Critical Nitrogen Deposition Loads in High-Elevation Lakes of the Western U.S. Inferred from Shifts in Diatom Community Structure

Jasmine Saros
University of Maine

David Clow
U.S. Geological Survey

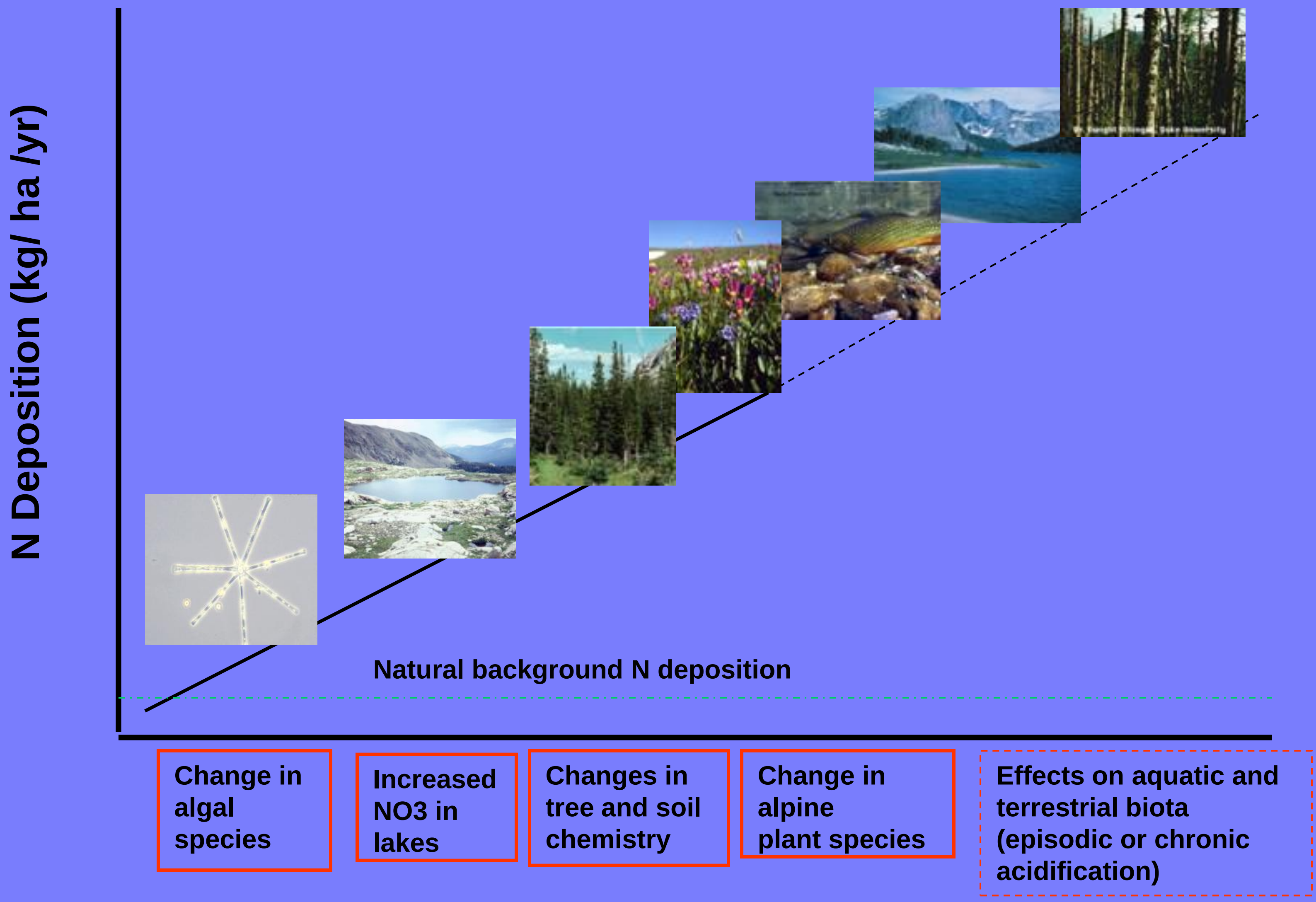
Tamara Blett
