Spawning salmon deliver marine-derived contaminants to southeast Alaskan streams

Sonia Nagorski, University of Alaska Southeast

AWRA Conference, September 17, 2019

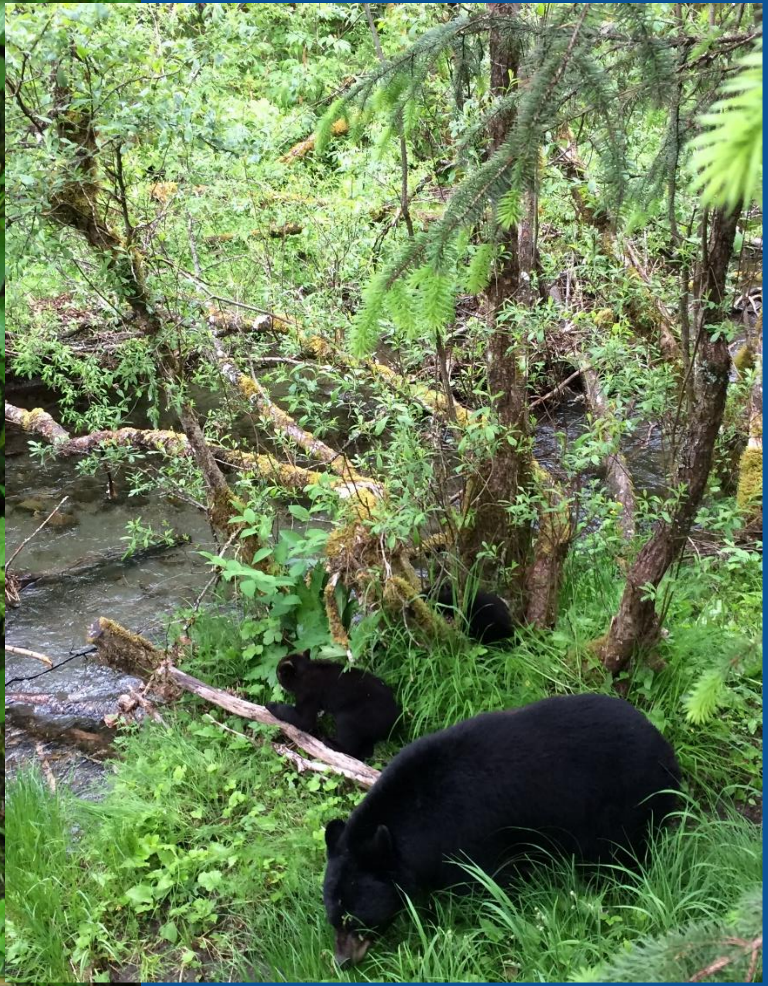
Collaborators

- John Hudson, Independent Aquatic Ecologist, Juneau, AK.
- Eran Hood and Jason Fellman, University of Alaska Southeast
- John DeWild, David Krabbenhoft, and staff at USGS Mercury Research Lab, Middleton, WI
- Gina Ylitalo at Northwest Fisheries Science Center, Seattle, WA
- Undergraduate research assistants: Chris Salazar, Alex Whitehead, and Alex Botelho (UAS)

Salmon in the trees

Increase

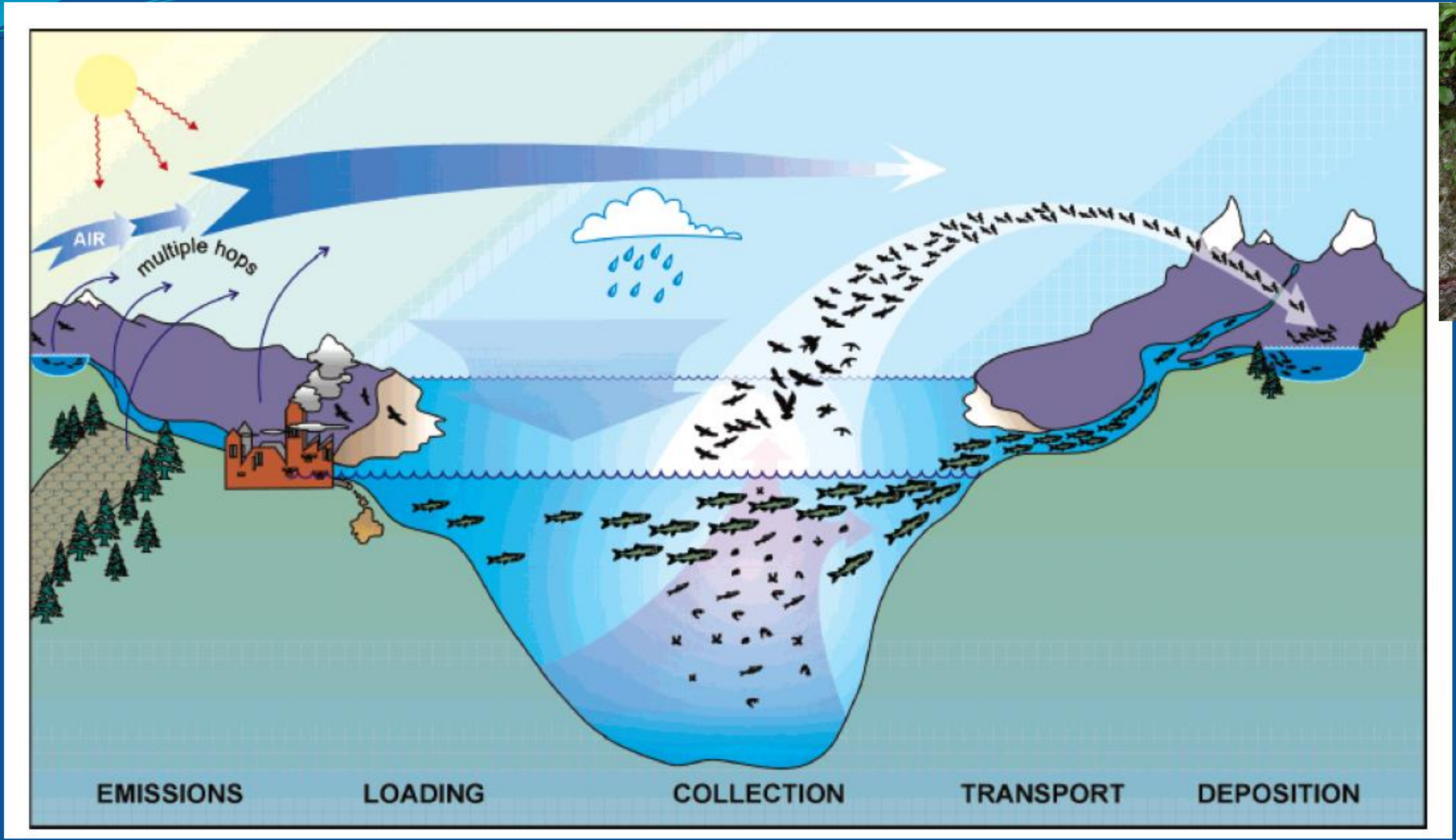
- **streamwater nutrient concentrations and biofilm abundance** (Mitchell and Lamberti 2005; Chaloner et al. 2004, 2007; Tiegs et al. 2011; Hood et al 2019)
- **Benthic macroinvertebrate abundance** (Minikawa 1997, Wipfli et al. 1998, Lessard and Merritt 2006)
- **fish growth and fat content** (Wipfli et al. 2003, Heinz et al. 2004)



- >4000 salmon-supporting streams in southeast AK
- $1 billion annual industry


Salmon growth
--Accumulate pollutants
--Hg projected to double by 2050
North Pacific
East
Pacific
South Pacific
2,000 nM
Google

