# A Survey of Cadmium in Pacific Oysters (*Crassostrea gigas*) of the U.S. West Coast

Accumulation pathways, subcellular distribution, and implications for the shellfish industry

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# Why look at cadmium in oysters?

1999 and 2003- Hong Kong rejected oyster shipment

- BC, Canada and Hood Canal, WA
- oyster > 2 ppm Cd ML import standard

2005 - Hong Kong rejected oyster shipment of Hood Canal

- Cadmium level in sample was 3.9 ppm
- oyster > 3.7 ppm Cd ML U.S. FDA standard

# Why look at cadmium in oysters?

- Codex Alimentarius deliberated a 1-ppm ML for molluscan shellfish
- Is there an economic risk?
- Is there a human health risk?

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# What is Cd and why is it a human health concern?

- Natural and anthropogenic sources
  - Geology
  - Residential , agriculture, industry, mining
- Oysters accumulate Cd naturally
- In humans
  - Cd accumulates in liver and kidneys
  - Long biological half-life (10-30 yrs)
- Can cause:
  - kidney dysfunction
  - liver disease
  - skeletal decalcification

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USDA United States Department of Agriculture

Oregon State University OSU

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Pacific Shellfish Institute

Sea Grant California

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THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

ALASKA SEA GRANT MARINE ADVISORY PROGRAM

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# Primary Objectives

- Evaluate Cd distribution in U.S. West Coast Pacific oysters
- Identify factors that influence Cd concentration in oysters
- Evaluate impact to shellfish industry and human health
- Find ways to reduce concentrations in final product

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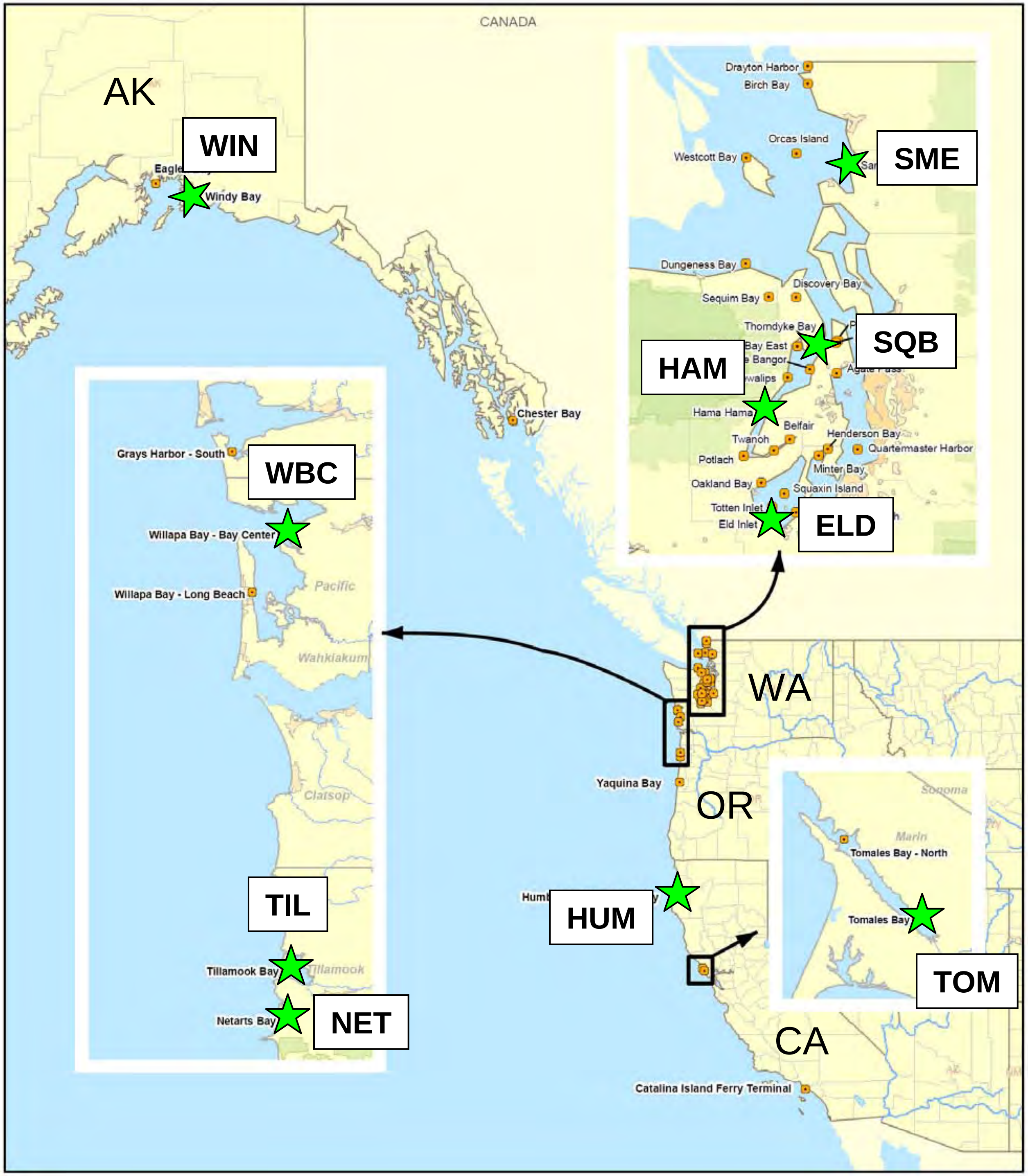
# Research Goals

- Cadmium distribution in Pacific oysters
  - California
  - Oregon
  - Washington
  - Alaska