National Park Service

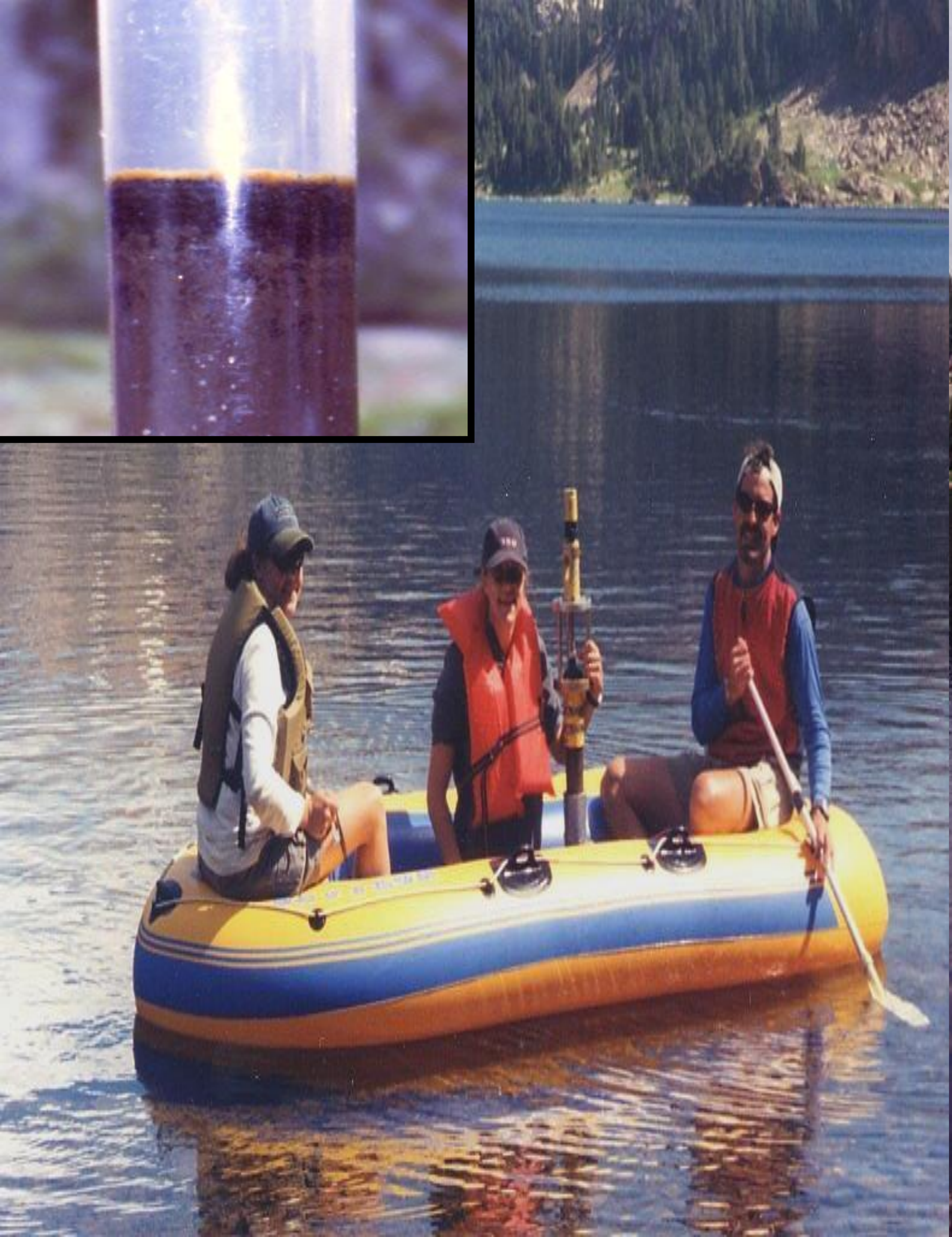
Alex Wolfe
University of Alberta

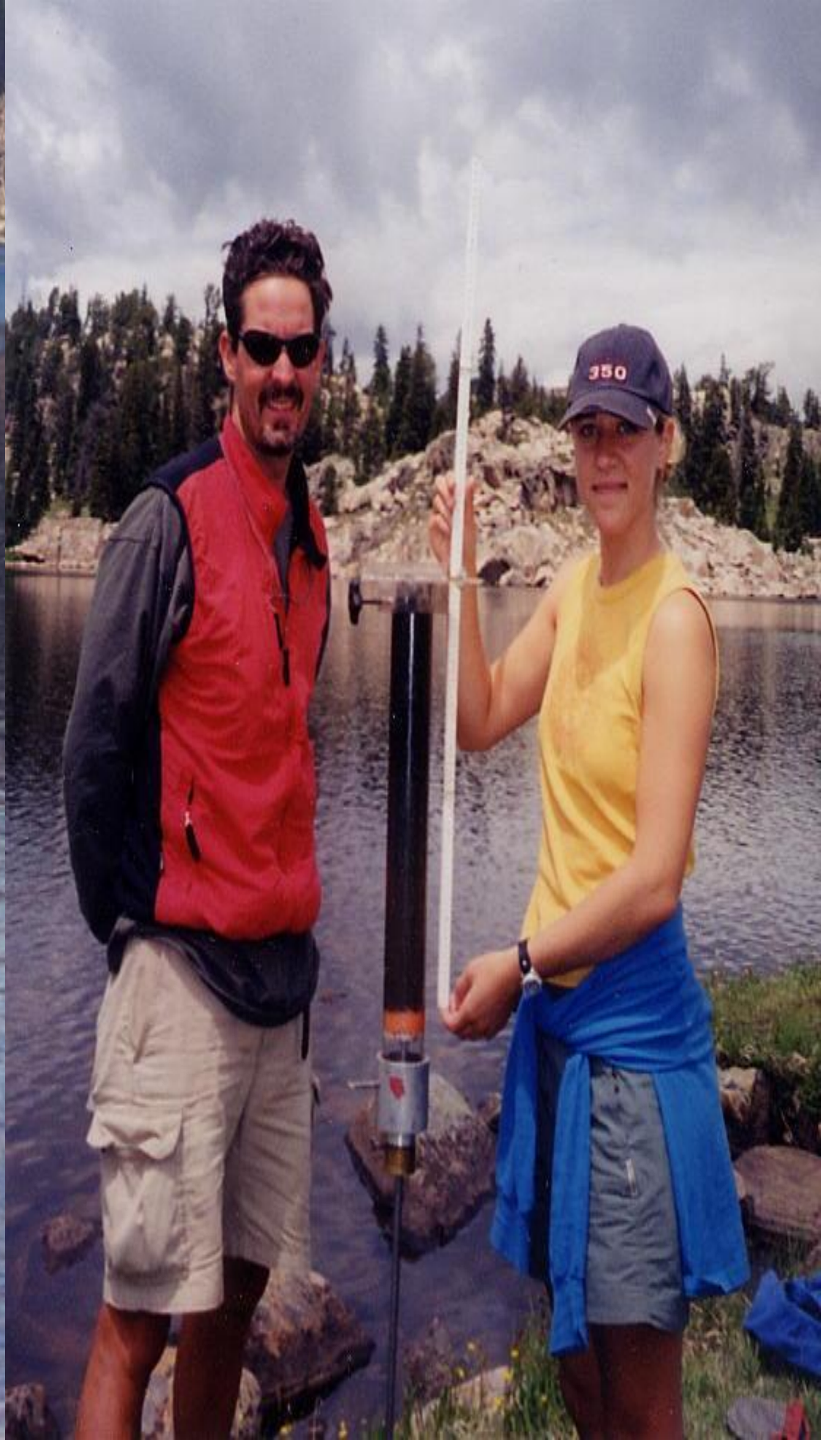
Critical loads of N deposition

- Now a frequently used method to quantify ecosystem response to N deposition
- Terrestrial plants and lichens yield a critical N load of 3.1 to 10 kg ha^{-1} yr^{-1} in western U.S. ecosystems (e.g., Bowman et al. 2006; Fenn et al. 2008)
- The use of thresholds to adequately prevent ecosystem degradation, however, has been questioned recently (Schlesinger 2009)

