Developing Critical Loads for Atmospheric Deposition of Nitrogen to high Alpine Lakes in the Pacific Northwest using Sediment Diatoms

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Outline

- Background
- Study sites
- Study Design
- Results
- Conclusions

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What is a Critical Load?

- A critical load is "the quantitative estimate of an exposure of one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge."

- Furthermore, one can develop a critical load for the same system, from different start-end points (diatoms, pH, lichens, terrestrial, etc.)

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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.

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Previous work and motivation

- 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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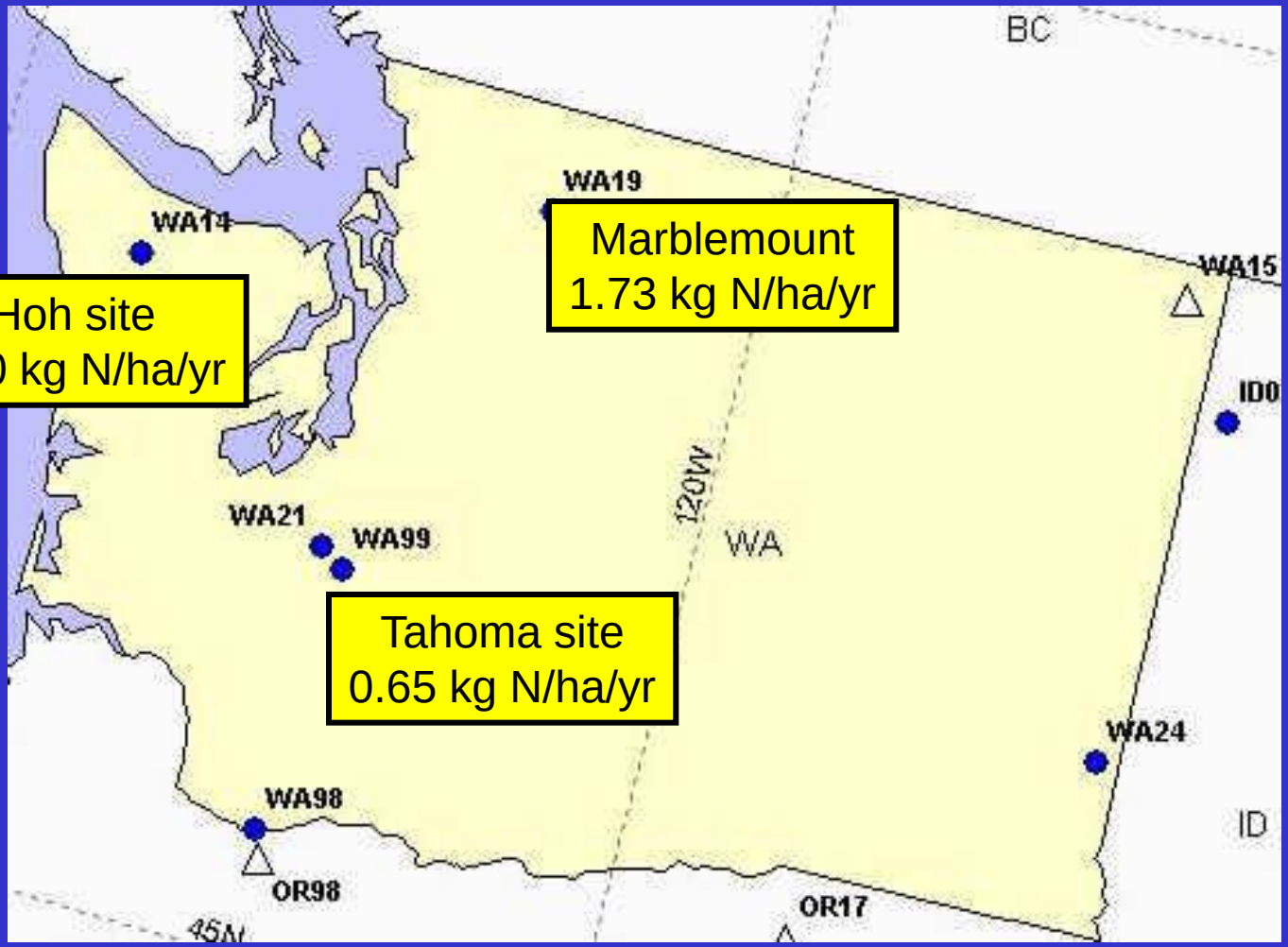
NADP sites in WA and annual inorganic N for 2008



