Summary of 2005 Sinclair Inlet Caged Bivalve Study

Using Caged Mussels to Characterize Exposure and Effects over Small Spatial Scales in Sinclair & Dyes Inlet, WA

3 Models: 1) BLM; ITM; ERM

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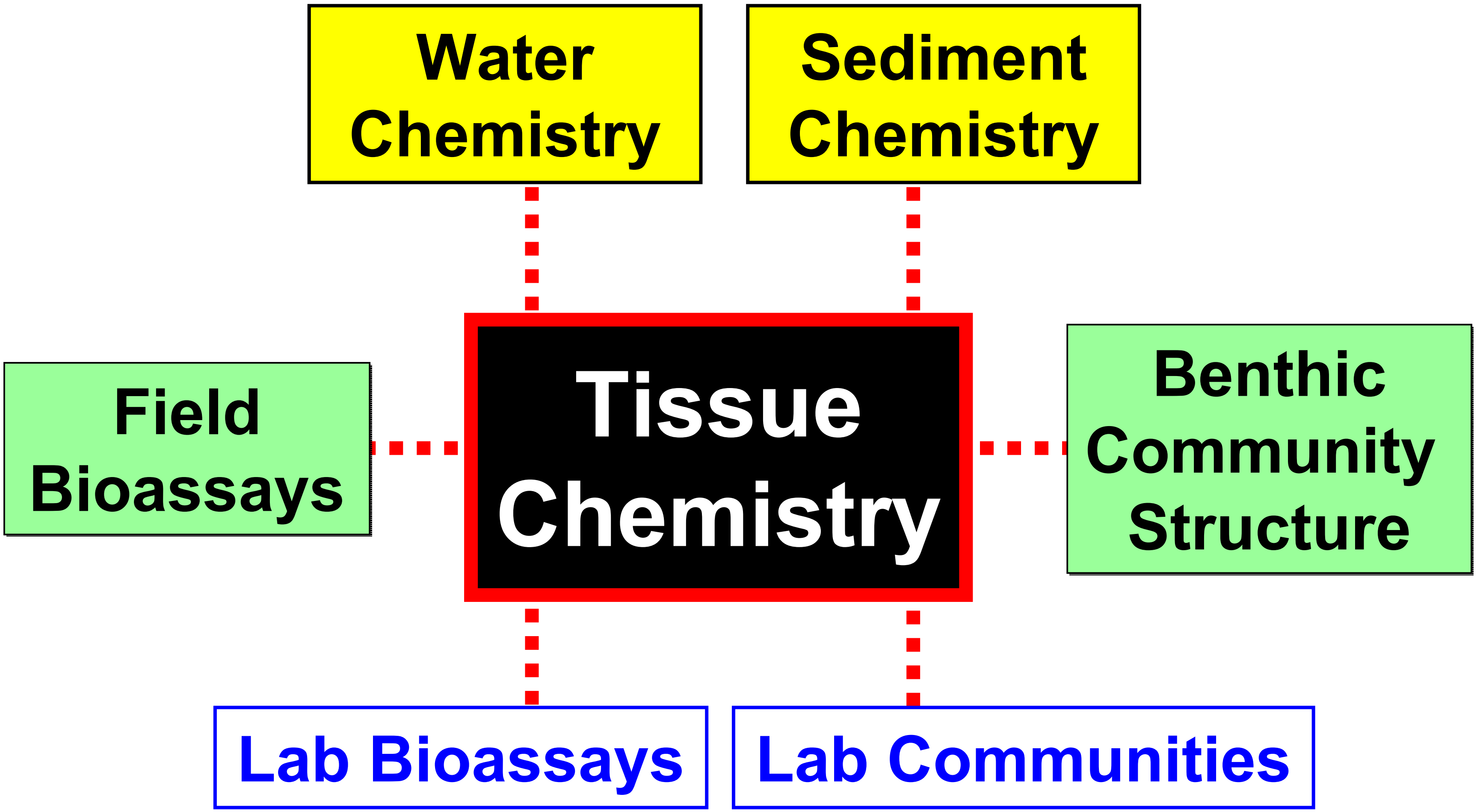
Take Home Message

We all know how to measure toxicity; the real variable in risk assessment is the exposure assessment

- The internal dose makes the poison, not chemicals in water or sediment
- Chemicals in all environmental compartments need to be assessed
- Tissue chemistry should be part of any ecological risk assessment; only direct measure of bioavailability
- Any methods used to develop water & sediment quality guidelines can be used to develop tissue quality guidelines

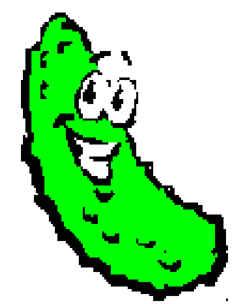
Bioaccumulation Links Model (BLM)

Tissue chemistry is the common thread linking other approaches



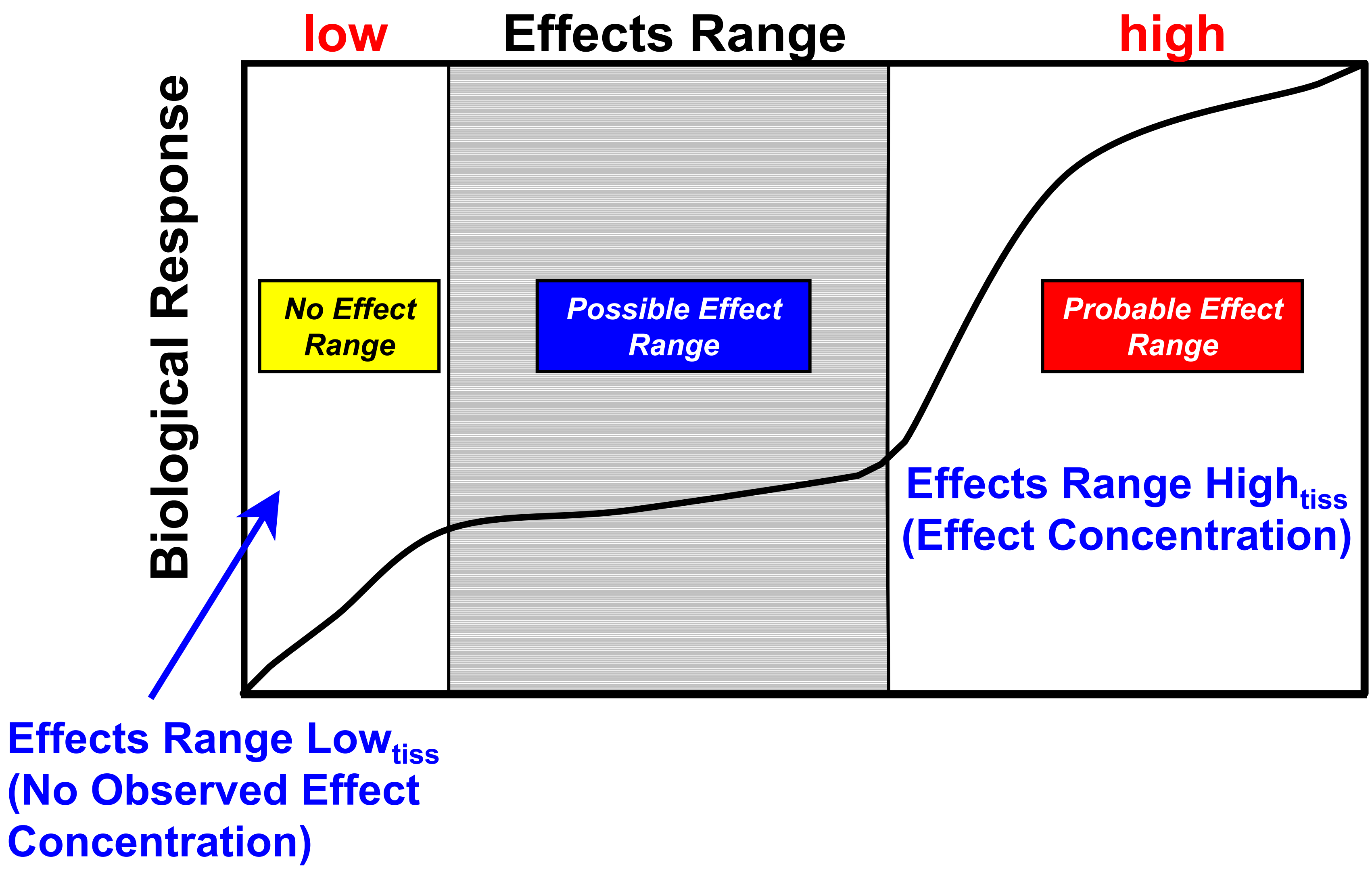
In situ
Testing Model
(ITM)

Lab
Model



Effects Range Model (ERM)

Tissue Residue Effects Model



Asking the Right Questions

1. Are chemicals entering the system?
2. Are chemicals bioavailable?

Characterizing Exposure

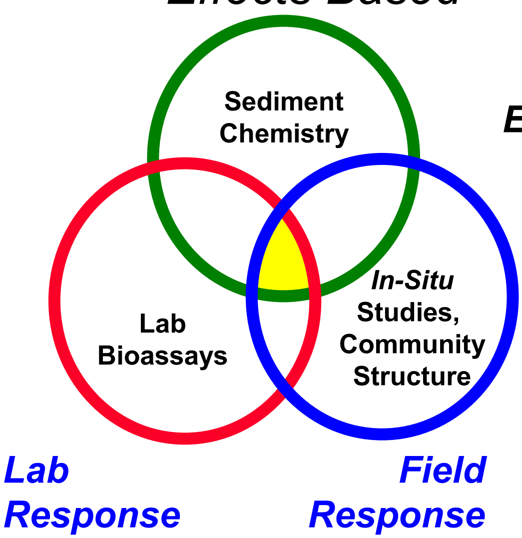
3. Is there a measurable effect?
4. Are chemicals causing this effect?

Characterizing Effects

Borgmann 2000: *"Traditional approaches (e.g., Sediment Quality Triad) successfully address questions 1 & 3 but do not directly address 2 & 4."*