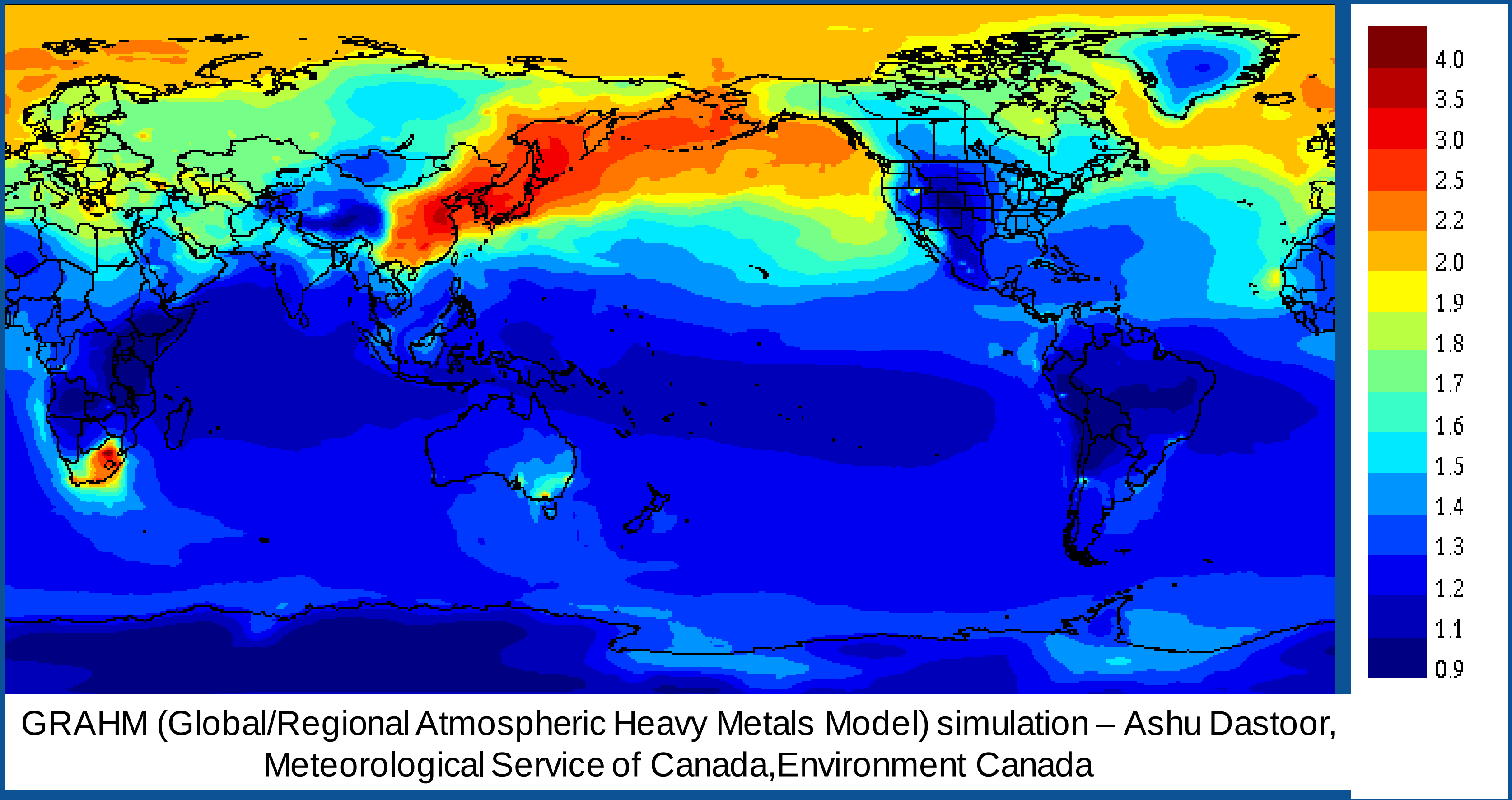
Biovectors: Migrating animals may transport and focus pollutants



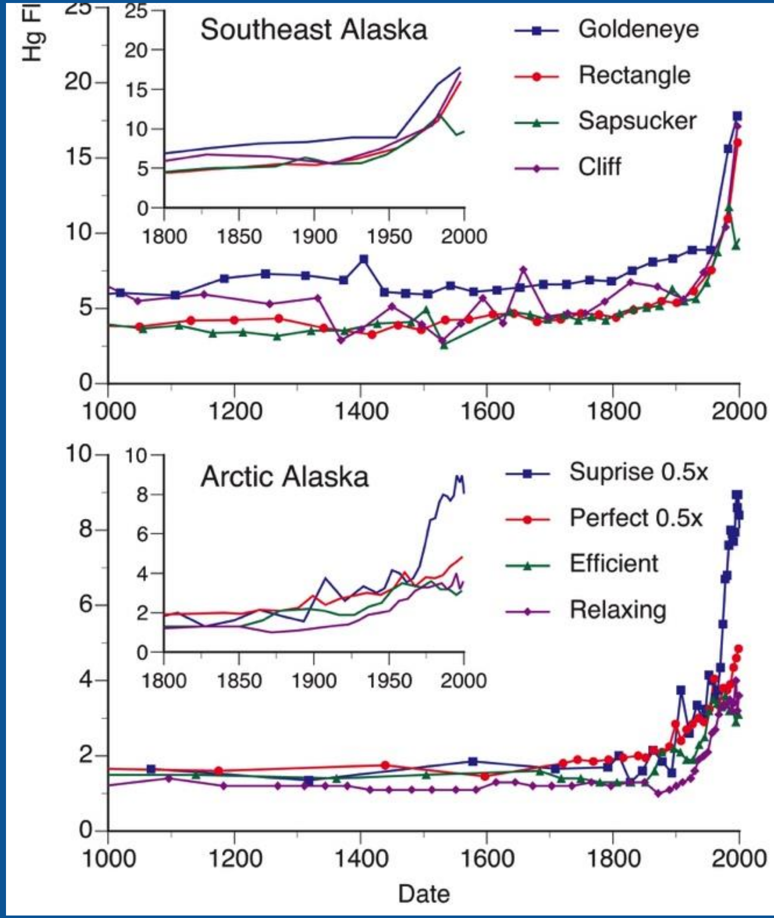
From Blais et al. *Environ. Sci. Technol.* 2007

Long-range atmospheric deposition of contaminants

Average elemental mercury surface concentrations for July 2001 (ng/m3)