Sensitivity of diatoms to N deposition



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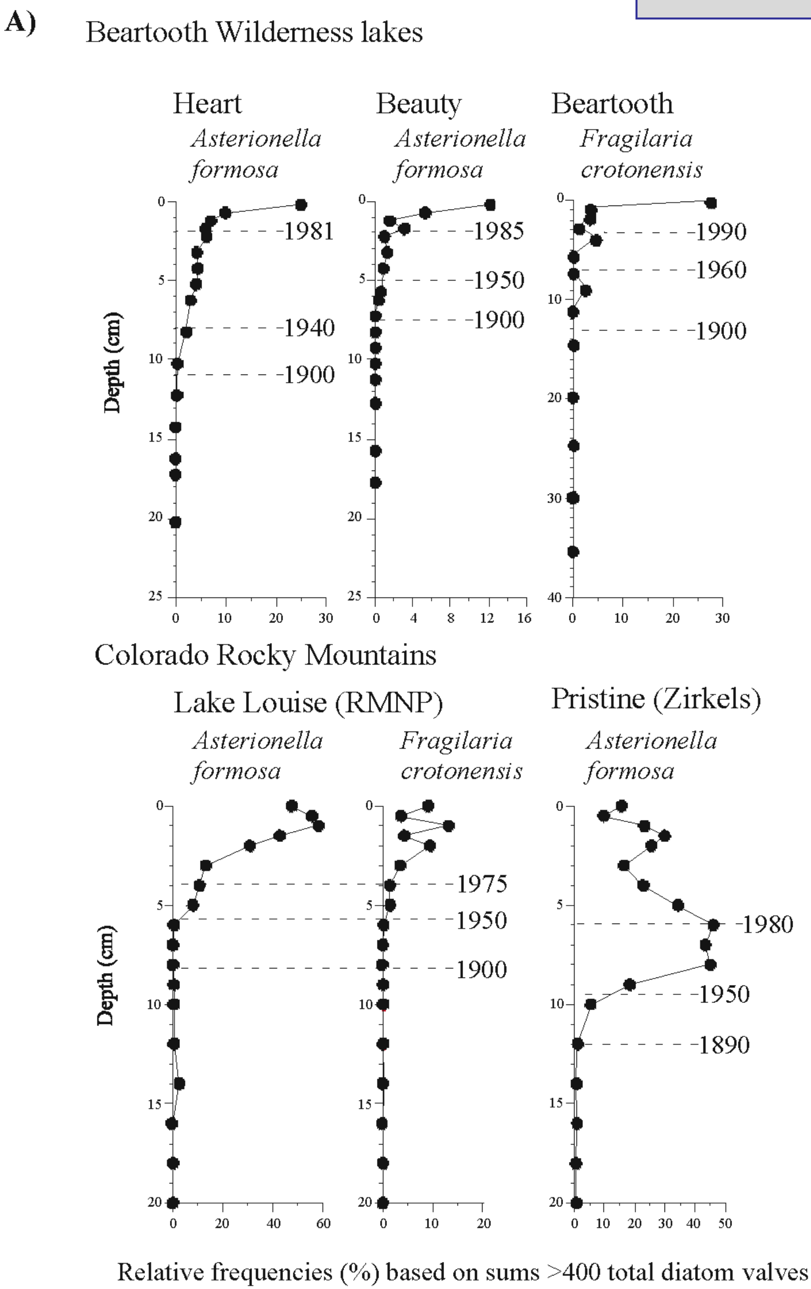
