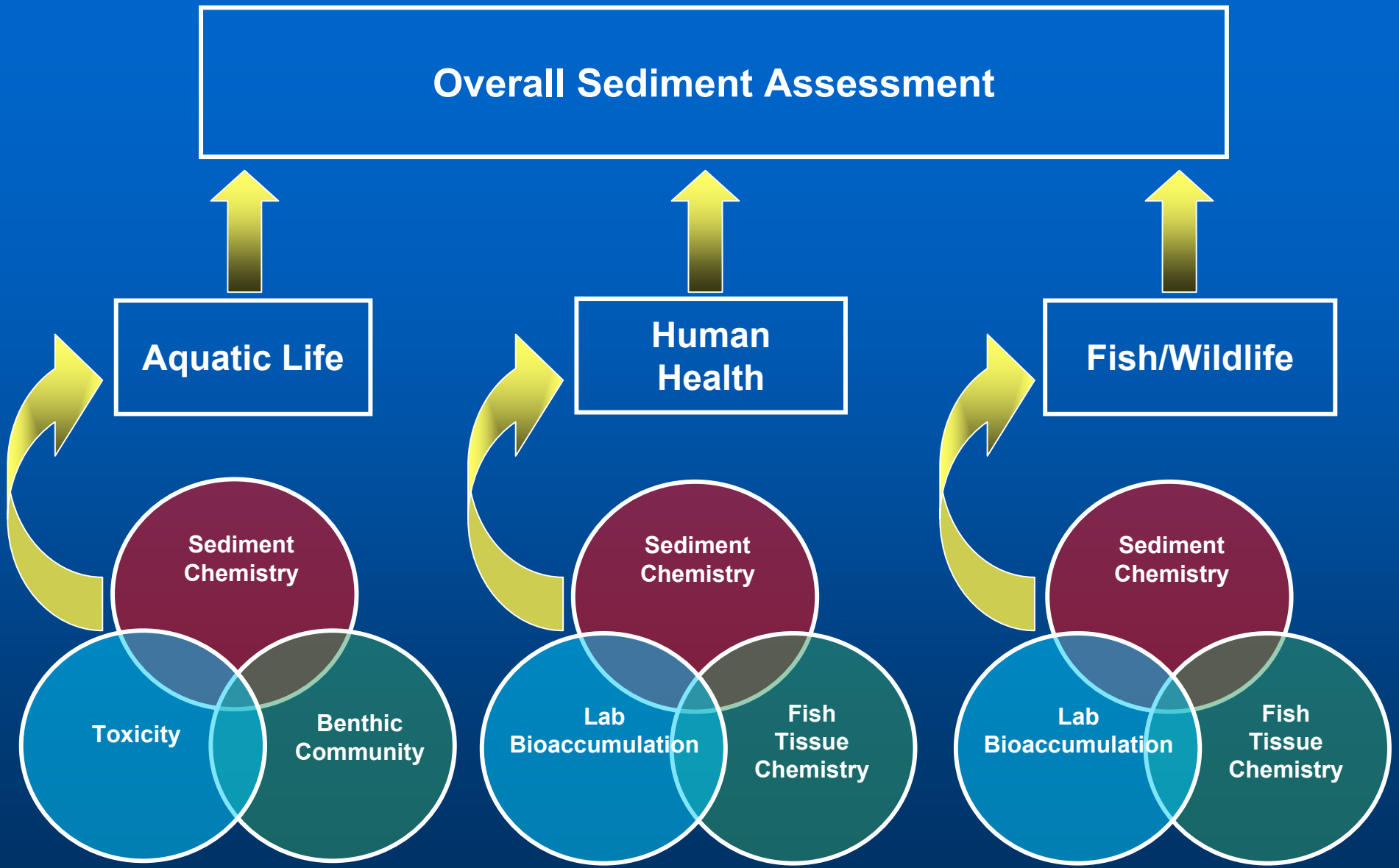
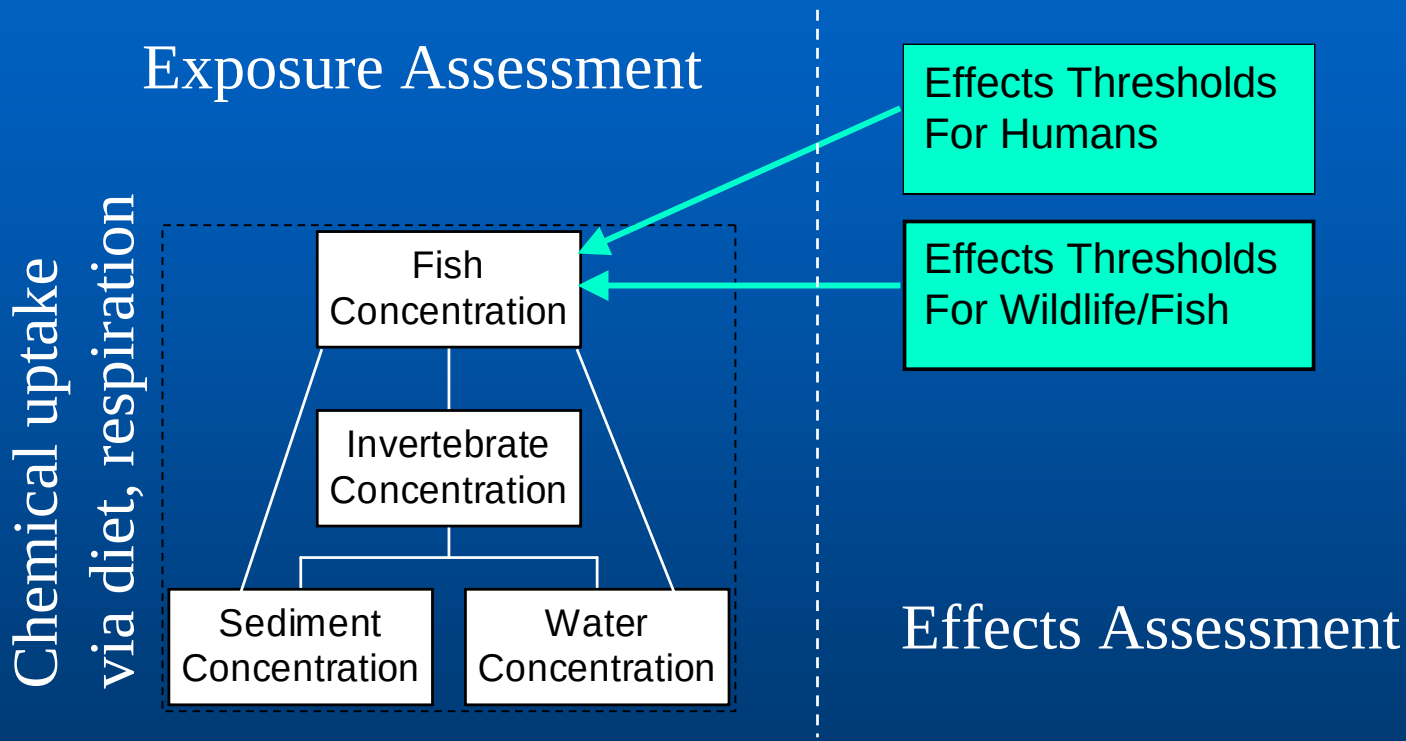
California Sediment Quality Objectives Bioaccumulation Methods

A Presentation to the SQO
Sediment Quality Advisory Committee
December 1, 2005

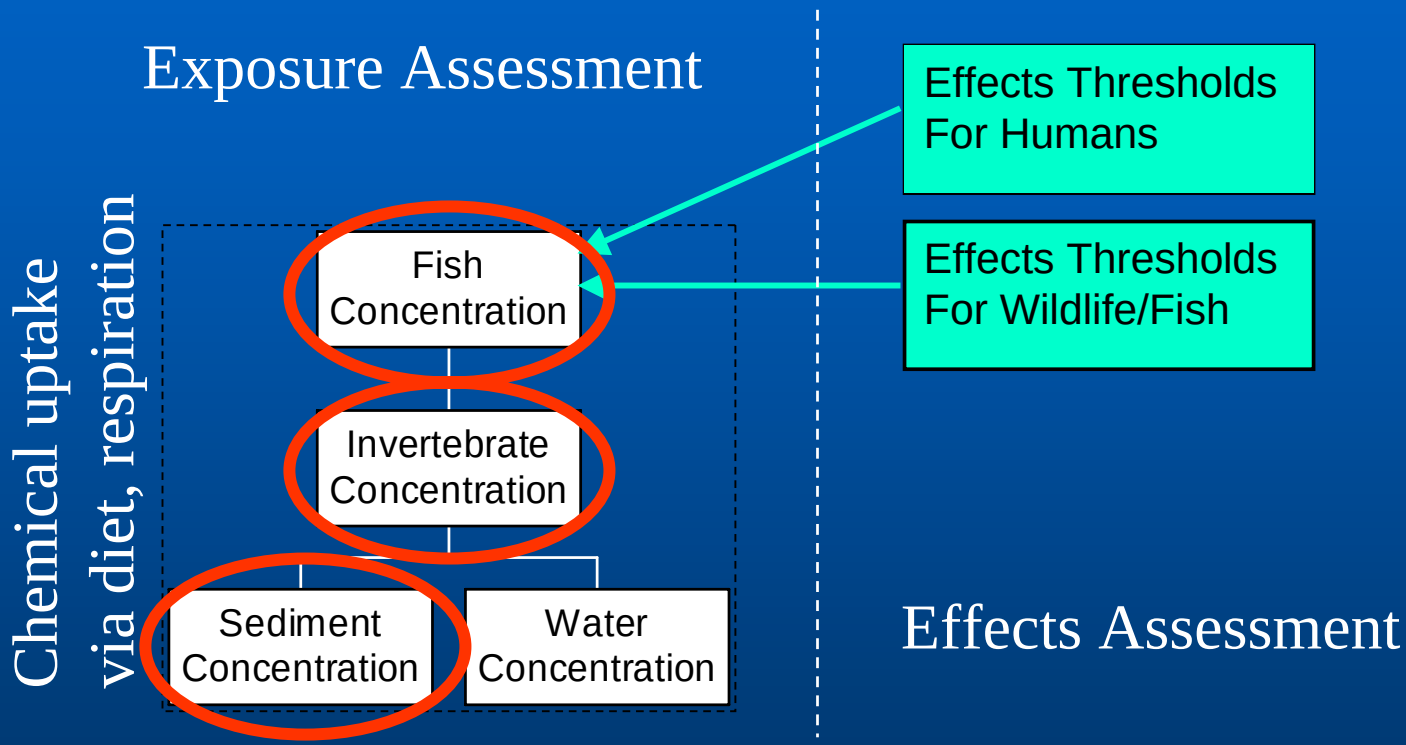
- Focus of talk is on indirect effects implementation framework
  - Multiple Lines of Evidence
  - Application – similarities and differences from direct effects
  - Decision framework
  - Examples


Overall Sediment Assessment
Aquatic Life
Human Health
Fish/Wildlife
Sediment Chemistry
Toxicity
Benthic Community
Sediment Chemistry
Lab Bioaccumulation
Fish Tissue Chemistry
Sediment Chemistry
Lab Bioaccumulation
Fish Tissue Chemistry