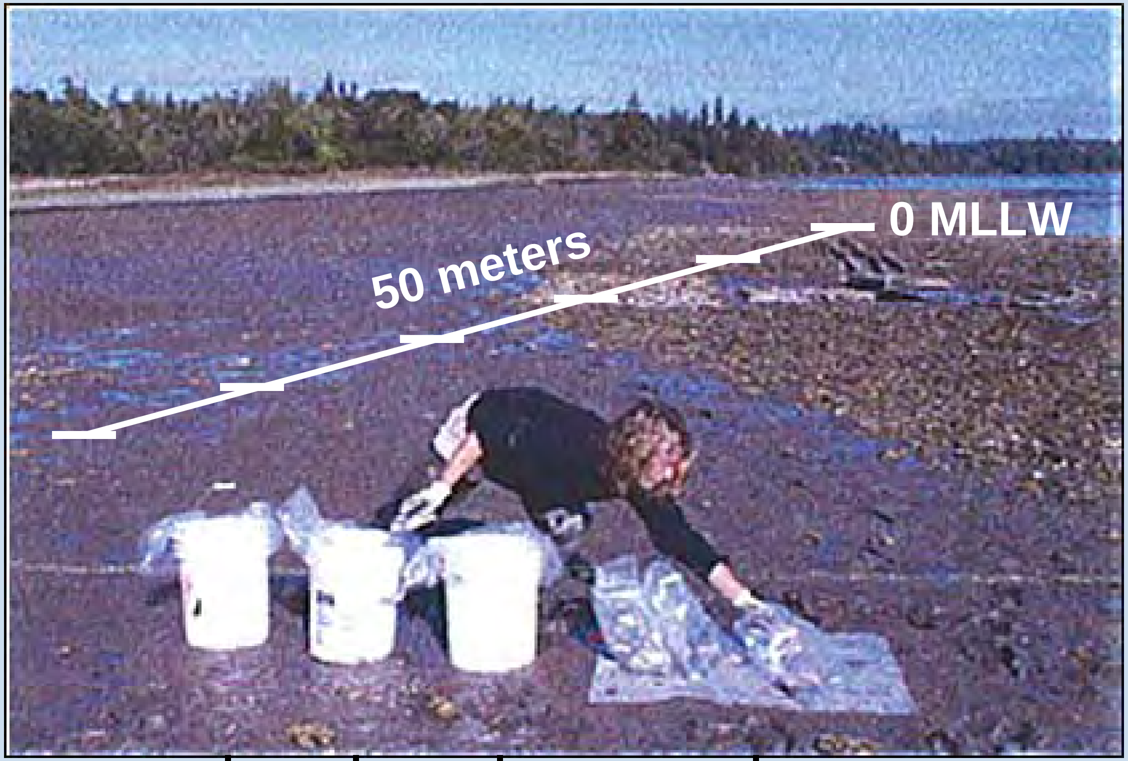
# Sampling Station Locations




★ Seasonal sampling

Thanks to all participating oyster growers!

# Oyster Tissue Composite Sampling




sample collection bucket

scrub bucket

rinse bucket

3 collection bags
20 oysters each
4” to 6”

# Cadmium Seasonal Sampling

## Seawater

- Total Cd/Zn
- Dissolved Cd/Zn
- Seston
- TSS
- Plankton counts and speciation

## Sediment

- Cd/Zn
- TOC
- Grain Size

## Oyster Tissue

- Total Cd/Zn

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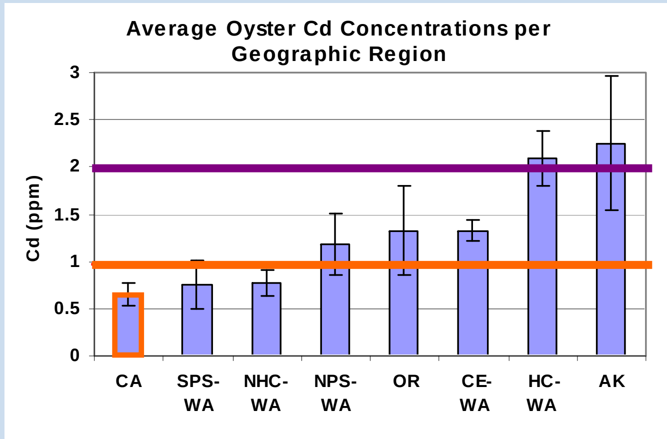
# California

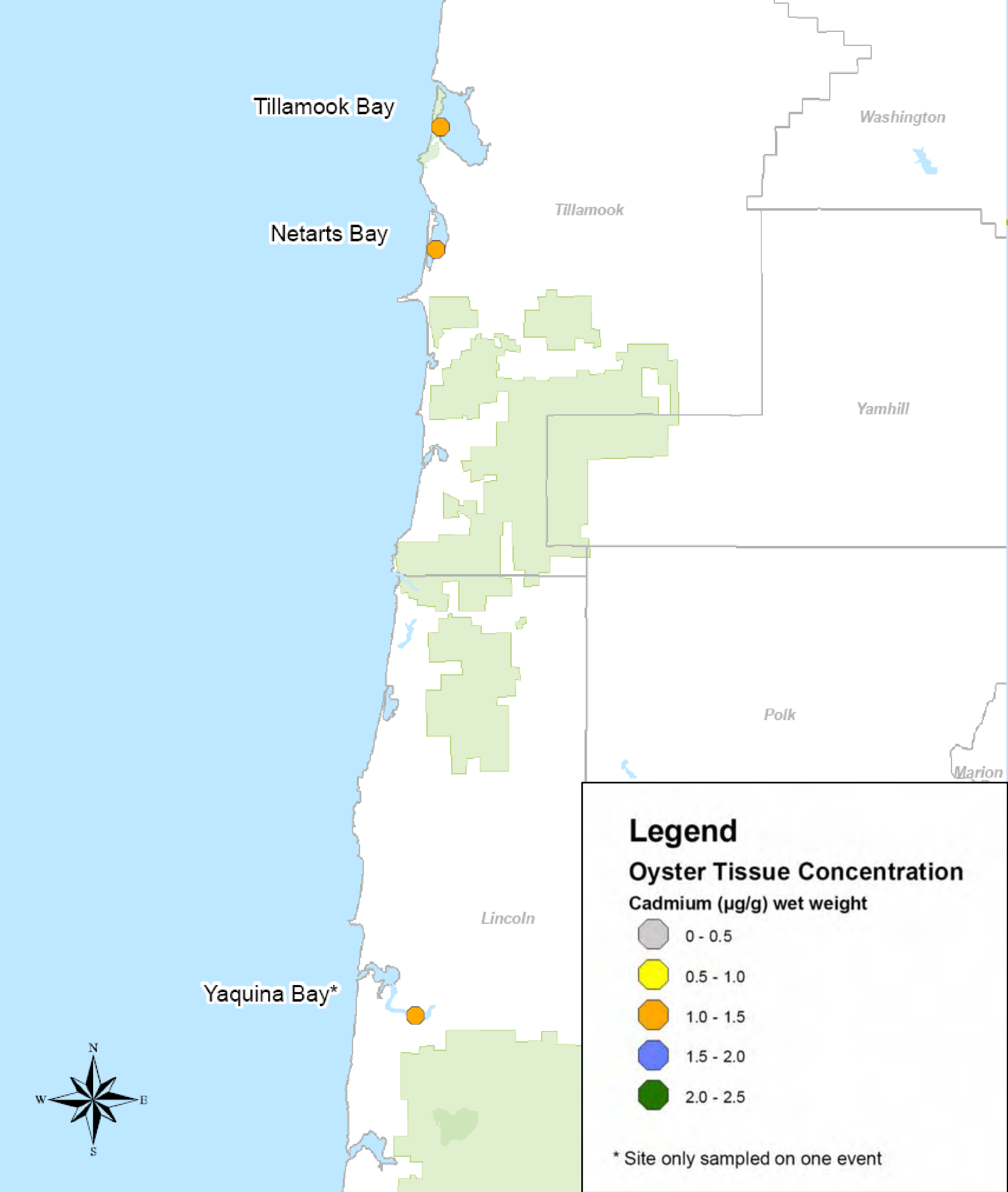
oyster composites (n = 13)

range: 0.44 to 0.78 ppm

mean: **0.65 ± 0.12 ppm**

(average from 2004 to 2006)