Sediment Quality

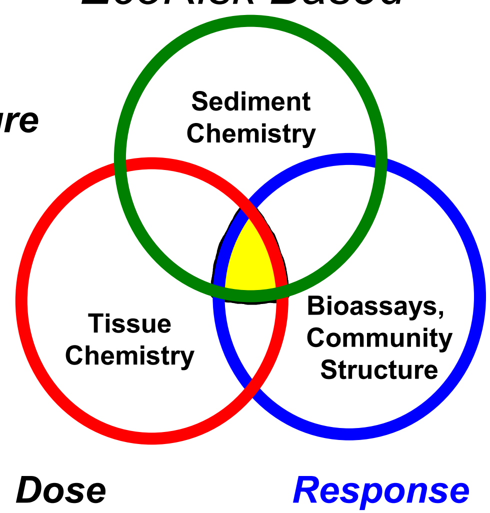
Effects Based



Exposure

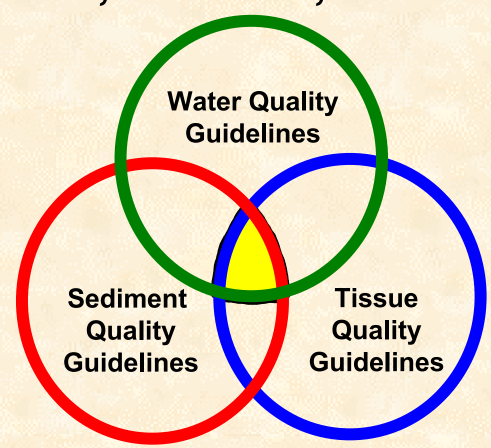
Exposure Dose Response

EcoRisk Based



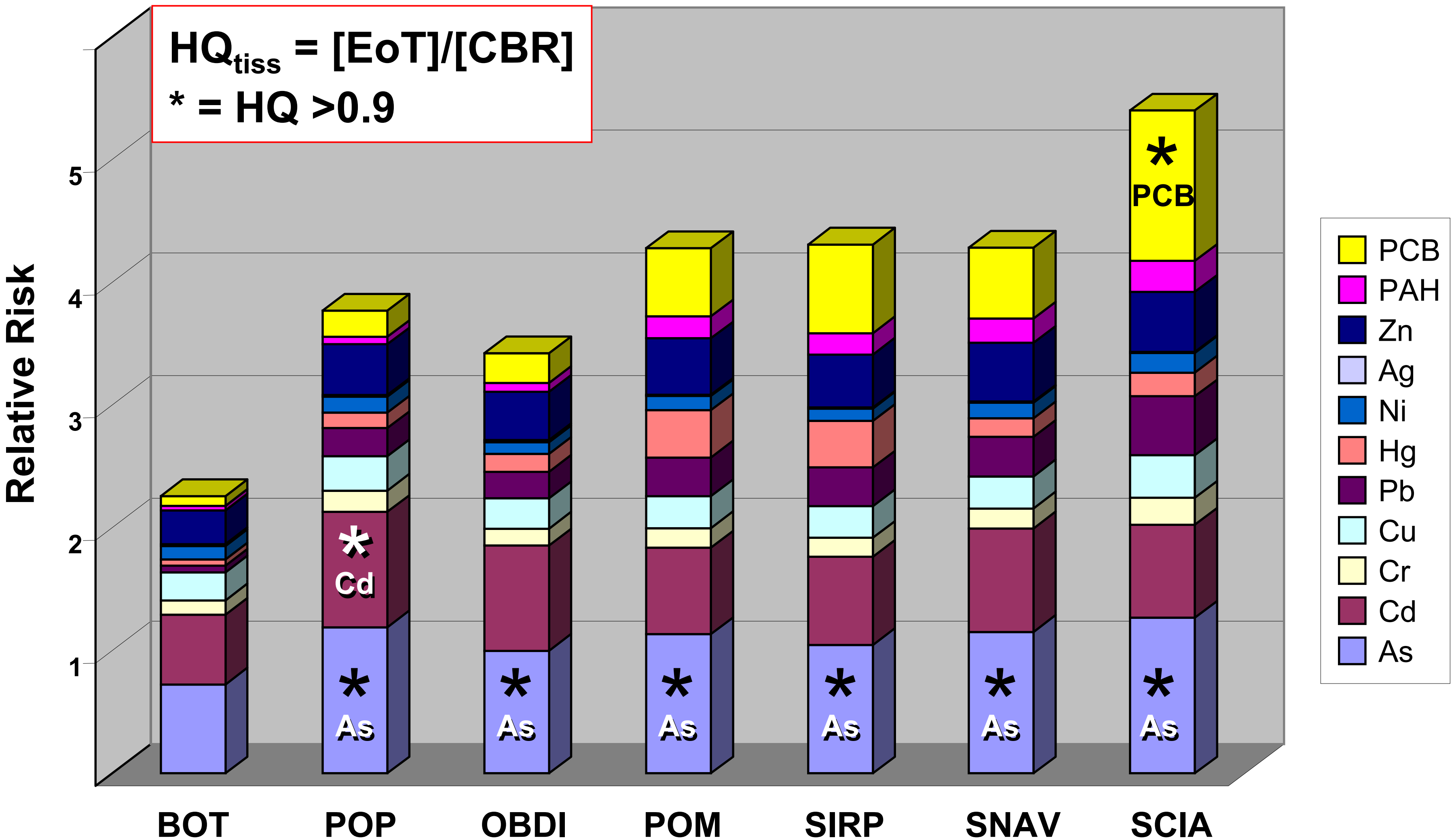
The newest approaches from EPA suggest even more integration:

Harmonization of Water, Sediment, Tissue



Drawn from Reiley et al 2002

Estimated Tissue Hazard Quotients (HQ) for Chemicals of Concern



Same Method used to Develop water-effect ratios (WERs) & Sediment Hazard Quotients

Study Objectives

Overall goal

- Develop risk assessment based performance targets for developing management plans and cleanup priorities

Specific objective

- Characterize chemical exposure & associated biological effects and establish "*Zones of Influence*" over small spatial scales

Help answer the following key questions

- Are chemicals of concern *entering* Sinclair Inlet?
- Are chemicals of concern in Sinclair Inlet *biologically available*?
- Are biologically available chemicals associated with *current* or *past discharges* and what is the *source*?
- Are chemicals *causing effects*?

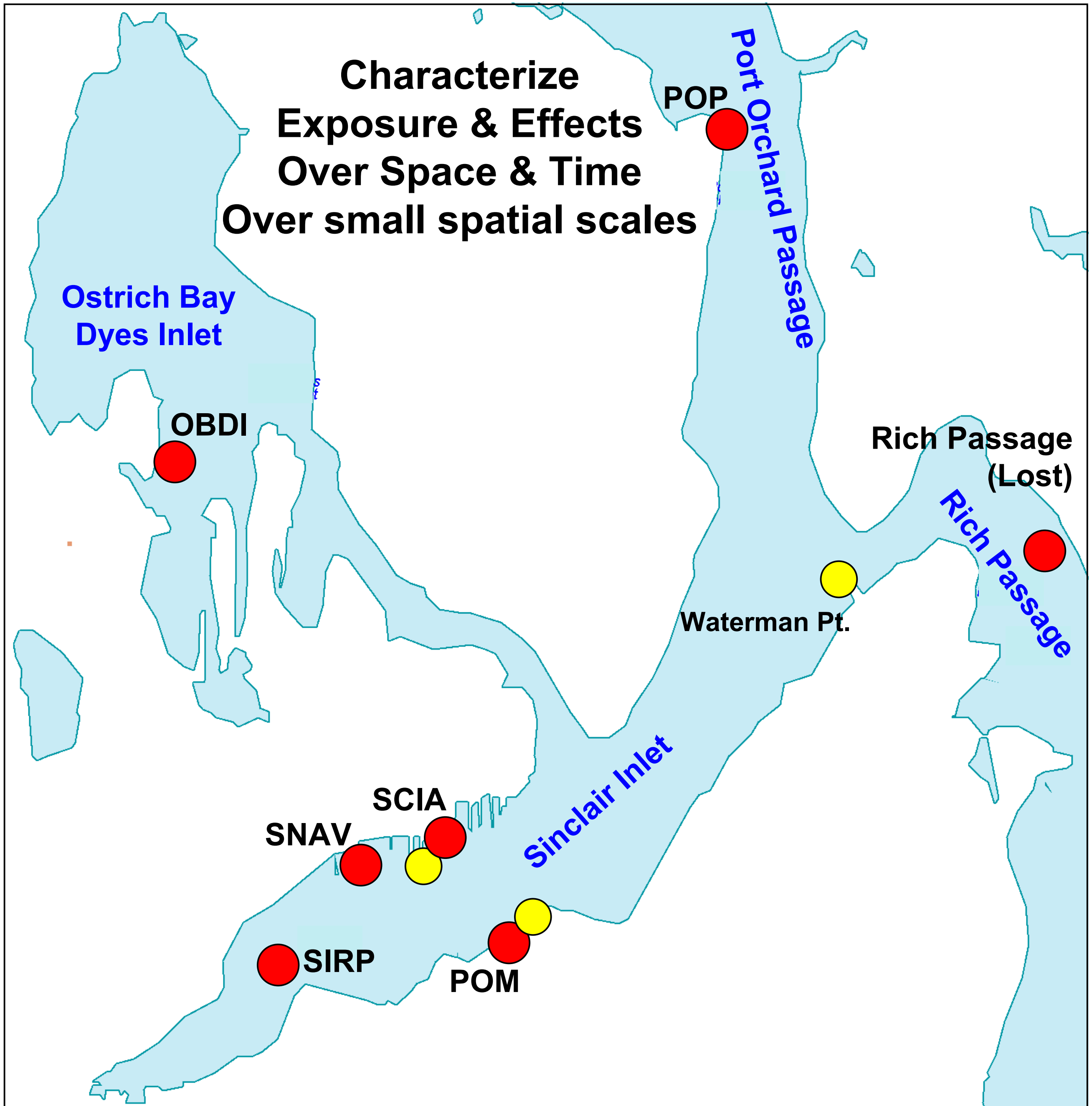
There is a need to characterize & understand chemical exposure before characterizing & understanding effects

Approach

Field experiment using caged bivalves

- Collect, cage & transplant cultured marine bivalves
- Characterize exposure through bioaccumulation
- Distinguish between current & past discharges
  - Bivalve bioaccumulation in water column deployments near bottom
  - Differences in uptake near possible sources versus distant
  - Bioaccumulation versus water & sediment chemistry
  - Shipyard versus other sources
- Characterize potential effects through growth metrics (biomarkers)
- Compare data with water, sediment, & tissue quality guidelines
- Develop performance targets based on exposure & effects endpoints

Characterize exposure & effects
Over small spatial scales



2005 Sinclair Inlet Caged Mussel Study

Key Ecological Risk Assessment (ERA) Questions

Exposure Questions

Chemicals entering system?
Chemicals bioavailable?
What is the source(s)?

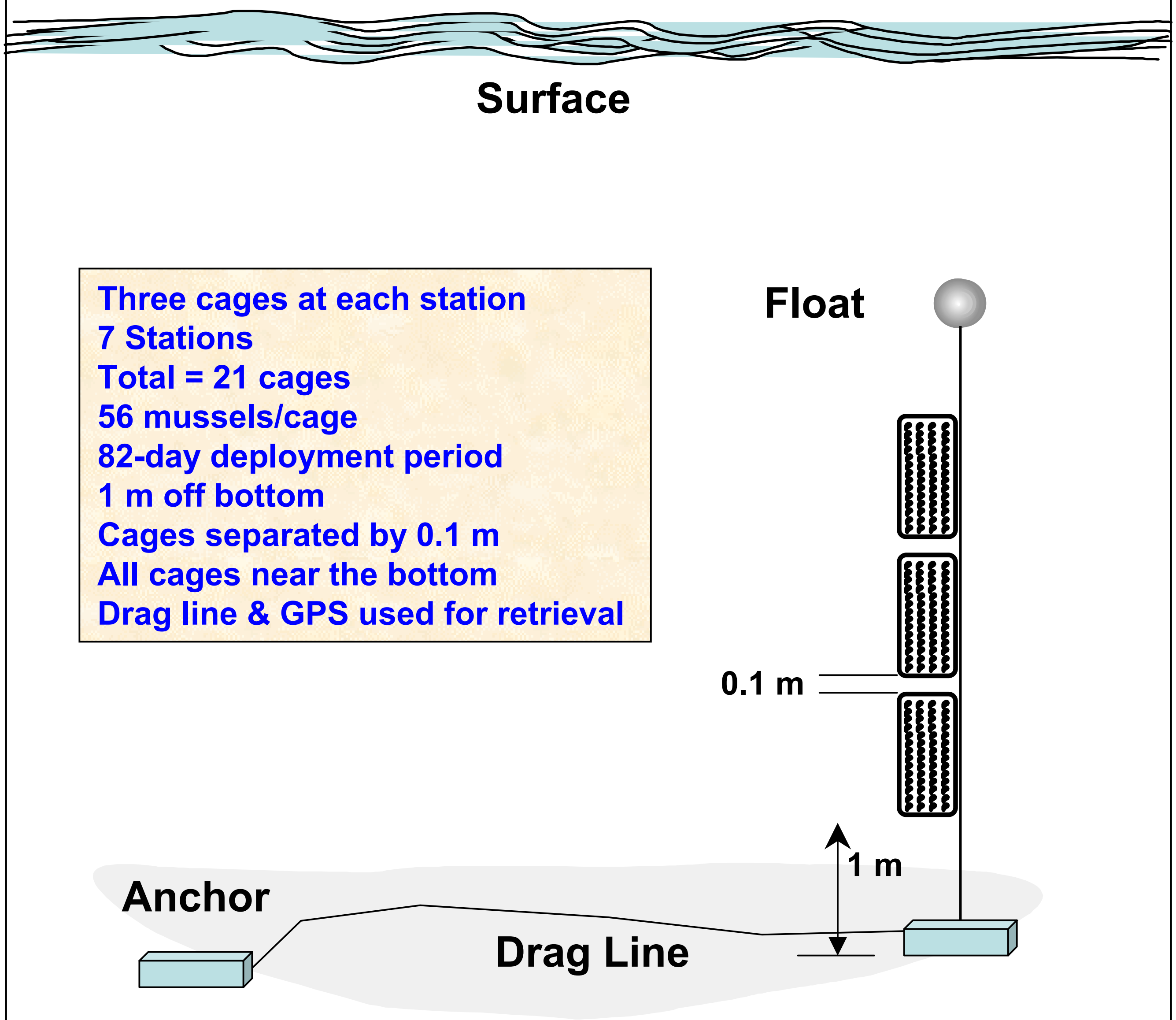
Effects Questions

Measurable effects?
Chemicals causing effects?