Marblemount
1.73 kg N/ha/yr

Hoh site
0.80 kg N/ha/yr

Tahoma site
0.65 kg N/ha/yr

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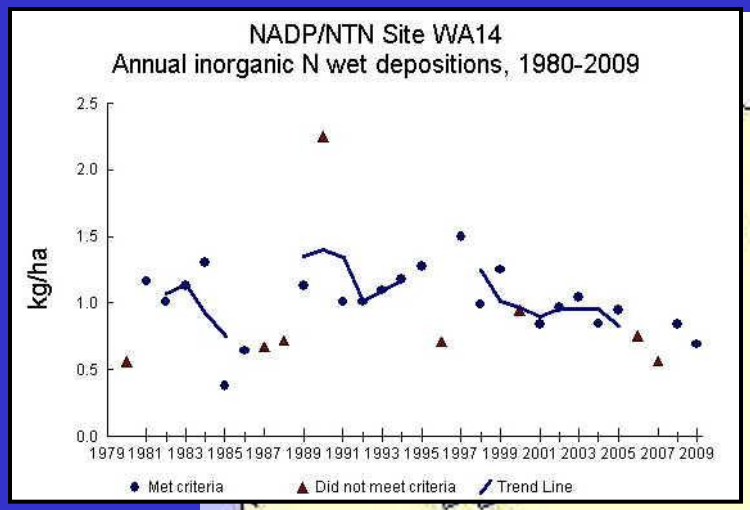
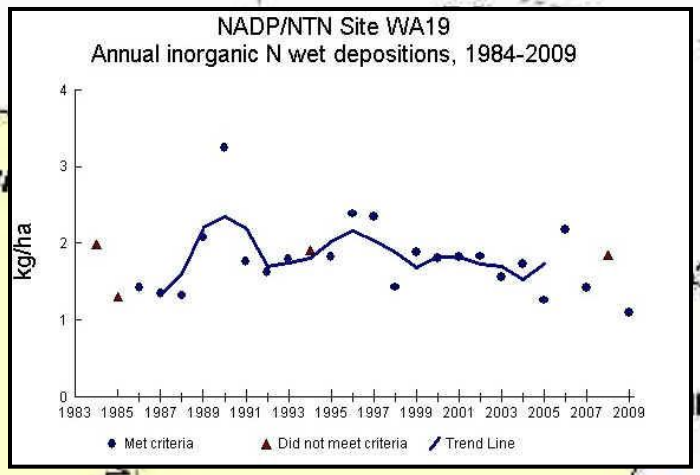
NADP sites in WA and annual trends





Current Project motivation

- No high elevation data for WA
- Focus on high elevation lakes because it is believed these are most sensitive ecosystems to increased deposition
- Park managers wanted to know how WA lakes compared to the results from ROMO.
- Project goal – Is there evidence of a critical load for lakes in WA national parks, or what are baseline conditions.

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USGS-NPS critical loads Project

- Focused on high elevation (above tree line) lakes at the three national parks in WA.
- Estimated deposition using bulk samplers (Fenn)
- Followed a similar methodology to the study at ROMO and focused on effects to diatoms
  - First to respond to environmental change
- Took sediment cores for dating and diatoms
  - Diatom and dating to reconstruct historical changes, look for changes in diatoms sensitive to N

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USGS-NPS critical loads Project

- Collected water quality samples for nutrients, ANC, Chl-a, major ions
  - Lakes were very oligotrophic, many non-detects
  - DIN:TP ratios were 0 to 5.0

- Surface sediment for C:N and ^{15}N
  - Not presented today

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Lake Site selection criteria

- Above tree line
- Lakes above 4000 feet
- Minimal vegetation (talus preferred)
- Little to no fish
- Oligotrophic, low ANC
- Low visitor presence
- Accessible (?)
- Less than 25 ha
- At least 10 feet deep
- Good spatial spread with elevation gradient and E-W pair
- Overlap with ongoing lake monitoring in parks