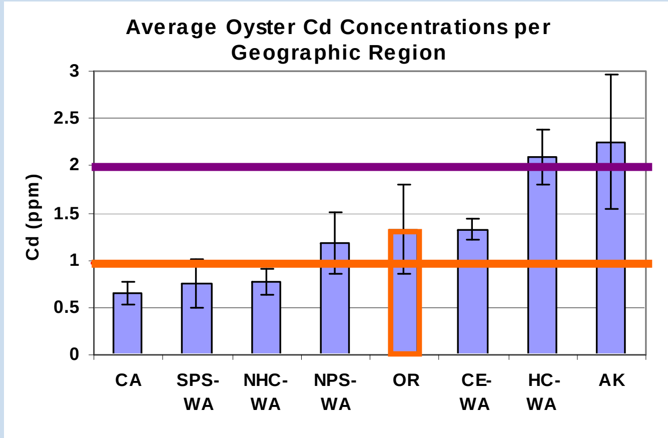

# Oregon

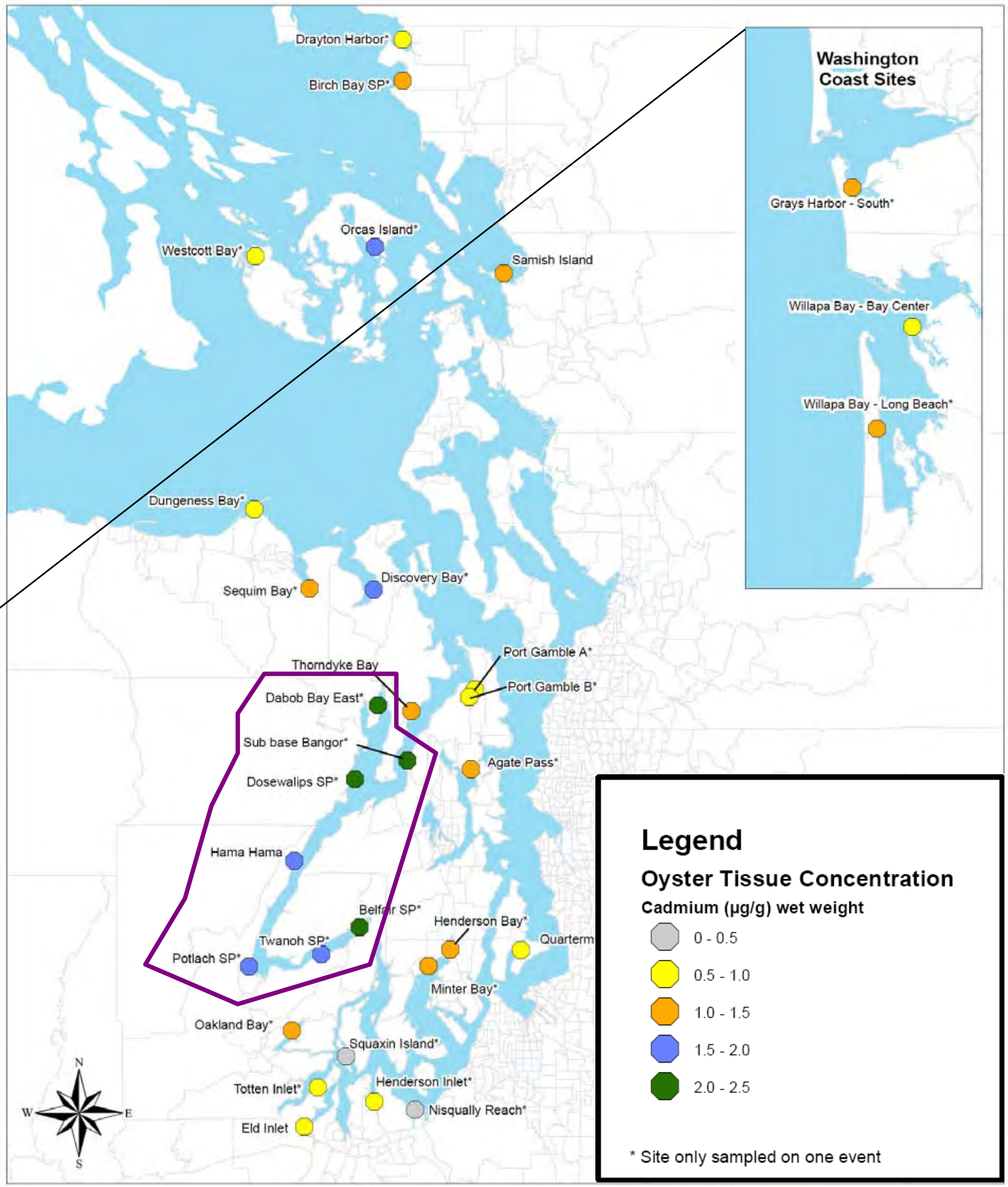
oyster composites (n = 9)

range: 0.75 to 2.04 ppm

mean: **1.33 ± 0.48 ppm**

(average from 2004 to 2006)





