

Mountain blues to blue-greens?
Watershed, lake, & food web factors influence N-fixing cyanobacteria in mountain lakes

OLA CyanoHAB Meeting
Lara Jansen, Dan Sobota, Yangdong Pan, Angela Strecker

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Cyanobacterial blooms can happen anywhere?

Highly productive

Lake Okeechobee

Moderately productive

Three Mile Lake (CAN)

Low productive

Lake Superior

Under ice

Baltic Sea

Murukesan 2022; Reint et al. 2021, 2023

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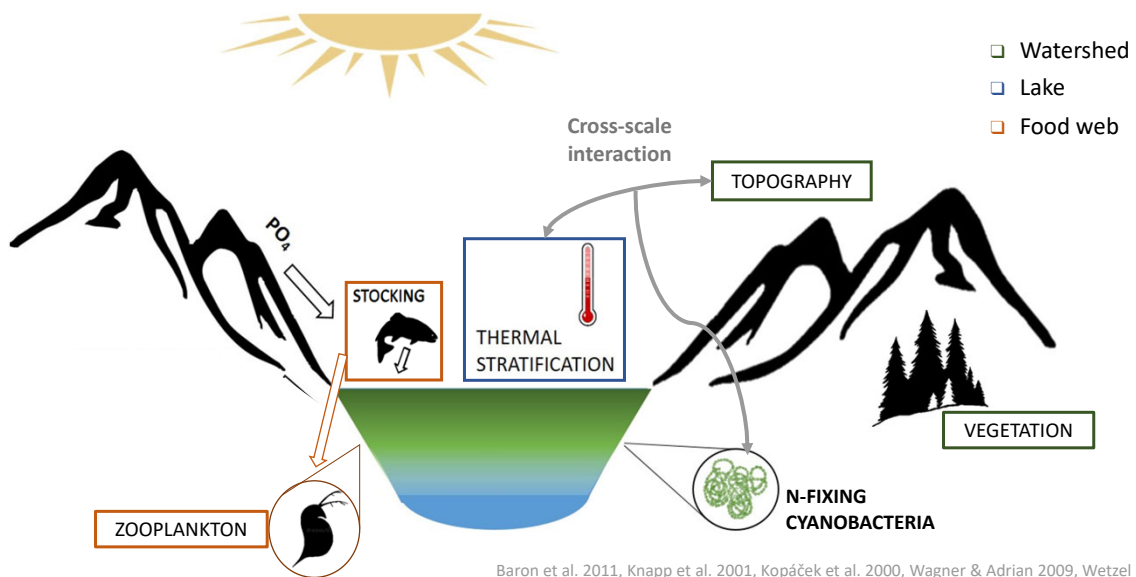
Cyanobacterial blooms in the high elevations



Johnson, Eilers

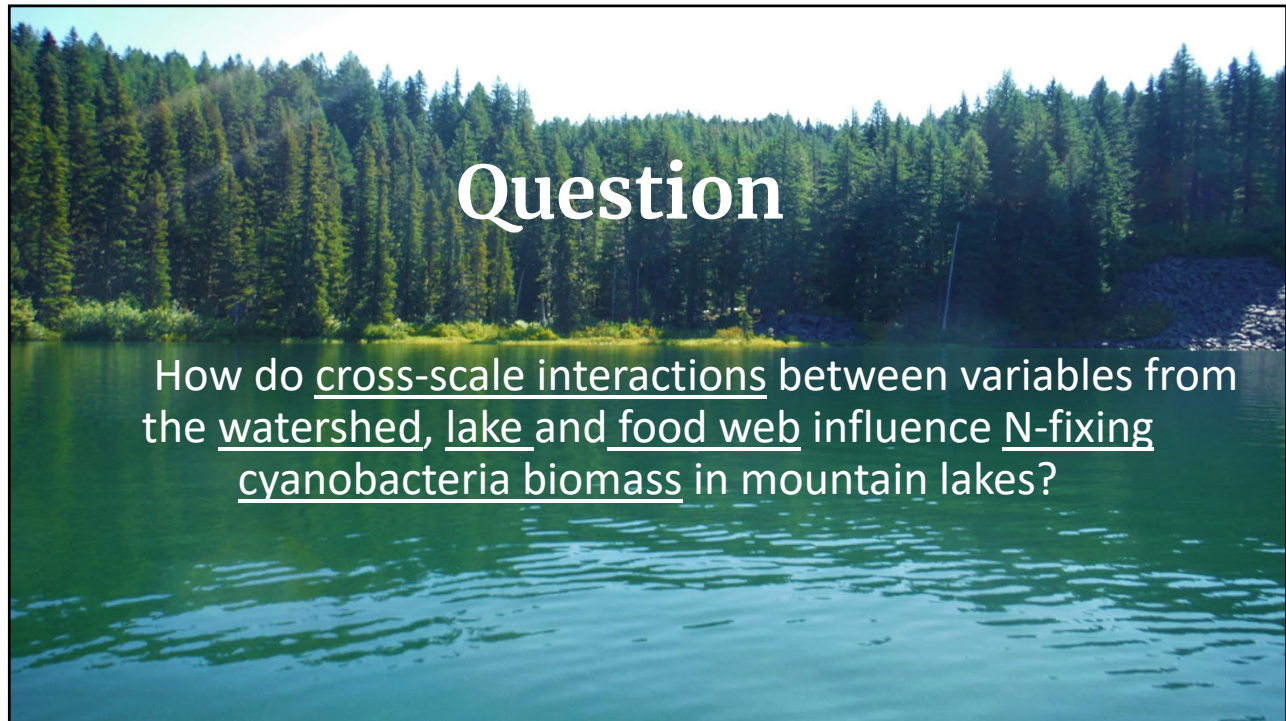
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Within a mountain range, potential primary drivers

