Contaminants in High Elevation Lakes of Washington's National Parks

Robert Black, Patrick Moran, Rich Sheibley and Anthony Paulson - Washington Water Science Center, USGS Tacoma, WA

Matt Vijayan- University of Waterloo, Canada

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Why Examine Contaminants at High Elevations in National Parks?

-Contaminants from warmer climates volatilize, move through the atmosphere, and condense and deposit in cooler climates

-Organochlorines - Unique properties; volatility, chemical stability, lipid soluble, resistant to biodegradation and deposited by ‘cold condensation’.

-Mercury deposition is driven more by current local sources and particulate matter

-Mercury and Organochlorines - Toxic

-Snow, Ice and Tree Bark are good surfaces for deposition

-Well documented, and is having ecological and human health impacts- particularly in arctic regions

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Study Design

- Fish considered to be the most sensitive endpoint, tissue collected at multiple lakes
- Sampled all 3 Western Washington National Parks
- Spanned a range of climatic conditions; rainfall, temperature, average basin aspect

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2002 Review

- Sampled 14 lakes in 3 National Parks
- Elevations ranged from 3200-6300 ft
- Fish were collected with a light-weight gillnet, weights and lengths recorded
- Composite samples of 5 fish, males preferred
- Analyzed at ppb level for Organochlorines and Mercury

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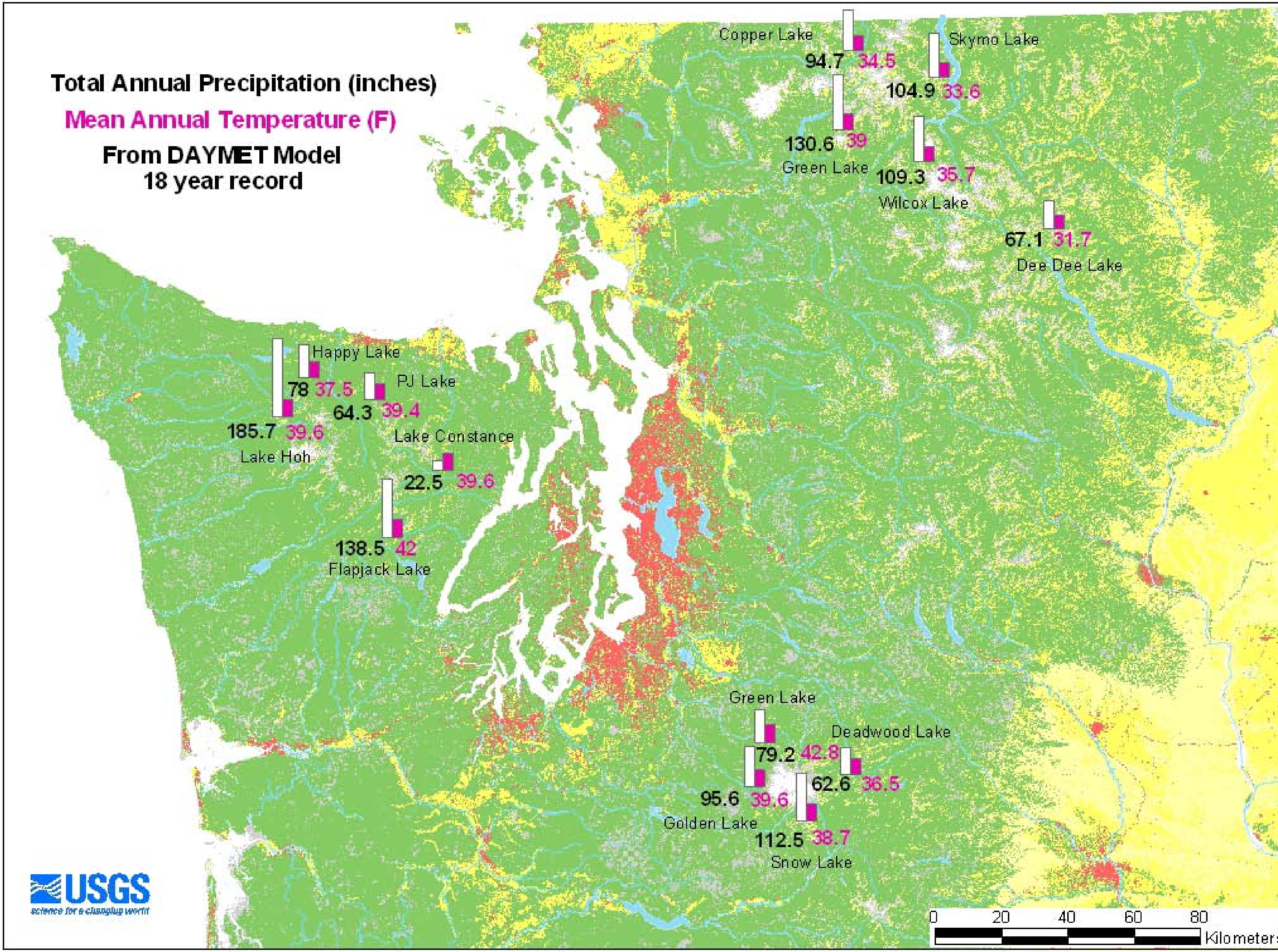
Total Annual Precipitation (inches)
Mean Annual Temperature (F)
From DAYMET Model
18 year record
Copper Lake
94.7 34.5
Skymo Lake
104.9 33.6
130.6 39
Green Lake
109.3 35.7
Wilcox Lake
67.1 31.7
Dee Dee Lake
Happy Lake
78 37.5
PJ Lake
64.3 39.4
185.7 39.6
Lake Hoh
Lake Constance
22.5 39.6
138.5 42
Flapjack Lake
Green Lake
79.2 42.8
Deadwood Lake
62.6 36.5
95.6 39.6
Golden Lake
112.5 38.7
Snow Lake
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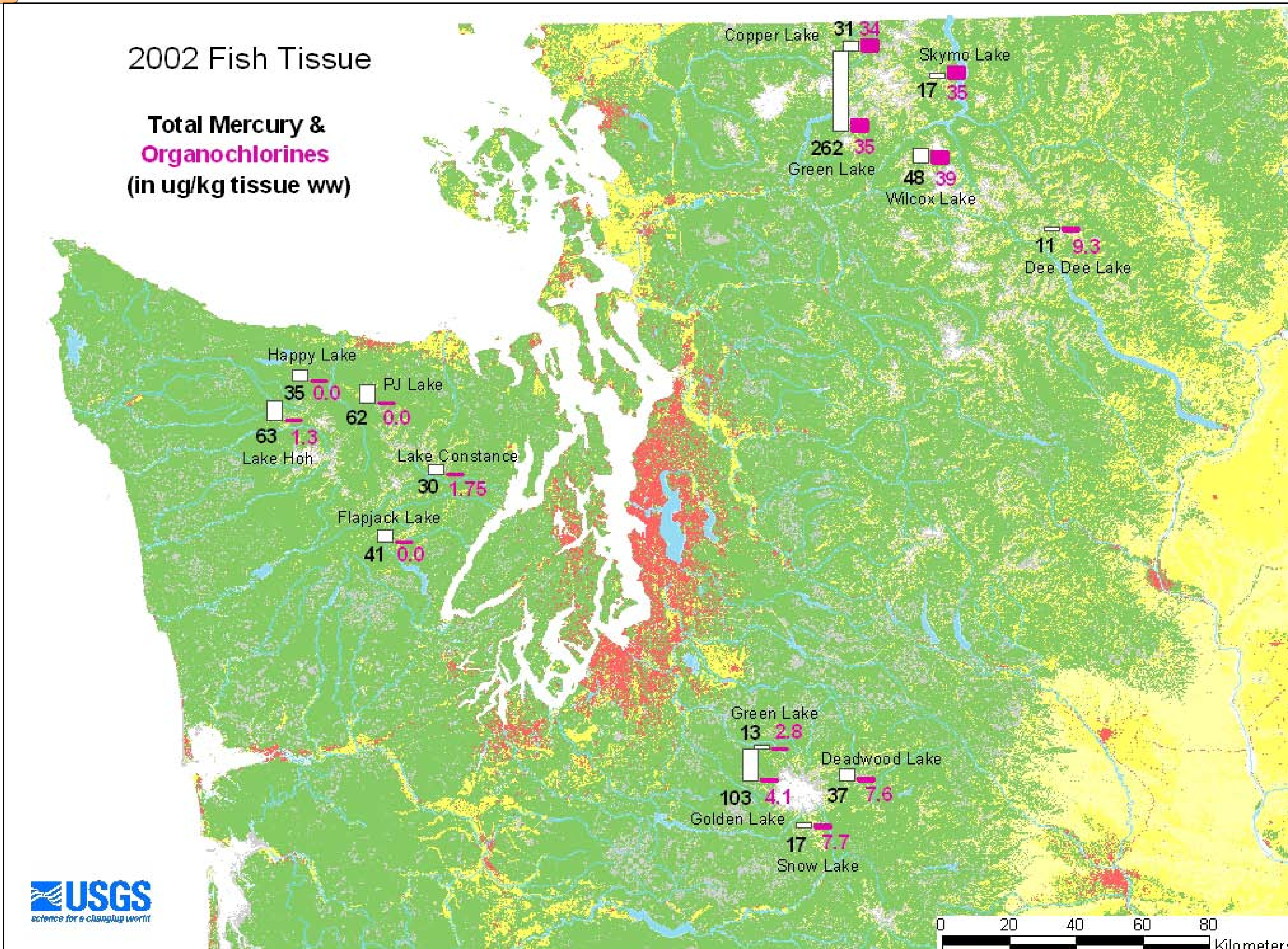
0 20 40 60 80
Kilometers