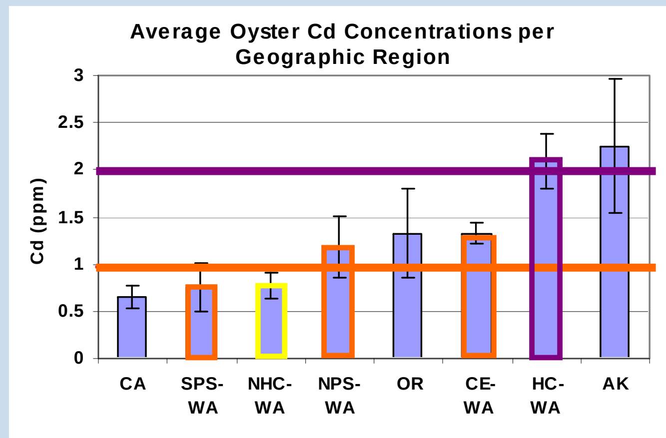

# Washington

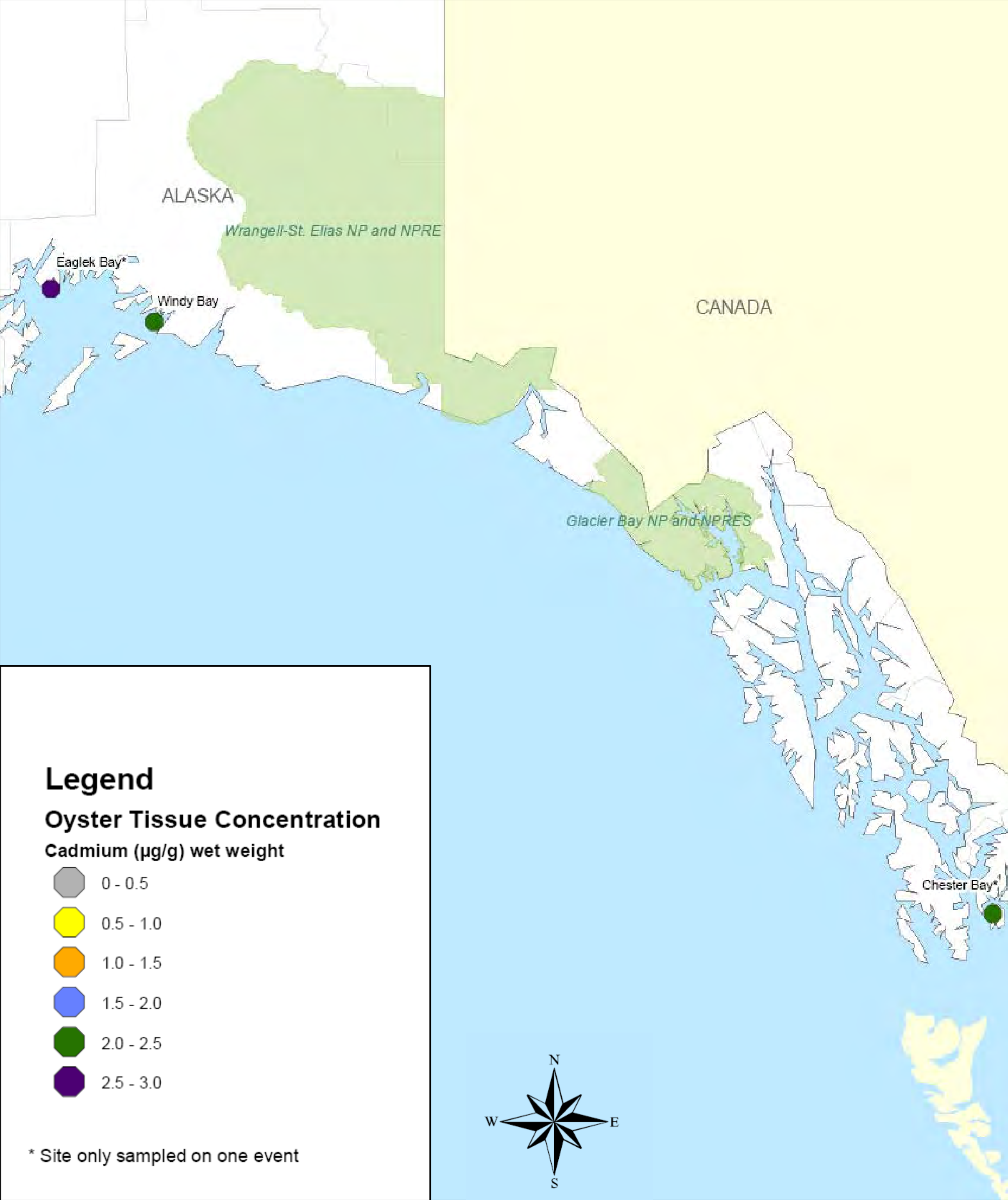
oyster composites (n = 92)

range: 0.44 to 2.5 ppm

mean: **1.24 ± 0.57 ppm**

(average from 2004 to 2006)





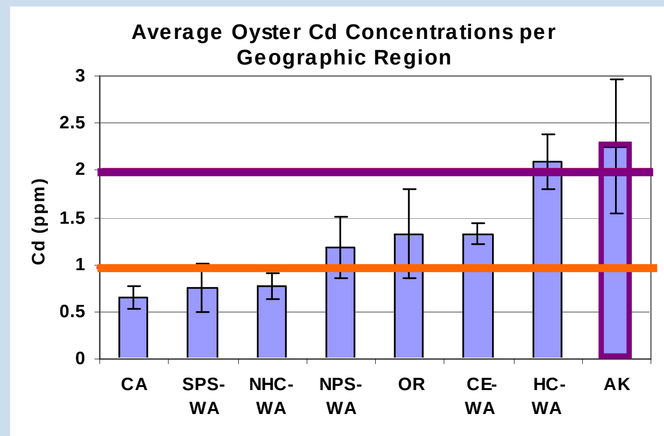

# Alaska

oyster composites (n = 9)

range: 1.64 to 3.98 ppm

mean: **2.25 ± 0.71 ppm**

(average from 2004 to 2006)

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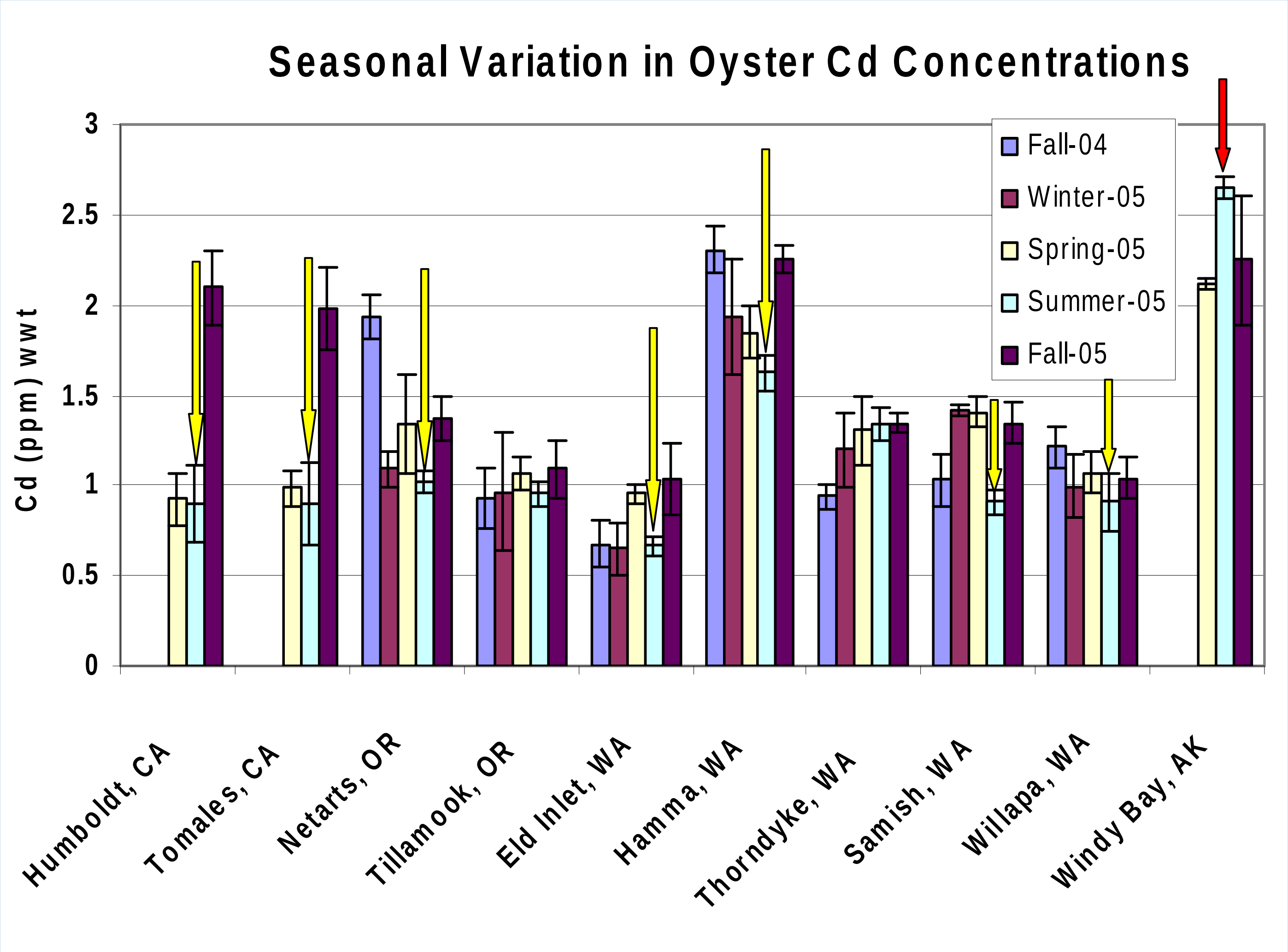
# Seasonal Variations in Cadmium