Conceptual Model



Multiple Lines of Evidence Approach



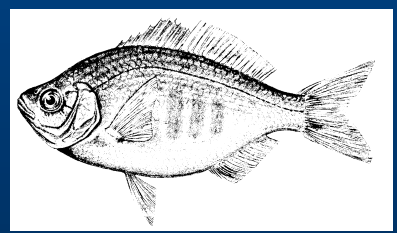
Indirect Effects
Multiple Lines of Evidence (MLOE)

Human Lines of Evidence

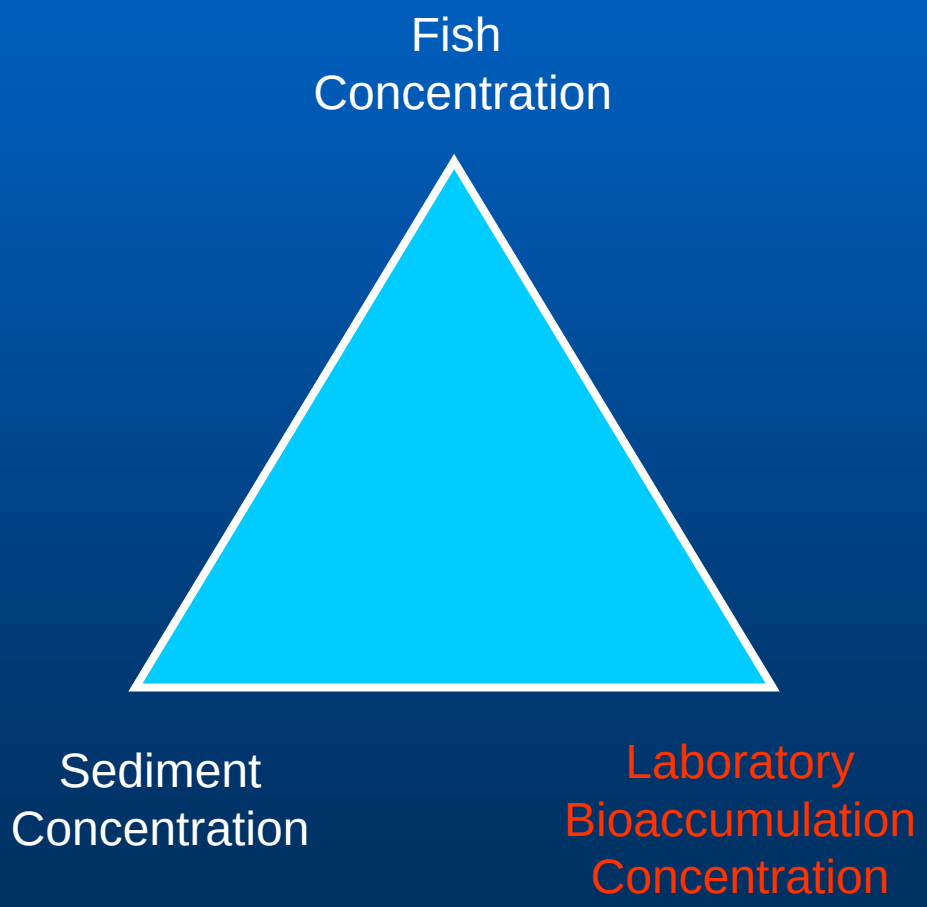
Fish and Wildlife Lines of Evidence

1. Fish Line of Evidence

- **Tissue contaminant concentration in field captured fish**
  - **Assesses beneficial use impairment.**
  - **Water body scale**

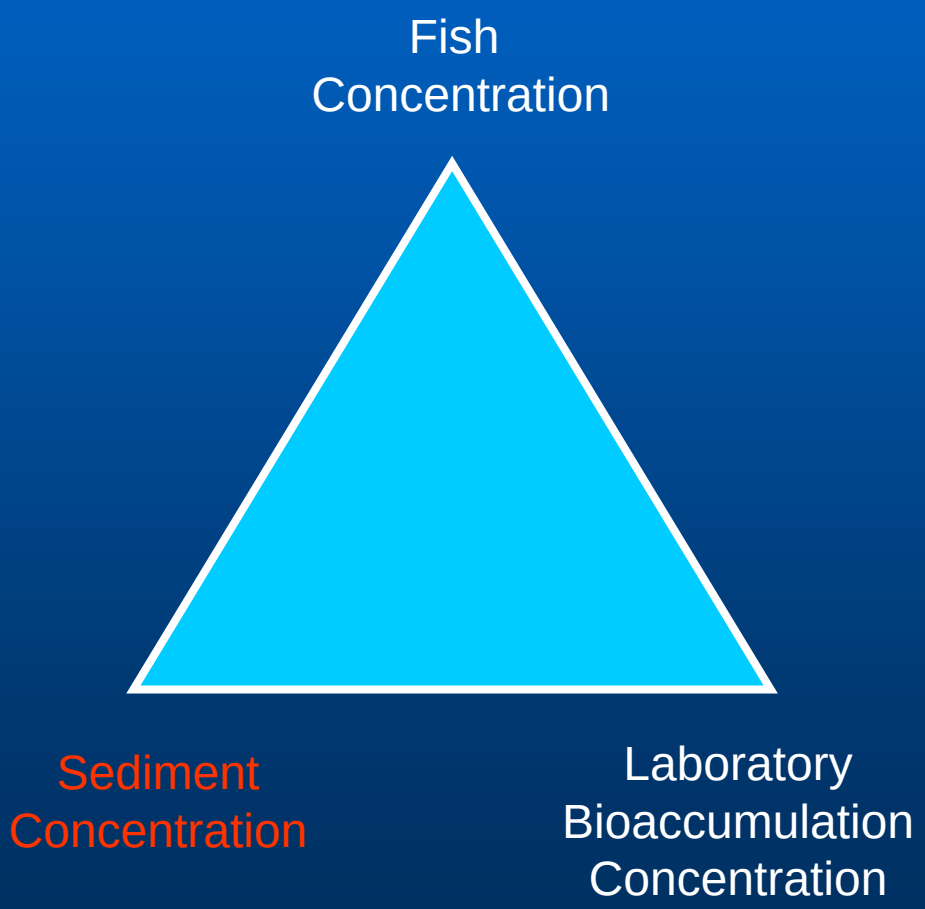


2. Bioaccumulation Line of Evidence



- **Contaminant concentrations in laboratory bioaccumulation tests**
  - **Are sediment contaminants bioavailable?**
  - **Has limitations**
    - **Difficulty achieving equilibrium**
    - **Laboratory extrapolation**

3. Sediment Line of Evidence



- **Contaminant concentrations in sediments**
  - **Assess whether sediments are a potential source, based on observed concentrations**
  - **Station - scale**

Indirect Vs. Direct Effects Similarities

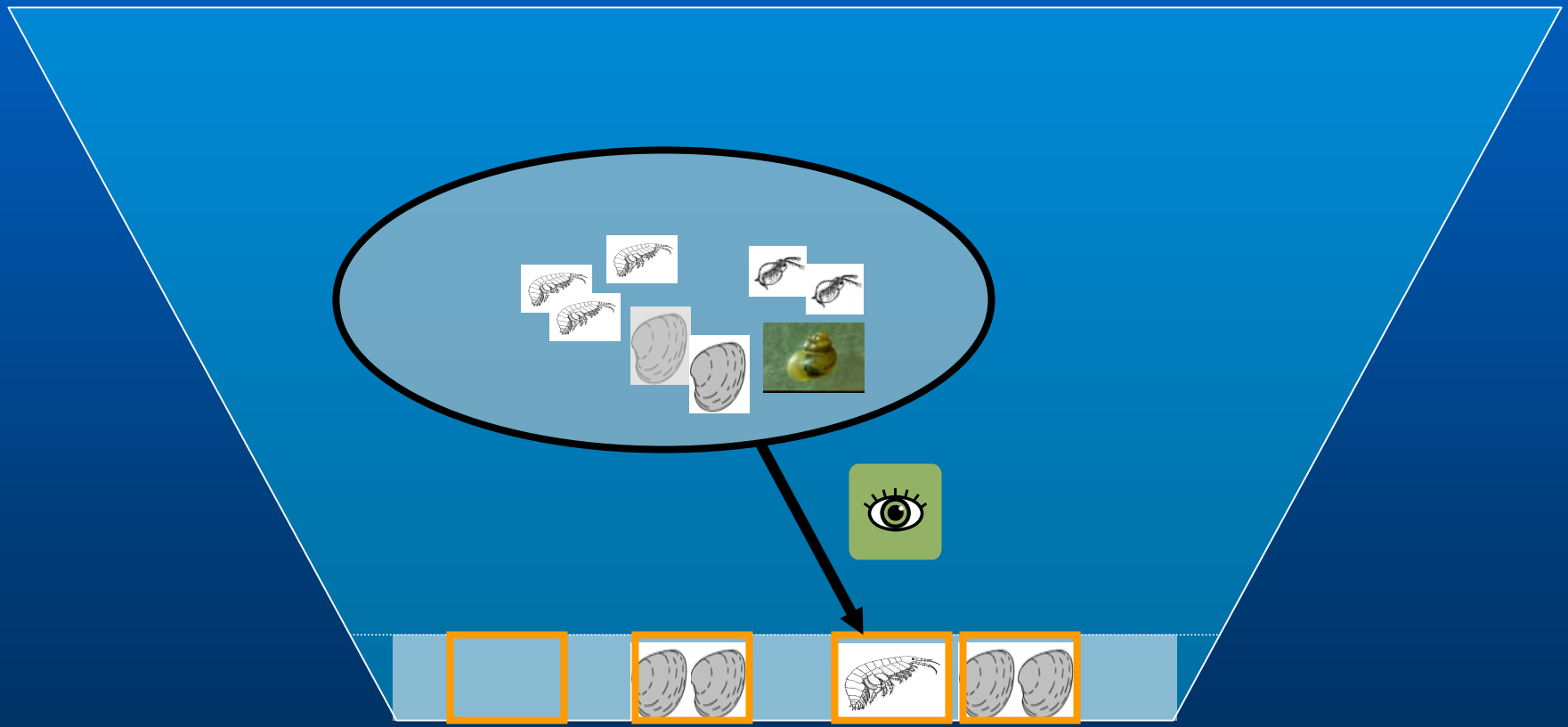
- Multiple Lines of Evidence (MLOE)
- Ordinal ranking (categories)
- Multiple thresholds
- Final conclusion – station scale

Indirect Vs. Direct Effects Differences

- Indirect effects - LOE are based on exposure
- Different scale of evaluation
- Different number of thresholds
- Sequential application