2002 Fish Tissue
Total Mercury &
Organochlorines
(in ug/kg tissue ww)
Copper Lake
31 34
Skymo Lake
17 35
262 35
Green Lake
48 39
Wilcox Lake
11 9.3
Dee Dee Lake
Happy Lake
35 0.0
PJ Lake
62 0.0
63 1.3
Lake Hoh
Lake Constance
30 1.75
Flapjack Lake
41 0.0
Green Lake
13 2.8
Deadwood Lake
103 4.1
37 7.6
Golden Lake
17 7.7
Snow Lake
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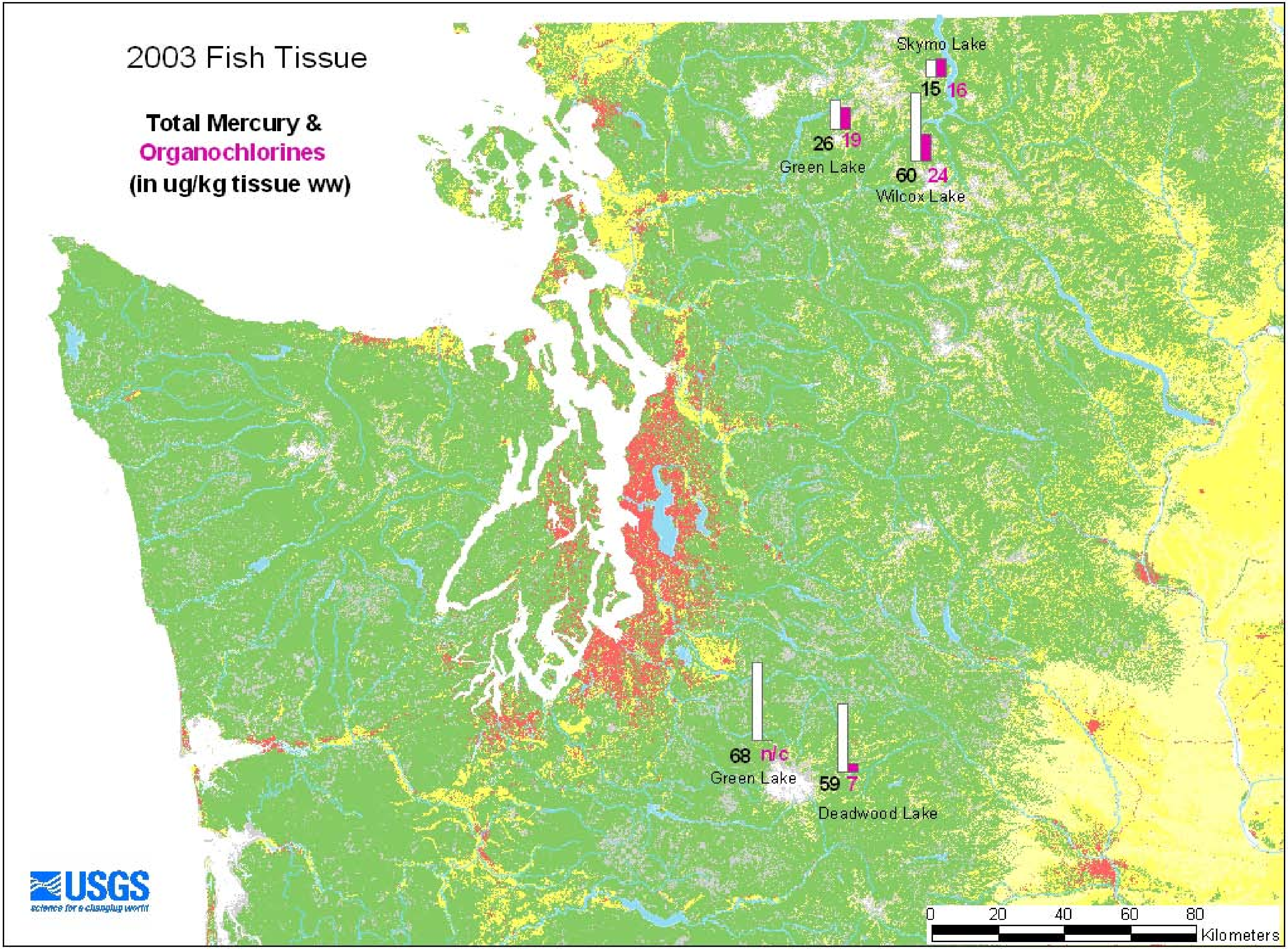
0 20 40 60 80
Kilometers