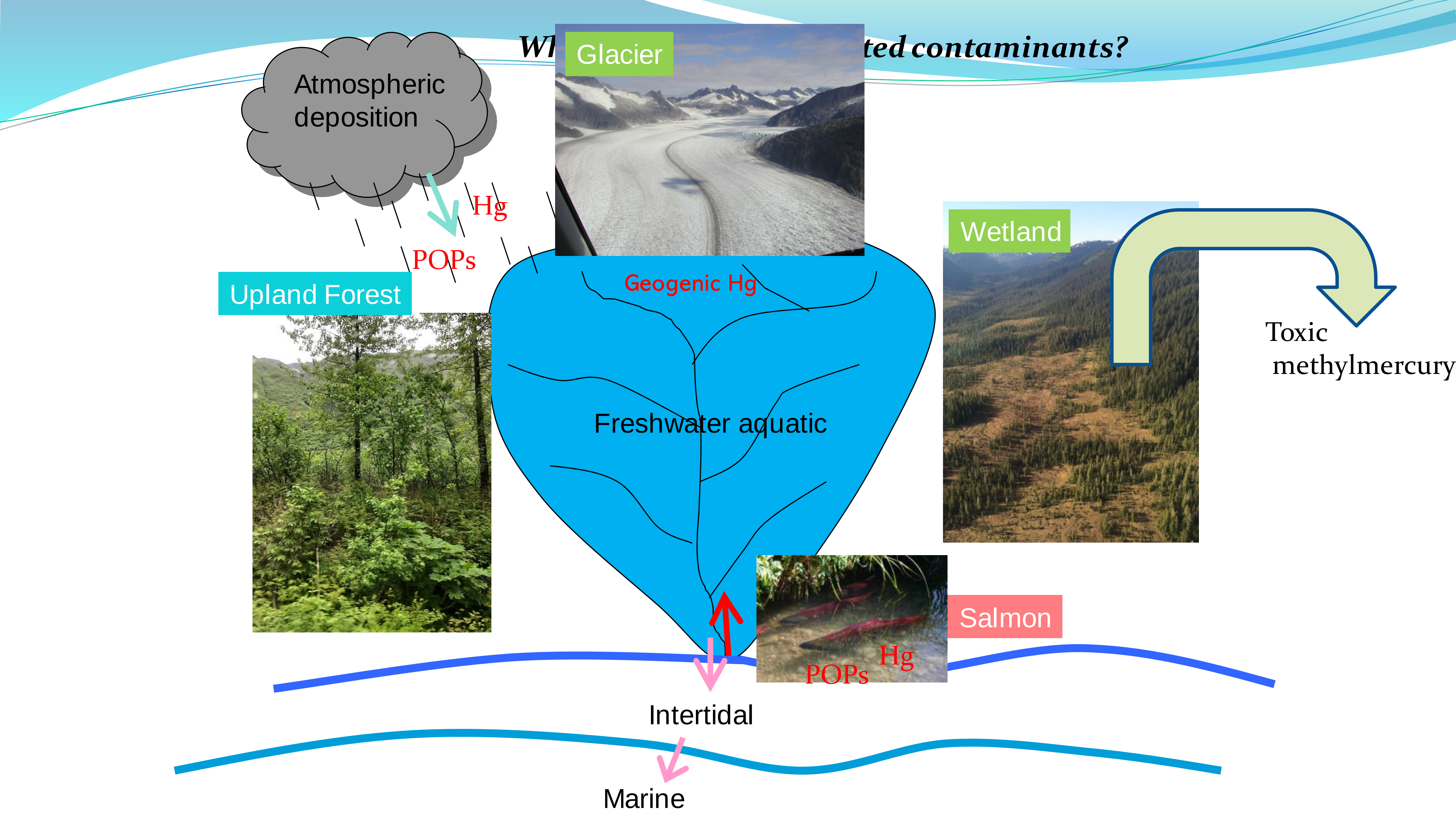


GRAHM (Global/Regional Atmospheric Heavy Metals Model) simulation – Ashu Dastoor, Meteorological Service of Canada, Environment Canada



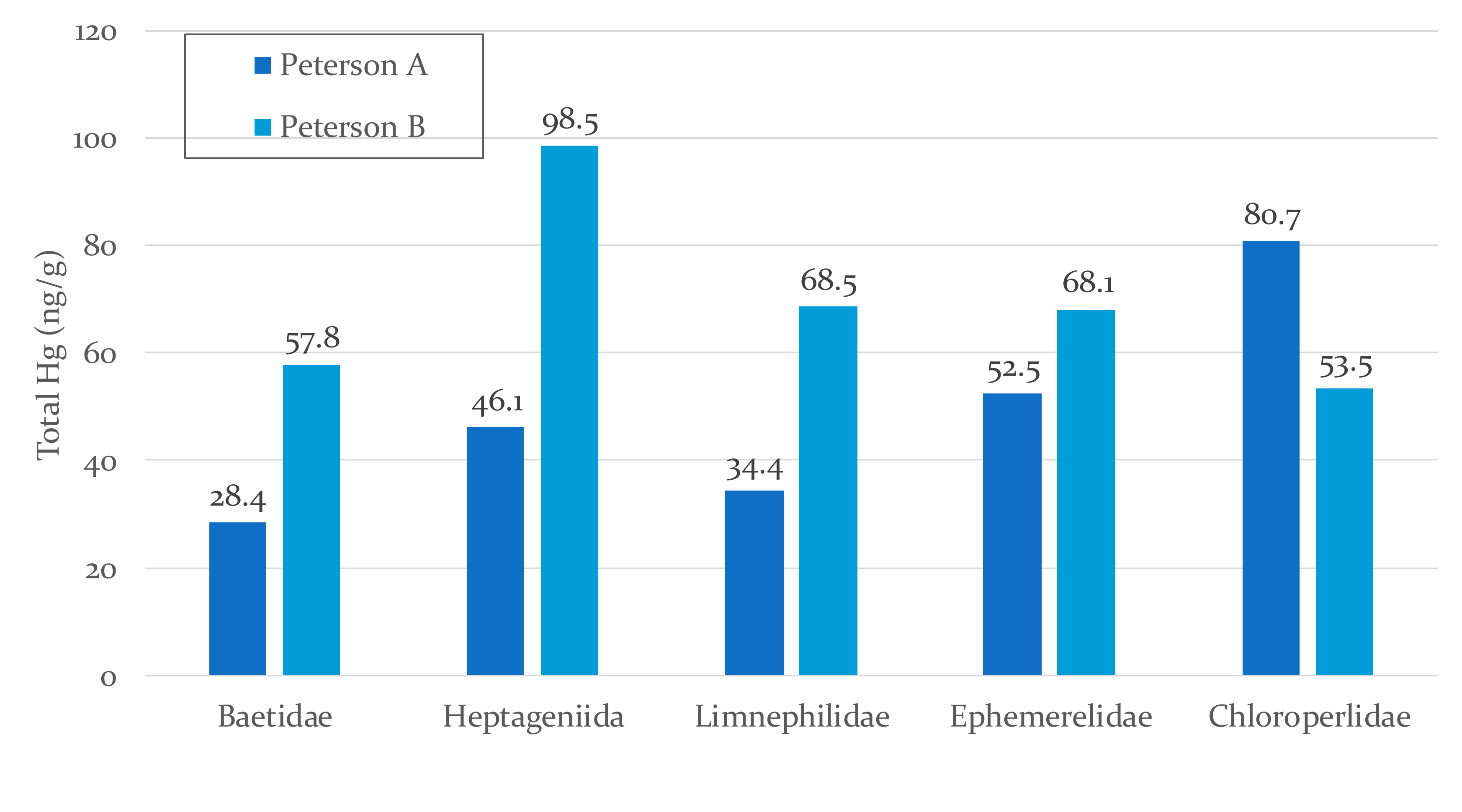
Engstrom et al. ES&T, 2014

- Chichagof Island lake sediment cores show 2.9±0.5-fold increase since industrialization



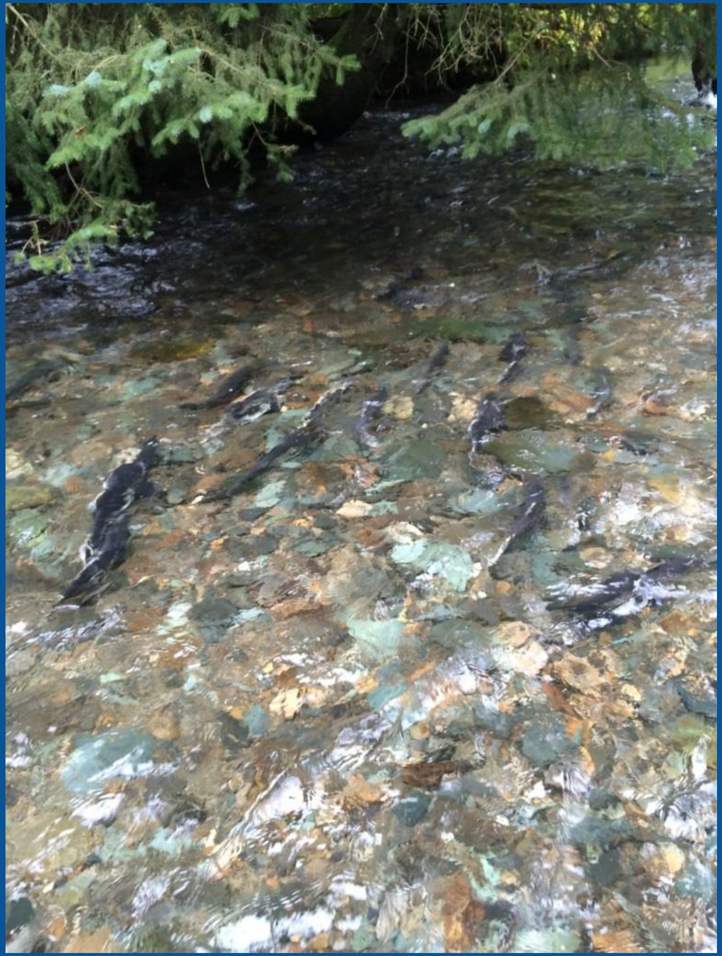
Wh
ted contaminants?
Atmospheric deposition
Hg
POPs
Glacier
Upland Forest
Geogenic Hg
Freshwater aquatic
Wetland
Toxic methylmercury
Salmon
Hg
POPs
Intertidal
Marine

