# REGIONAL BIOLOGICAL RECEPTOR AND SEDIMENT RELATIONSHIPS

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#### **Simple Fish/Sediment Bioaccumulation Linkage** Often Assumed in Sediment Cleanup Remedies for Bioaccumulatives



## **Additional Complexities in Fish/Sediment Linkage**

- Variations in external inputs
  - Point sources (industrial and municipal)
  - Non-point sources (stormwater)
- Dredging releases
  - Navigation and remediation projects
- Recirculation in the food web
  - Biota can be significant pool of bioaccum. mass
- Robust, long-term monitoring data needed to tease out exposure linkages affected by sediment cleanup



## Puget Sound Ecosystem Monitoring Program (PSEMP)

- English sole sentinel species
  - Representative of benthic sediment-to-biota linkage
  - Megasite-scale fidelity; 500 to 2,000-acre home range
- Monitoring program
  - 1997 to 2018 monitoring of 10 representative stations
  - Statistically robust sampling plan (e.g., composites prepared from 60+ similar 5- to 6-year-old specimens)
  - Bioaccumulative COCs (skin-off muscle fillets)
    - Comparable analytical methods over time
  - Liver lesion prevalence



## **Overlap of PSEMP with Five Sediment Cleanup Sites**

Site	Cleanup Implementation
Seattle Waterfront/	1992
Elliott Bay	Capping
Bainbridge Island/	1994 to 2001
Eagle Harbor	Capping
Duwamish River/	1999 to 2015
Waterway	Dredging & Capping/Cover
Bremerton/	2000 to 2001
Sinclair Inlet	Dredging & Capping/Cover
Tacoma City Waterway/	2002 to 2006
Commencement Bay	Dredging & Capping/Cover



• All five cleanup sites have robust sediment and fish tissue datasets

## **Eagle Harbor Sediment and Tissue Monitoring**

- Primary COCs are HPAHs
- Surface sediment (0 to 10 cm) HPAH concentrations (USEPA)
- Robust English sole liver lesion monitoring (PSEMP)
  - NMFS linked liver lesions (cancer) and reproductive impacts to sediment PAH exposure in lab studies
  - Eagle Harbor previously exhibited the highest liver lesion prevalence on the West Coast
  - 1984 to 2010 monitoring data



**English Sole** 

Liver Lesion

## **Eagle Harbor English Sole Liver Lesion Monitoring**

#### **PSEMP Trawls Across 1994 Cap Area**



#### **Natural Recovery/Capping Trends**

Data source: Myers et al. 2008; WDFW 2010

Sediment Remedy Effectiveness Retrospective Workshop

PSEMP English Sole Trawls

## Hockey Stick Relationship Between Sediment HPAH Concentration and Liver Lesion Prevalence

- 1994 capping (54 ac) achieved a fivefold reduction of Eagle Harbor sediment HPAH SWAC
- Corresponding liver lesion recovery to near reference conditions after 5-year recovery period (fish age)
- Hockey stick relationship consistent with NMFS laboratory studies and regional data; cancer mode



## **PSEMP Time Trends of English Sole Bioaccumulative COCs**

Time Trends of Persistent Organic Pollutants in Benthic and Pelagic Indicator Fishes from Puget Sound, Washington, USA

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- 1. Washington Dept. of Fish & Wildlife (WDFW)
- 2. National Marine Fisheries Service (NMFS)

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## **Increased Seattle Waterfront/Elliott Bay PCB Trends**

- 1992 Pier 53 cap (5 ac)
- PSEMP trawls northwest of cap area

Time Period	Surface Sediment PCB SWAC (500 ac) µg/kg dry wt	English Sole Skin-Off Fillet PCB µg/kg wet wt
1997 to 2007	65 ± 16	59 ± 8
2008 to 2018	155 ± 13	106 ± 17

• Sediment and/or English sole tissue levels influenced by stormwater loading?