2003 Fish Tissue
Total Mercury &
Organochlorines
(in ug/kg tissue ww)
Skymo Lake
15 16
26 19
Green Lake
60 24
Wilcox Lake
68 n/c
Green Lake
59 7
Deadwood Lake
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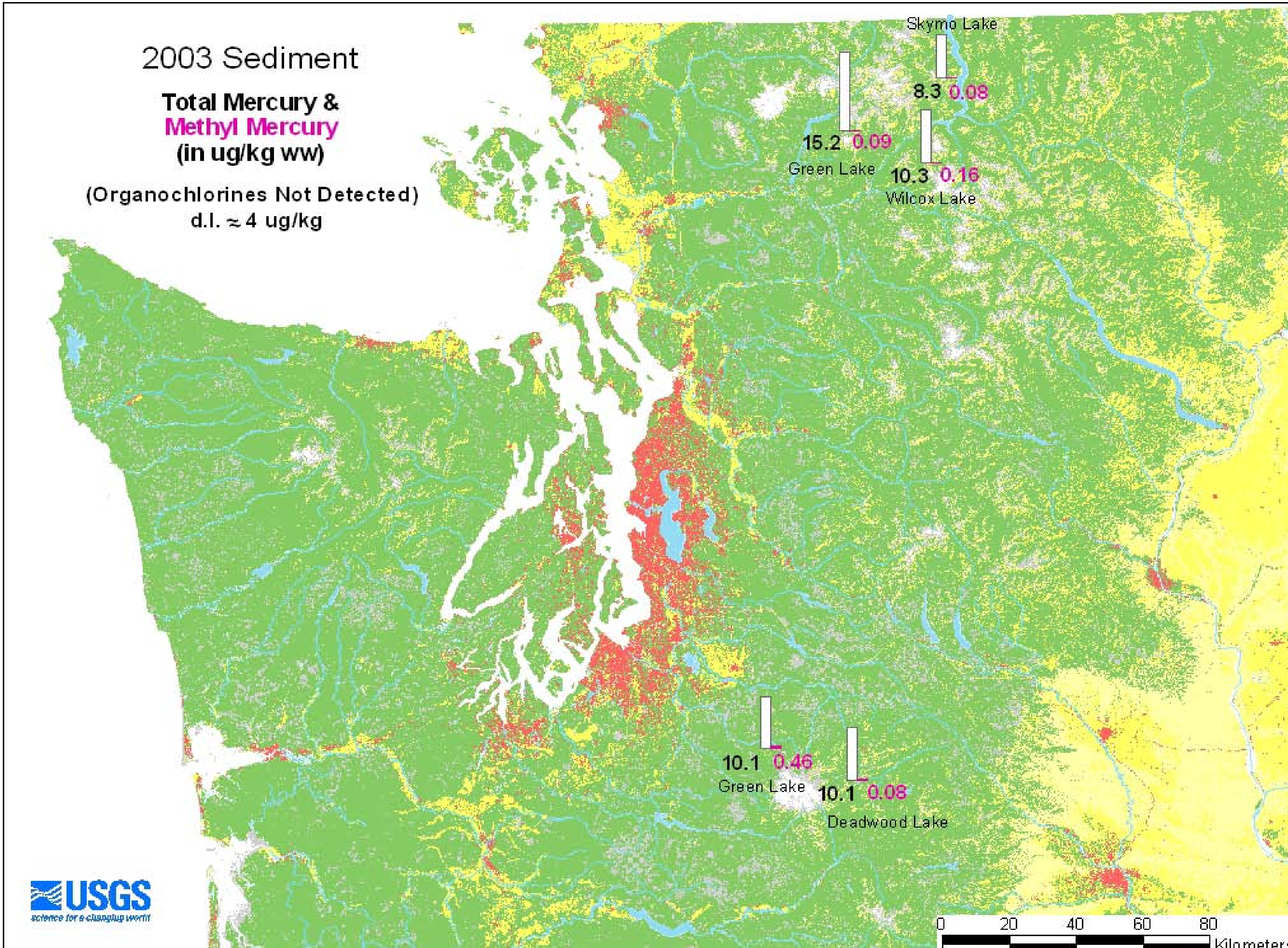
0 20 40 60 80
Kilometers


2003 Sediment
Total Mercury &
Methyl Mercury
(in ug/kg ww)
(Organochlorines Not Detected)
d.l. ≈ 4 ug/kg
Skymo Lake
8.3 0.08
15.2 0.09
Green Lake
10.3 0.16
Wilcox Lake
10.1 0.46
Green Lake
10.1 0.08
Deadwood Lake
0 20 40 60 80
Kilometers
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Are elevated contaminant levels related to physiographic factors?