Caged mussel station
Indigenous mussel collection

Deployment Configuration

Three cages at each station
7 Stations
Total = 21 cages
56 mussels/cage
82-day deployment period
1 m off bottom
Cages separated by 0.1 m
All cages near the bottom
Drag line & GPS used for retrieval

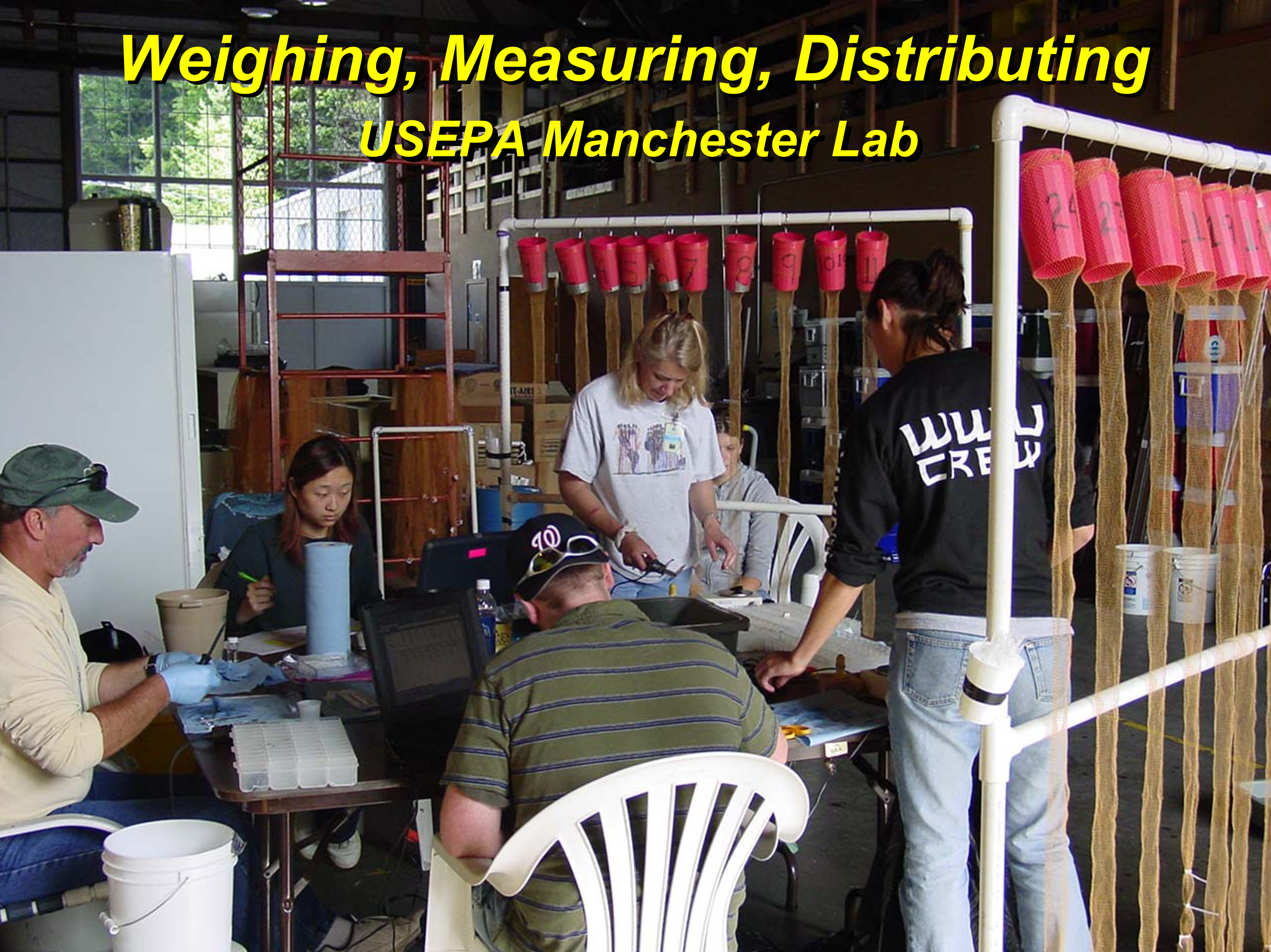


Mussel Sorting

Taylor United Mussel Farm
Shelton, WA

Weighing, Measuring, Distributing

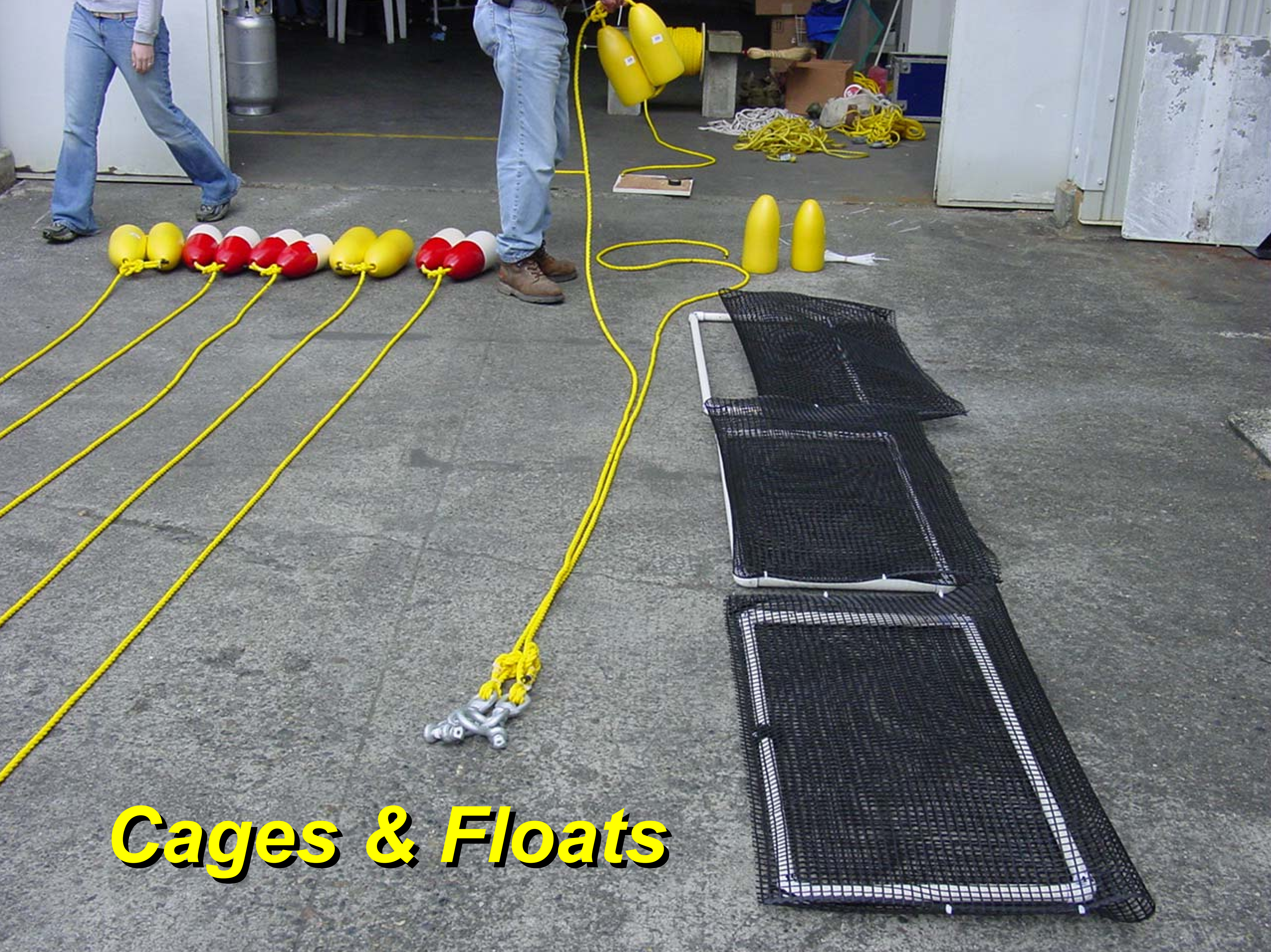
USEPA Manchester Lab




Full Shell

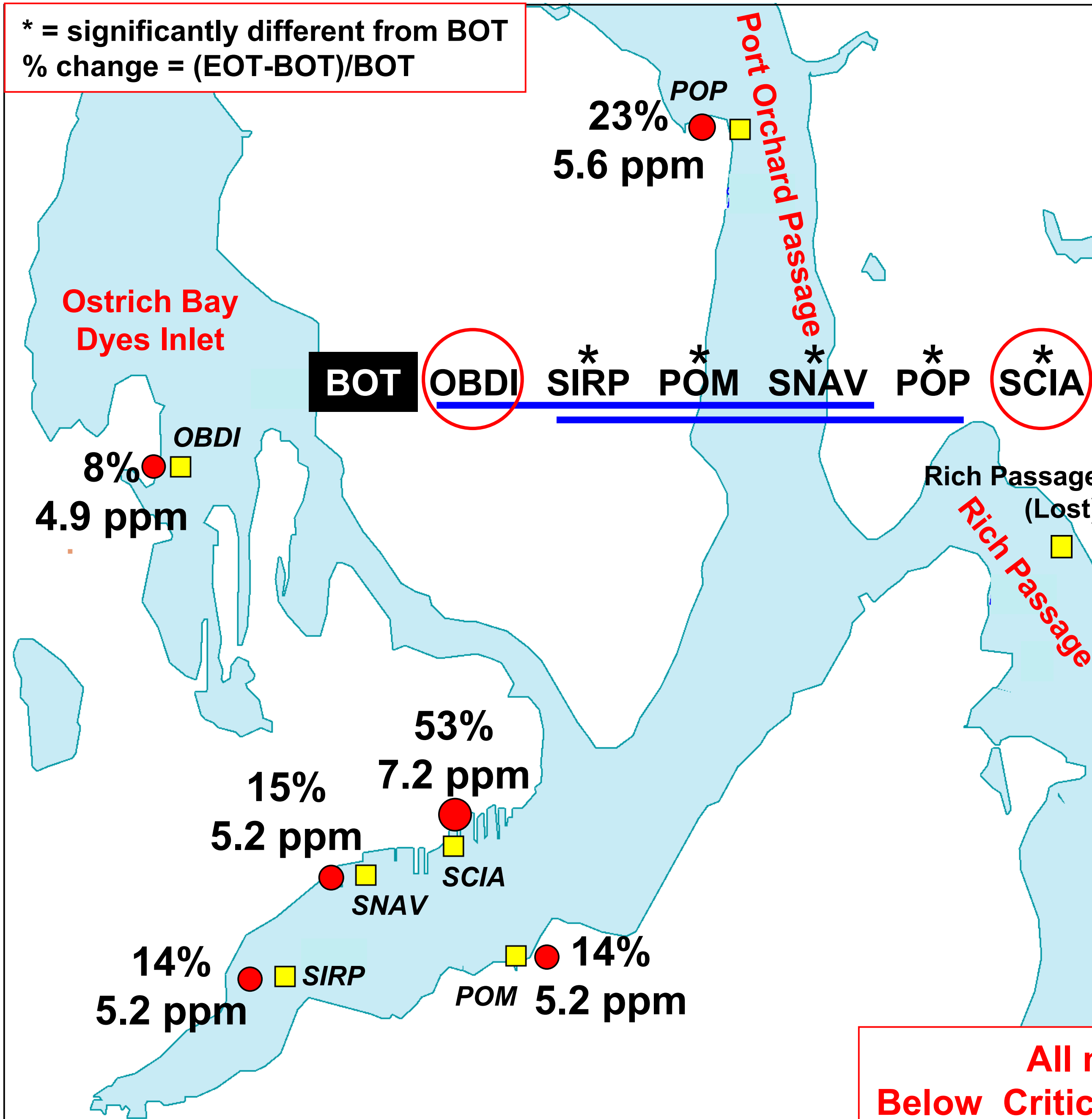
Recording, Distributing

Attaching Bags to Cages


Cages & Floats


Cages & Anchor
Prior to Deployment

* = significantly different from BOT
% change = (EOT-BOT)/BOT



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Cu

Percent Increases above BOT

BOT = 4.6 ppm (ug/g dw)

National Mean 10.5 ppm

CBR = 25 ppm dw
Mean SFG = 20 ppm dw
(Salazar & Salazar, 2006)

All measurements Below Critical Body Residue (CBR)

