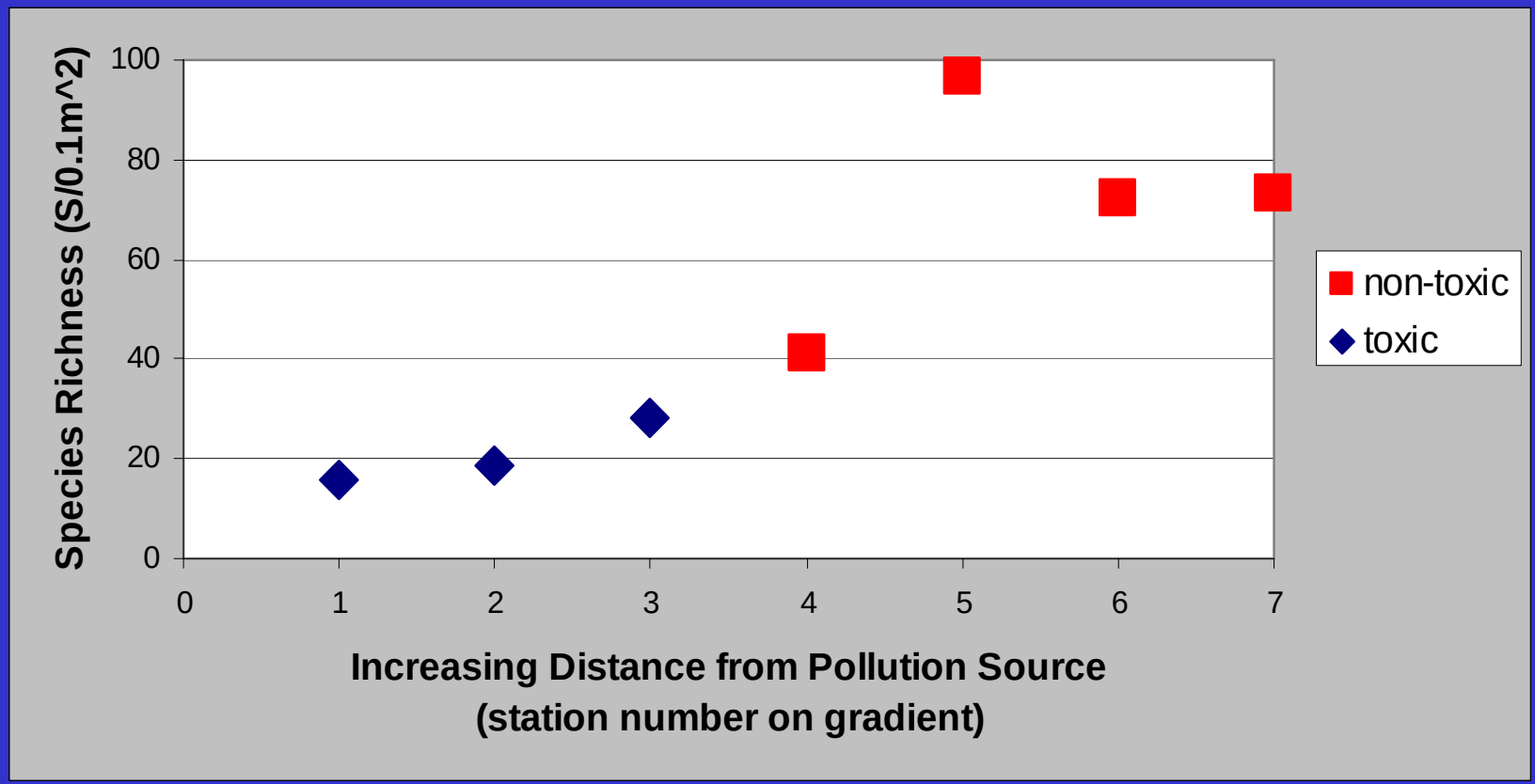
(Palos Verdes Shelf and Santa Monica Bay, CA)



Adapted from Swartz et al. Mar. Ecol. Prog. Ser. 31: 1-13, 1986

Pollution, Acute Toxicity, and Benthic Species Richness

(Palos Verdes Shelf and Santa Monica Bay, CA)



Adapted from Swartz et al. Mar. Ecol. Prog. Ser. 31: 1-13, 1986

Summary Points

- Sediment Quality Triad Provides the Framework, Bioavailability is the Key
- Different Measurement Endpoints Answer Different Questions (Assessment Endpoints)
- Reliance On Any One Endpoint is Problematic
- Weight of Evidence Required Should Be Proportional to the Weight of the Decision

Review Questions

- List three (3) common contaminants found in sediments
- Agricultural runoff is a form of point/nonpoint source pollution (circle one)
- List two (2) costs of sediment contamination
- The EPA has the authority to address contaminated sediments (T/F)

Review Questions

- Weight of _____ required should be proportional to the weight of the decision
- The use of three separate lines of evidence to assess potential sediment contamination is commonly referred to as the Sediment Quality _____
- Empirically derived sediment quality guidelines rely on paired field sediment chemistry with field or laboratory effects data (T/F)

Review Questions

- All sediment toxicity test species are equally sensitive to all contaminants (T/F)
- Bioassessments: an evaluation of the _____ condition of a waterbody using surveys of the structure and function of the community of resident biota of the waterbody
- Name three (3) endpoints commonly measured in sediment toxicity assays