- Used a Non-parametric Multivariate Treatment of the contaminant pattern across the 14 lakes to look for relationships to environmental variables

- Nonmetric Multideminsional Scaling (NMS)

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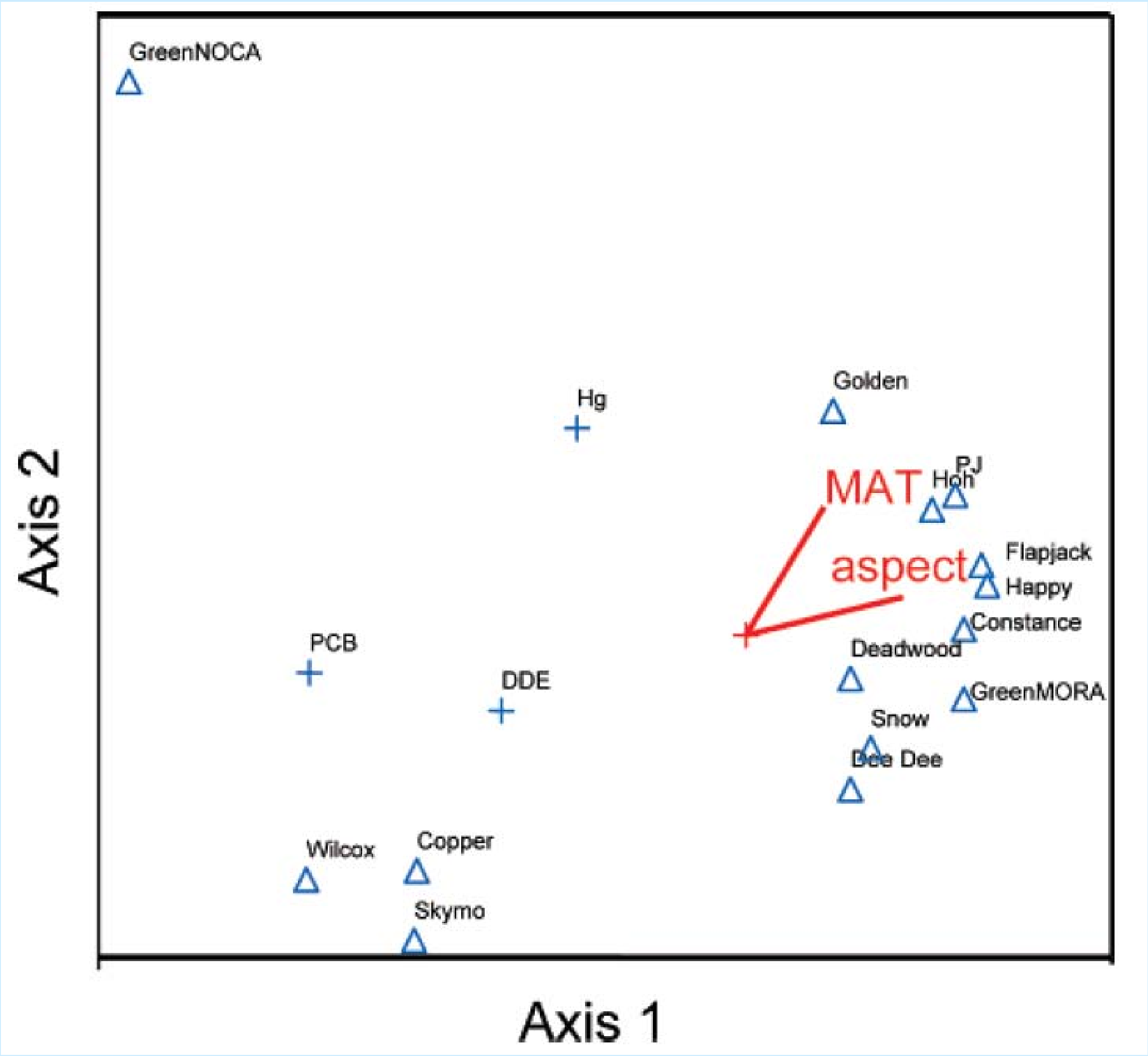

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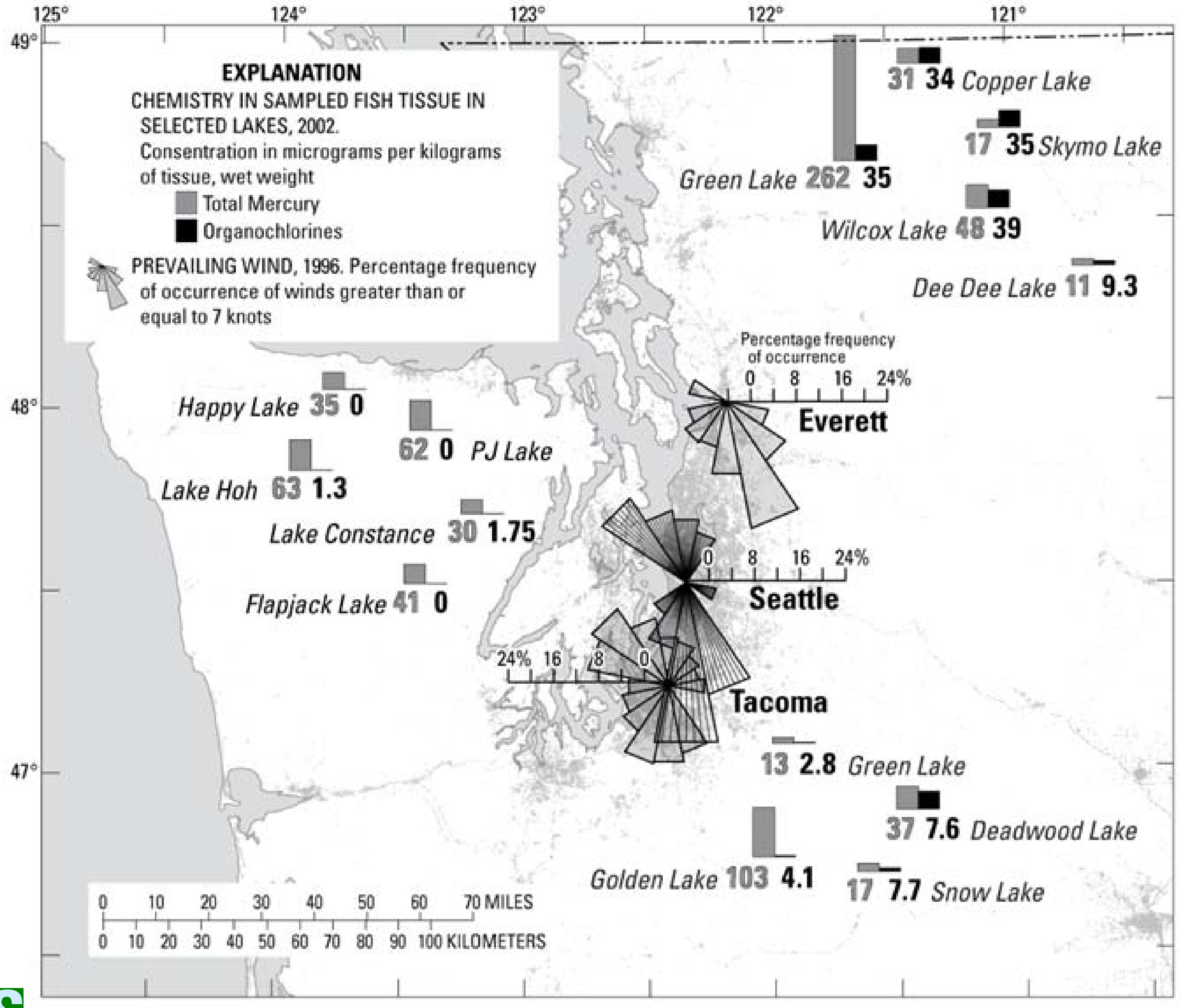