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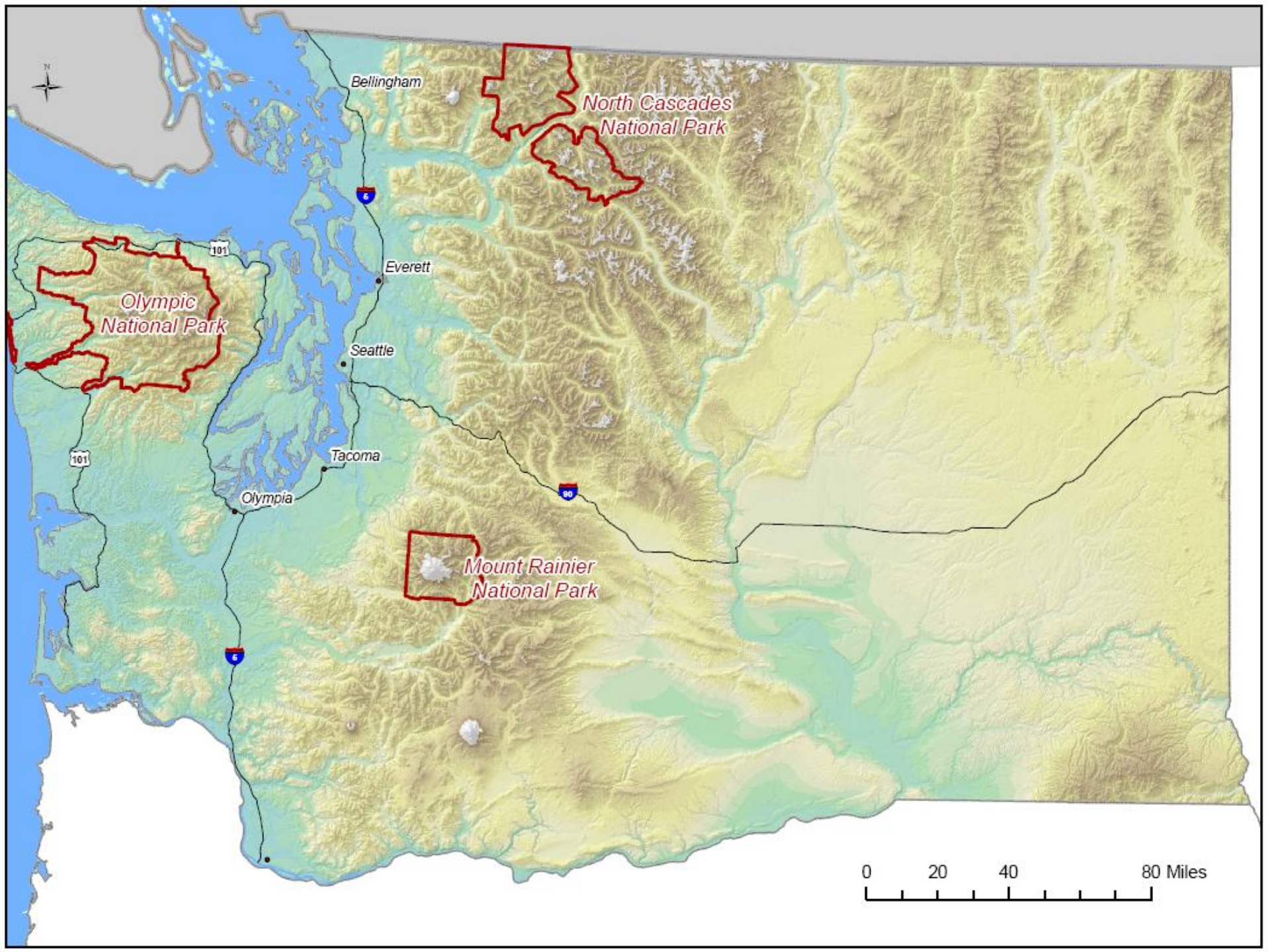
Bellingham
North Cascades
National Park
Everett
Olympic
National Park