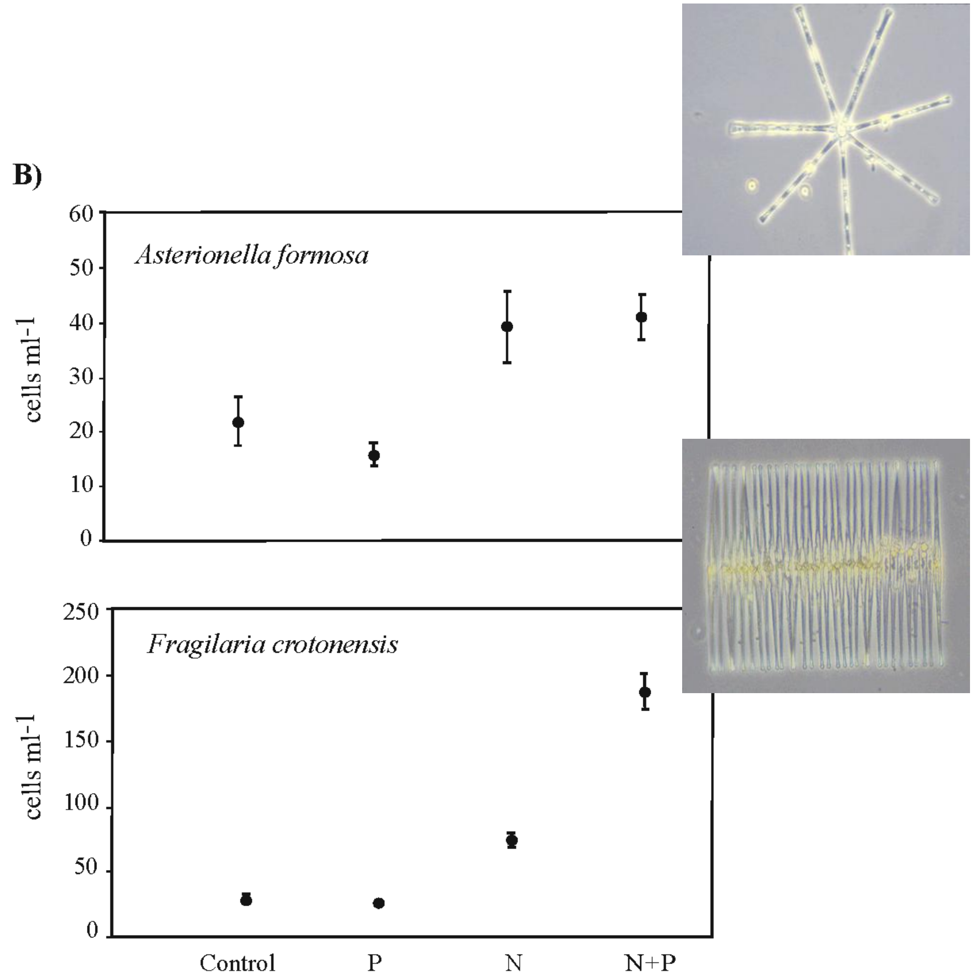
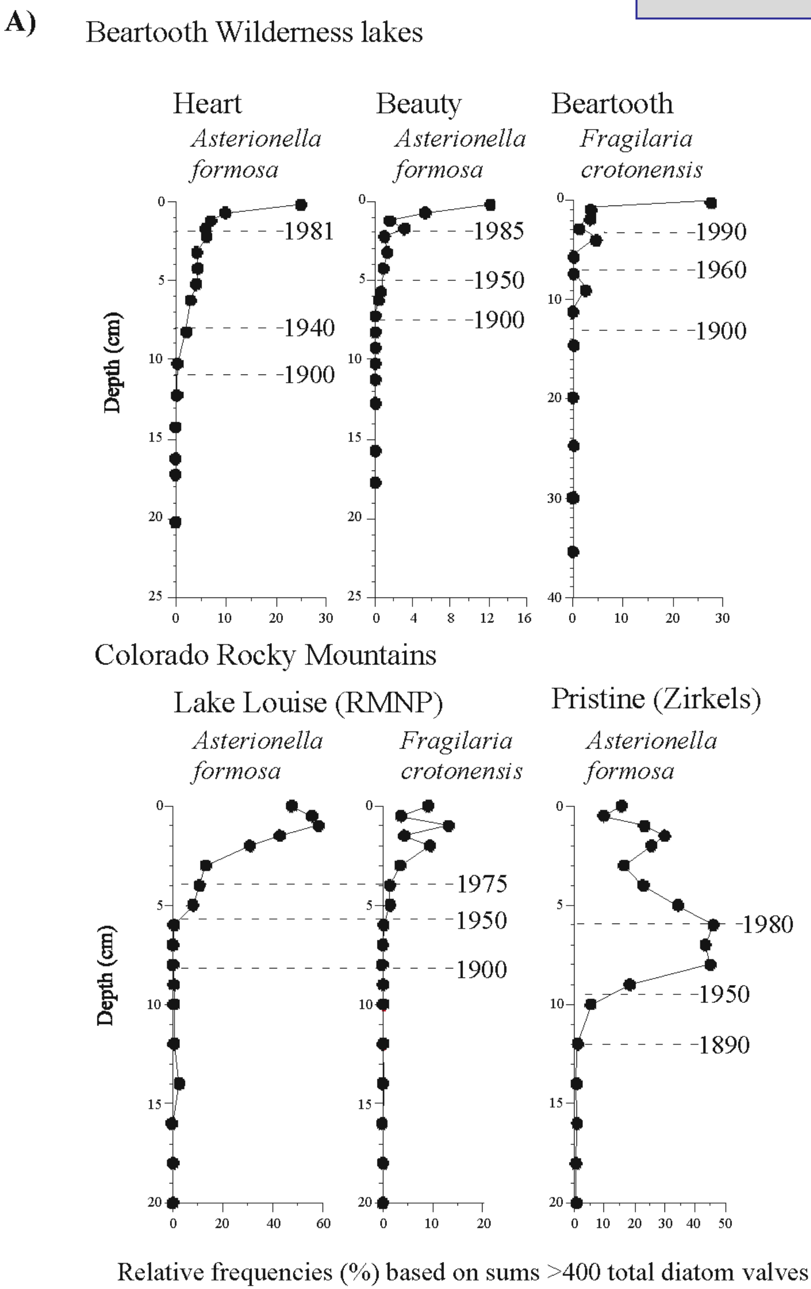
These species respond to nitrogen