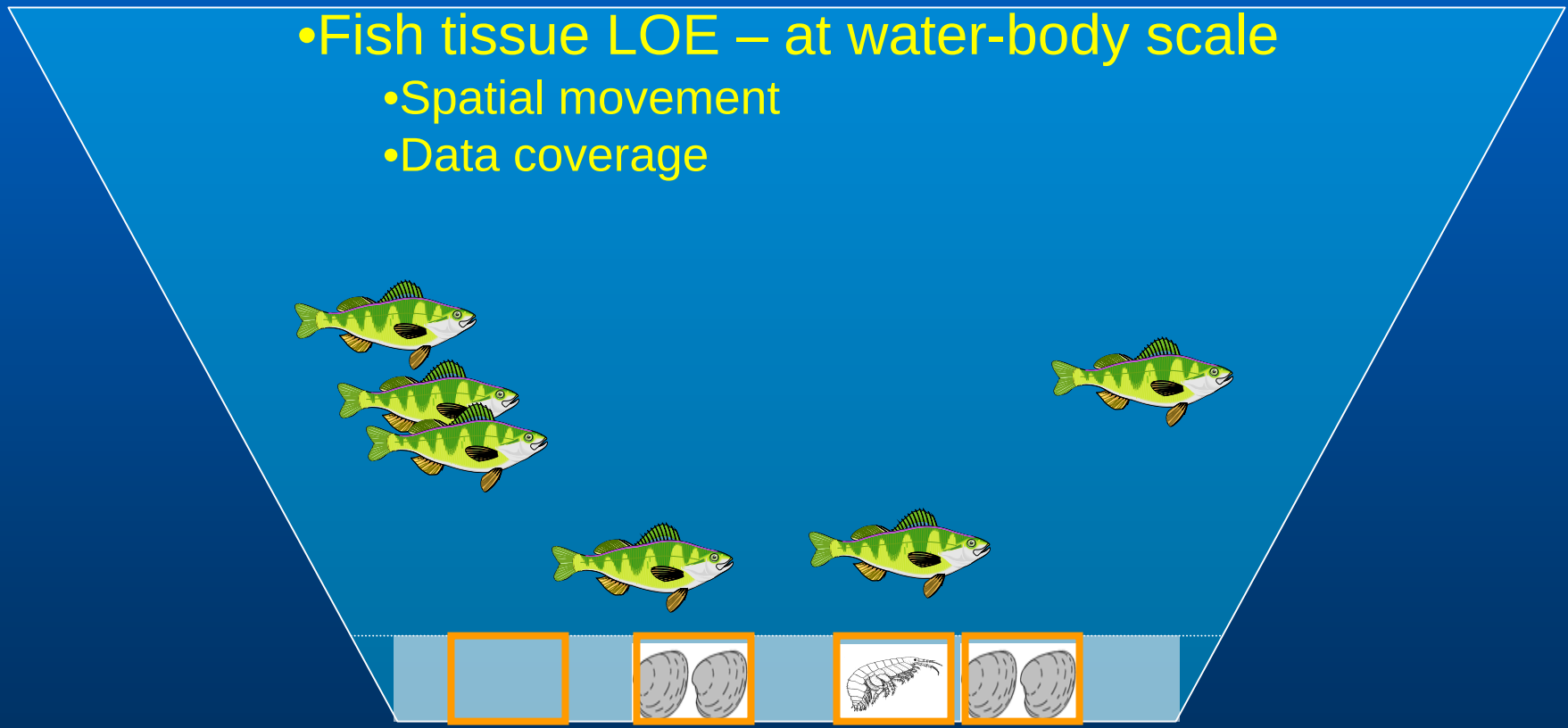
Scale of Evaluation

- Direct effects – triad applied at site scale



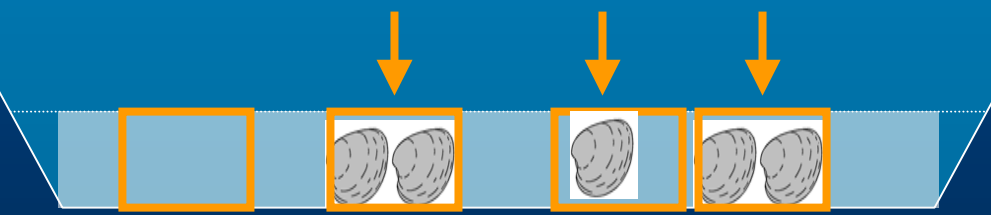
Scale of Evaluation

- Direct effects – triad evaluated at site scale
- Fish tissue LOE – at water-body scale
  - Spatial movement
  - Data coverage



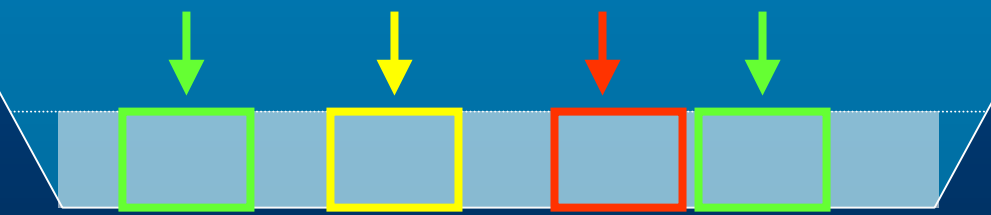
Scale of Evaluation

- Direct effects – triad evaluated at site scale
- Fish tissue LOE – at water-body scale
  - Spatial movement
  - Data coverage
- Bioaccumulation LOE – at water-body scale
  - Uncertainty of individual results → combine
  - Data coverage and cost



Scale of Evaluation

- Direct effects – triad evaluated at site scale
- Fish tissue LOE – at water-body scale
  - Spatial movement
  - Data coverage
- Bioaccumulation LOE – at water-body scale
- Sediment LOE – at site scale



Sequential Application

1. Fish tissue chemistry
   - Are receptors protected?

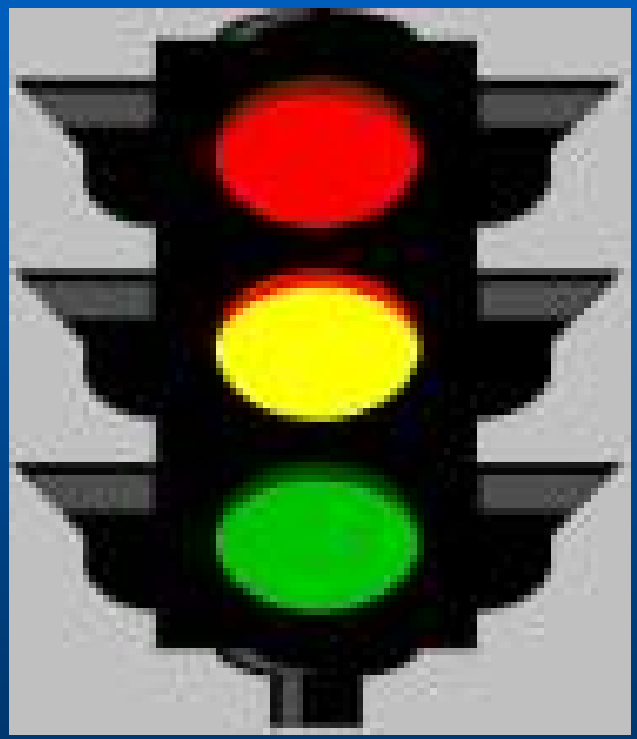
↓

2. Lab bioaccumulation
   - Could sediments cause exposure?

↓

3. Sediment chemistry

Three Risk Categories for Fish and Sediment Lines Of Evidence



Higher Risk

High Threshold

Intermediate Risk

Low Threshold

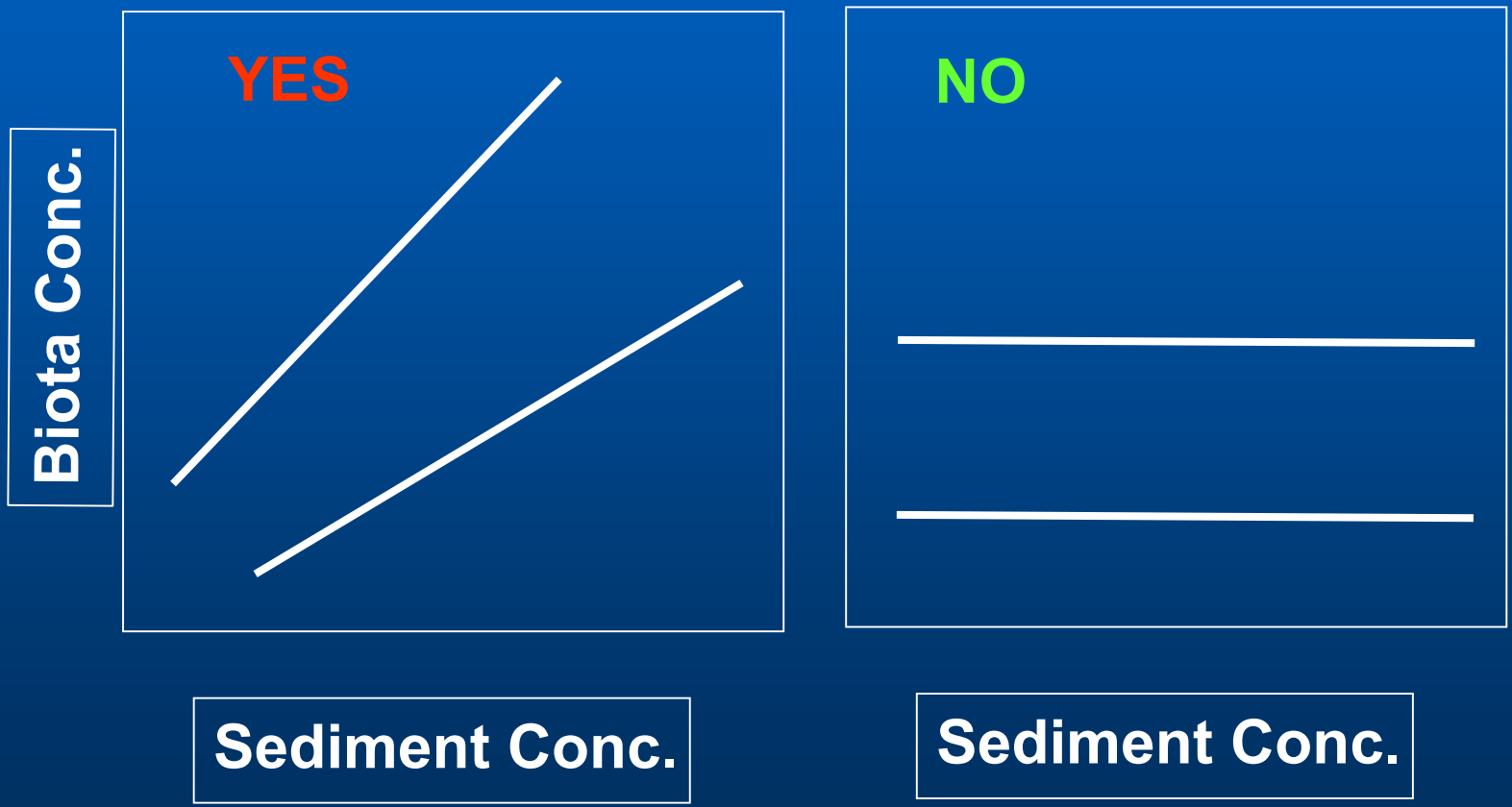
Lower Risk

Use of Two Thresholds and Three Categories

- Approaches are Probability Based
  - Risk Assessment Model
    - Is risk highly likely?
    - Is risk highly unlikely?
    - Is risk likelihood uncertain?
- Force Agencies to Settle on Clear Goals
- Simplify Application
- Combination of LOE -> Four Categories

Two Categories for Bioaccumulation Line Of Evidence

Is sediment contaminant bioavailable?