Seattle
Tacoma
Olympia
Mount Rainier
National Park
0
20
40
80 Miles

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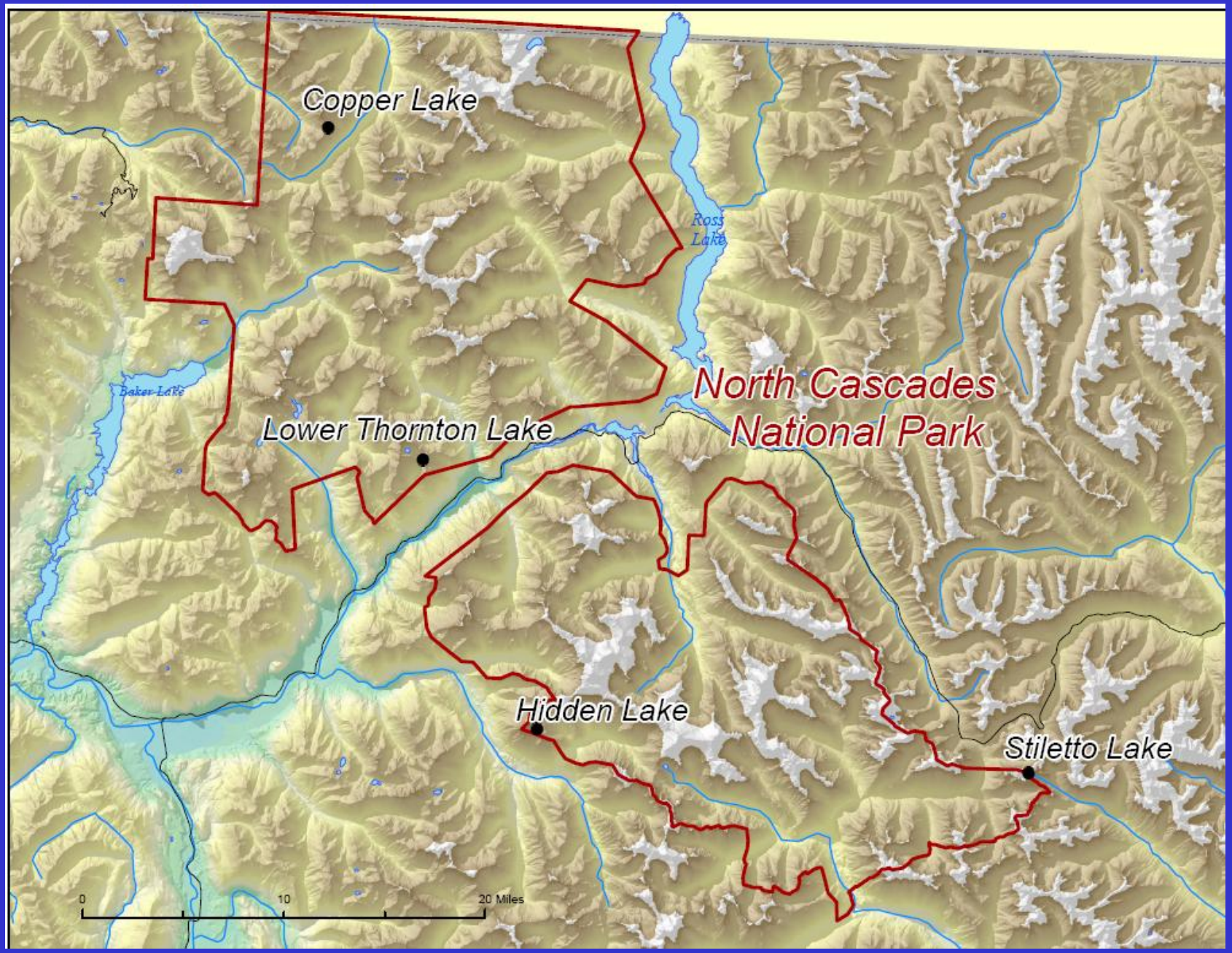