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Individual or Population Survival?

A targeted rainbow trout cDNA microarray

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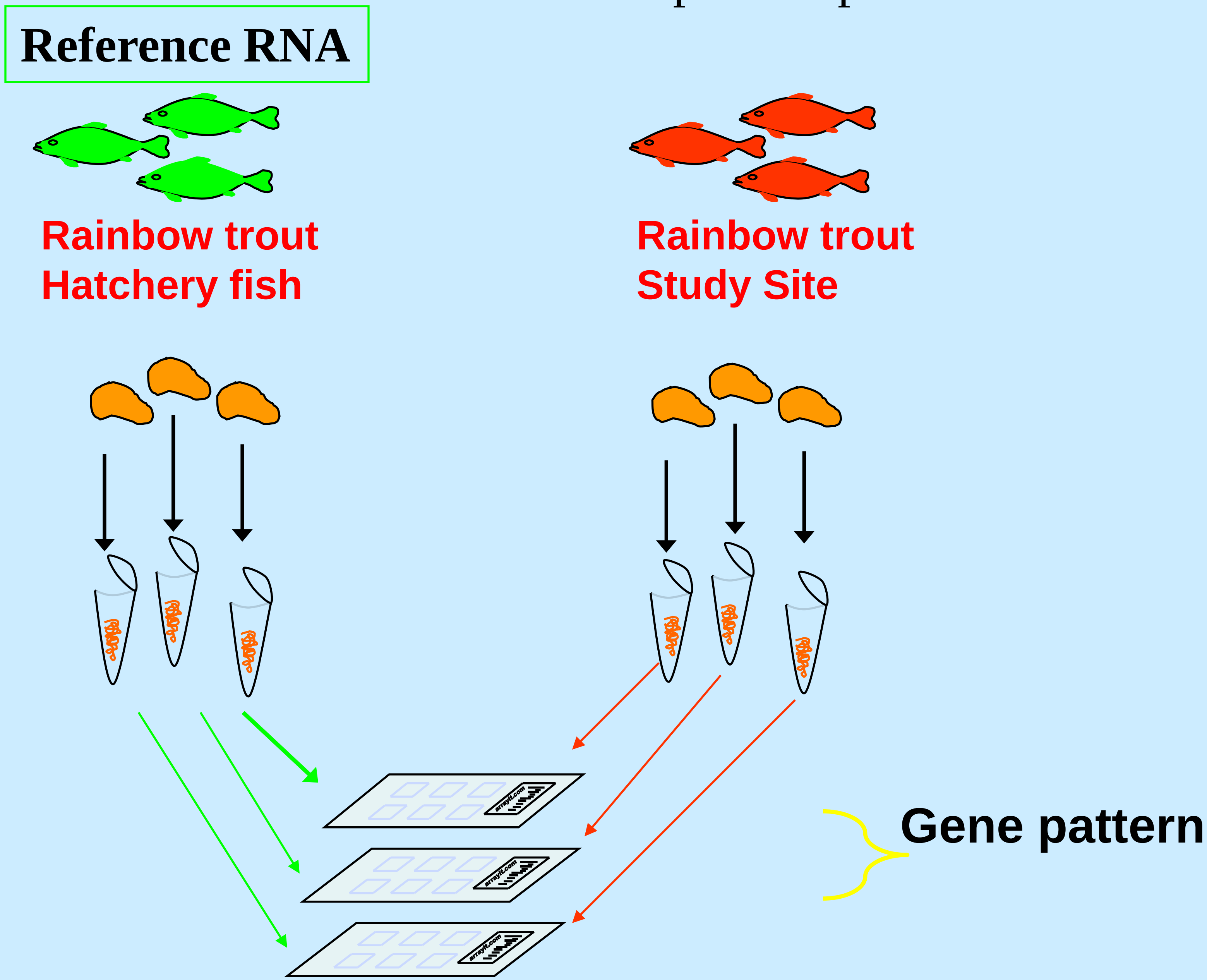
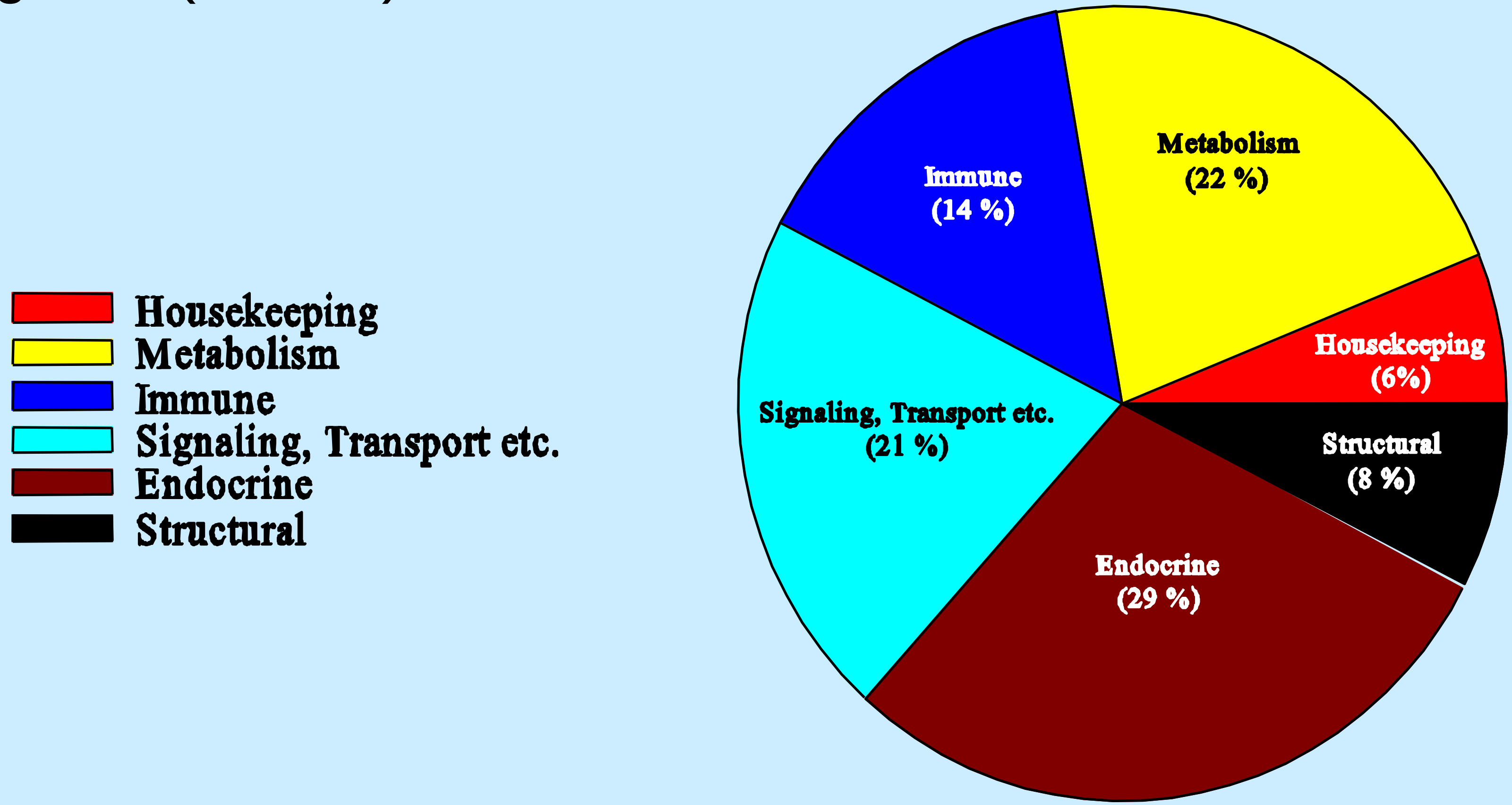
Sample comparison