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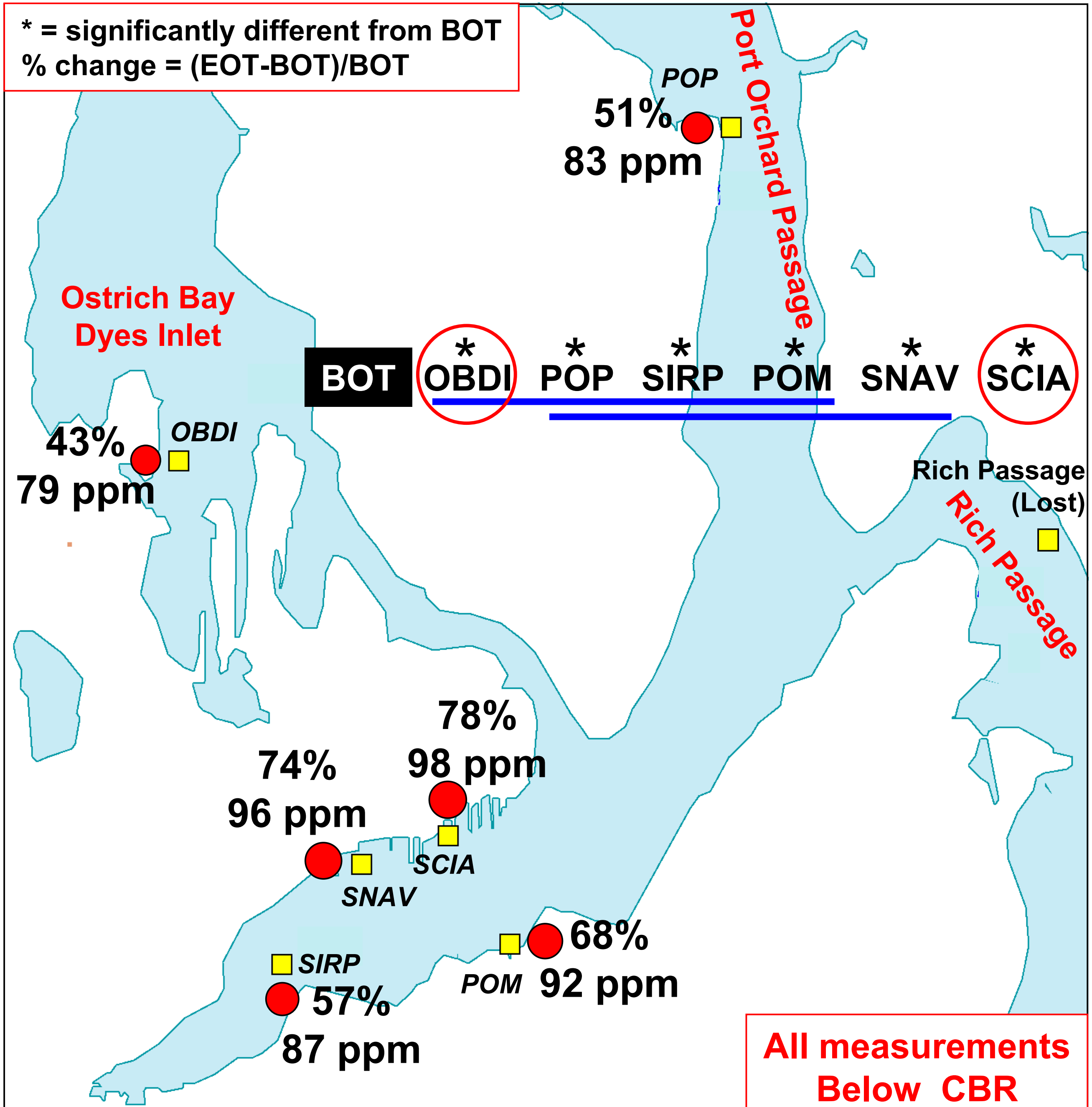
Zn



Percent Increases above BOT ●

BOT = 55 ppm (ug/g dw)

National Mean 127 ppm

CBR = 200 ppm dw
Scope for Growth
(Martin et al. 1984)

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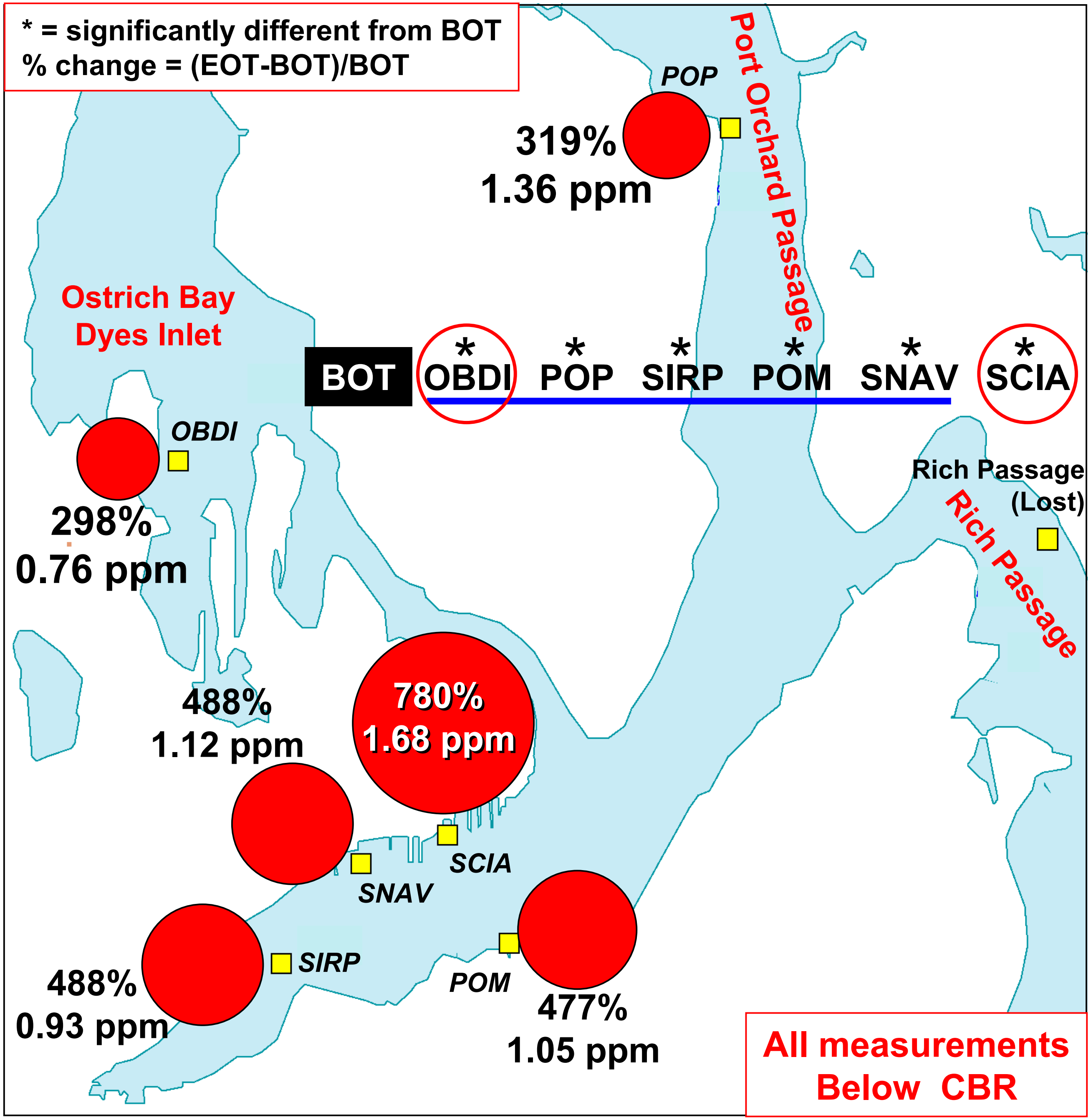
Pb



Percent Increases above BOT ●

BOT = 0.19 ppm
(ug/g dw)

National Mean
2.68 ppm

CBR = 3.5 ppm dw
Scope for Growth
(Widdows & Johnson 1988)

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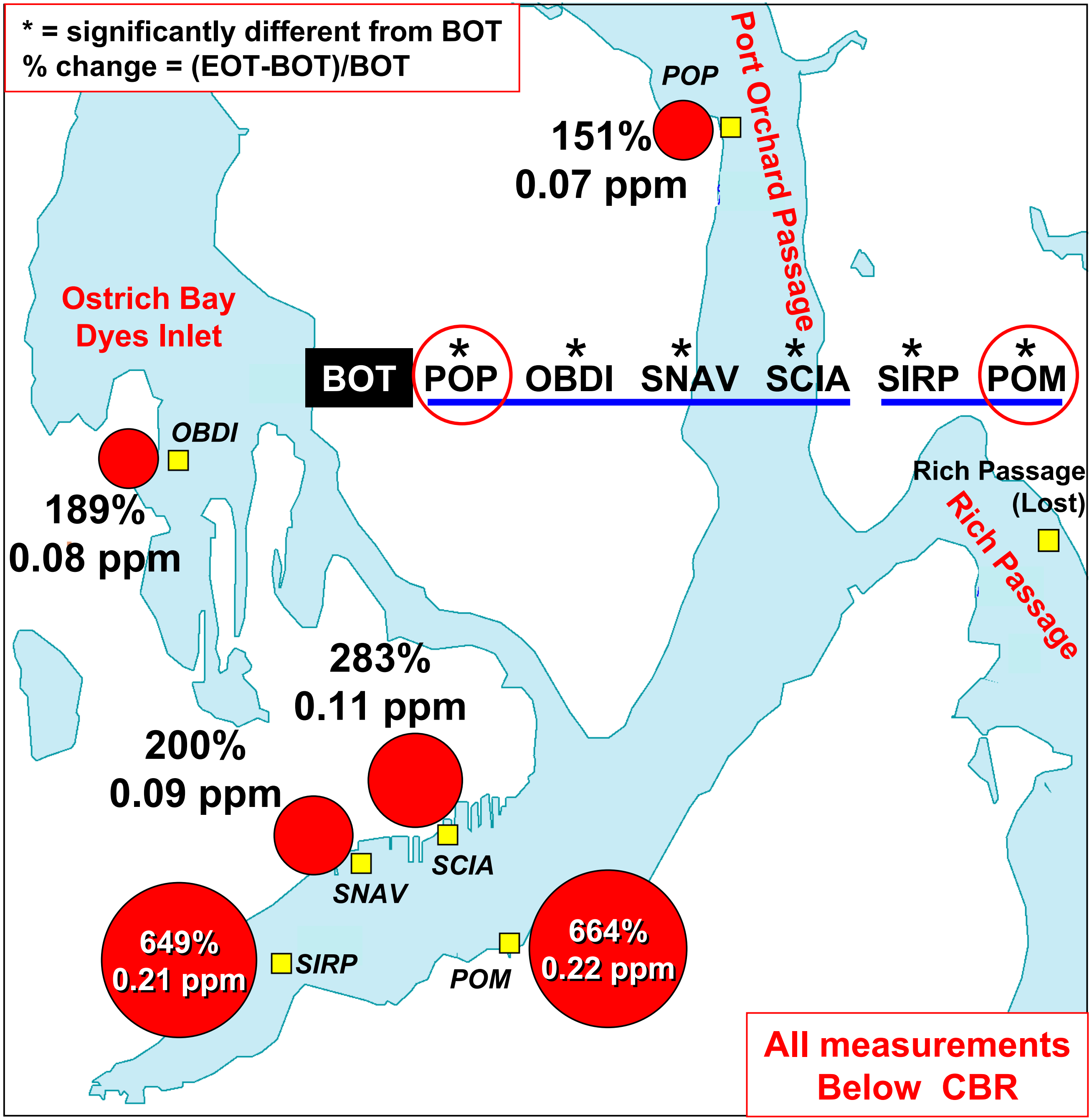
Hg

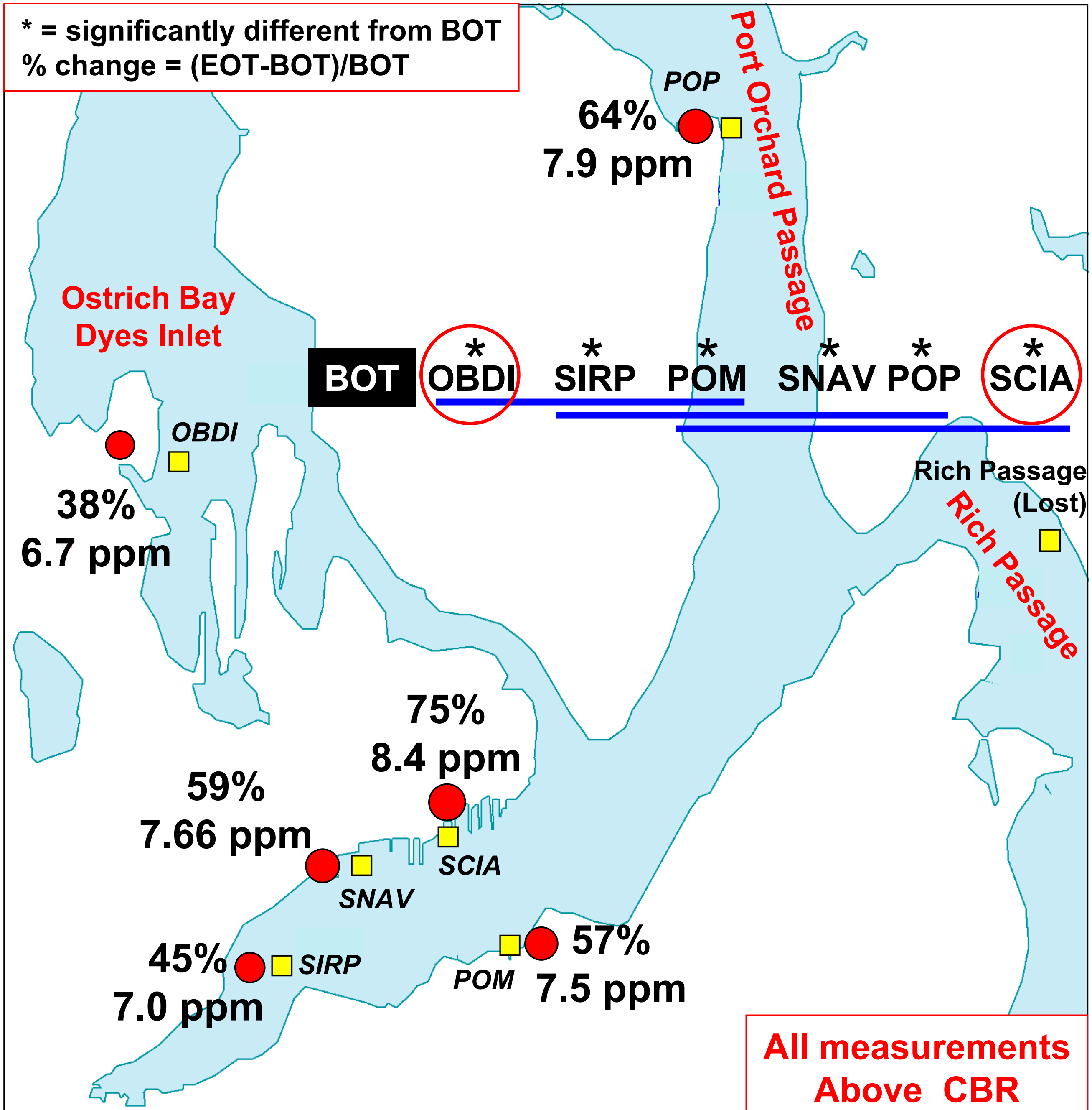


Percent Increases above BOT ●

BOT = 0.028 ppm
(ug/g dw)