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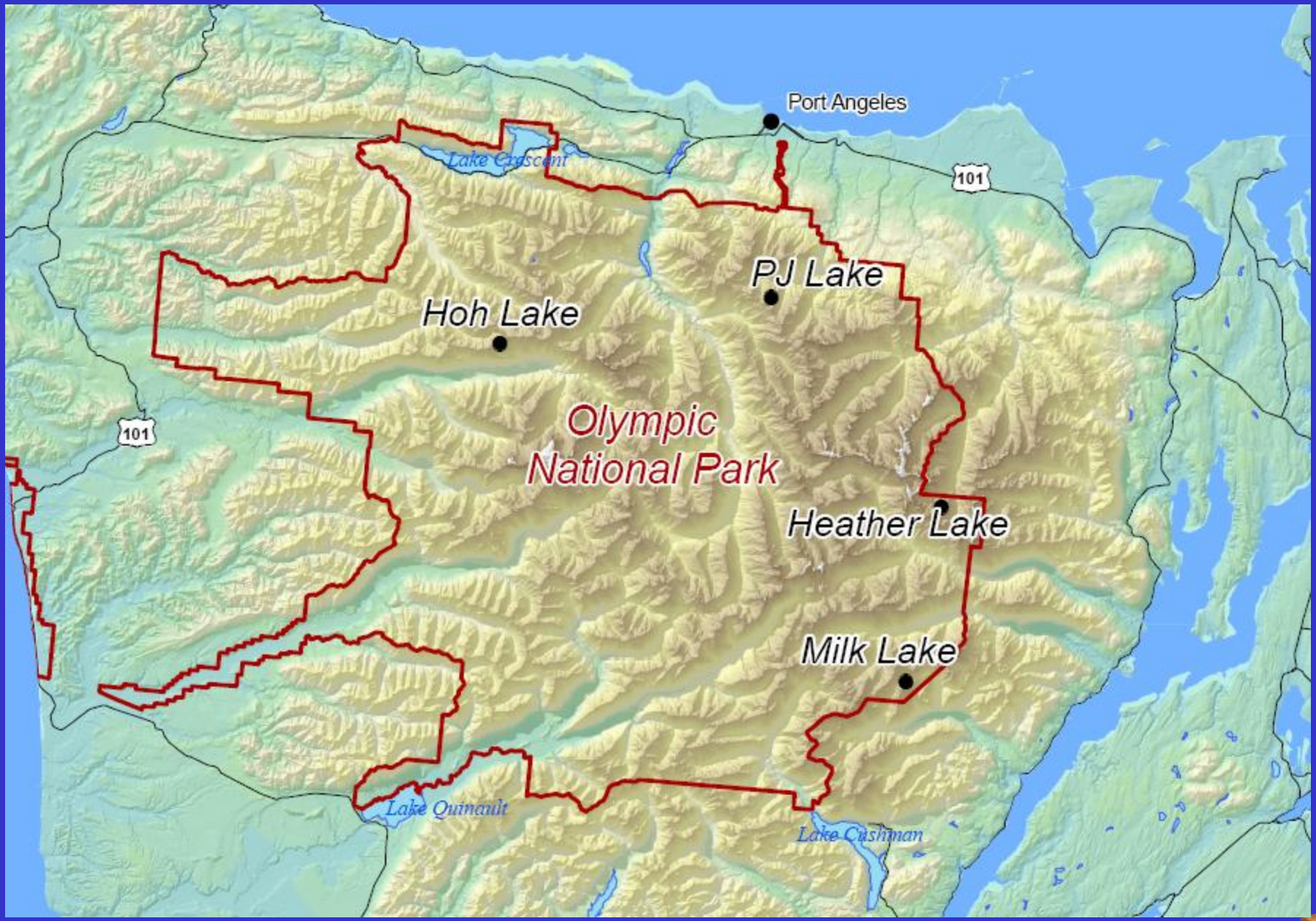
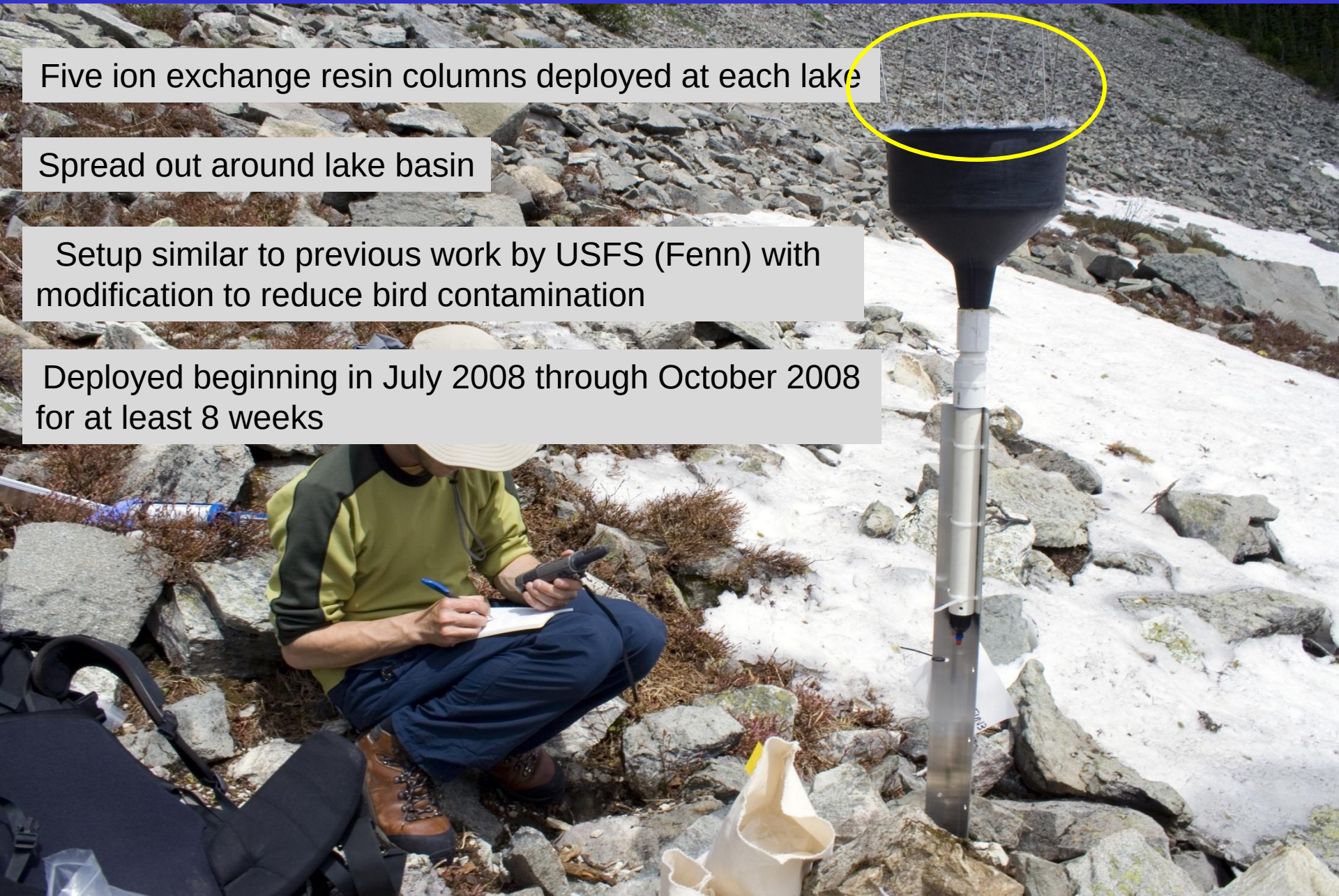