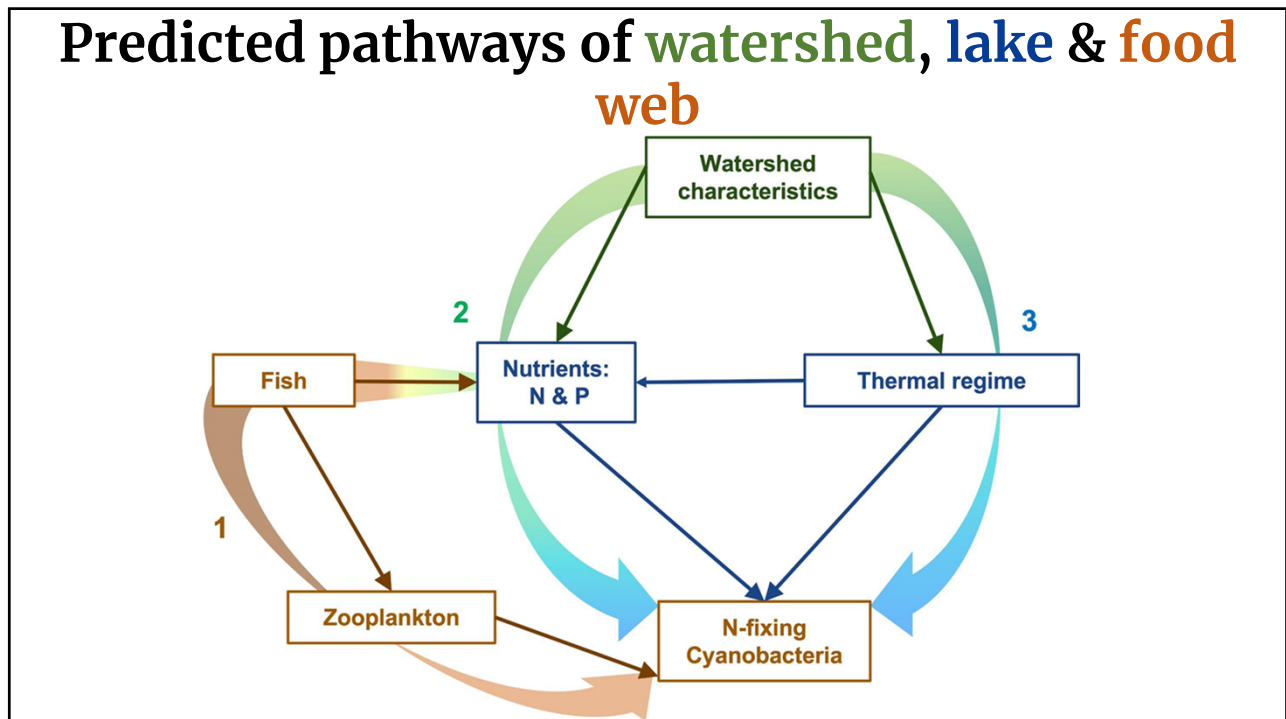


Baron et al. 2011, Knapp et al. 2001, Kopáček et al. 2000, Wagner & Adrian 2009, Wetzel 2001