Percent of genes by class

All genes (n= 207)



Aluru, Vijayan. Aquatic Tox. April 2008.

Microarray Conclusions

- A number of edocrine genes in fish collected from the mercury contaminated sites were either highly activated or highly deactivated compared to laboratory controls and fish from lakes with lower contamination.

- The genes that were affected have been shown to respond to elevated mercury.

Conclusions

- Pattern of tissue concentrations suggest proximity to sources is important; a local scale back-trajectory wind model would be useful
- Sensitive measures of gene activity can be used as a starting point for further fish health investigations and help couple biological effects to chemical monitoring
- Infrequent, long-term monitoring is recommended at some of these sites

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Research Recommendations

- Couple Biological Conditions Assessment with Chemical Monitoring
  – Microarray: “Do elevated Hg levels have a measurable effect on biota?”
- Microarray results from USGS Puget Sound urban stream study suggest microarray techniques may be effective way to couple biota assessment to chemical monitoring.

Puget Sound Urban Trout Microarray Findings

- ↑ Urban density and road crossings = ↑ Sediment PAH
- ↑ Sediment PAH = ↑ PAH detoxification gene activity
- ↑ PAH detoxification gene activity = ↓ growth gene activity
- Coupling biological effects with chemical monitoring

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USGS Critical loads project

- Project to examine impacts of nitrogen deposition on lake diatom communities.
- Diatoms are ‘first responders’ to environmental change therefore a good indicator.
- Fossil remains preserved well in sediment records.
- Measured deposition and cored 10 lakes across Olympic, North Cascades, and M. Rainier national parks.

Previous work and motivation

- At ROMO, researchers were able to relate shifts in lake sediment diatoms to nearby NADP data to show that a critical load for diatoms existed at 1.5 kg N/ha-yr (Baron 2006).

- Recent work by Saros et al. (2010) showed a critical load of 1.4 kg N/ha-yr for lake diatoms in eastern Sierra Nevada and Yellowstone NP, however no impact in Glacier NP yet.

- In 2006, a workshop was held to discuss the need for developing critical loads for nitrogen and sulfur for the Pacific Northwest.

- Long term NADP data in Washington State at low elevation (less than 1500 feet), show N deposition close to or higher then 1.5 kg N/ha/yr ROMO effects level.

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USGS-NPS critical loads Project

- Initial deposition data is showing that higher elevation may be receiving more N load compared to low elevation NADP sites.