Data analysis by A. Christy, PSI

# Laboratory Experiments

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- Radiotracer $^{109}Cd$
  - Subcellular distribution
  - Dissolved uptake
  - Assimilation efficiency
  - Efflux rates
  - Biokinetic modeling

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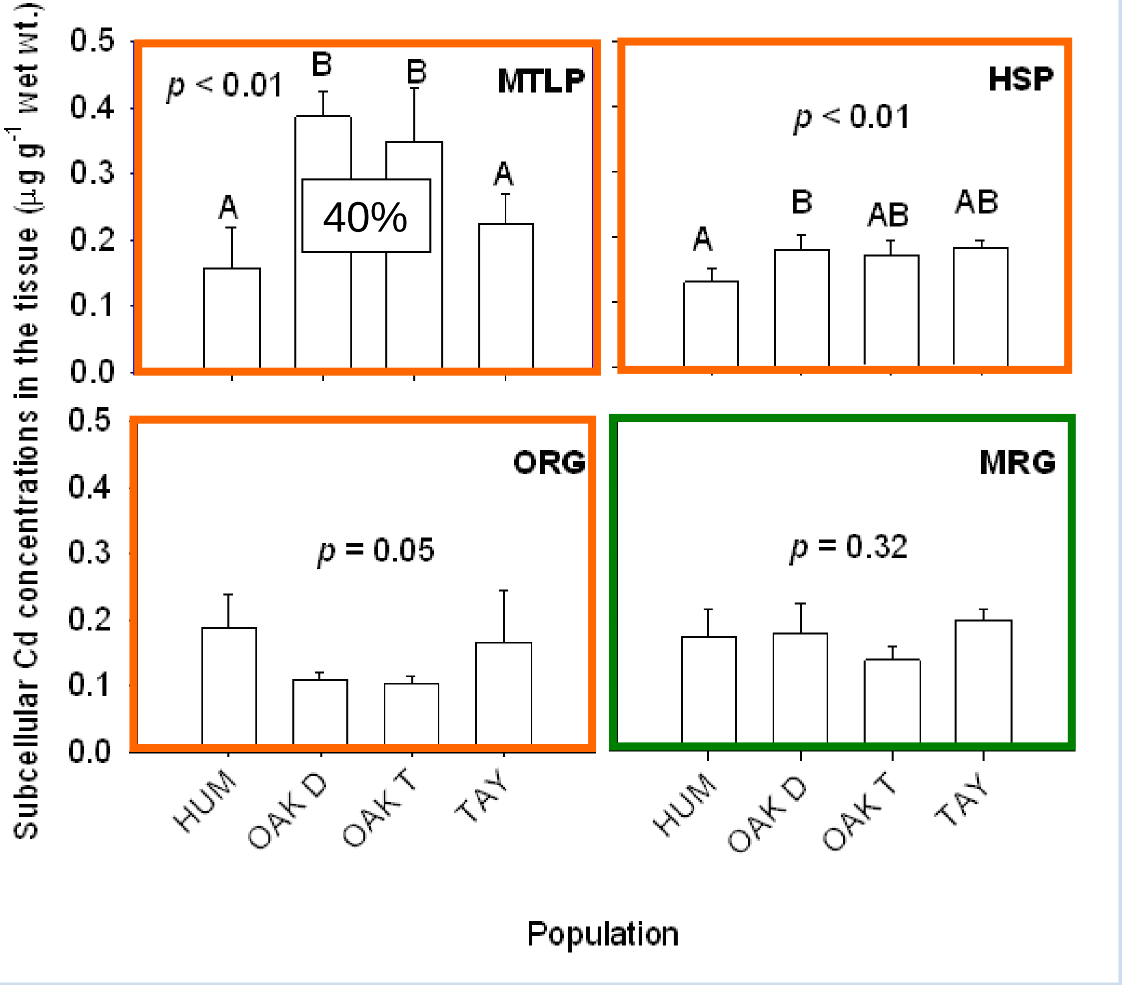
# Cadmium Subcellular Distribution

- Organelles (OR)
- Metallothioneins (MT)
- Heat-sensitive proteins (HSP)
- Metal-rich granules (MRG)
- Cellular debris (CD)

- Insights into oyster detox and trophic transfer

# Cadmium Subcellular Distribution



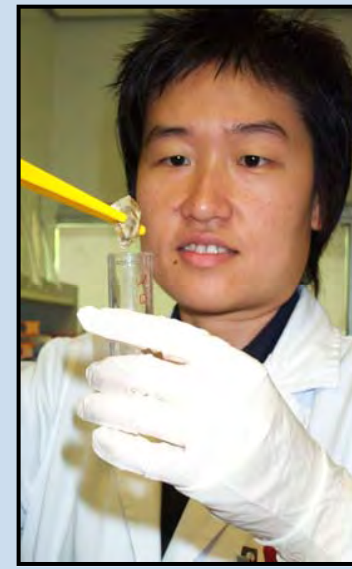

- **undetected in cell debris**
  - not shown
- **metal detoxification**
- **bioavailable (~78%)**
- **not bioavailable (~22%)**

HUM = Humboldt Bay, CA
OAK = Oakland Bay, WA
TAY = Thorndyke Bay, WA
D = diploid
T = triploid

MTLP = metallothionein-like protein; HSP = heat sensitive protein; ORG = organelles; MRG = metal rich granules

# Uptake and Efflux Kinetics

- – Water (dissolved)
- – Sediment
- – Phytoplankton
- – Different food concentrations



Chia-Ying Chuang

- Parameters used for uptake modeling

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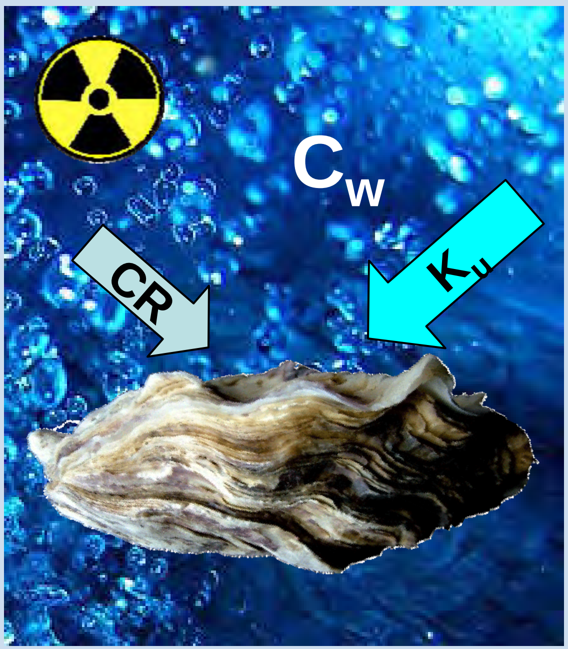
# Uptake and Efflux Kinetics (cont.)