National Mean
0.184 ppm

CBR = 0.56 ppm dw
Scope for Growth
(Martin et al. 1984)



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As

Percent Increases above BOT ●

BOT = 4.82 ppm
(ug/g dw)

National Mean
10.5 ppm

CBR = 6.66 ppm dw
Scope for Growth
(Martin et al., 1984)

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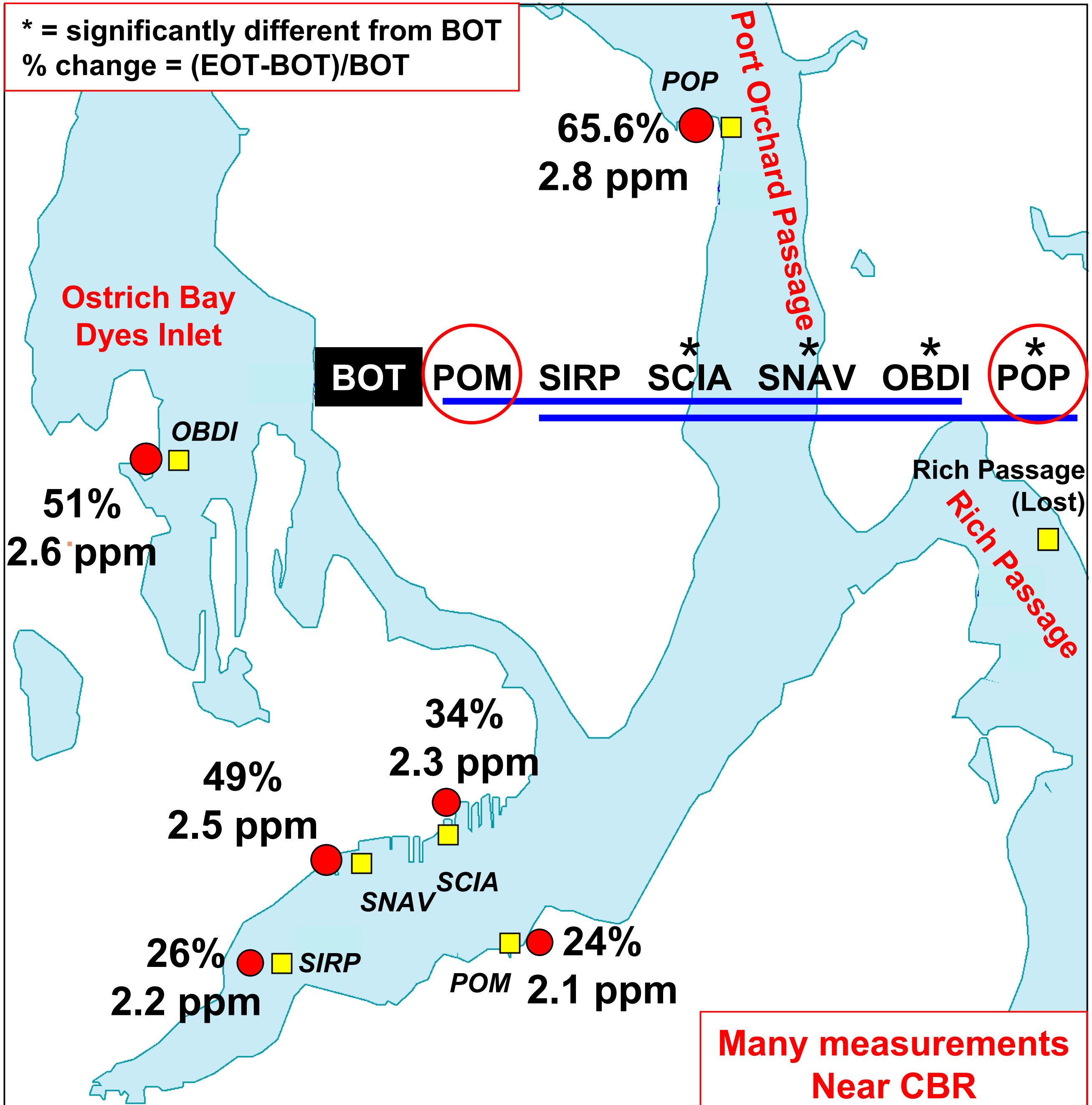
Cd



Percent Increases above BOT

BOT = 1.70 ppm
(ug/g dw)

National Mean
2.68 ppm

CBR = 3 ppm dw
Scope for Growth
(Widdows & Johnson, 1988)

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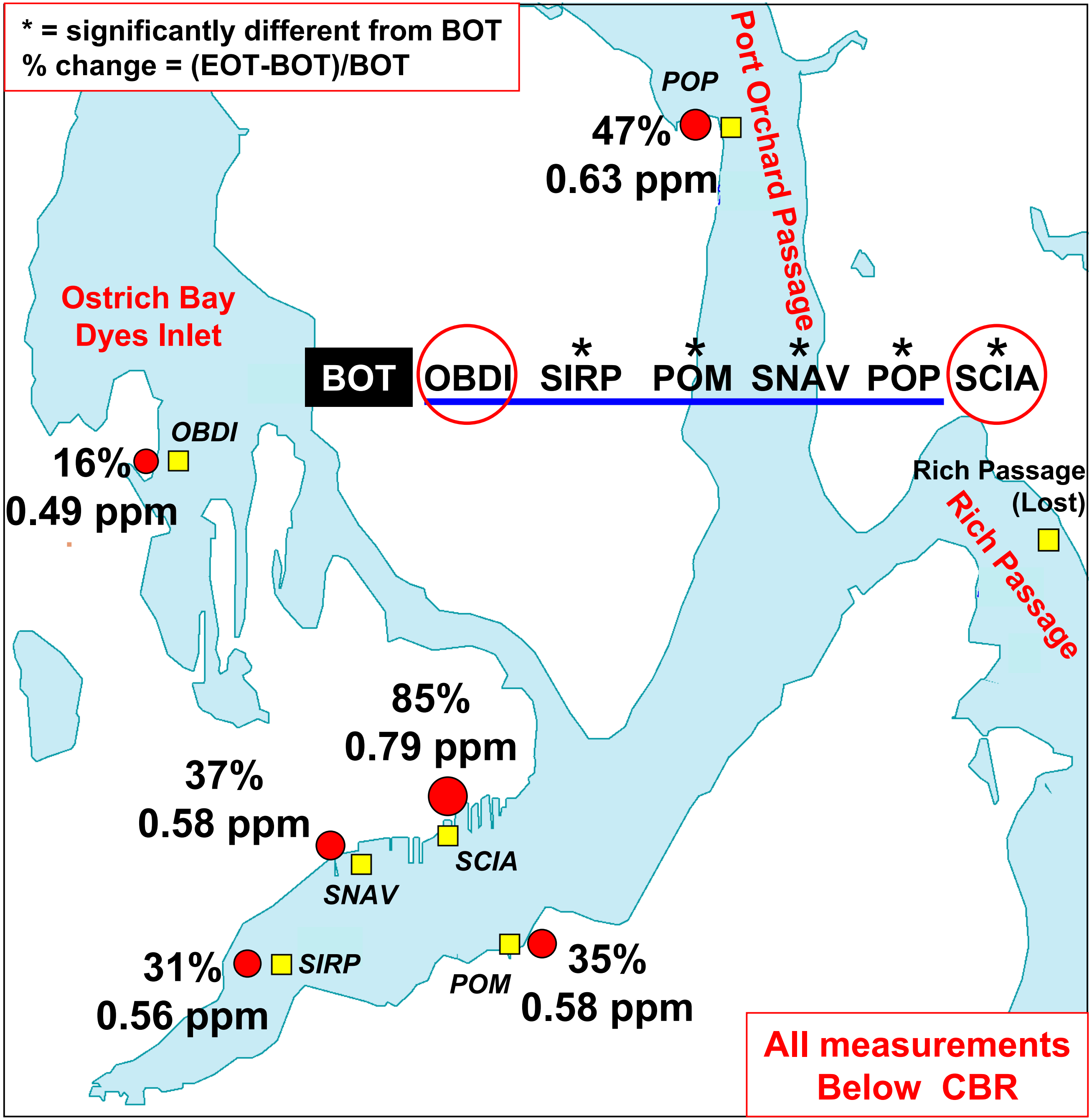
Cr

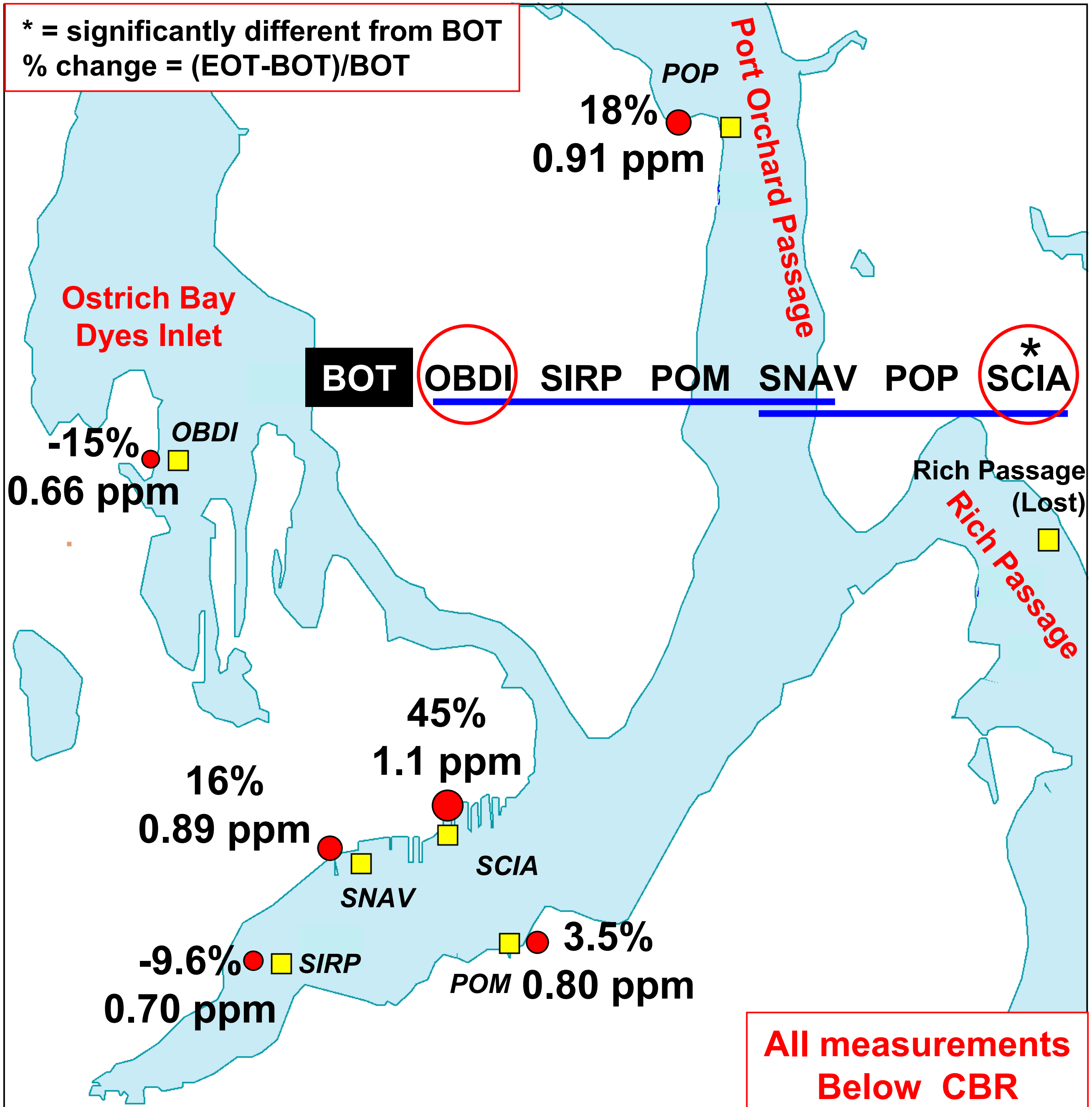


Percent Increases above BOT ●

BOT = 0.43 ppm
(ug/g dw)