Benthic macroinvetebrates above and below waterfall barrier at Peterson Creek



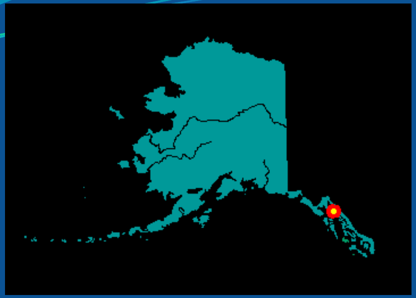
Purpose of this study

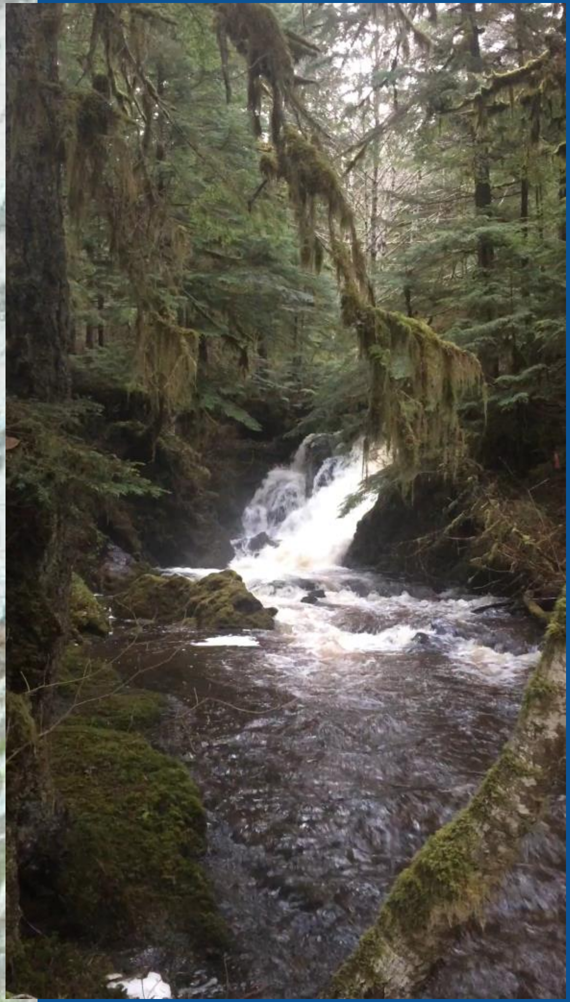
- To investigate the relationship between salmon spawner density and contaminant levels in streams



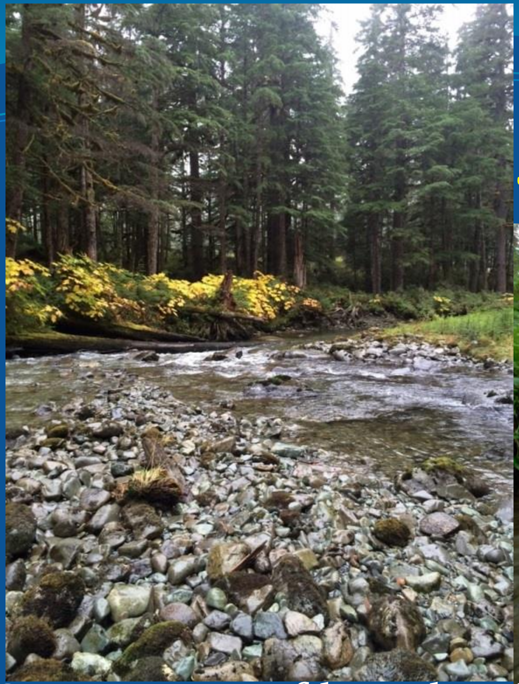
- To assess concentrations of marine-derived pollutants in various aquatic components (water, sediment, biofilm, macroinvertebrates, juvenile fish)
- Measure upstream (salmon absent) vs. downstream (salmon present)
- Compare across streams with varying spawner density