## Uptake from dissolved phase

$K_u$ = uptake rate constant

$K_{ew}$ = efflux rate constant




**Dissolved Uptake**


**Depuration**

$C_W$ = Cd concentration in water,  CR = clearance rate

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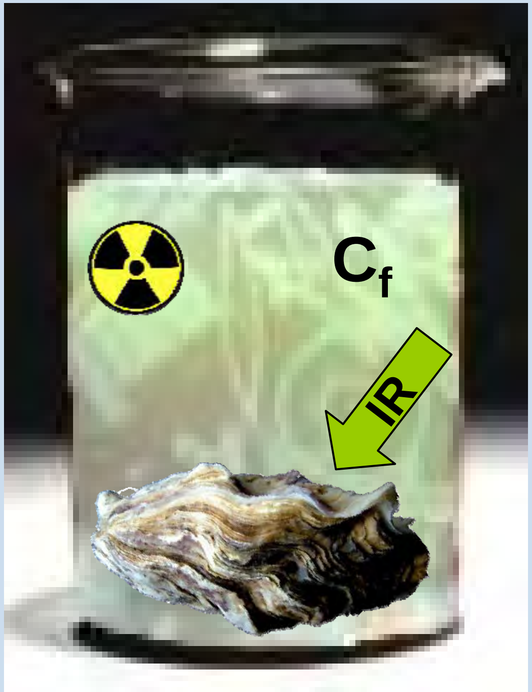
# Uptake and Efflux Kinetics (cont.)

## Uptake from food

AE = Assimilation Efficiency (%)




Diatom or sediment

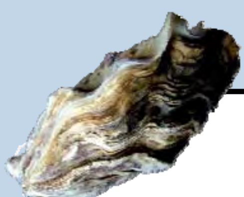

Depuration

$C_f$ = conc. in food ; IR = ingestion rate

$K_e$ = efflux rate

# Bioaccumulation Modeling

- Assuming oysters accumulate Cd from dissolved phase and food
- Cadmium concentration in oyster ($C_{ss}$) under steady-state conditions can be predicted:



$$C_{ss} = \frac{(K_u \times C_w)}{(K_{ew} + g)} + \frac{(IR \times AE \times C_f)}{(K_{ef} + g)}$$

**Water** (first term) **Food (diatom or sediment)** (second term)

**g = growth rate**

# Cadmium Concentration Predictions

| State | Site | Predicted Oyster Total Cd (ppm) | | Actual Oyster Total Cd | Predicted % agreement of mean | |
|---|---|---|---|---|---|---|
| | | sediment | diatom | (ppm dwt) | sediment | diatom |
| CA | HUM | 9 | 11 | 4 - 21 | 71 | 85 |
| OR | NET | 7 | 7 | 5 - 11 | 86 | 91 |
| WA | ELD | 3 | 4 | 3 - 6 | 73 | 87 |

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# Bioaccumulation Pathways

What's the main source of Cd?

Relative contribution from:

Water $Rw = (K_u) / (K_u + AE \times IR \times Kd)$

Food $Rf = 1 - Rw$

Kd = Cd partition coefficient (L/g) in sediment

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# Bioaccumulation Pathways (cont.)

| State | Site | Water ($R_w$) % | Food ($R_f$) % |
|---|---|---|---|
| WA | WBC | 73 | 27 |
| WA | SME | 90 | 10 |
| WA | SQB | 92 | 8 |
| WA | HAM | 91 | 9 |
| WA | ELD | 30 | 70 |
| CA | HUM | 4 | 96 |
| OR | NET | 88 | 12 |

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# Field trials of oyster-growing methods

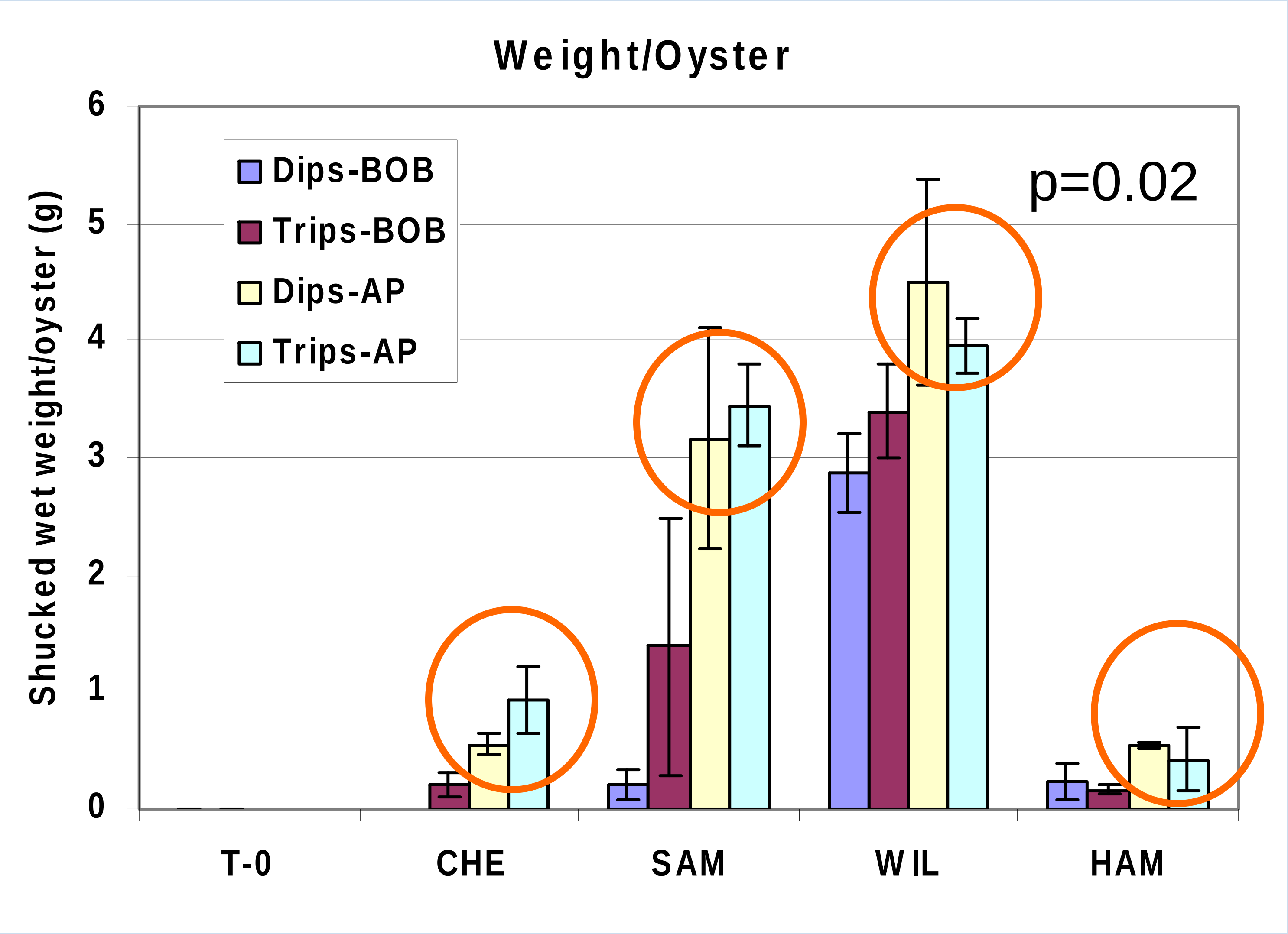
Seeds grown
- 117 days
- April to August