National Mean
3.72 ppm

CBR = 3.6 ppm dw
Scope for Growth
(Martin et al. 1984)



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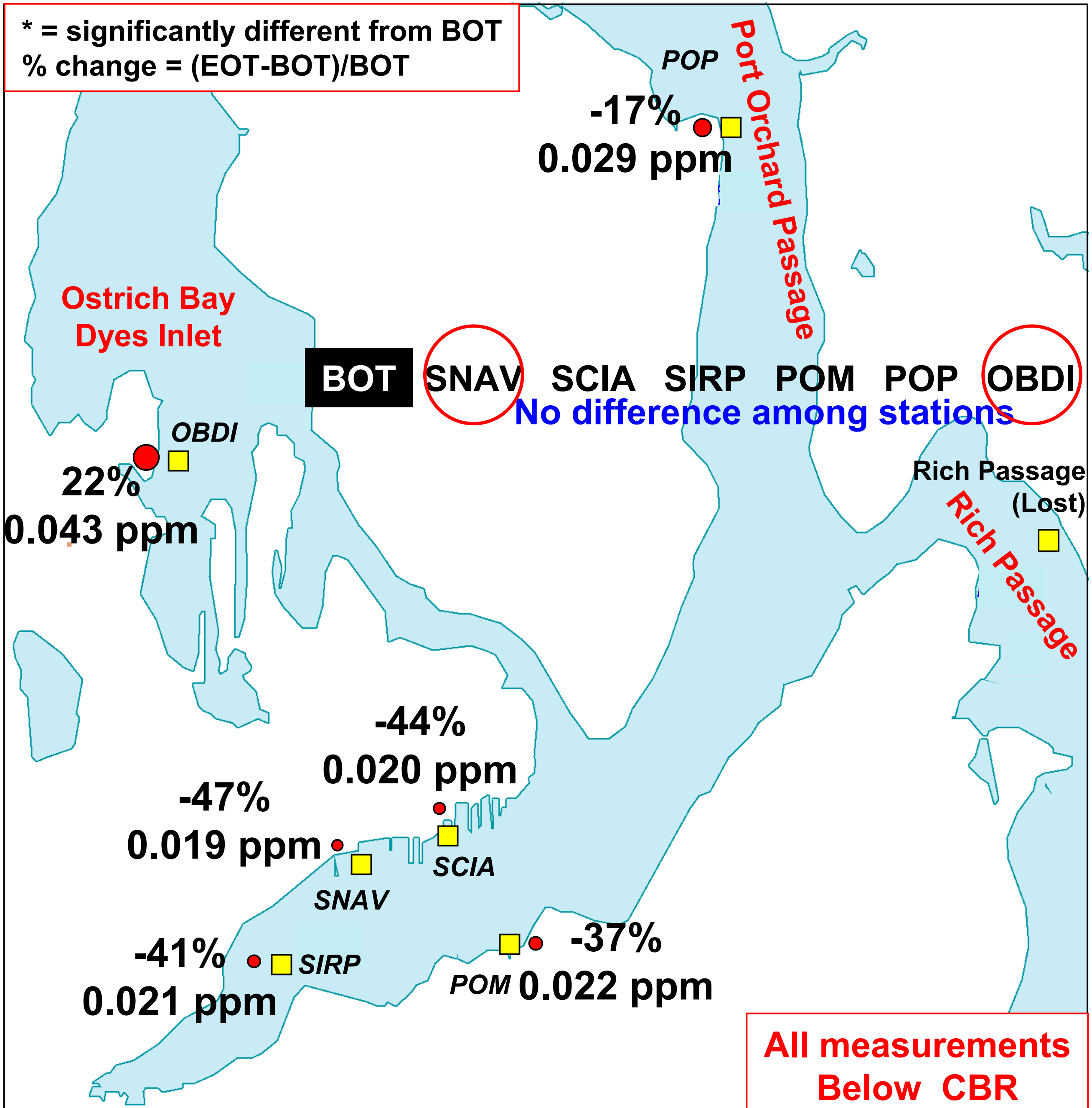
Ni

Percent Increases above BOT ●

BOT = 0.77 ppm
(ug/g dw)

National Mean
3.1 ppm

CBR = 7 ppm dw
Scope for Growth
(Phelps et al., 1981)



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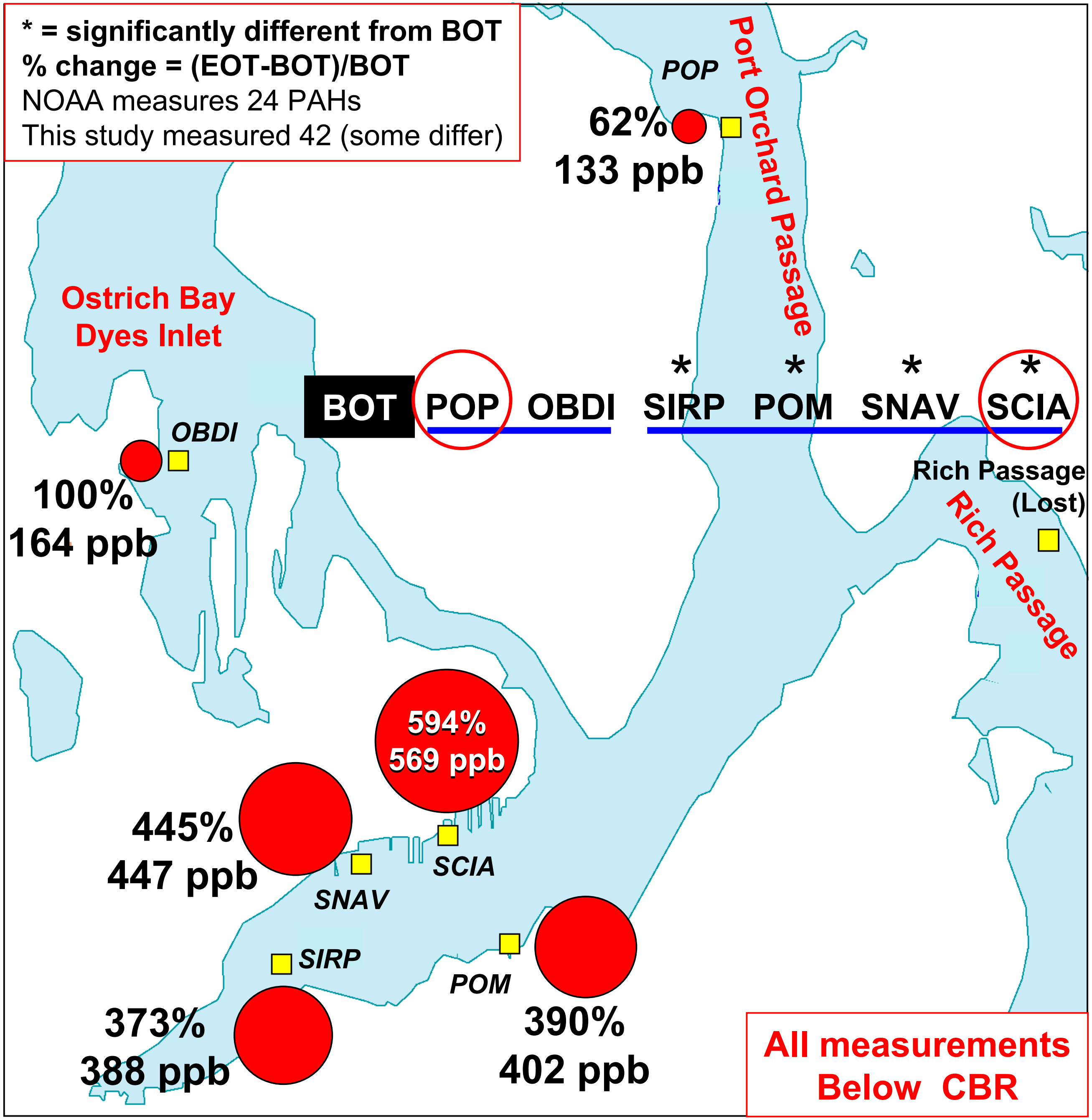
Ag

Percent Increases above BOT ●

BOT = 0.035 ppm
(ug/g dw)

National Mean
0.284 ppm

CBR = 2.5 ppm dw
Scope for Growth
(Martin et al., 1984)



2005 Sinclair Inlet Caged Mussel Study

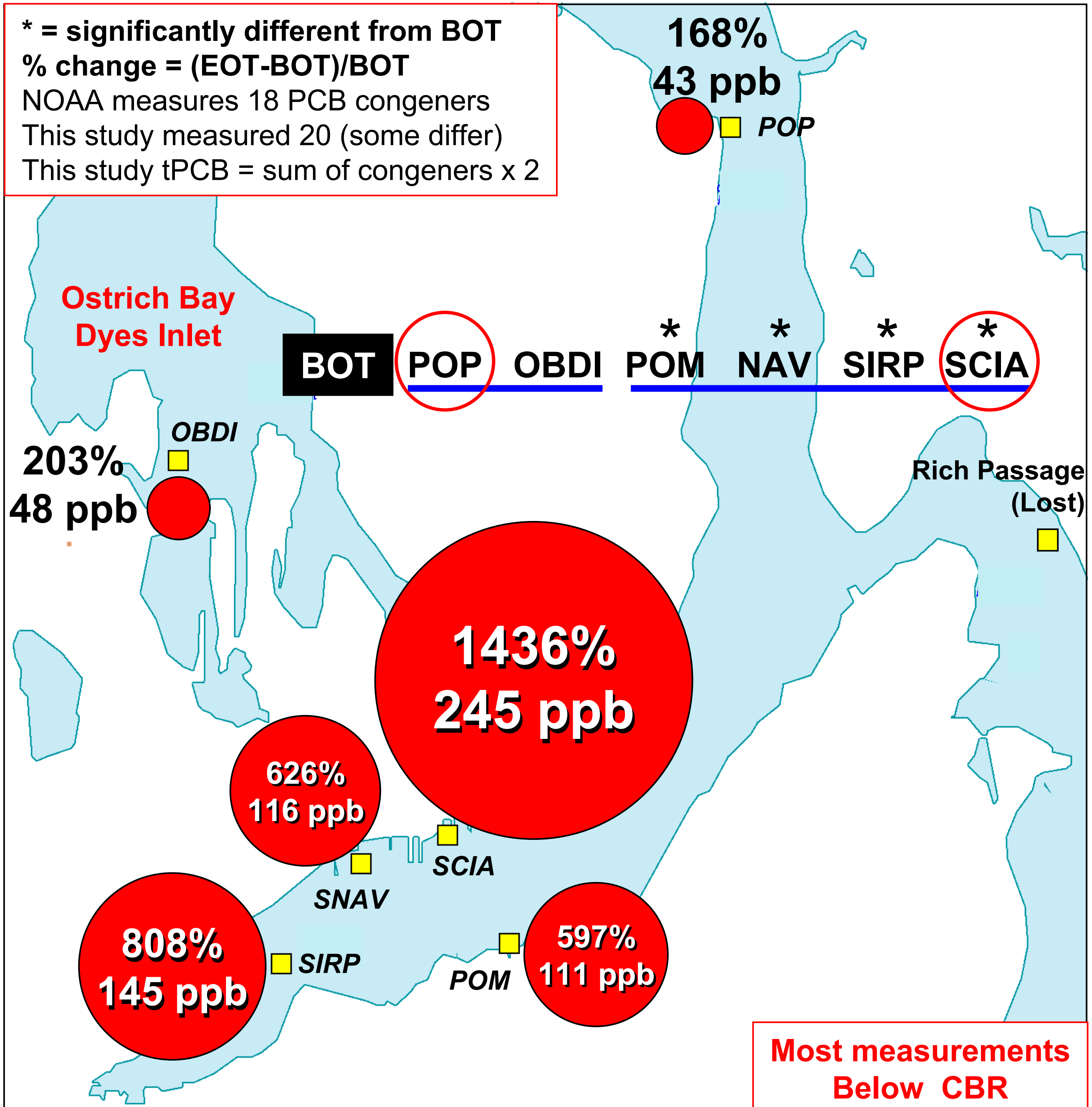
tPAH

Percent Increases above BOT ●

BOT = 82.0 ppb
(ng/g dw)

National NOAA Data
Mean = 1498 ppb
Median = 604 ppb

CBR = 2,250 ppb dw
Scope for Growth
(Widdows & Donkin 1992)