Port Angeles
Lake Crescent
101
PJ Lake
Hoh Lake
Olympic
National Park
101
Heather Lake
Milk Lake
Lake Quinault
Lake Cushman

Estimating bulk deposition



Five ion exchange resin columns deployed at each lake

Spread out around lake basin

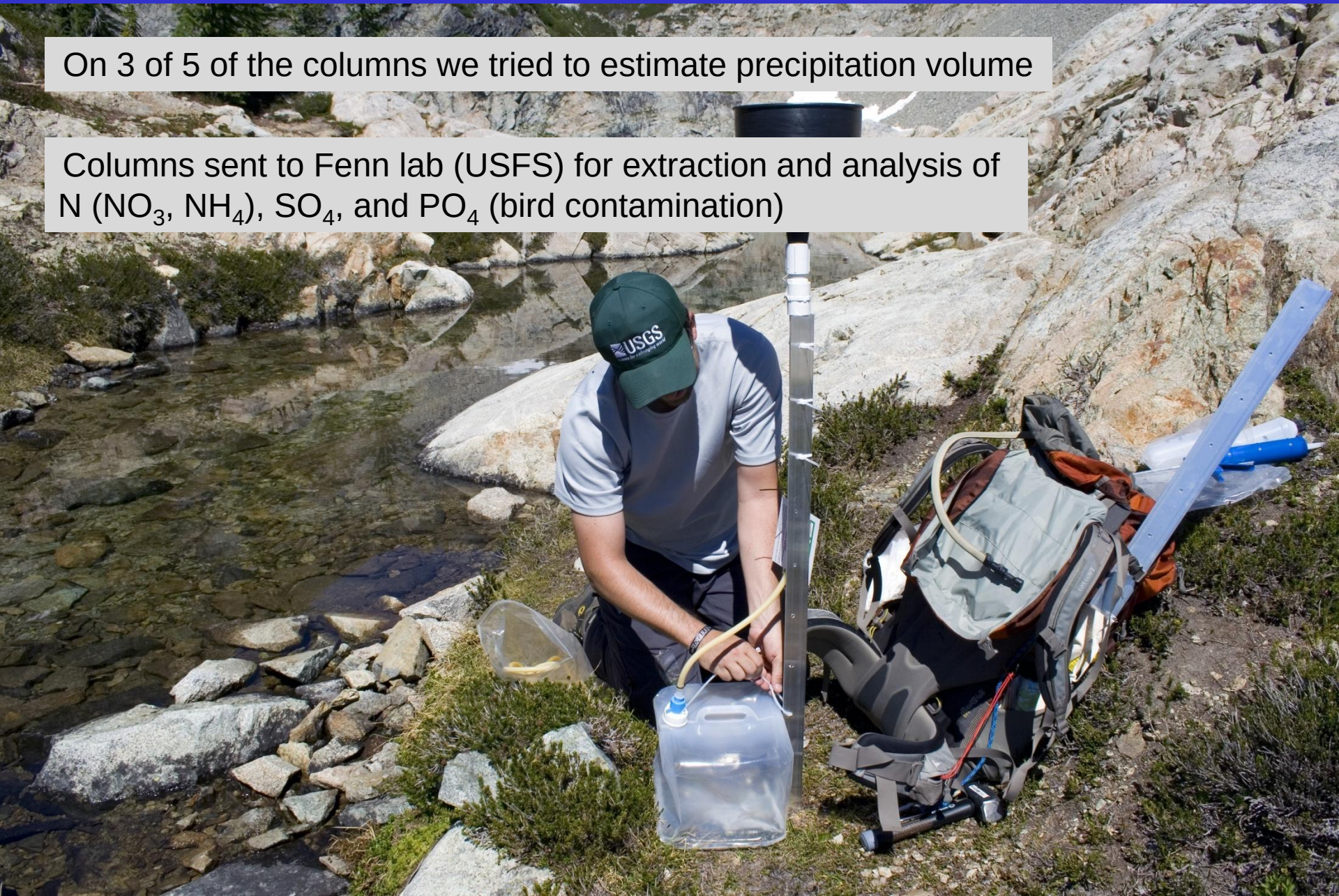
Setup similar to previous work by USFS (Fenn) with modification to reduce bird contamination

Deployed beginning in July 2008 through October 2008 for at least 8 weeks

Estimating bulk deposition

On 3 of 5 of the columns we tried to estimate precipitation volume

Columns sent to Fenn lab (USFS) for extraction and analysis of N (NO_3, NH_4), SO_4, and PO_4 (bird contamination)



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

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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

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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

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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