### **Decreased Duwamish River/Waterway PCB Trends**

- Multiple early actions (partial list)
  - 2003 to 2005: Duwam./Diag. dredge cap/cover (6.7 ac)
  - 2011 to 2012: Slip 4 dredge & cap (3.8 ac)
  - 2013 to 2015: Boeing Plant 2 dredge & backfill (17.5 ac)
- PSEMP and PRP/USEPA trawls in different areas

Time Period	Surface Sediment PCB SWAC (500 ac) µg/kg dry wt	English Sole Skin-Off Fillet PCB µg/kg wet wt
2007	346 ± 69	361 ± 72
2017	172 ± 24	259 ± 39



## **Commencement Bay Sediment Cleanup Remedies**



### **PSEMP English Sole PCB Tissue Monitoring Trends** Mouth of Thea Foss Waterway

- PSEMP sentinel trawls at not directly aligned with cleanup areas
- Early natural recovery
- Spikes in tissue levels
- 2019 Commencement Bay-wide tissue monitoring data pending (USEPA/PSEMP)



Data source: TetraTech 1985; WDFW 2018

## Mixed Mouth of Thea Foss Waterway PCB Trends

- Final cleanup actions reduced PCB SWAC
  - Thea Foss Waterway: 2002 to 2006 dredge and cap/cover (81 ac)
  - Middle Waterway: 2003 to 2004 dredge and cap/cover (10 ac)

Time Period	Surface Sediment PCB SWAC (500 ac) µg/kg dry wt	English Sole Skin-Off Fillet PCB µg/kg wet wt
1995 to 2002	40 ± 9	52 ± 13
2008 to 2018	15 ± 3	103 ± 3



Surface Sediment Total PCB (µg/kg dry wt.)



#### **Bremerton/Sinclair Inlet Sediment Remedies** Marine Operable Unit B Cleanup and Navigation Dredging



### **PSEMP English Sole PCB Tissue Monitoring Trends** Bremerton/Sinclair Inlet

- PSEMP sentinel trawls aligned adjacent to cleanup and navigation dredging areas
- Spikes in tissue PCB levels



## **Mixed Bremerton/Sinclair Inlet PCB Trends**

- Sediment cleanup and navigation dredging actions reduced PCB SWAC
  - 2000 to 2001 dredge and cap/cover (45 ac)

Time Period	Surface Sediment PCB SWAC (500 ac) µg/kg dry wt	English Sole Skin-off Fillet PCB µg/kg wet wt
1995 to 2000	98 ± 23	87 ± 16
2008 to 2018	43 ± 17	77 ± 14

1995 to 2000 2008 to 2018

**PSEMP English Sole Trawls** 



Surface Sediment Total PCB (µg/kg dry wt.)

## Relationship Between Sediment and Bottom Fish Tissue PCB Levels in Puget Sound Urban Areas?

- Sediment PCB SWAC "hot spots" (>500 µg/kg dry wt) no longer present in region
- Diminishing returns with lower sediment PCB SWAC levels (<100 µg/kg dry wt)?
- Additional tissue and surface water monitoring data and focused research would help



Surface Sediment Total PCB SWAC (µg/kg dry; mean ± std. err.)

#### **Ongoing Sources Complicate Fish/Sediment Linkage** Particularly at lower sediment bioaccumulative concentrations



#### San Francisco Bay PCB Exposure Control Strategy Primary focus on reducing non-point stormwater sources in watershed (\$\$\$)

Source Category	PCB Loading (kg/yr)
Stormwater runoff	20
Central Valley drainage	11
Municipal dischargers	2.3
Industrial discharges	0.035
Navigation dredging	Net Loss
Sediments	Net Sink

Source: California Regional Water Quality Control Board 2008, 2012

Central Valley Wastewater Dredging Hot Spots

California Regional Water Quality Control Board San Francisco Bay Region Municipal Regional Stormwater NPDES Permit

> Order No. R2-2015-0049 NPDES Permit No. CAS612008 November 19, 2015



## **Key Take-Home Messages**

- Remediation can reduce surface sediment levels
- However, simple (e.g., proportional) fish/sediment bioaccumulation linkages oversimplify the real world
  - Diminishing effectiveness at lower sediment cleanup levels?
- Sediment is a watershed issue
  - Need for coordination of cleanup and water quality programs
- Current state of the sediment cleanup practice
  - Tendency to overestimate what we know about sediment sites and underestimate conditions that can affect remedy effectiveness