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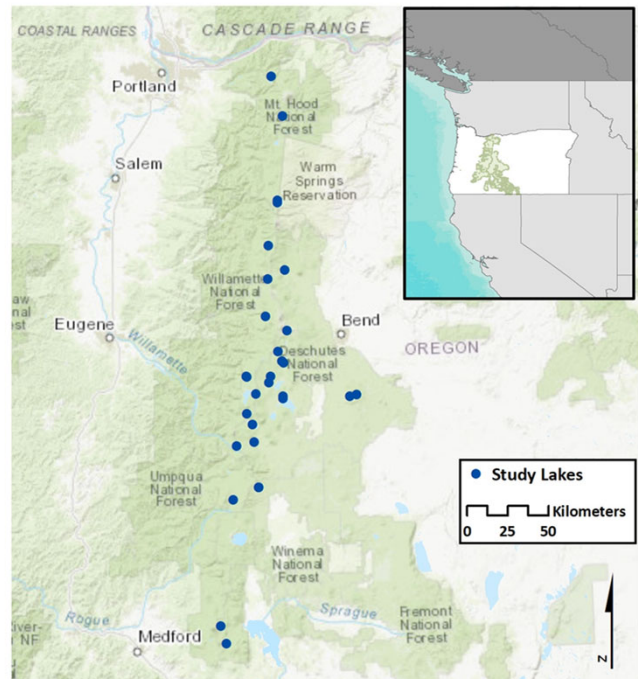
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Study selection

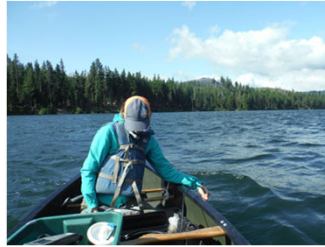
- Compilation of historic lake data
- Select lakes that span ranges of:
 - Total P
 - Elevation \approx Temperature
 - Fish stocking
- 29 lakes selected with ranges of:
 - P: 1-150 $\mu\text{g/L}$
 - Elevation: 960-1,980 m
 - Fish stocking: 0-130 kg/ha



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Data collection

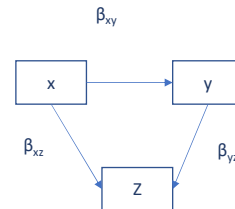
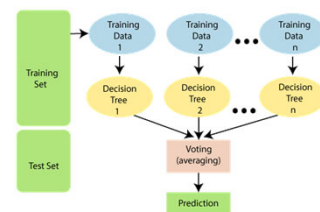
- Field collection periods: early and late Summer 2019
- Collection at the deepest point in the lake
 - Depth profile-WQ
 - 5m integrated nutrient samples
 - Phytoplankton taken at 1m
 - Zooplankton tow of entire depth
- ODFW fish stocking records
- Watershed data from: EPA LakeCat, Atlas of Oregon Lakes, PRISM, NADP, NOAA-NSIDC