2005 Sinclair Inlet
Caged Mussel Study

tPCBs

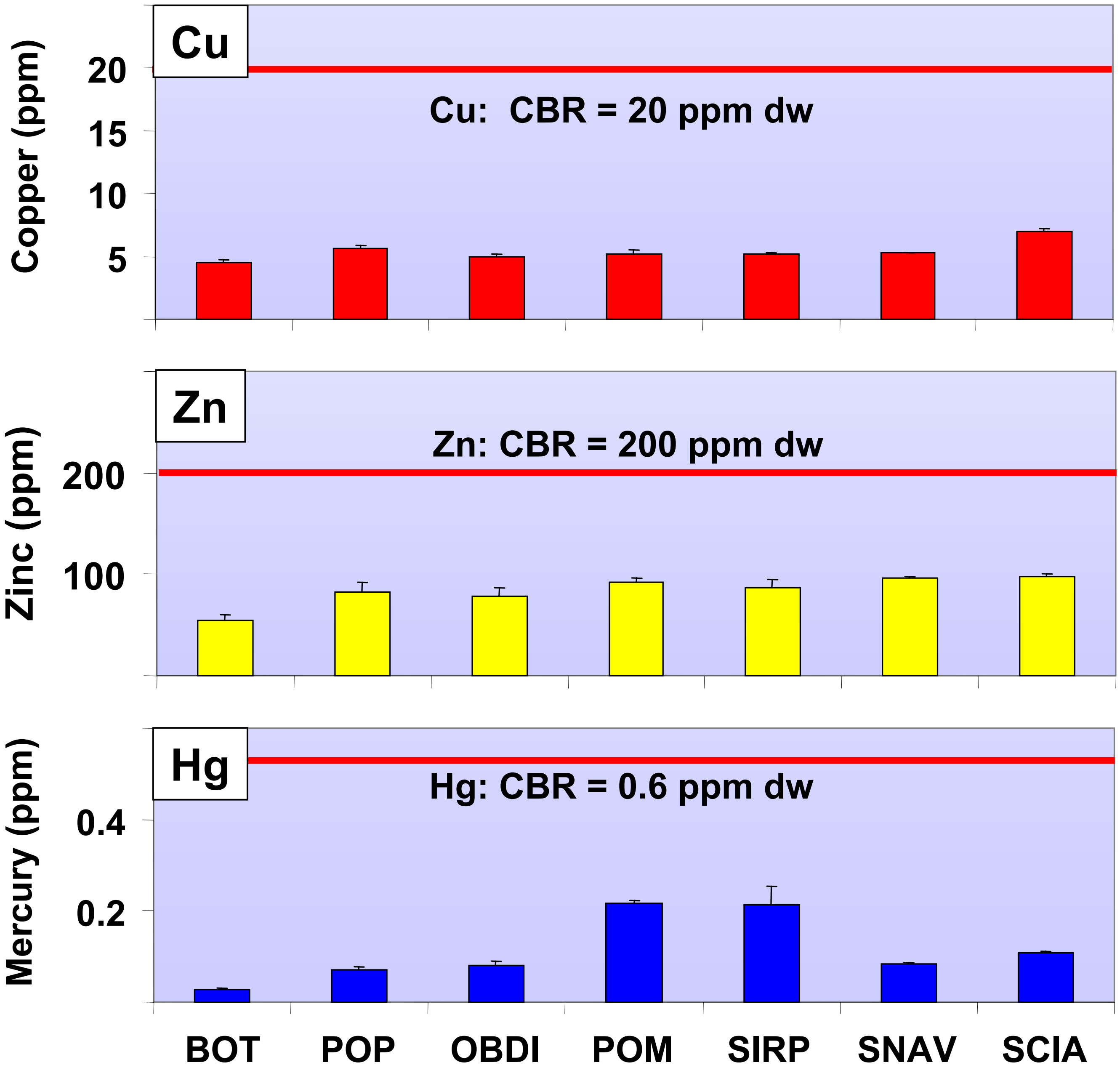
Percent Increases above BOT ●

BOT = 15.9 ppb
(ng/g dw)

National
Mean = 255 ppb
Median = 96 ppb

CBR = 200 ppb dw
Mussel Growth
(Krishnkumar et al 1991)

Critical Body Residues (CBRs) for Mussels

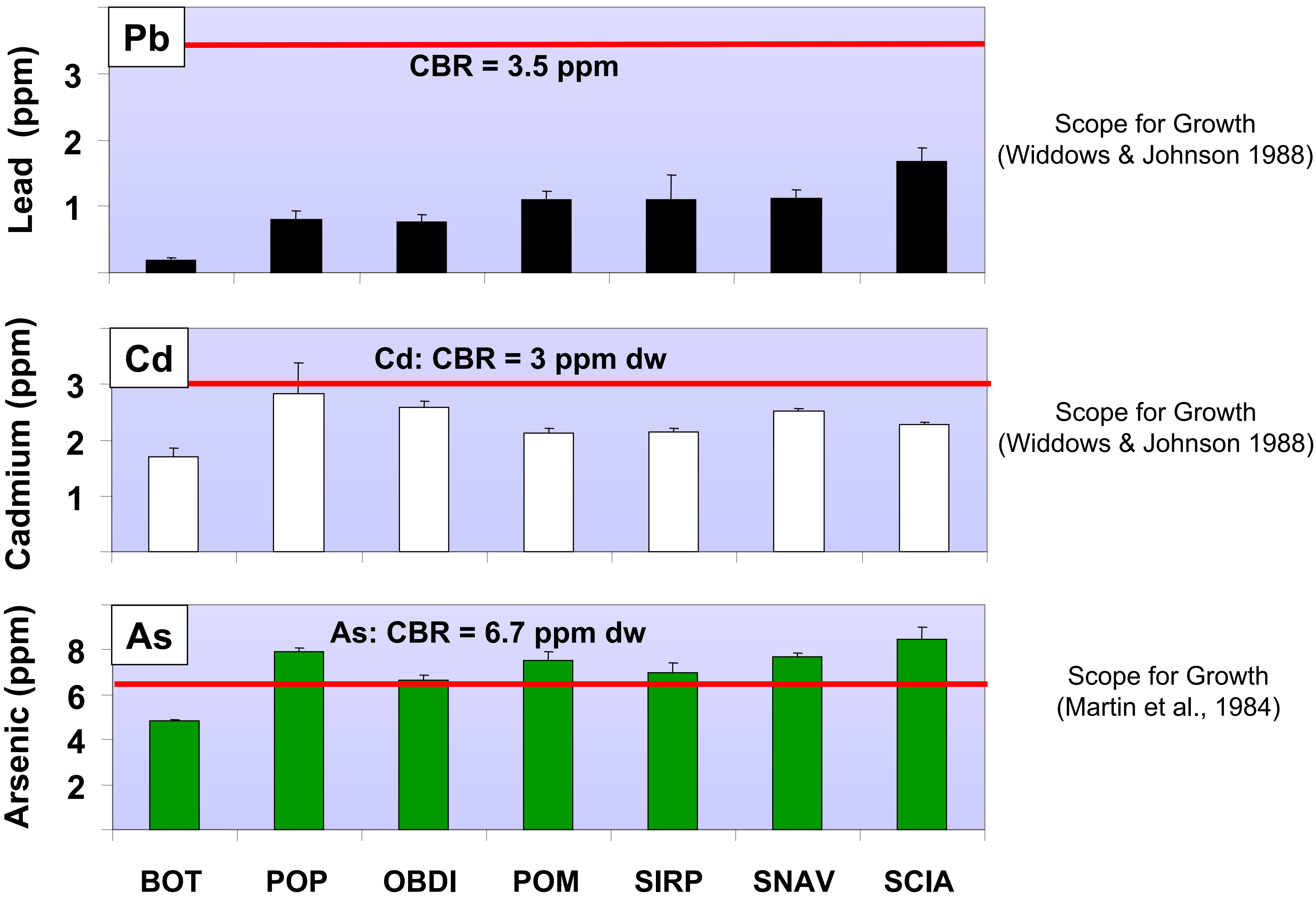


Scope for Growth
(Salazar & Salazar 2006)

Scope for Growth
(Martin et al. 1984)

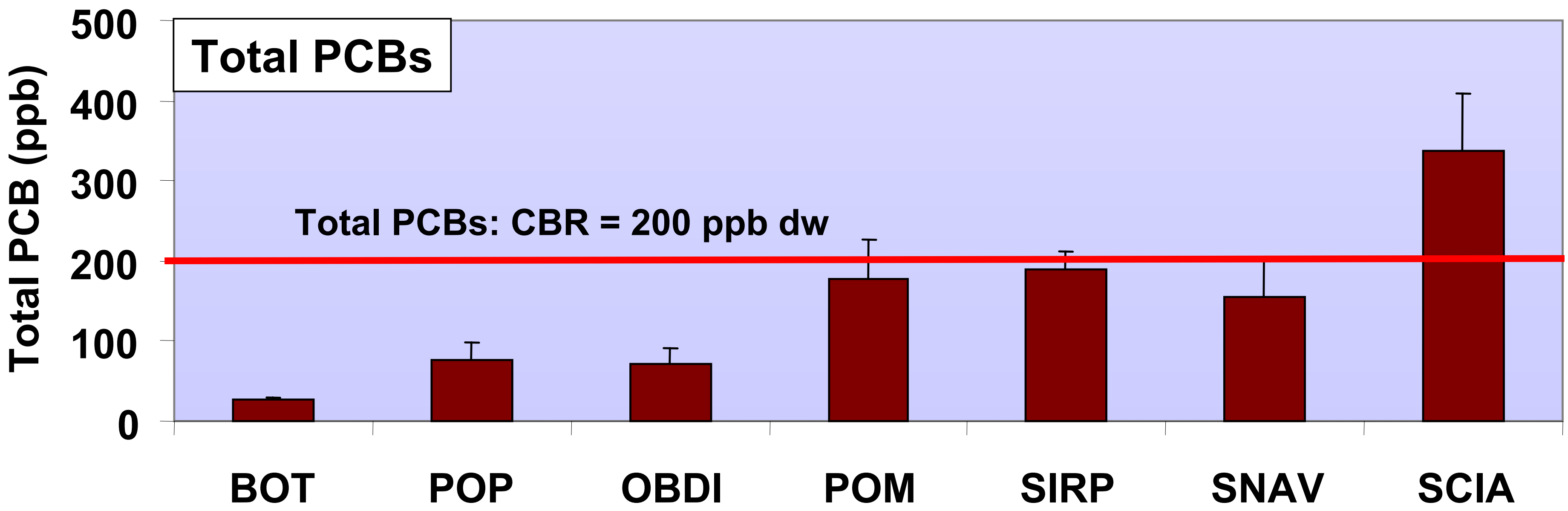
Scope for Growth
(Martin et al. 1984)

Critical Body Residues (CBRs) for Mussels



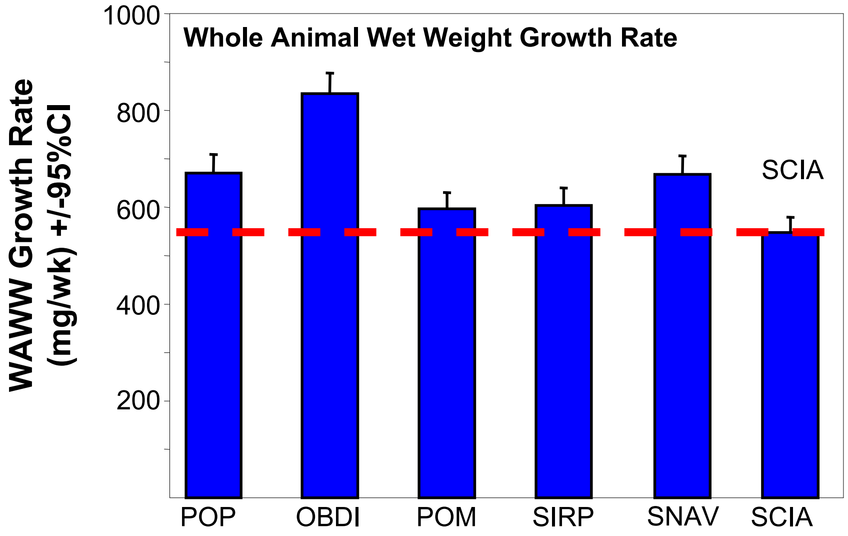
Critical Body Residues (CBRs) for Mussels