Study sites: 5 Juneau- area watersheds





Sampling for mercury and POPs



Hg

Stream water: filtered and particulate fractions

Streambed sediment

Biofilm on incubated leaves

Hg + POPs

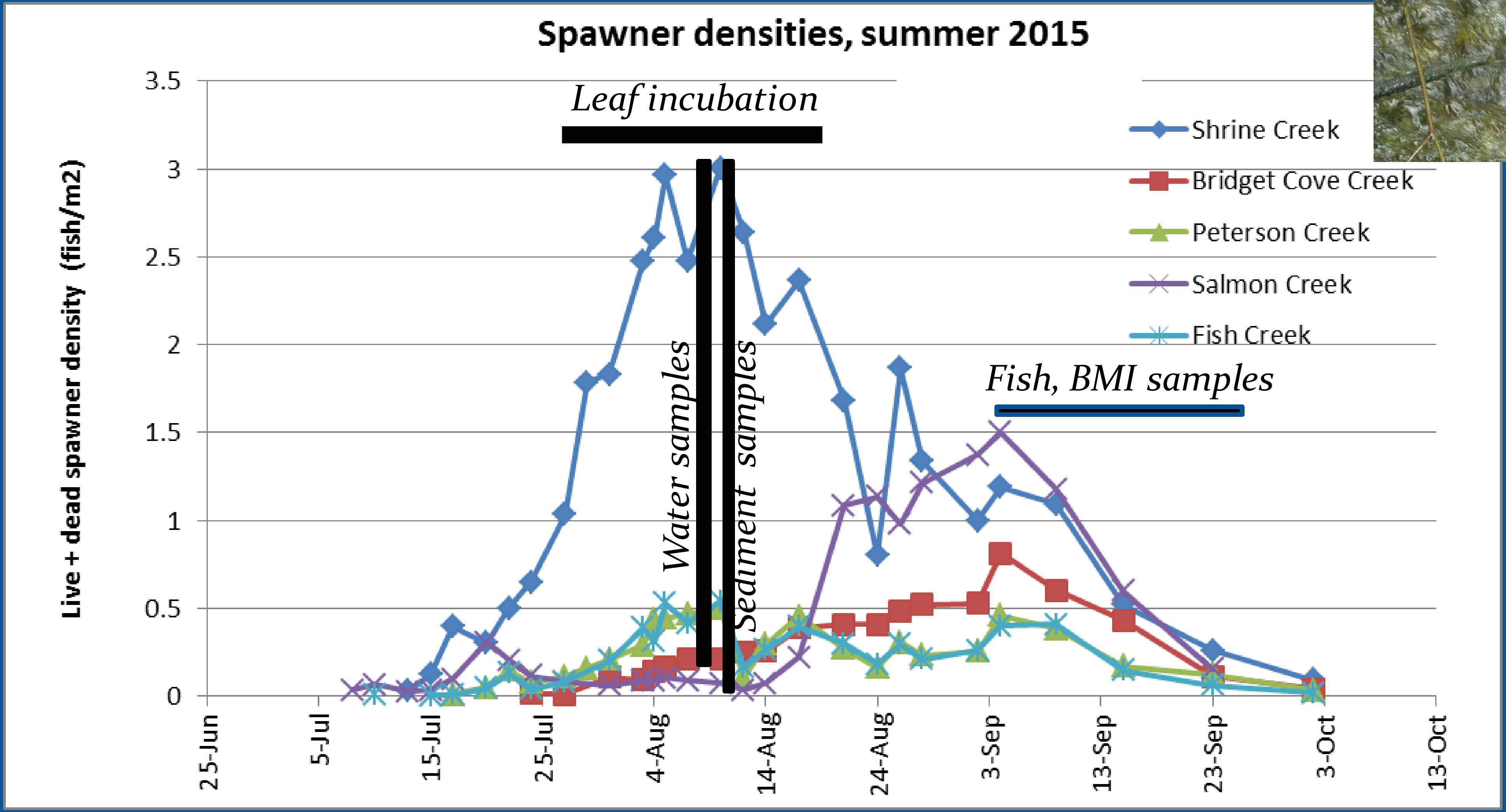
Benthic macroinvertebrates

Juvenile/resident fish

+ Fish density counts 1-3x/ week

Results

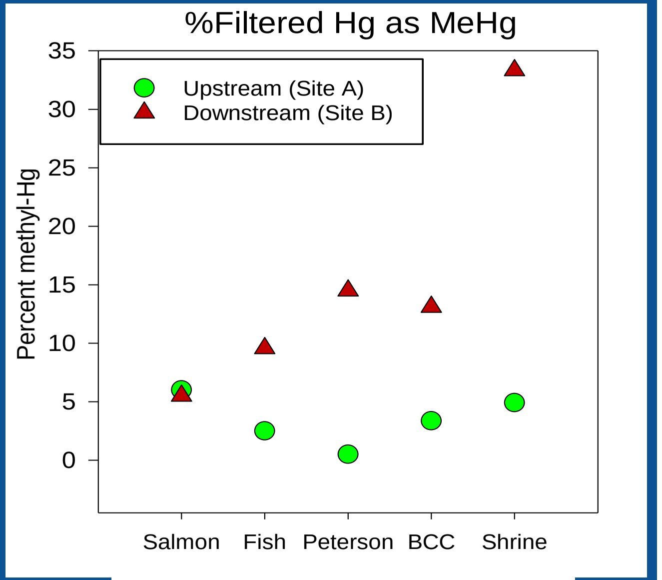
- 1. Salmon spawner densities varied among streams



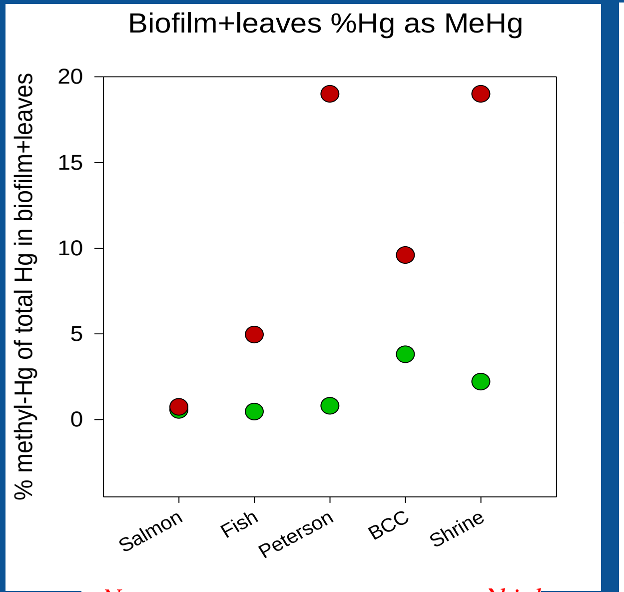
Results

2. Contaminant concentrations were higher in the lower reaches where salmon spawners were present (one-way paired t-test, *p*<0.05) for:

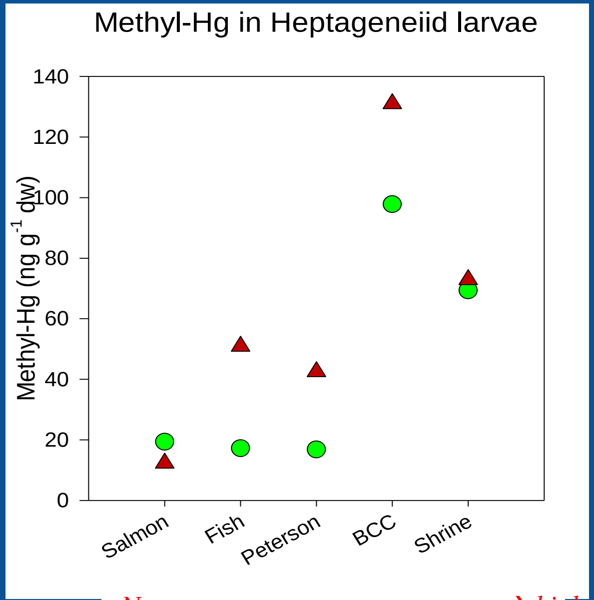
- %methyl-Hg in filtered water and in biofilm
- methylmercury in Heptageniidae mayfly larvae
- Methylmercury in streambed sediments



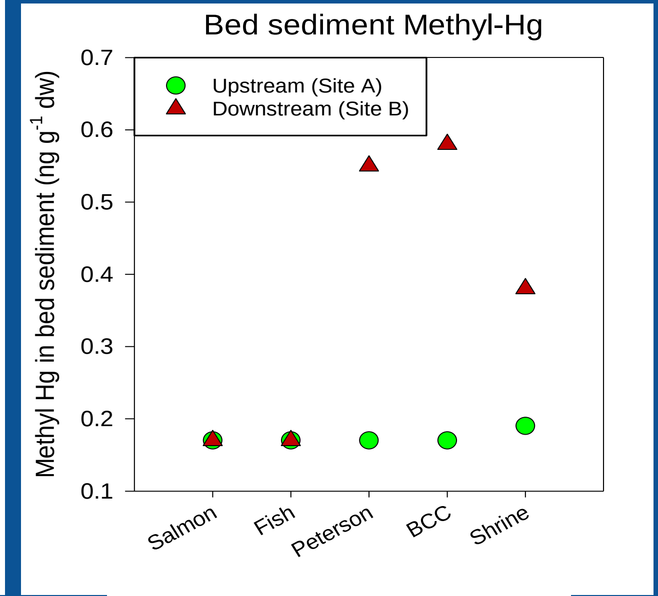
No spawners---------------------------→highest spawner density



No spawners-------------------------→highest spawner density



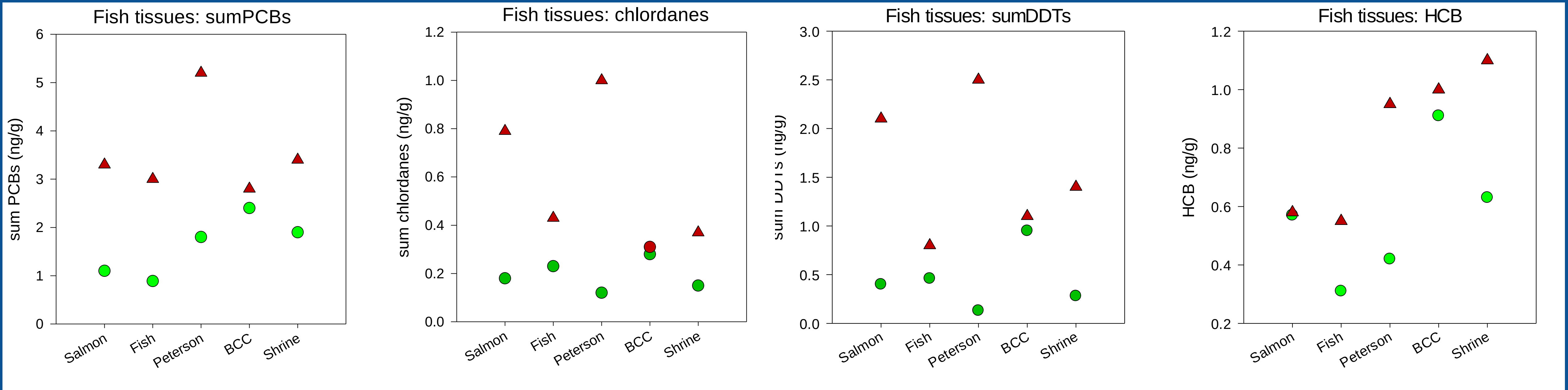
No spawners--------------------------→-highest spawner density