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Statistical Analyses

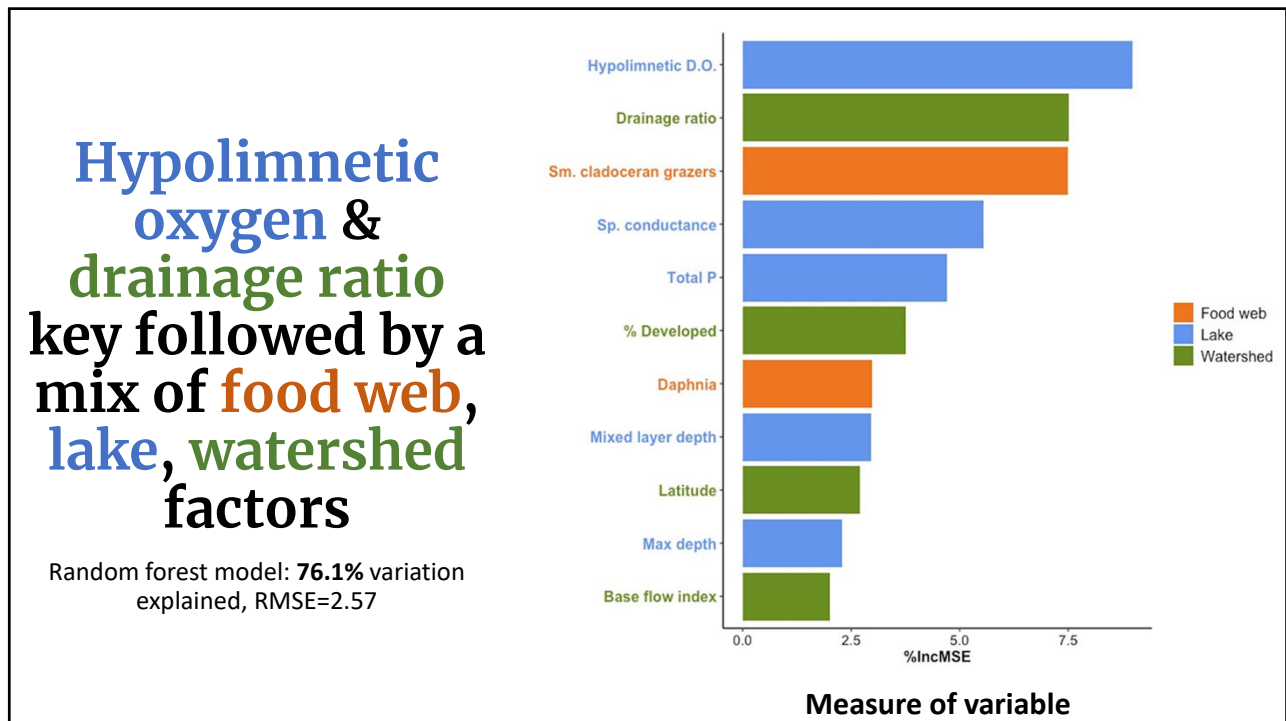
- **Broad:** Identify key food web, lake, & watershed predictor of **N-fixer cyanobacteria BV**
 - **Random Forest**- algorithm to determine 'best predictors' via parallel decision trees
- **Focused:** Test predicted pathways, selecting predictors based on prior knowledge and Random Forest results
 - **Structural Equation Modeling (SEM)**-path analysis based on maximum likelihood



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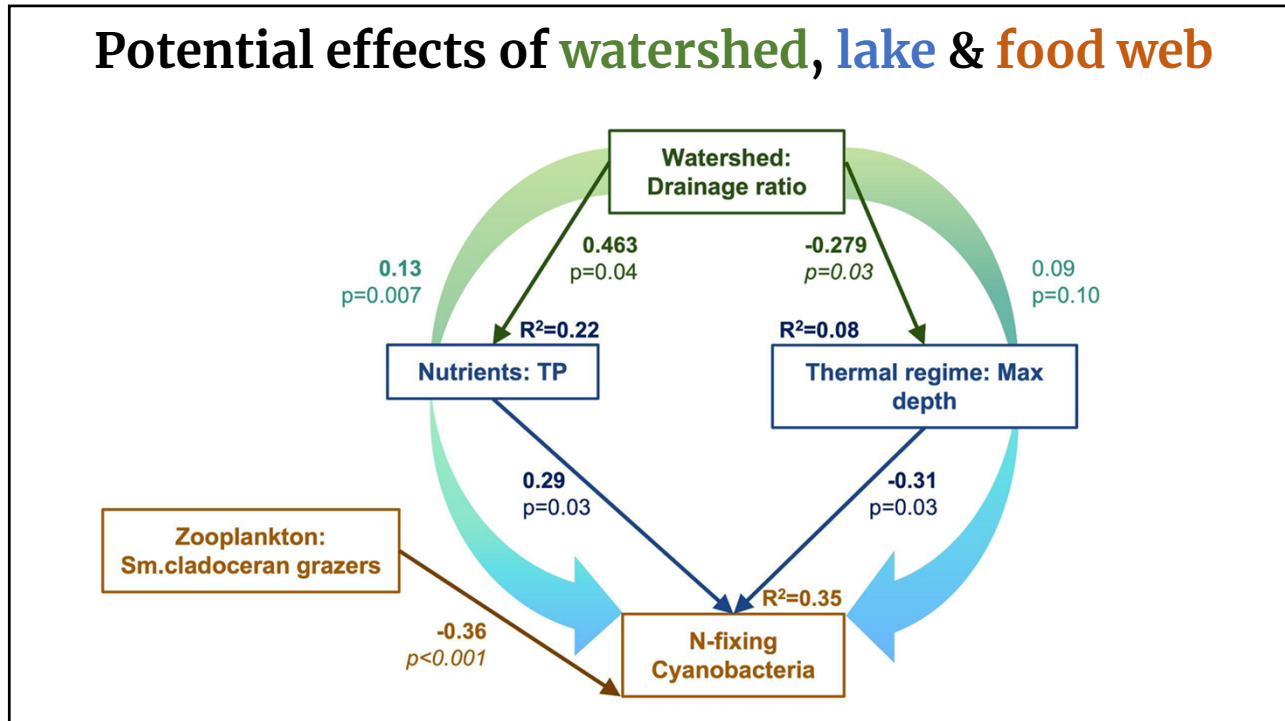