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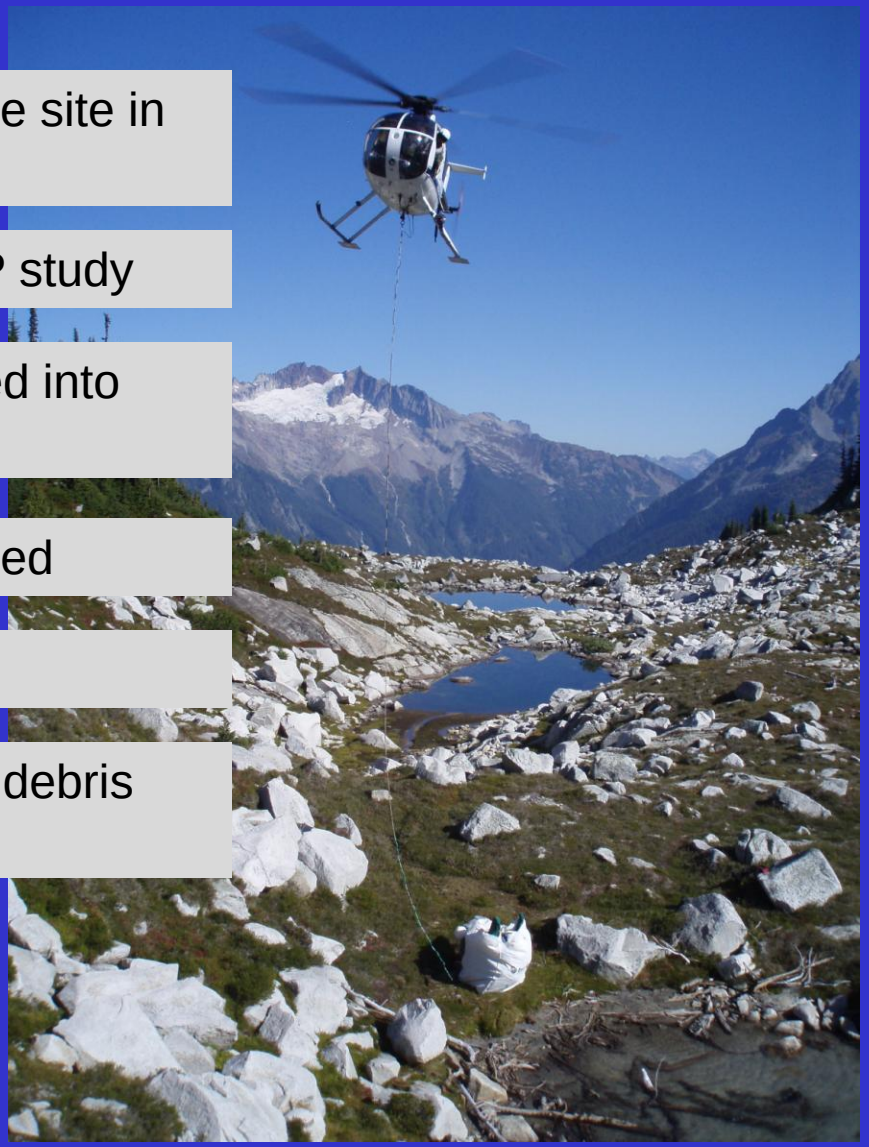
Sediment Coring and diatoms

- Lakes were cored in summer of 2009, one site in 2010
- Used same coring equipment as WACAP study
- Flown in via helicopter to most sites, hiked into close sites
- Of the 12 original lakes, only 10 were cored
  - One had high elk disturbance
  - One was too forested, and high debris flow into lake



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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

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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.)

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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).

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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

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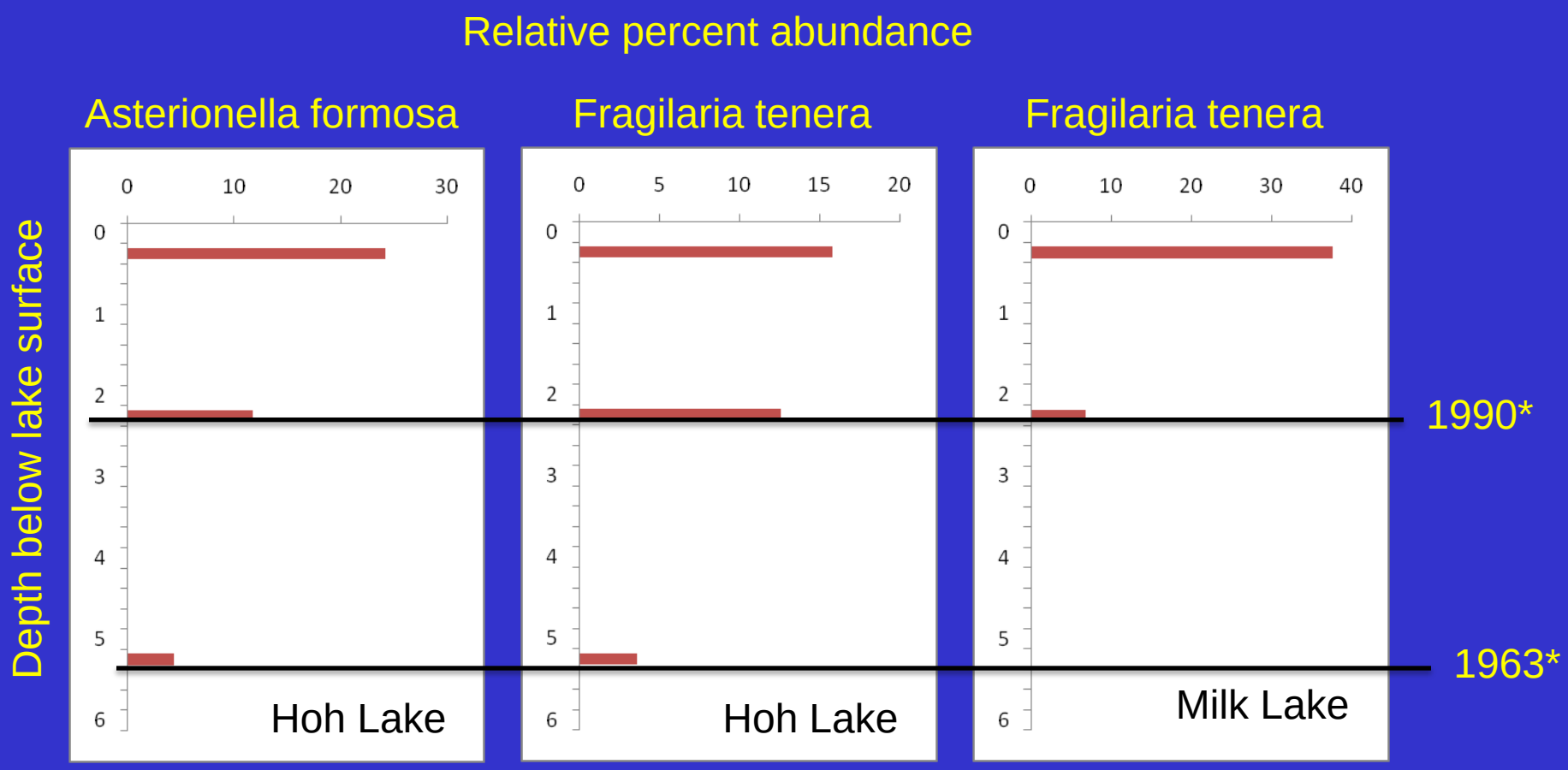
Diatom profiles, so far