Use of Two Categories For Bioaccumulation LOE

- Scientific Steering Committee
  - Verify if sediment-associated contaminants are bioavailable

- Uncertainty inhibits use of specific body burden thresholds

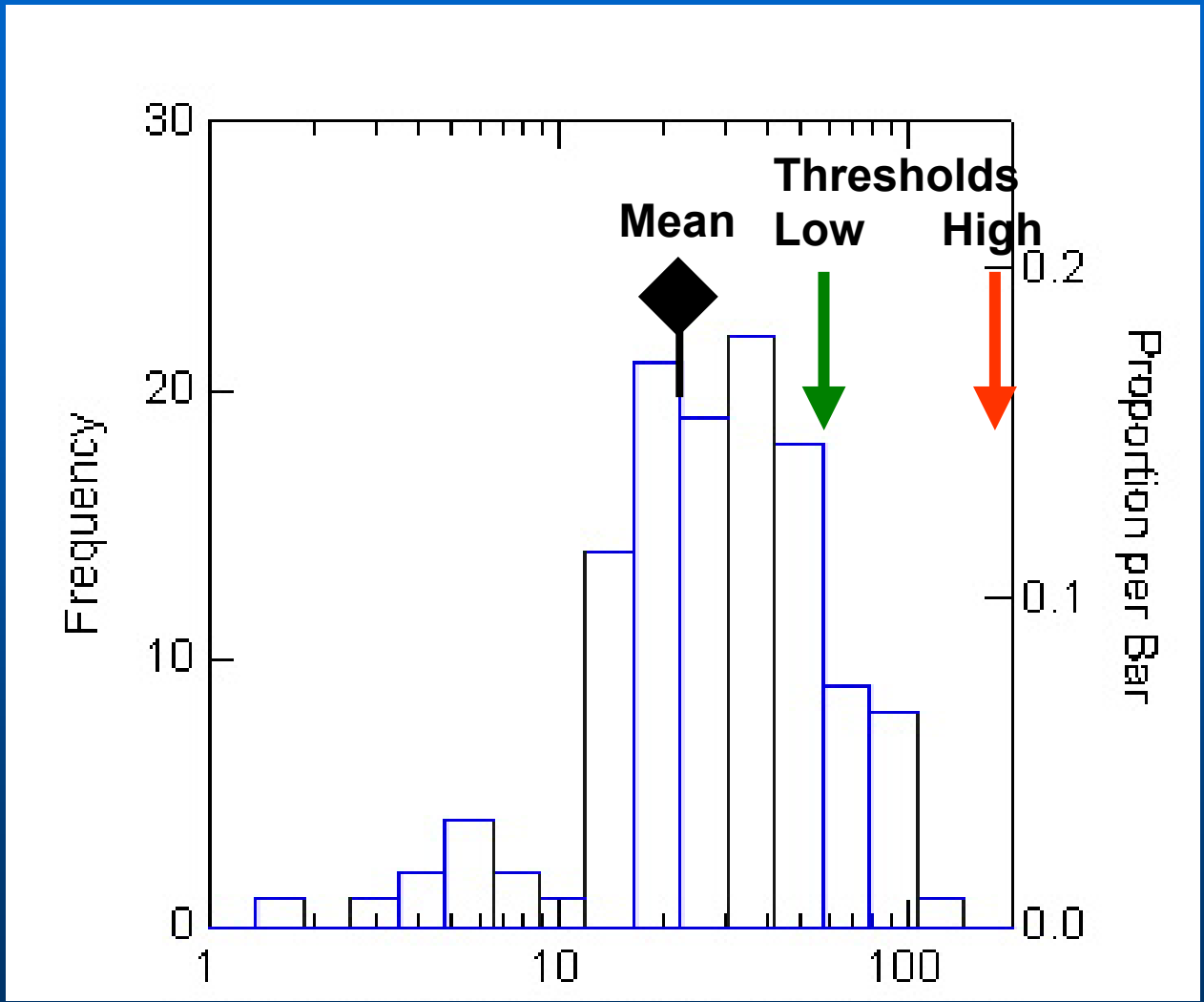
Combination of MLOE -> Four Categories

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
●	-	-	Sediment is protective
⊡ ●	● ●	- -	Sediment is protective
⊡ ●	● ●	● ●	Sediment is protective
⊡	●	⊡	SQO *possibly* exceeded
⊡	●	●	SQO *probably* exceeded
●	●	⊡	SQO *probably* exceeded
●	●	●	SQO highly probably exceeded

Application Example

- **1. Fish Tissue Chemistry LOE**
  - **Calculate average concentration**
  - **Compare to effects thresholds (e.g., for human health effects)**
  - **Low threshold = low risk**
  - **High threshold = high risk**

In this example, average concentration is lower than both thresholds



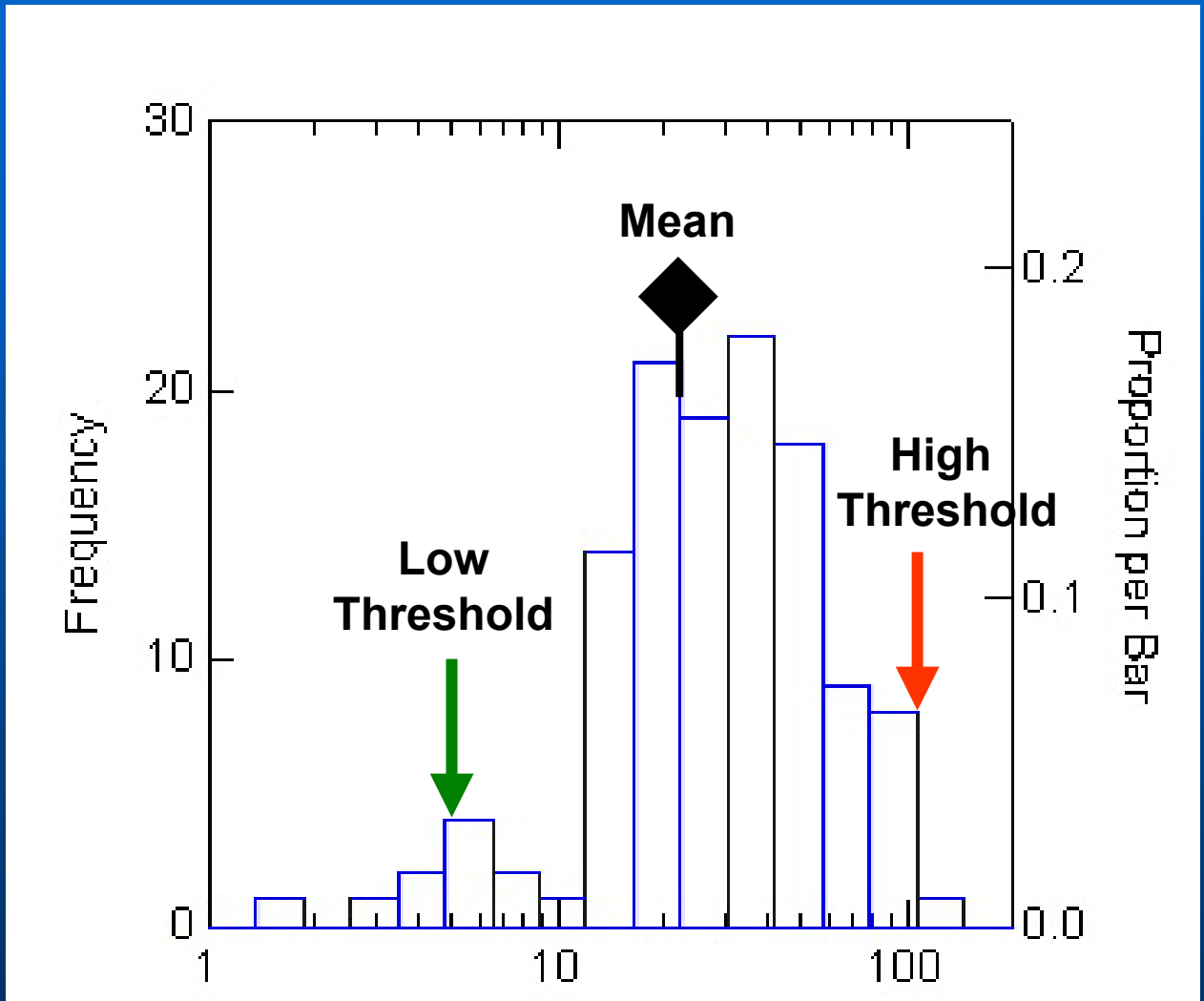
1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
●	-	-	Sediment is protective
⊡ ●	● ●	- -	Sediment is protective
⊡ ●	● ●	● ●	Sediment is protective
⊡	●	⊡	SQO *possibly* exceeded
⊡	●	●	SQO *probably* exceeded
●	●	⊡	SQO *probably* exceeded
●	●	●	SQO highly probably exceeded

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
●	-	-	Sediment is protective

- Fish tissue chemistry in lowest risk category
- Conclude that sediments are protective for human health endpoint
- In this case, would not need to evaluate other LOE.
- But what if thresholds were different?

Another Application Example

In this example, average concentration is between the thresholds



1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
●	-	-	Sediment is protective
⊡ ●	● ●	- -	Sediment is protective
⊡ ●	● ●	● ●	Sediment is protective
⊡	●	⊡	SQO *possibly* exceeded
⊡	●	●	SQO *probably* exceeded
●	●	⊡	SQO *probably* exceeded
●	●	●	SQO highly probably exceeded

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
▫ ●	● ●	- -	**Sediment is protective**
▫ ●	● ●	● ●	**Sediment is protective**
▫	●	▫	**SQO *possibly* exceeded**
▫	●	●	**SQO *probably* exceeded**

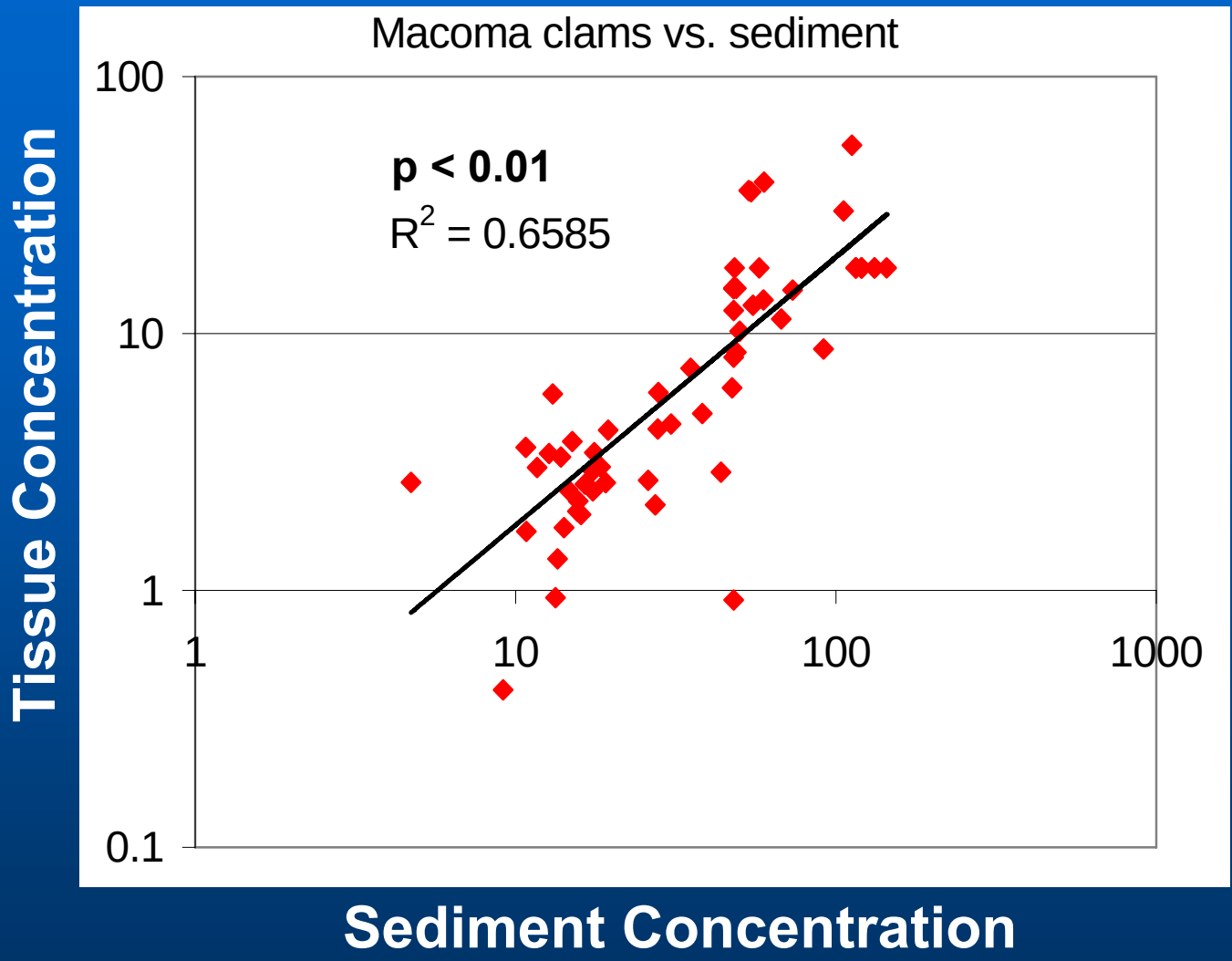
- Fish tissue chemistry indicates intermediate risk
- In this case, would need to proceed to other LOE