No spawners--------------------------→-highest spawner density

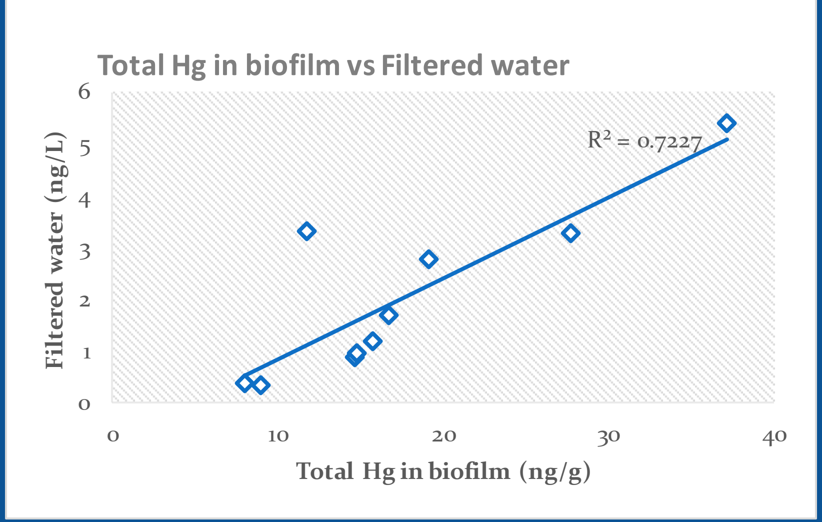
2. Contaminant concentrations were higher in the lower reaches where salmon spawners were present (one-way paired t-test, $p<0.05$) for:

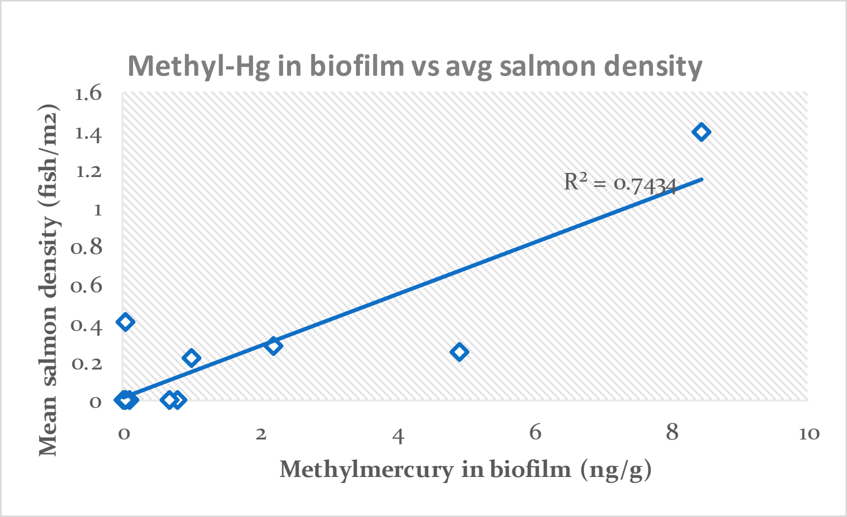
- ΣHCBs, ΣDDTS, Σchlordanes, and ΣPCBs in fish tissues



- Several other POPs (dieldrin, oxychlordane, and ΣBDEs), where present, were higher at the lower sites.
- The POPs data indicate a stronger marine-derived influence than the Hg, which has geogenic sources as well.

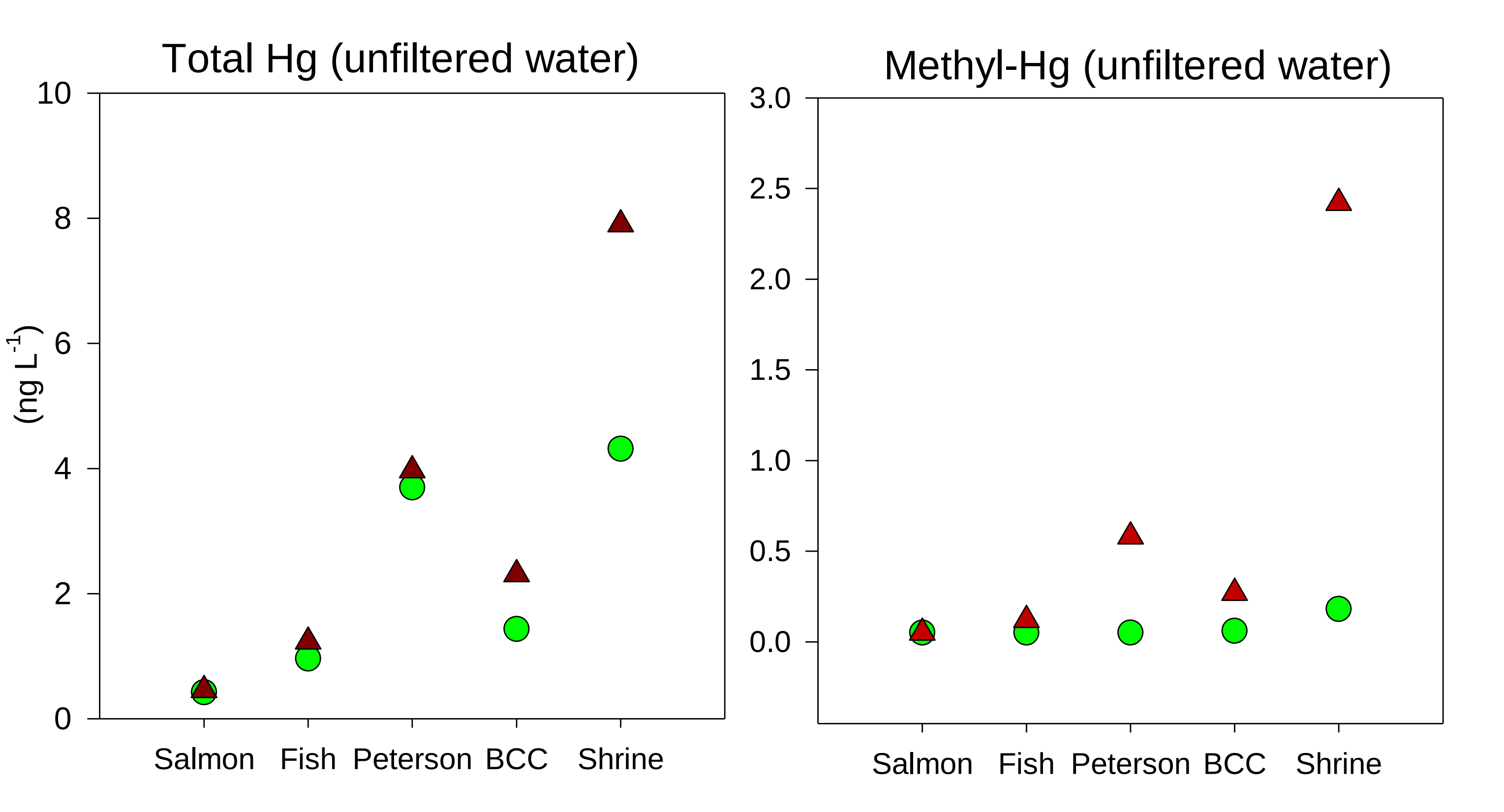
- 3. Total and methyl-Hg in biofilm (via incubated leaf packs) were strongly correlated with
  - aqueous total Hg
  - aqueous methyl-Hg
  - spawner density,
    - indicating their potential usefulness as a passive integrator of MeHg and monitoring/assessment tool.