* Approximate dates based on WACAP data for Hoh Lake

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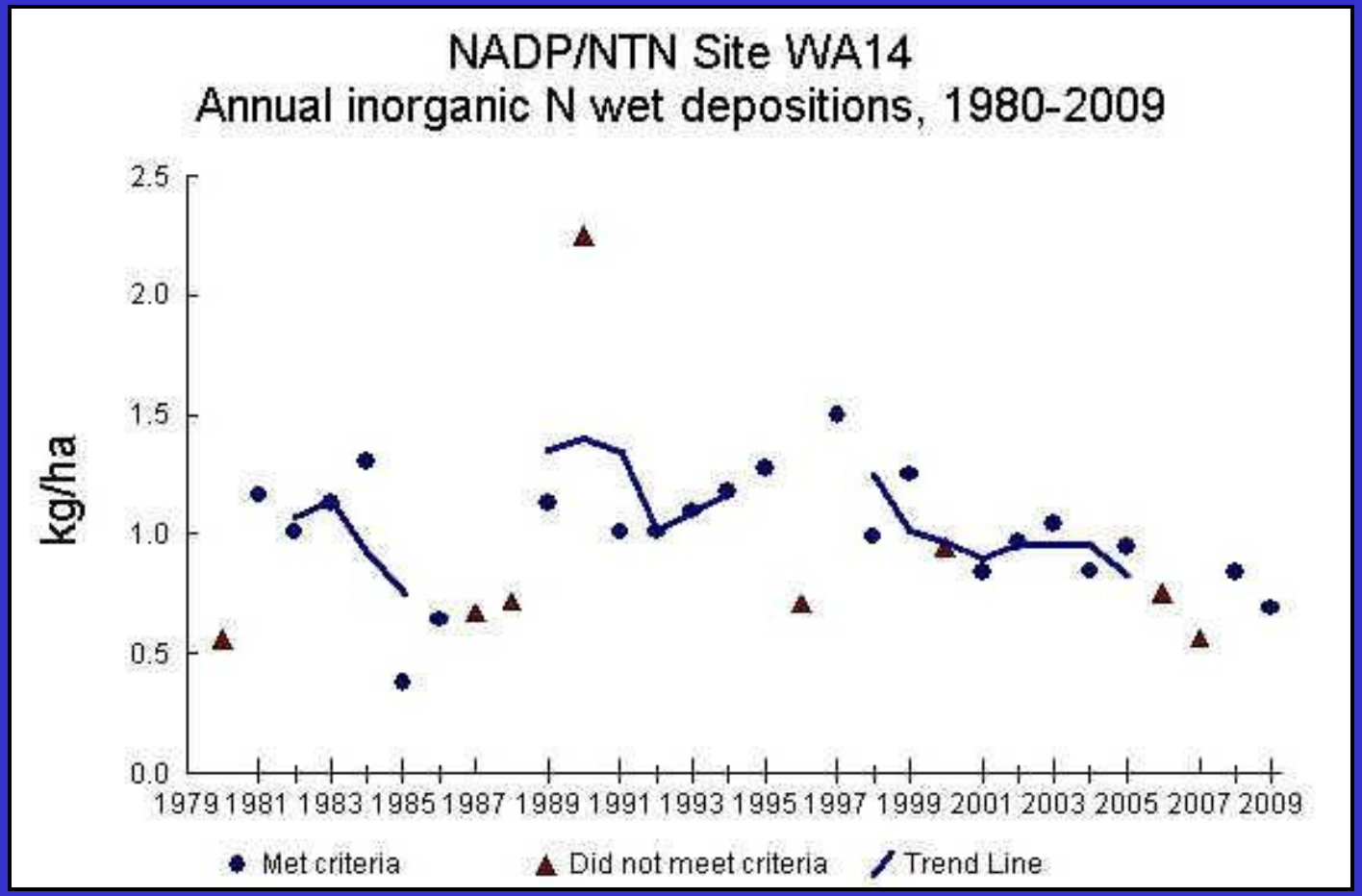
Deposition data summary - OLYM



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 ?

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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’

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Questions?