2. Laboratory Bioaccumulation LOE

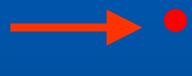
- Answers whether contaminant is bioavailable from the sediments
- 28-day *Macoma* tests combined Bay-wide
- Significant positive slope indicates bioavailability

- Positive slope
- Statistically Significant

- Indicates bioavailability



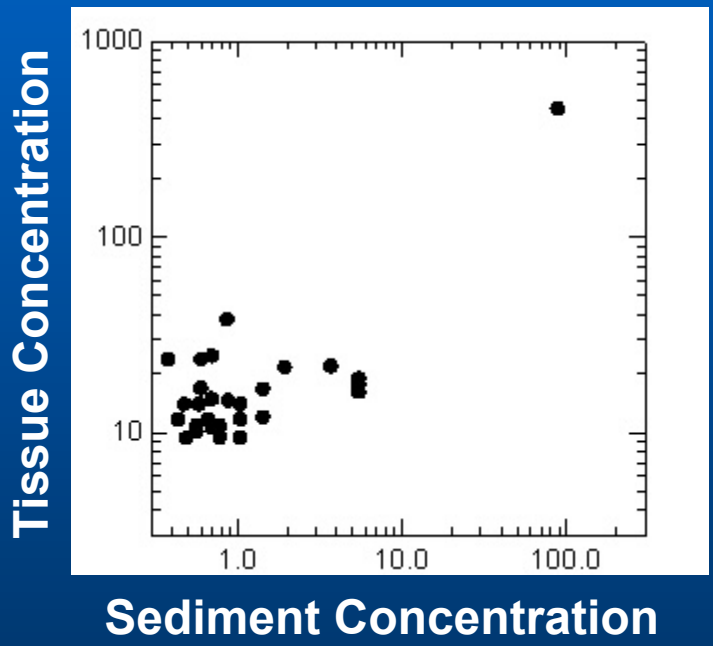
1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
		- -	Sediment is protective
			Sediment is protective
			SQO *possibly* exceeded
			SQO *probably* exceeded

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
			Sediment is protective
			SQO *possibly* exceeded
			SQO *probably* exceeded

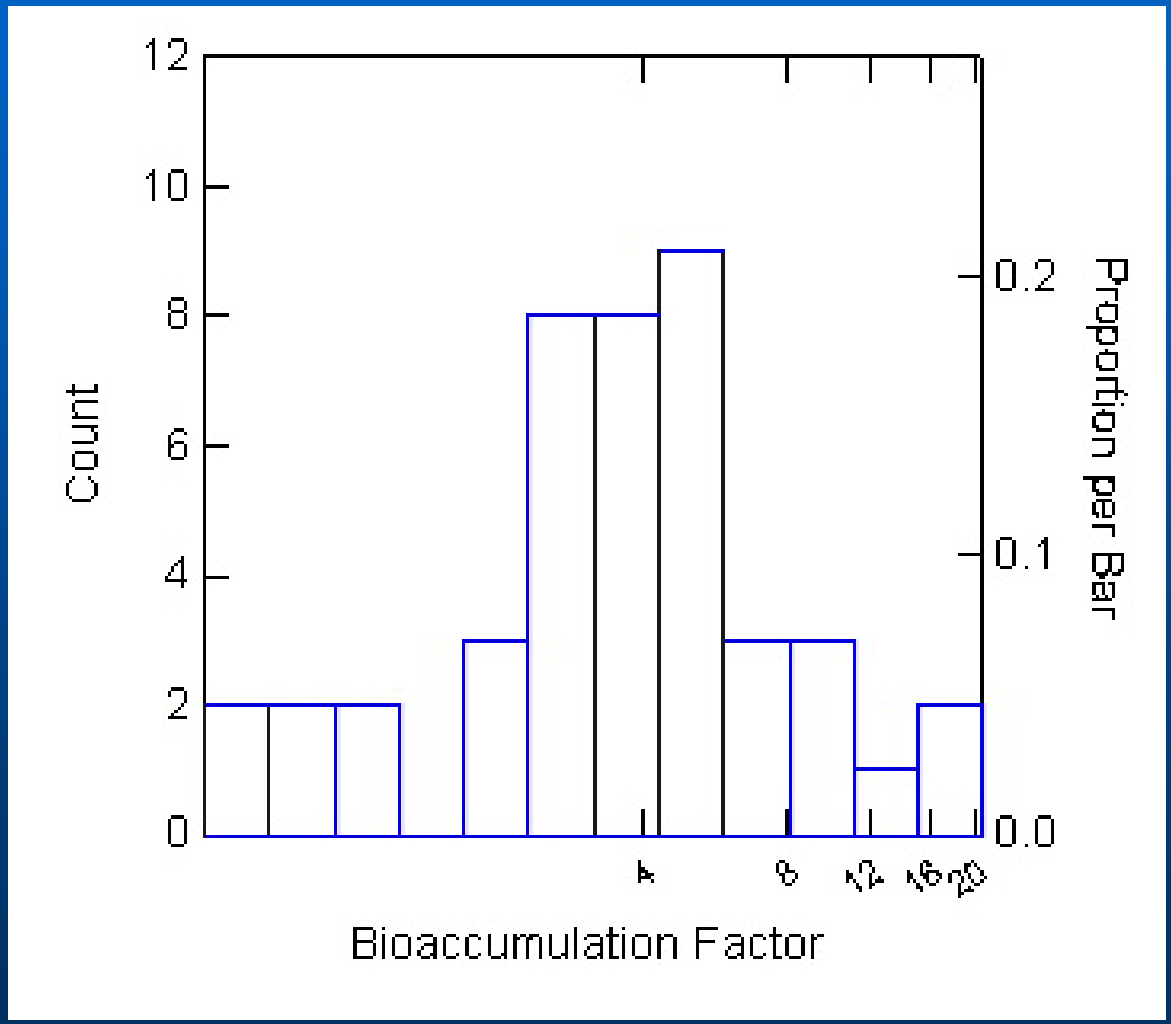
- Bioaccumulation test indicates bioavailability of sediment-bound contaminant
- In this case, would proceed to evaluating individual sediments

3. Sediment Chemistry LOE

- **Develop translator between sediment and fish tissue**
  - **Bioaccumulation Factor**
- **Back-calculate from fish tissue threshold to sediment**
- **Evaluate individual sediments**

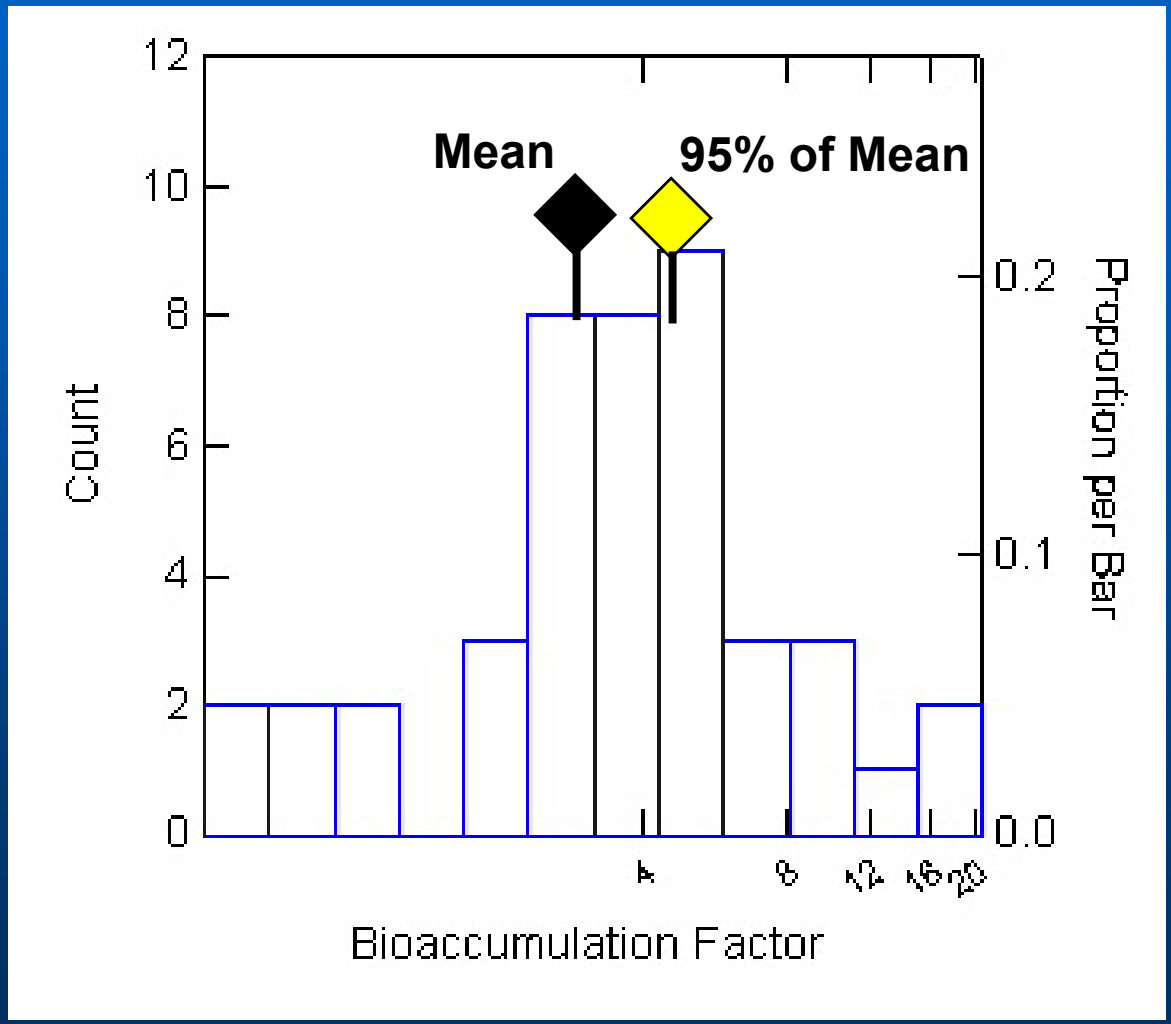


- **Develop translator between sediment and fish tissue (Bioaccumulation Factor)**



Geometric Mean = 3.5

95% Upper Confidence Limit Of Geo Mean = 4.5



Threshold Type	Risk	Tissue Threshold	BAF	Sediment Threshold
High	Higher	130	3.5	130/3.5 = 37.1
Low	Lower	65	4.5	65/4.5 = 14.4

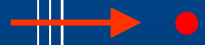
- Back-calculate from fish tissue threshold to sediment threshold

Sediment Category	Concentration	Number Samples
High	**>37.1**	**60**
Intermediate	**14.4-37.1**	**32**
Low	**<14.4**	**615**

- Evaluate individual sediments

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
			**Sediment is protective**
			**SQO *possibly* exceeded**
			**SQO *probably* exceeded**

- Most sediment stations are protective.