- Preliminary diatom results are showing possible effects from N deposition in Olympic, at levels less then observed in the Rockies and Sierras. (maybe as low as 1.0 kg N/ha-yr)

- Data Gap – no long-term permanent high elevation data available for WA.
  - Have preliminary commitment from USGS, NPS, USFS to establish a new NADP site

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Data Gaps and Needs

- Monitoring baseline data – Numerous monitoring efforts underway, but some lack chemical breadth and spatial coverage.
- Lack of high elevation long term data.
- Coordinate monitoring efforts to enhance spatial, temporal and chemical coverage.
- Process based monitoring and assessment (i.e.. all lakes, wetland, watersheds are not the same)
  - Mercury: Toxicity of mercury is highly related to the rate of methlylation mediated by levels of organic carbon in a system
  - Many contaminants are sorbed to fine particles. Therefore, potential exposure is related to sediment dynamics
- Back trajectory air modeling

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USGS/NPS Efforts Underway

- USGS/NPS in PNW annually prepare 5 to 10 proposals to address contaminant issues in and around the National Parks (Internal and external funding sources)
  - Stormwater runoff
  - Enhancement of existing monitoring programs
  - Monitoring for legacy and emerging contaminants in water and biota
  - Coupling changes in contaminants and biological conditions.
- Coordination with other natural resource monitoring and research groups would be welcome.

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Deposition data summary - MORA

Site	Days Deployed	NH4-N (kg/ha/yr)	NO3-N (kg/ha/yr)	DIN (kg/ha/yr)
Hidden	85	0.60	0.46	1.06
Eunice	76	1.05	0.92	1.98
Shriner	86	0.97	0.57	1.54
Snow	71	0.53	0.59	1.12
Park average		**0.79**	**0.64**	**1.42**
WA 99 Tahoma Woods	42	0.16	0.49	0.65
WA 21 La Grande	70	0.27	0.46	0.73

Deposition data summary - NOCA

Site	Days Deployed	NH4-N (kg/ha/yr)	NO3-N (kg/ha/yr)	DIN (kg/ha/yr)
Stiletto	66	0.40	0.70	1.10
Copper	59	1.05	1.24	2.29
Hidden	72	1.01	0.96	1.97
Thornton	71	1.12	1.34	2.46
Park average		**0.90**	**1.06**	**1.96**
WA 19 Marblemount	56	0.70	1.18	1.89

Deposition data summary - OLYM

Site	Days Deployed	NH4-N (kg/ha/yr)	NO3-N (kg/ha/yr)	DIN (kg/ha/yr)
Heather	65	0.20	0.47	0.66
Milk	68	0.48	0.57	1.05
PJ	80	0.24	0.36	0.60
Hoh	60	0.52	0.51	1.03
Park average		**0.36**	**0.48**	**0.84**
WA 14 Hoh Ranger Station	56	0.52	0.59	1.11

Deposition data summary

- High elevation data greater than lower elevation NADP data when scaled to same time period, expect OLYM
- Highest values in NOCA, lowest at OLYM similar to historic NADP data
- No trend with elevation or location within park

Sediment analyses

- Top and bottom slices analyzed for diatoms first
  - Look for biggest diatom differences
- Choose 3-4 lakes to examine more closely for diatom profiles and dating
- Infer Critical Load from changes in diatom communities and species sensitive to N
- Currently, only have top and bottom analyses done, plus a few others

Sediment analyses

- Diatom indicators of N enrichment
  - *Asterionella formosa*, *Fragilaria crotonensis* (Baron et al. 2000, Saros et al. 2005)
- Our top and bottom data
  - Only one lake had *Asterionella formosa* in top section, but significant (25% of total, Hoh Lake)
  - A second lake (Milk lake) had *Fragilaria tenera*, signs of more chronic conditions (Saros pers. Comm.)