aqua-purses

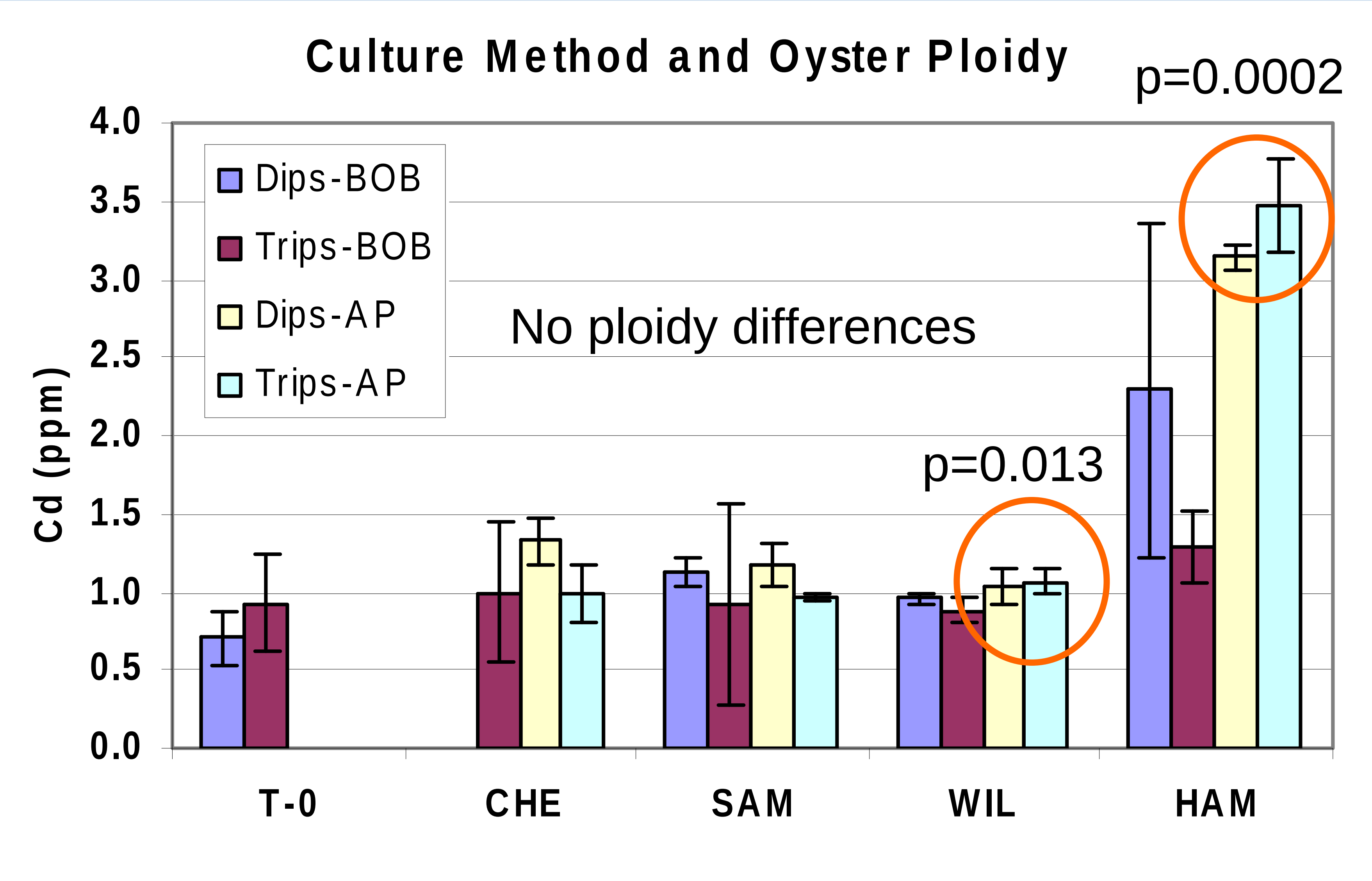
bag-on-bottom

**Experimental plot at Hamma Hamma, WA**

# Growing Methods - WA

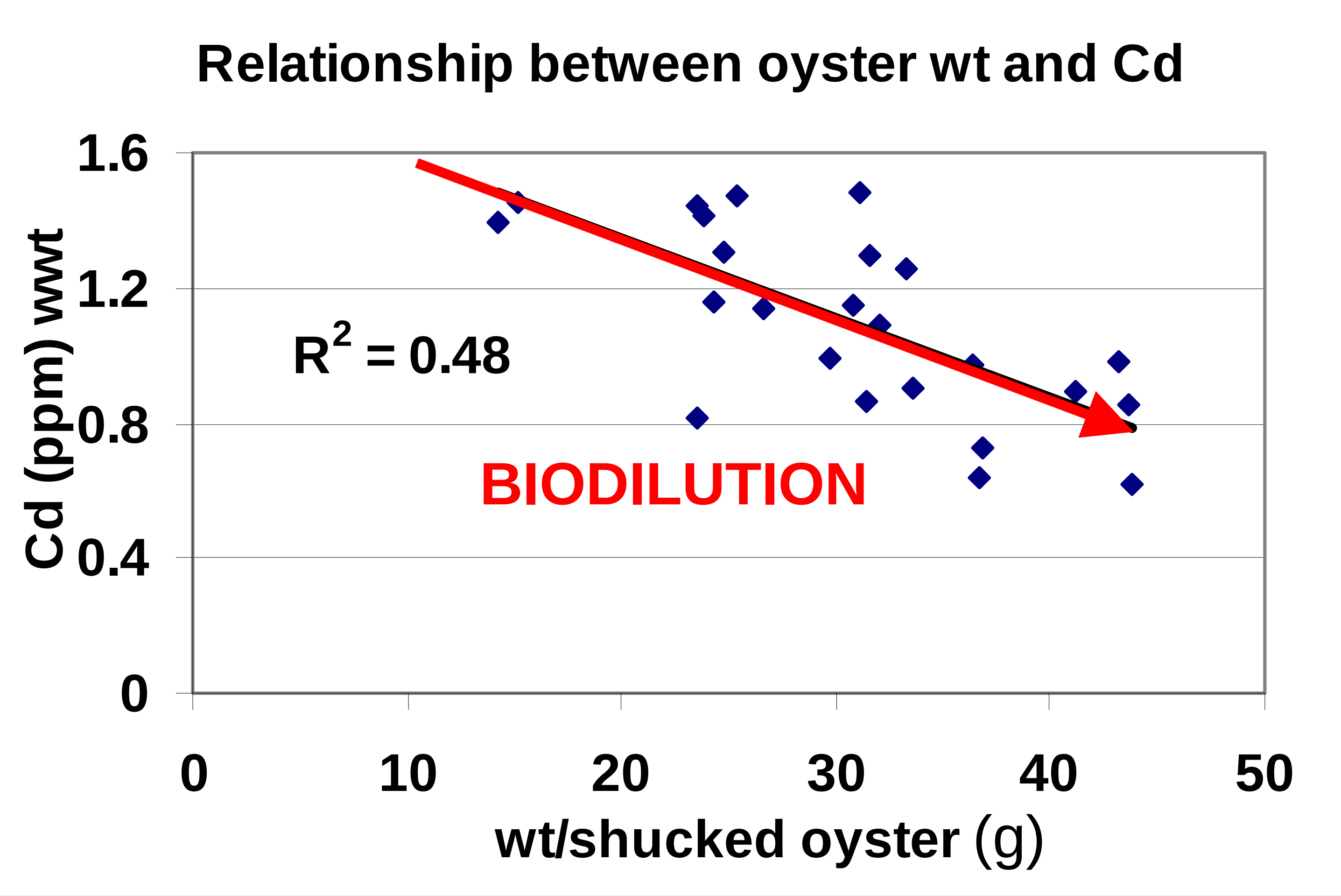


# Growing Methods (cont.)



# Does Growth Rate Influence Cd Uptake Rates?

## WA Sites with Fastest Growth Rates

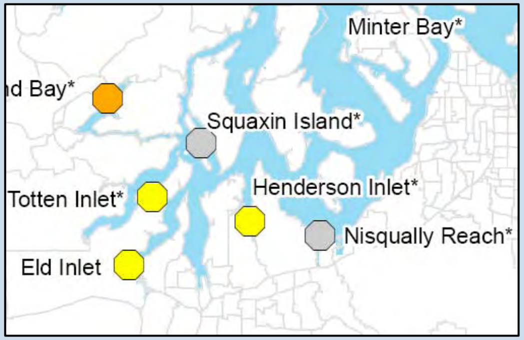


# Options to Minimize Cd in Oysters

- Harvest oysters in the summer and avoid fall

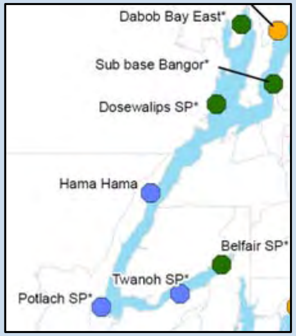
- Consider processing oysters
  - 18 to 27% decrease in Cd (OSU data)

- Grow / harvest at locations known to have oysters with lower Cd concentrations




South Puget Sound

vs.




Hood Canal

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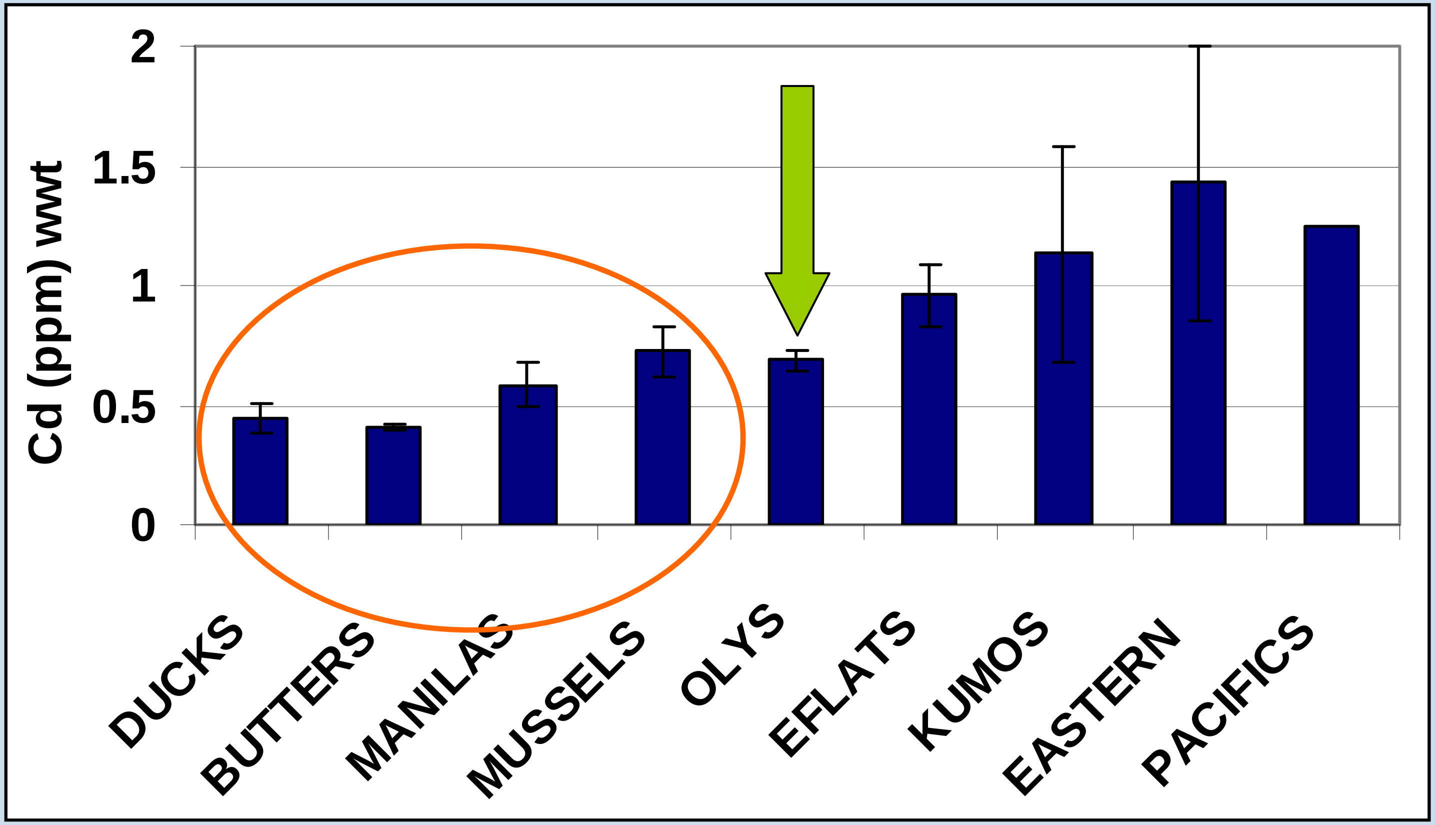
# Options to Minimize Cd in oysters (cont.)

Consider growing / harvesting Olympia oysters or a different shellfish species altogether



# Conclusions

- Regional and seasonal differences in oyster Cd concentrations were detected
- Subcellular Cd measurements indicate large portion is trophically bioavailable
- In general, the main source of Cd is from the dissolved phase (based on lab results)

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# Conclusions (cont.)

- Factors were identified that have a significant impact on Cd concentrations:
  - Growth rates
  - Growth methods
  - Seasonality
- Activities to reduce Cd residues in final products may include
  - Harvesting in the summer
  - Processing

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# Unanswered Questions

- What are the roles of salinity and temperature in Cd uptake?

- What are other sources of Cd in Hood Canal?
  - Riverine input
  - Upwelling
  - Residential runoff

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# Questions?

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