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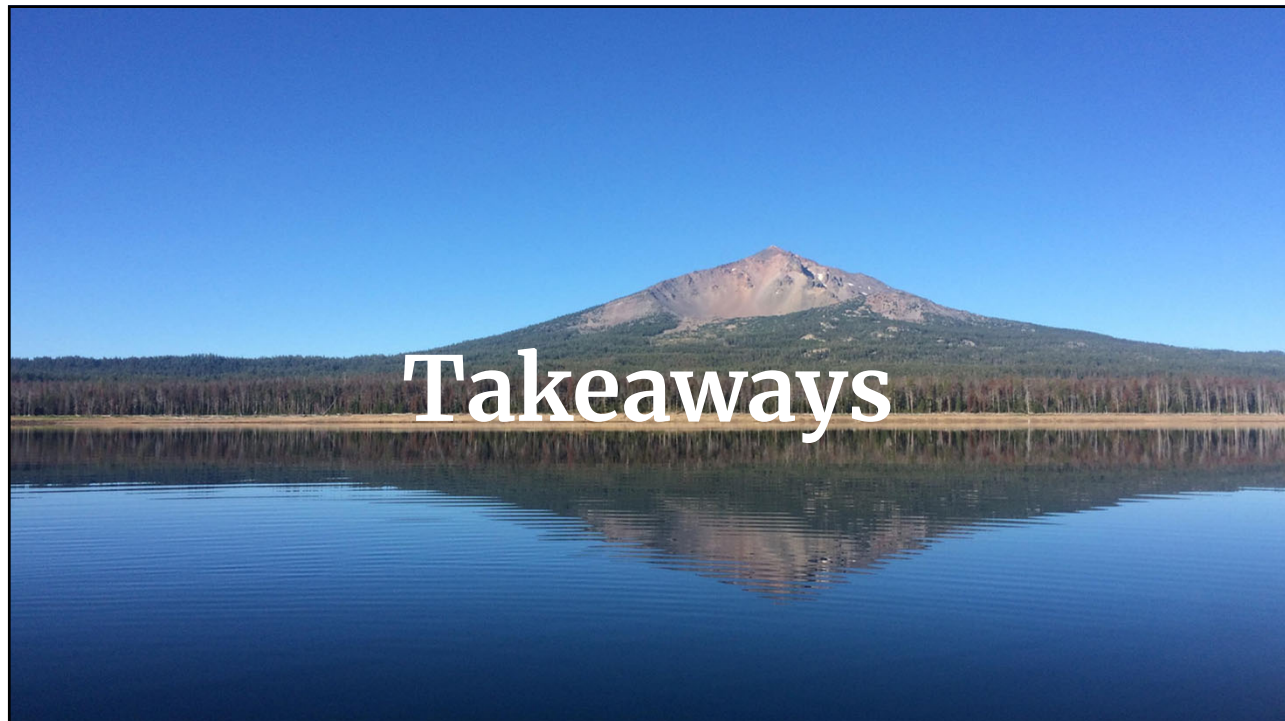


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Potential effects of watershed, lake & food web



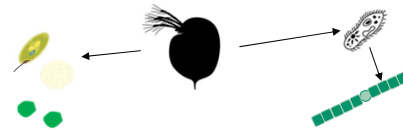
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Watershed size, depth and grazers all play a role

1. **Lake–Watershed:** watershed size drives nutrient export with potentially more P than N in the mountain forests²
2. **Lake: P** is key, which is affected by low hypolimnetic oxygen & depth³
3. **Food web:** Small cladocerans are less efficient grazers than large cladocerans, allowing:
 - o other algae to compete with N-fixers
 - o micrograzers of N-fixers to persist
 - o potential, but limited role of fish



1.DeMott 1982, Berquist et al. 1985, Reynolds 2006 2. Baron et al. 2011, Sadro et al. 2012, Williams et al. 2016 3. Nurnberg 1984, Karlsson-Elfgren 2004, Molot 2021

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Future research for mountain cyanoHABs

- **Critical P loads:** estimate in Western US mountains as P may be ↑
- **Food web:** experiments with grazing community via fish manipulation
 - o Ex: Diamond Lake¹
- **Watershed:** identify other lakes vulnerable to cyanoHABs with geospatial & satellite data²

1.Eliers 2011, 2023 2. Schaeffer et al. 2018

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