1. Fish Tissue Chemistry	2. Bioaccumulation Test	3.Sediment Chemistry	Conclusion
			Sediment is protective
			SQO *possibly* exceeded
			SQO *probably* exceeded

- Some sediment stations exceed objective, with varying degrees of confidence

Other issues

- Tissue threshold development assumptions
  - Risk factor
  - Consumption rates
- Bioaccumulation LOE
  - Site-scale comparisons to control sites
- Sediment LOE – calculation of BAF
  - Using mechanistic model
  - Uncertainty calculations (e.g., mean vs. individual observations)

Other issues and findings

- How scale up individual station results?
- Mechanistic model application
  - Corroborate empirical BAFs
  - Evaluate sources of uncertainty
    - Food web variation
    - Water vs. sediment sources

Framework

- Multiple lines of evidence
- Sequential application
- Spatial scale of application

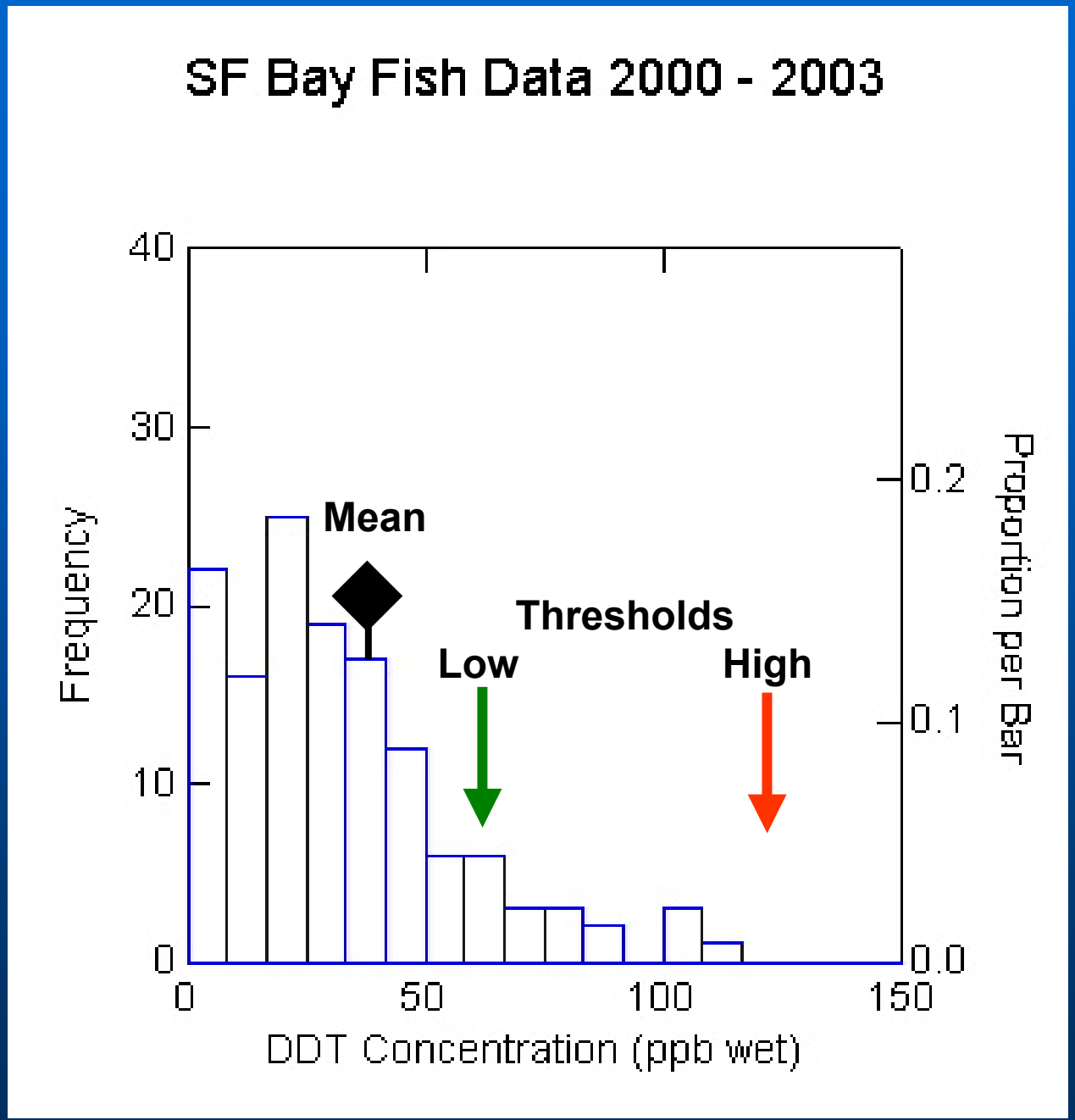
Example: SF Estuary Case Study

- 1. Fish Tissue Chemistry LOE
  - DDTs in fish - human health target
  - Recent fish tissue data
  - Fish tissue thresholds developed in coordination with Regional Board