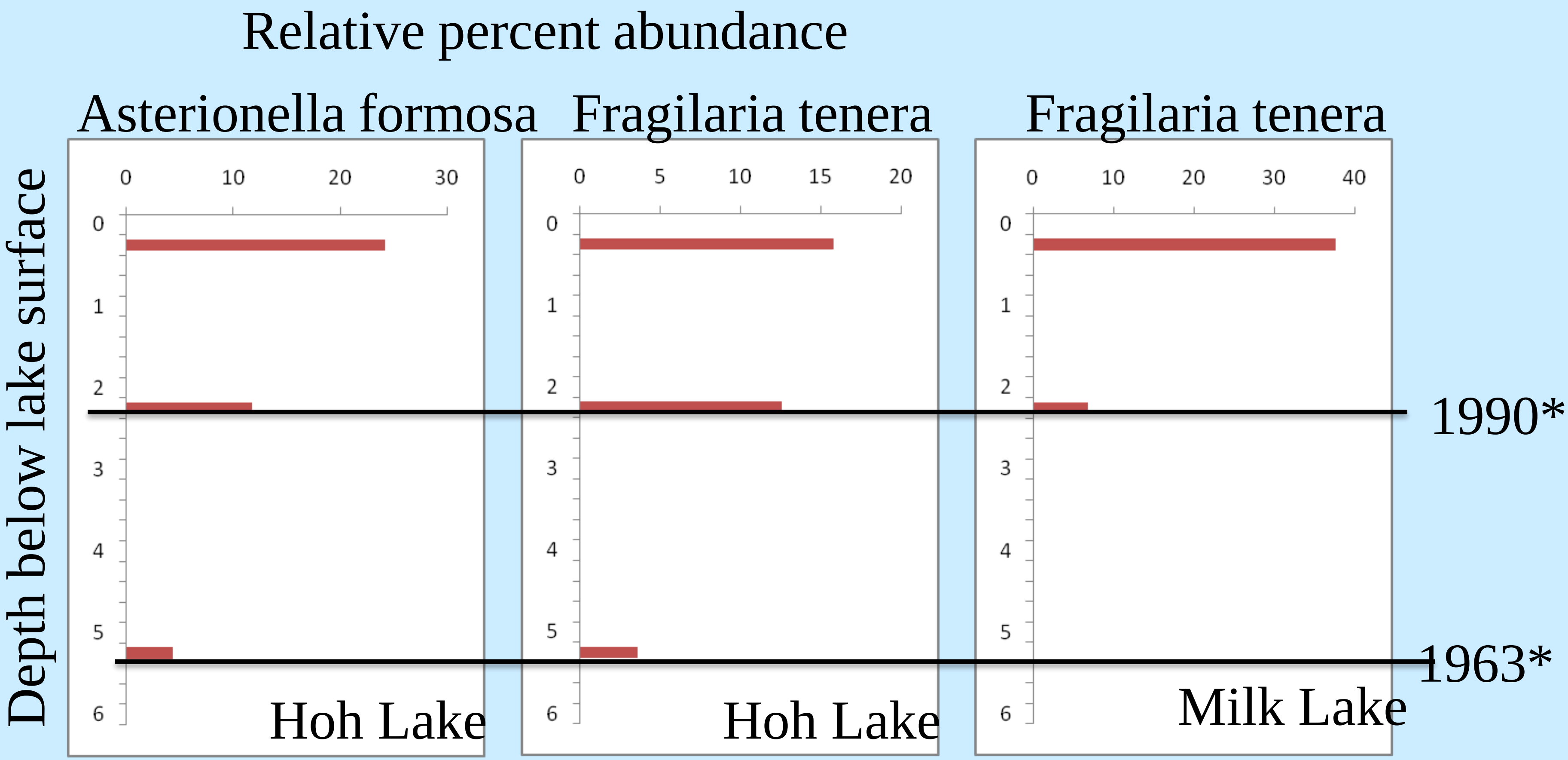
Sediment analyses

- Other lakes showed nothing beyond typical alpine flora (*Aulacoseira alpigena*, *Staurosirella pinnata*)
- Saw differences in most abundant species between parks
  - Olympic lakes looked different than North Cascades and Rainier
- Results are consistent with nutrient limitation studies in the area showing lakes might be more P limited then N limited (Saros 2009).

Choosing lakes for dating

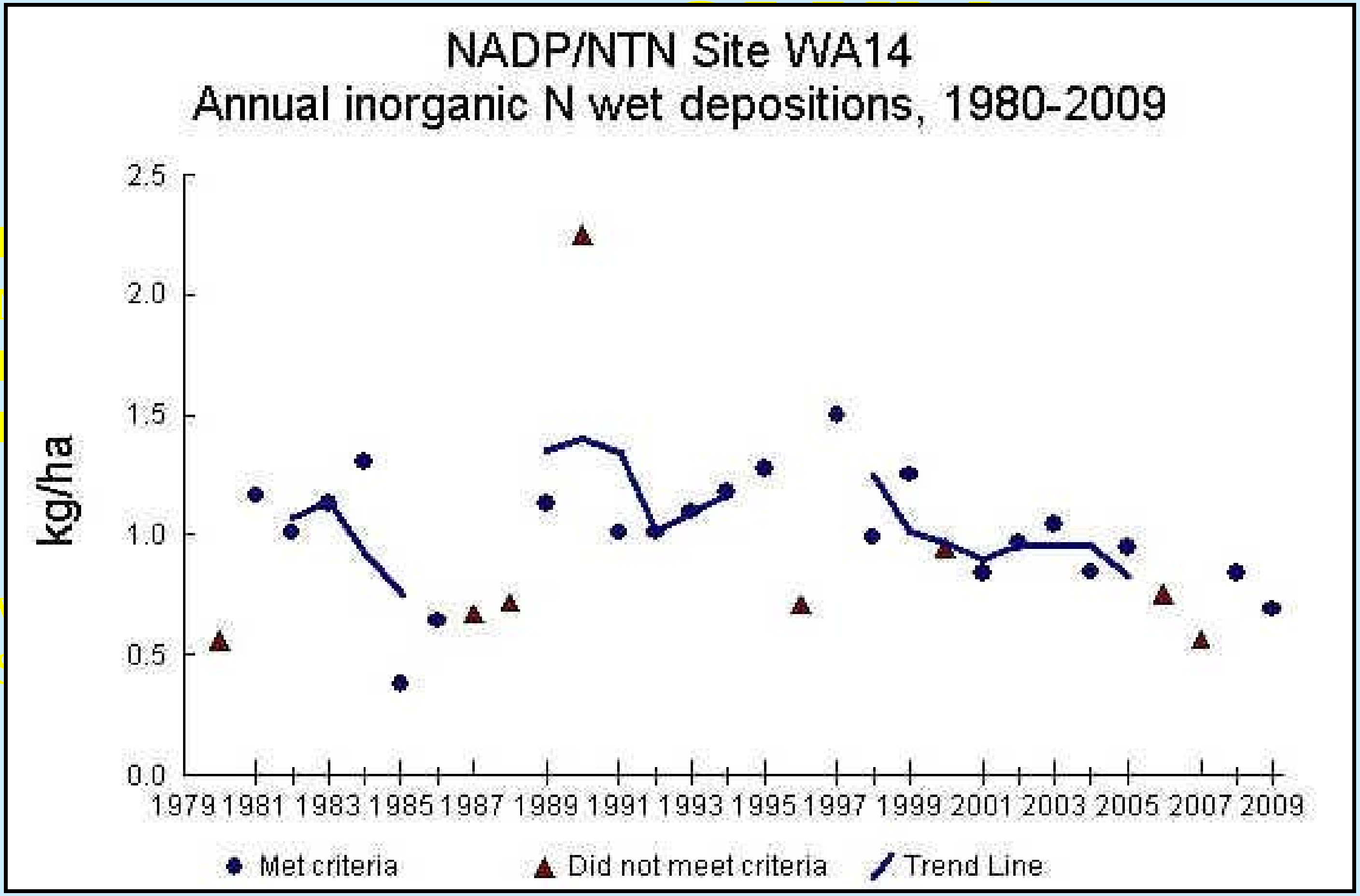
- The two lakes showing signs of diatom response to N, are in OLYM, which has some of the lower rates of N deposition.
- The other two lakes we chose to examine in more detail were based on the deposition data we collected.
- Currently analyzing more vertical sections from Hoh, Milk, Copper, and Snow lakes
  - Should have dating and diatom data back by December

Diatom profiles, so far



* Approximate dates based on WACAP data for Hoh Lake

Deposition data summary -



DIN (kg/ha/yr)

0.66
1.05
0.60
1.03
0.84

1.11

Possible effects level above 1.0 kg N/ha/yr ?

Conclusions

- Deposition from resin columns shows
  - Loads higher at elevation relative to lower NADP sites over same time period at NOCA and MORA
  - Highest values in NOCA, lowest in OLYM
- Still waiting on diatom and dating data, but…
  - Effects are being observed in OLYM
  - Possible CL around 1.0 kg N/ha/yr with biggest changes between 1963 and 1990
  - Our current ‘guesstimate’