Alder leaf packs, incubated for biofilm growth, resulted in particularly consistent spatial patterns

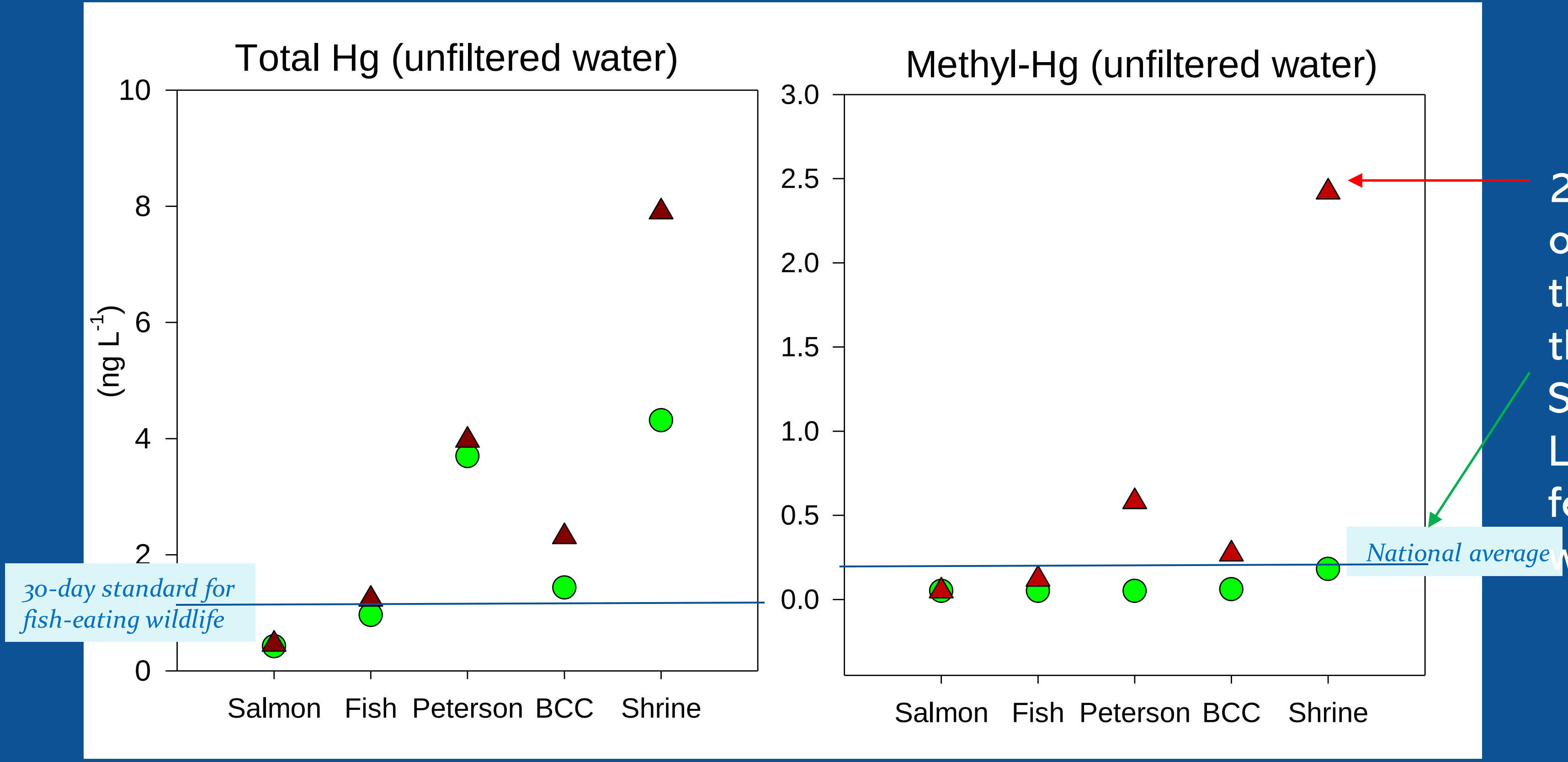
- 4. Other analytes followed this trend but did not pass statistical tests (likely due to small sample size (n=5)of individual streams.
  - For example, unfiltered total and methyl-Hg were consistently higher (up to 20x) in the lower reaches except for in Salmon Creek (no salmon present)



In the two streams with the highest spawner densities, filtered MeHg was 10 to 11-fold higher in the lower stream reach and made up 5-33% of the total Hg.

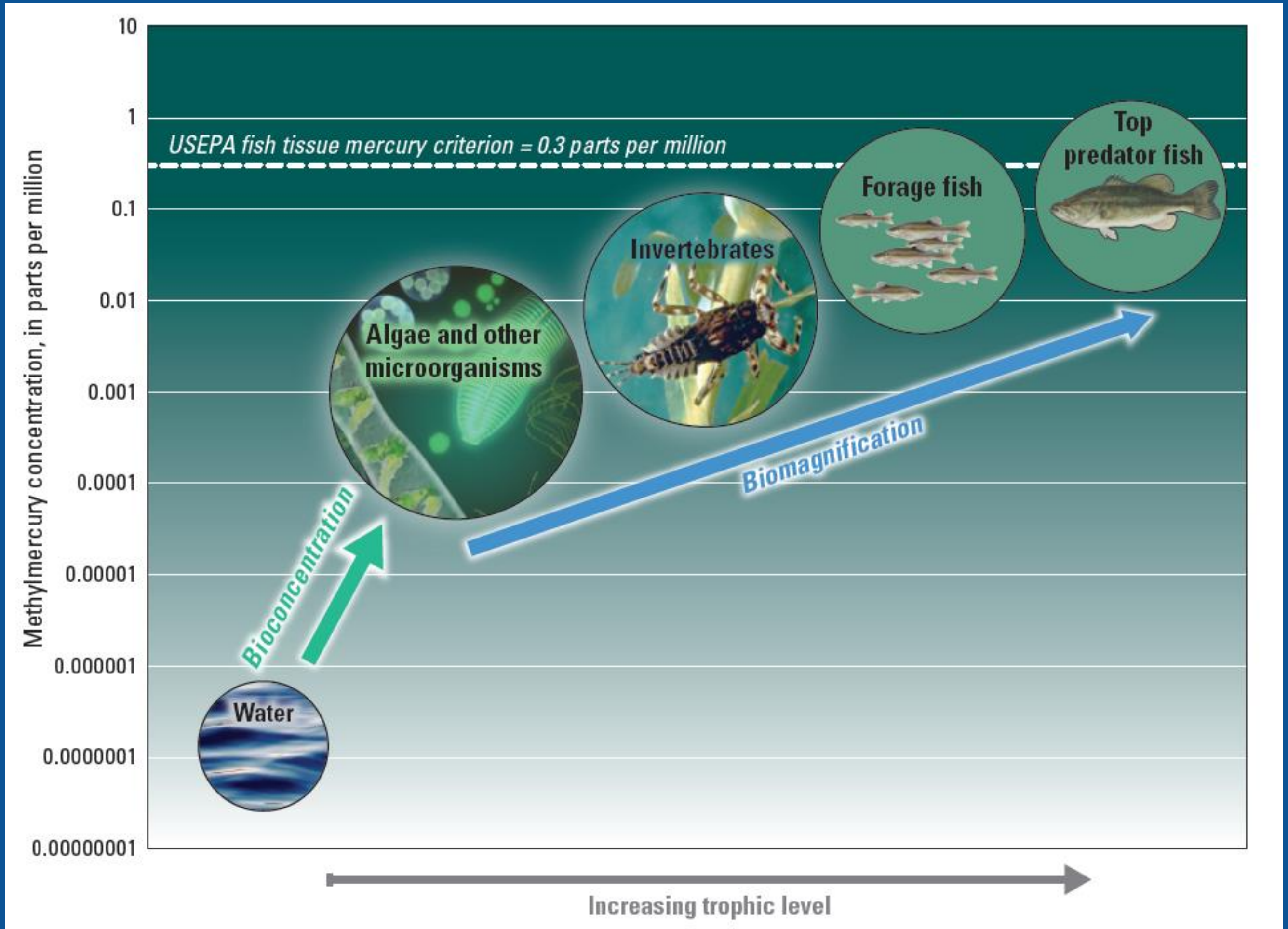
5. Comparison of concentrations relative to health criteria and other sites nationwide shows:

- exceedance of 30-day fish-eating wildlife criterion for total Hg occurred in 3 of the 5 streams, especially in the salmon-supporting reaches.
- unfiltered methyl-Hg in water is among the highest in the nation at Shrine B, the reach with the highest salmon density



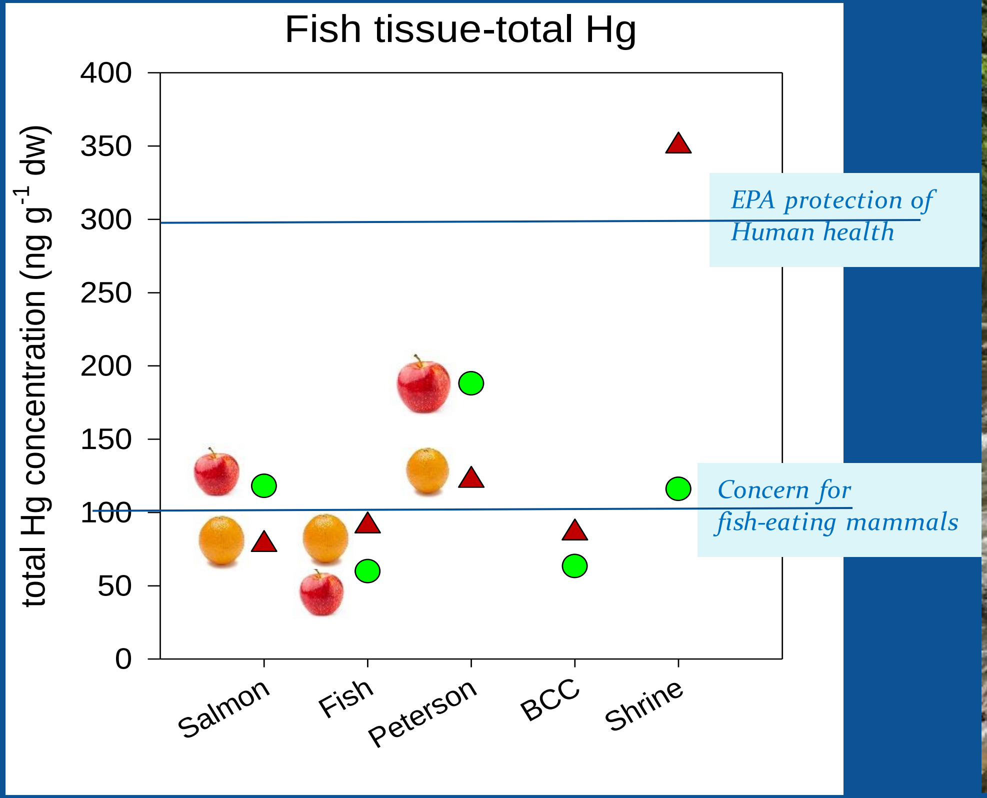
2.4 ng/L= Within the top 1% % of MeHg in streams and lakes in the U.S.A. and 12x higher than the national mean (*n*=336; Scudder et al. 2009).
Less than 1 km upstream, with few salmon, the concentration was only 0.18 ng/L).

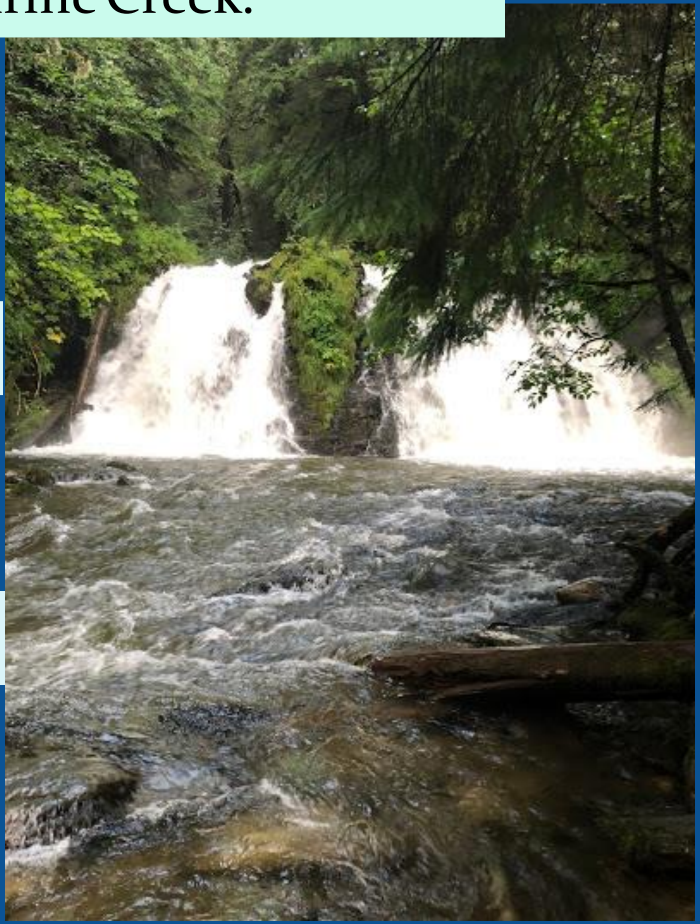
Methylmercury bioaccumulates and biomagnifies in aquatic ecosystems



Methylmercury concentrations in aquatic organisms increase with increasing methylmercury concentrations in water and with increasing trophic level. Fish at the top of the food web tend to have the highest concentrations of methylmercury. (From: USGS Circular 1395 **(Wentz et al. 2014).**

- Half the samples from resident/rearing fish exceeded 100 ng/g, which is the level of concern for fish-eating mammals (Fig.9)
- Only exceedance of human health criteria was for fish tissues in lower Shrine Creek.





Conclusions

- Contaminant loads appear to be measurably influenced by the presence of salmon spawners and carcasses
  - Mercury sources include a combination of spawner, geogenic, and atmospheric influences.
  - POPs occurrences in fish tissues were consistently enhanced in lower stream reaches, indicating a dominant marine source
    - inconsistent with Hg, which was also present in upper reaches
- Comparisons of concentrations in higher trophic organisms is challenging due to differences in presence (by species, age) above and below barriers.
- Passive integrators (e.g. incubated leaf packs) should be further explored as a meaningful monitoring tool in streams

- **Implications:**
  - **As salmon accumulate contaminants in the ocean and return to streams to spawn, they can have a measureable effect on contaminant concentrations in stream ecosystems.**
  - **Contributions by salmon should be better defined and monitored into the future as marine contaminant levels change**

Thank you!
Questions?

Acknowledgments

Funding: INBRE

John Hudson, Independent Aquatic Ecologist, Juneau, AK.
John DeWild, David Krabbenhoft, and staff at ***USGS Mercury Research Lab,*** *Middleton, WI*
Gina Ylitalo and Bernadita Anulacion at ***Northwest Fisheries Science Center****, Seattle, WA*
Eran Hood and Jason Fellman, University of Alaska Southeast
Undergraduate research assistants: Chris Salazar, Alex Whitehead, and Alex Botelho (UAS)