Arithmatic Mean = 32

Low Threshold = 65

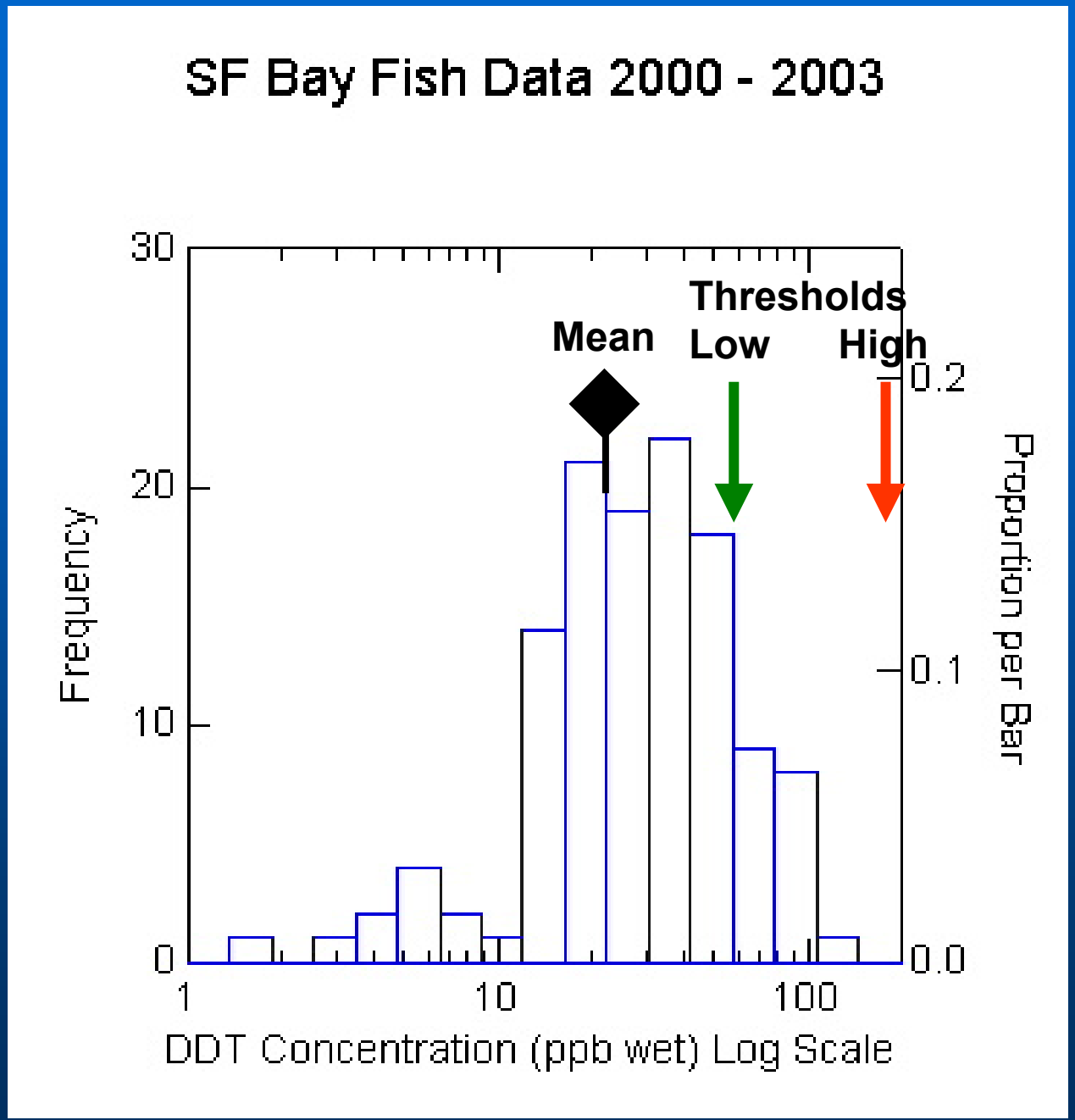
High Threshold = 130



Geometric Mean = 20

Low Threshold = 65

High Threshold = 130

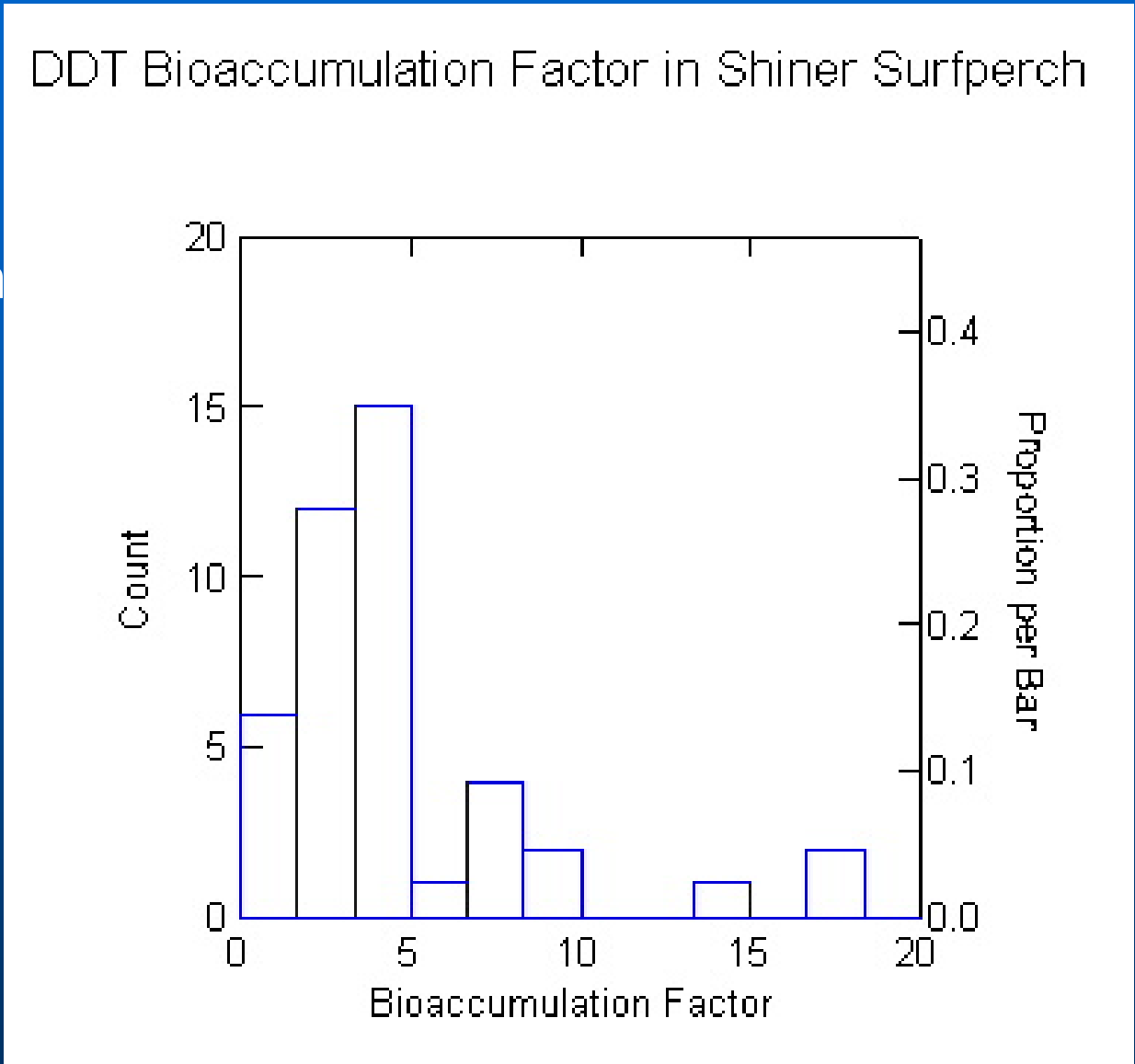


SF Bay Case Study

- Result for DDTs - sediments are protective for human health endpoint
- In this case, would not need to evaluate other LOE.
- But what if we work through the other two lines of evidence?
  - E.g., if fish tissue chemistry was between lower and higher threshold.

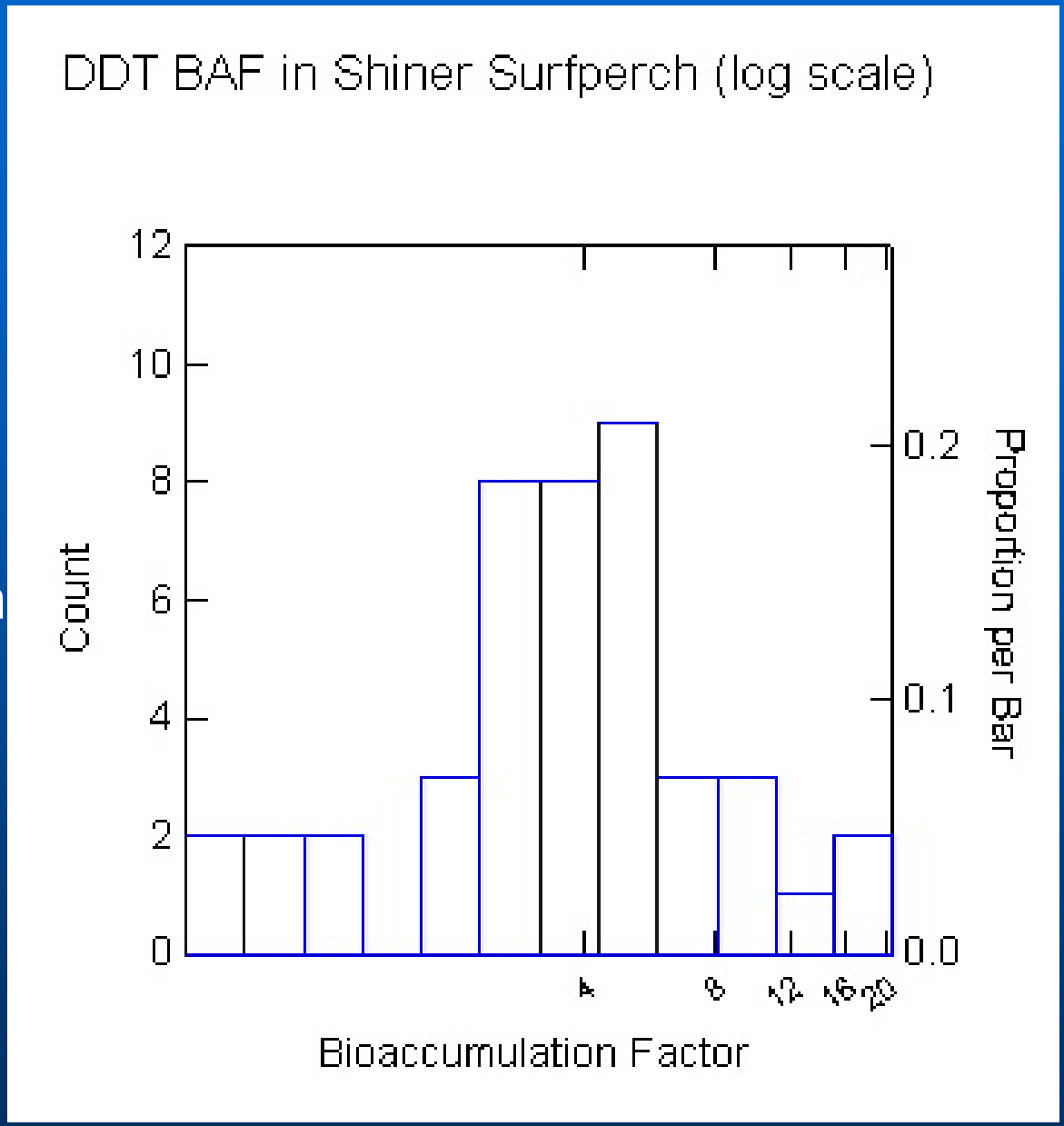
Determine Bioaccumulation Factor at This Spatial Scale

Distribution is Skewed



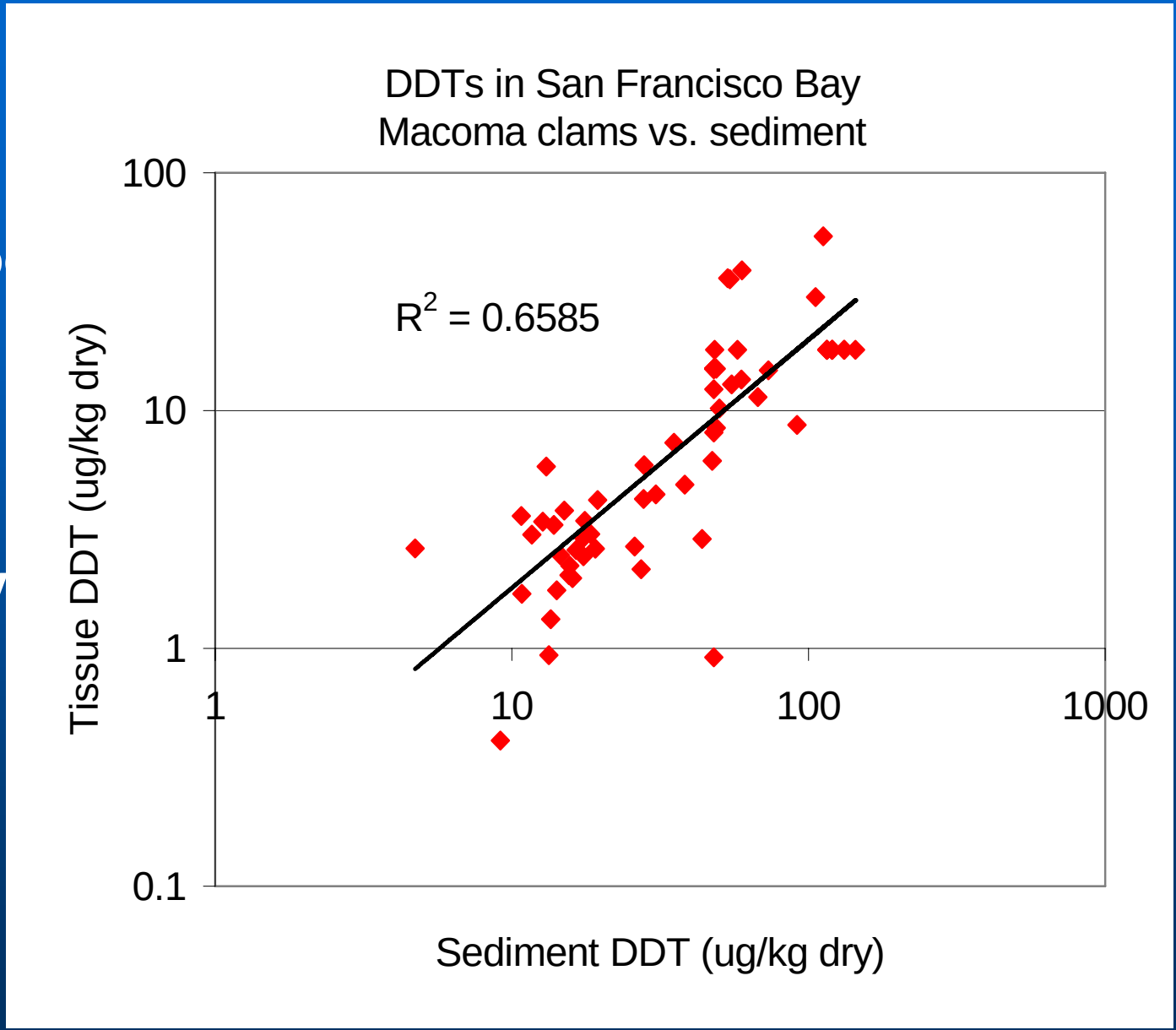
Transform to Achieve More Normal Distribution:

Allows Estimation Of Uncertainty



- Positive slop
- Statistically Significant

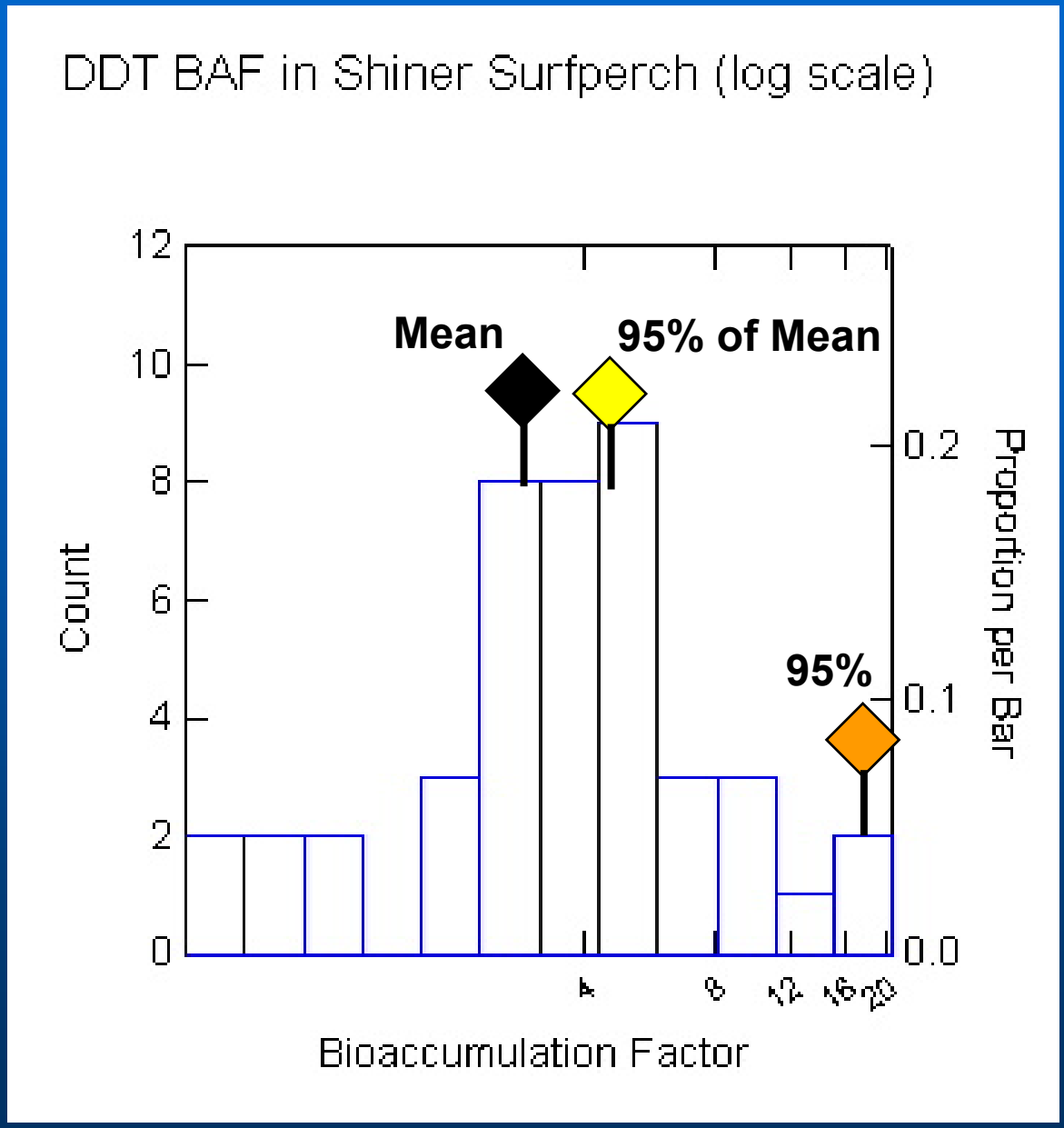
- Indicates bioavailability



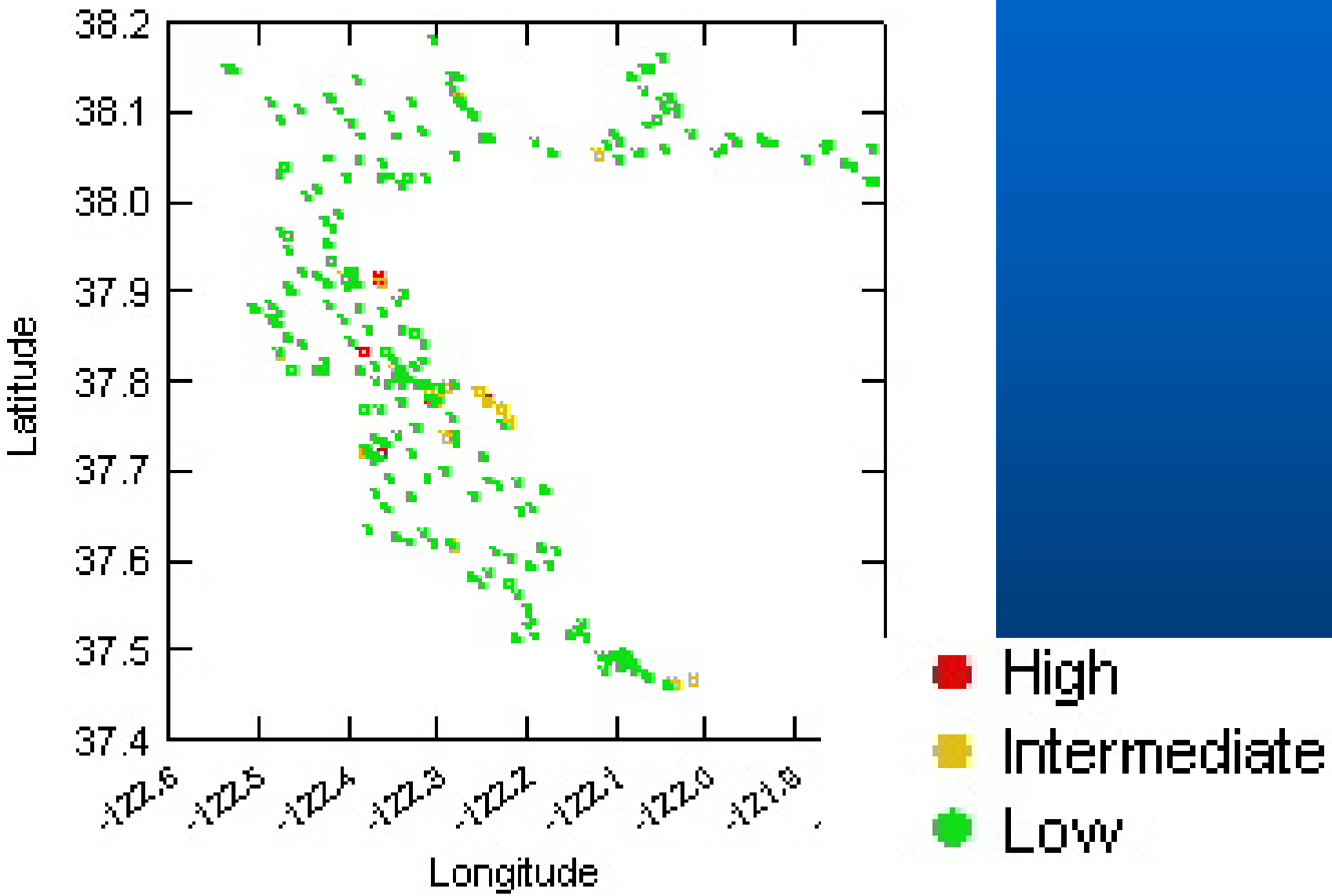
Geometric Mean = 3.5

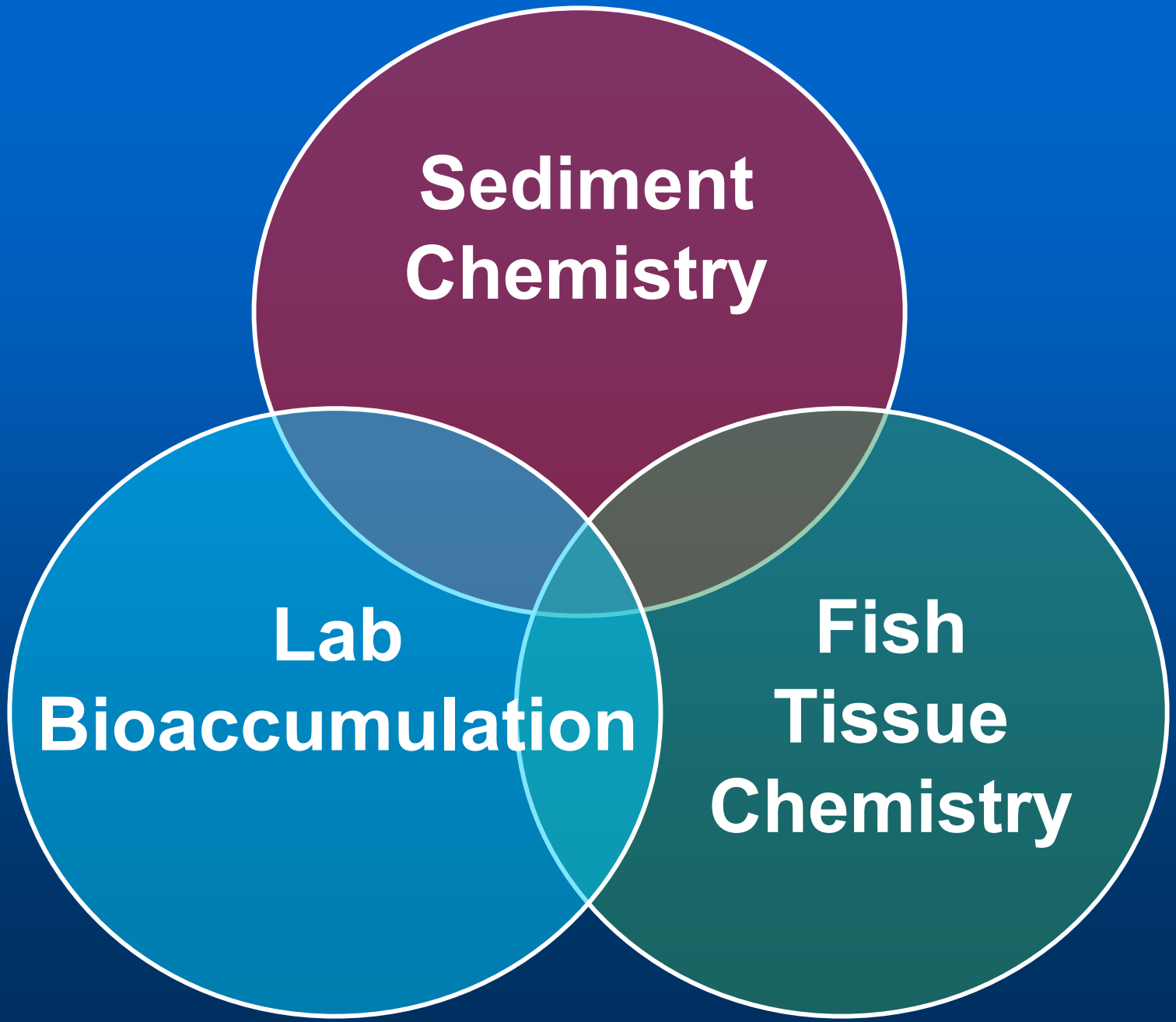
95% Upper Confidence Limit Of Geo Mean = 4.5

95% Upper Confidence Limit Of Individual Observations = 18.0



Sediment Results




Sediment Chemistry
Lab Bioaccumulation
Fish Tissue Chemistry