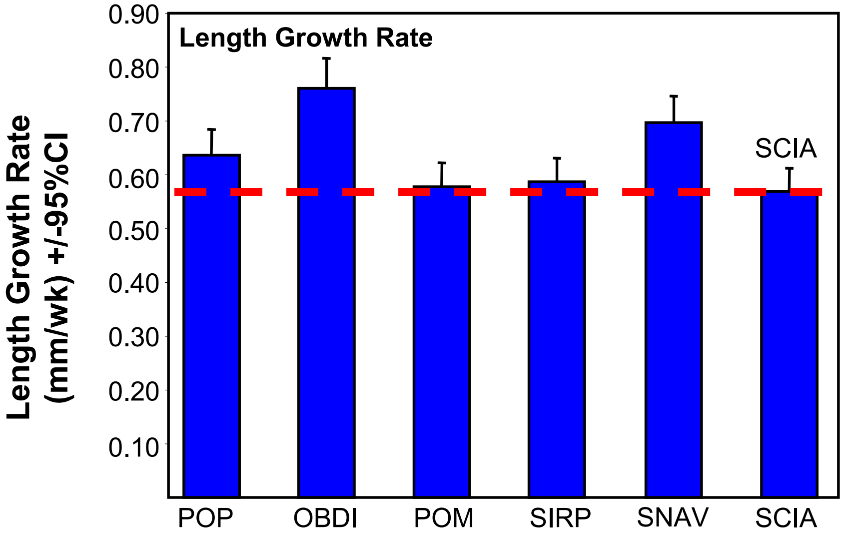
Total PCBs expressed as sum of 10 Homologs
Non Detected = (Detection Limit)/2

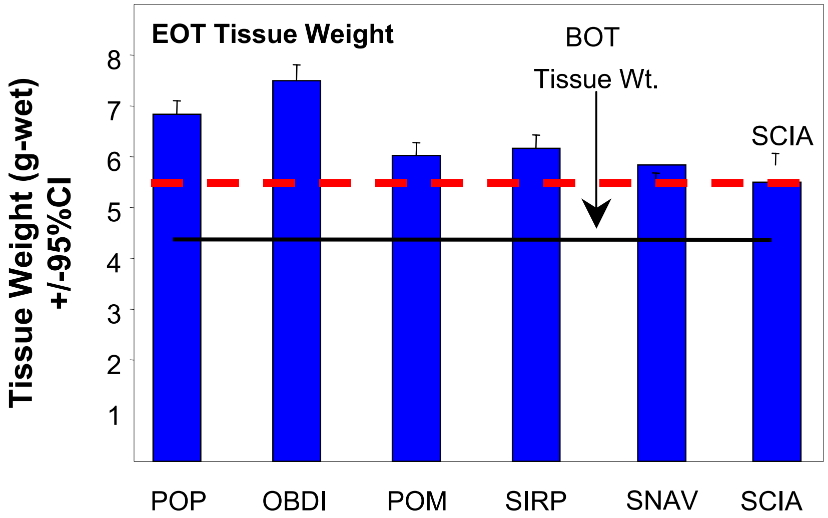


Mussel Growth
(Krishnakumar et al 1991)

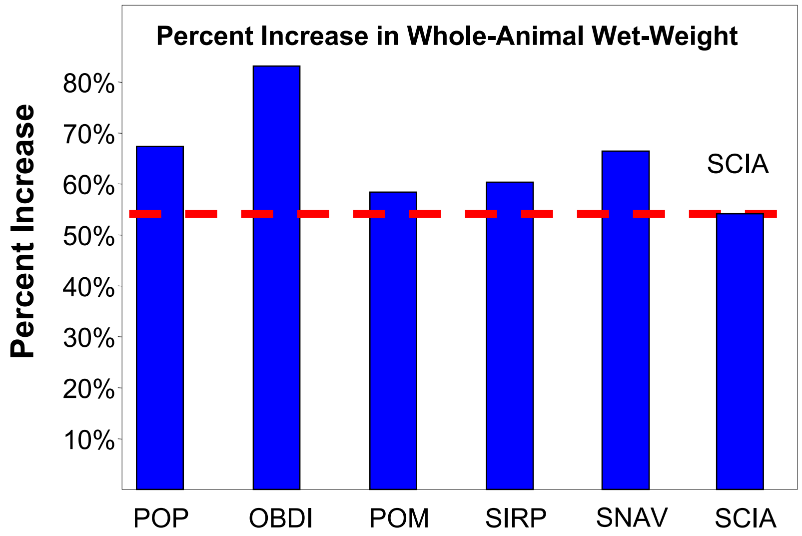
Mussel Growth Metrics - Actual

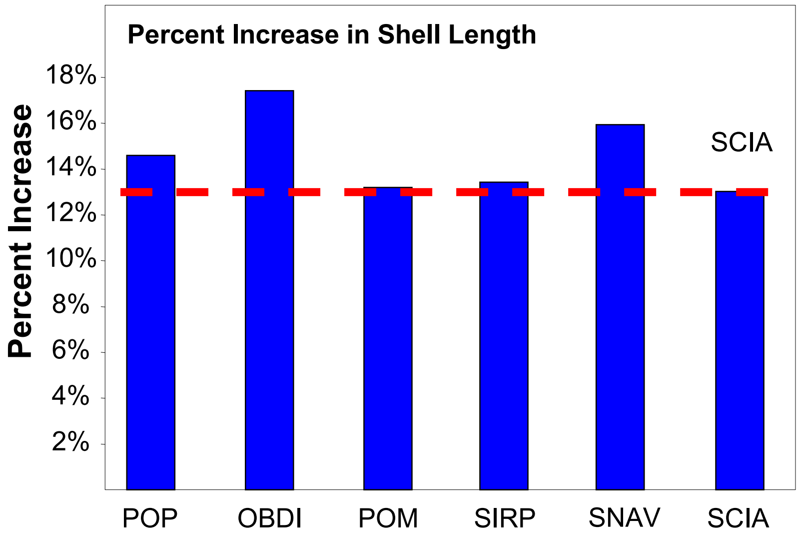


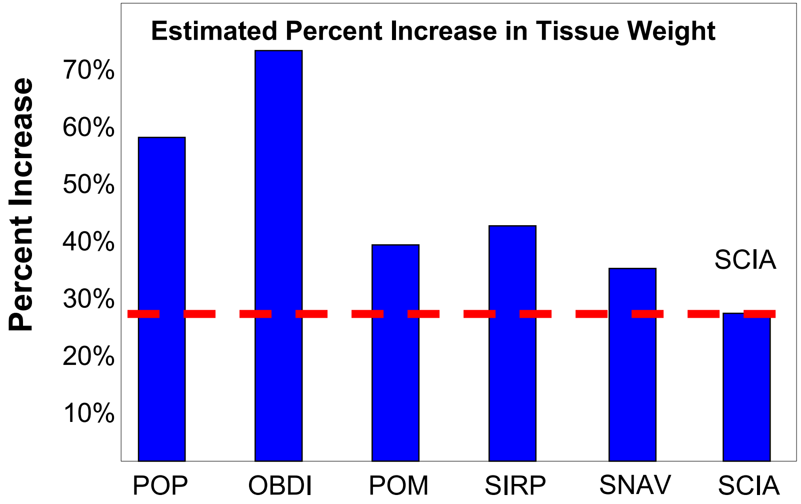




Mussel Growth Metrics - % Change







Ranking Tables – Mussel Tissue Chemistry

(1 = lowest rank; 6 = highest rank)

Metals

	OBDI	SIRP	POM	SNAV	POP	SCIA
Copper	1	2	3	4	5	6
Mercury	2	5	6	3	1	4
Zinc	1	3	4	5	2	6
Arsenic	1	2	3	4	5	6
Cadmium	5	2	1	4	6	3
Nickel	1	2	3	4	5	6
Lead	1	3	4	5	2	6
Chromium	1	2	3	4	5	6
Silver	6	3	4	1	5	2
Sum Ranks	***19***	***24***	***31***	***34***	***36***	***45***

SCIA ≠ OBDI

Organics

	POP	OBDI	POM	SIRP	SNAV	SCIA
tPAH	1	2	4	3	5	6
tPCB	1	2	3	5	4	6
Sum Ranks	***2***	***4***	***7***	***8***	***9***	***12***

SCIA ≠ POP

Mussel Growth

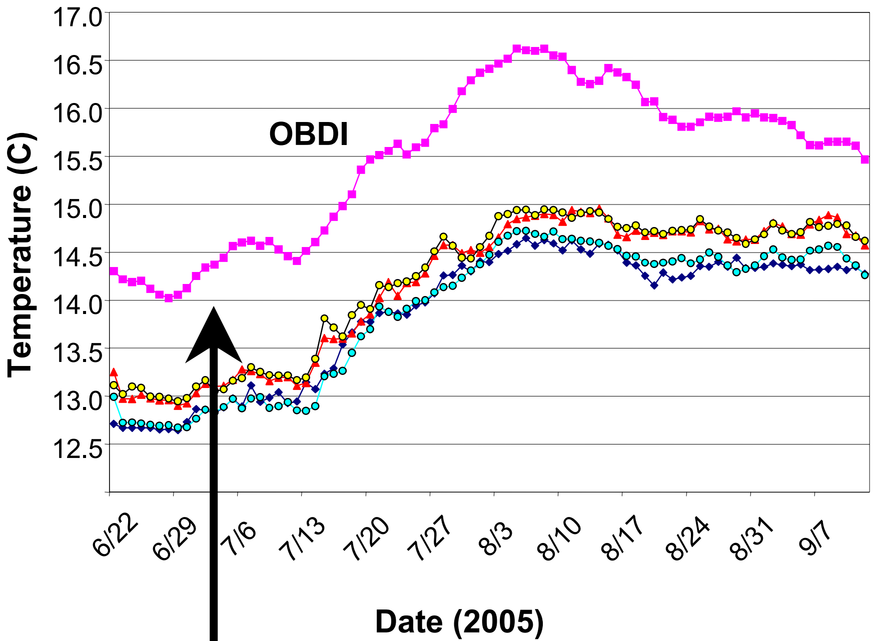
(1 = lowest rank; 6 = highest rank)

	SCIA	SIRP	POM	SNAV	POP	OBDI
Shell Length	2	1	3	5	4	6
Length GR	1	3	2	5	4	6
WAWW	1	2	3	4	5	6
WAWW GR	1	3	2	4	5	6
Tissue Weight	1	4	3	2	5	6
Shell Weight	3	1	2	4	5	6
Sum Ranks	***9***	***14***	***15***	***24***	***28***	***36***

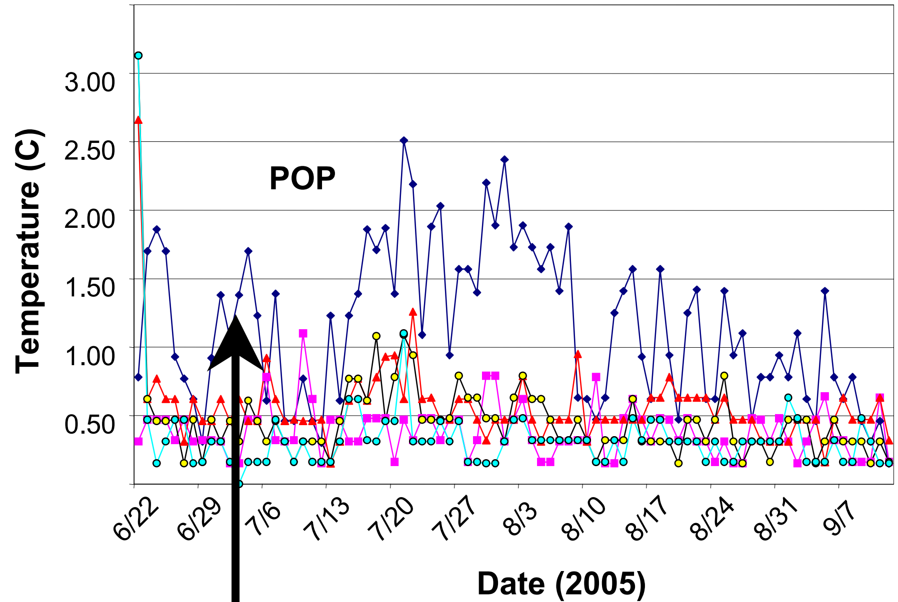
SCIA ≠ POP or OBDI

Seawater Temperature: Daily Averages & Ranges

Daily Mean Water Temperature

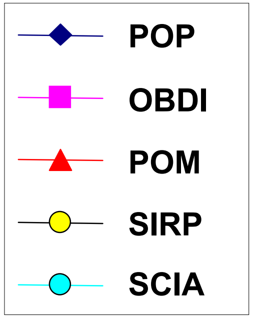


Range in Daily Water Temperature



Mean temperature alone could explain higher growth rates at OBDI. Using pooled mussel growth rankings, OBDI was the highest and SCIA was the lowest.

Although temperature variability could suggest reduced growth, POP growth was high and probably associated with greater flushing and current speed.



Summary & Conclusions

Based on our ecotoxicological interpretation and CBRs

- Ag, Cr, Cu, Ni, Zn & PAH do not represent significant risks in Sinclair Inlet
- While Pb may be or may become a significant risk, it is probably not affecting mussel growth. SCIA may be a source of Pb
- While Hg may be or may become a significant risk, it is probably not affecting mussel growth. SIRP and POM may be sources of Hg
- As and Cd may be affecting mussel growth, may represent significant risks
- While PCBs probably represent significant risks, concentrations that cause effects on mussel growth were only exceeded at one station (SCIA)
- SCIA and SNAV are significantly different in terms of chemical exposure and effects endpoints, demonstrating the importance of small spatial scales in the Inlet