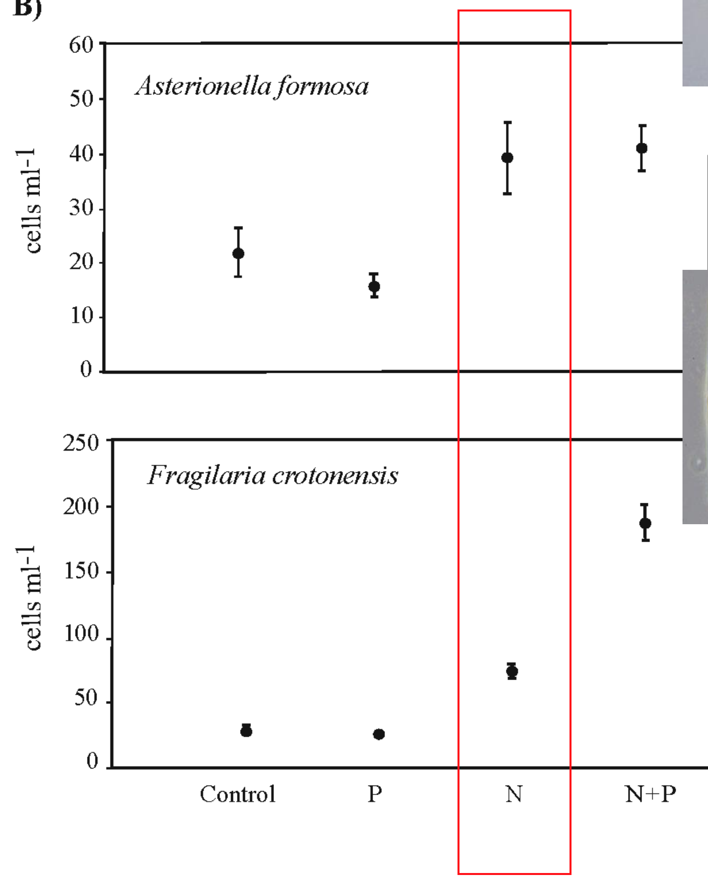


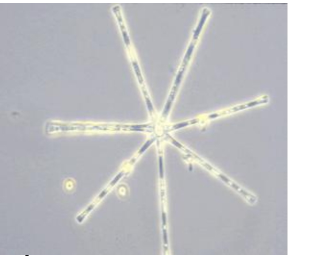


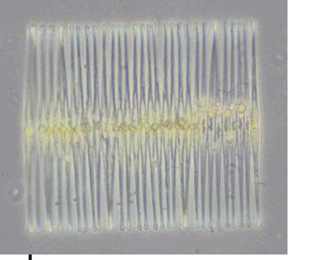
Saros et al. 2005

These species respond to nitrogen



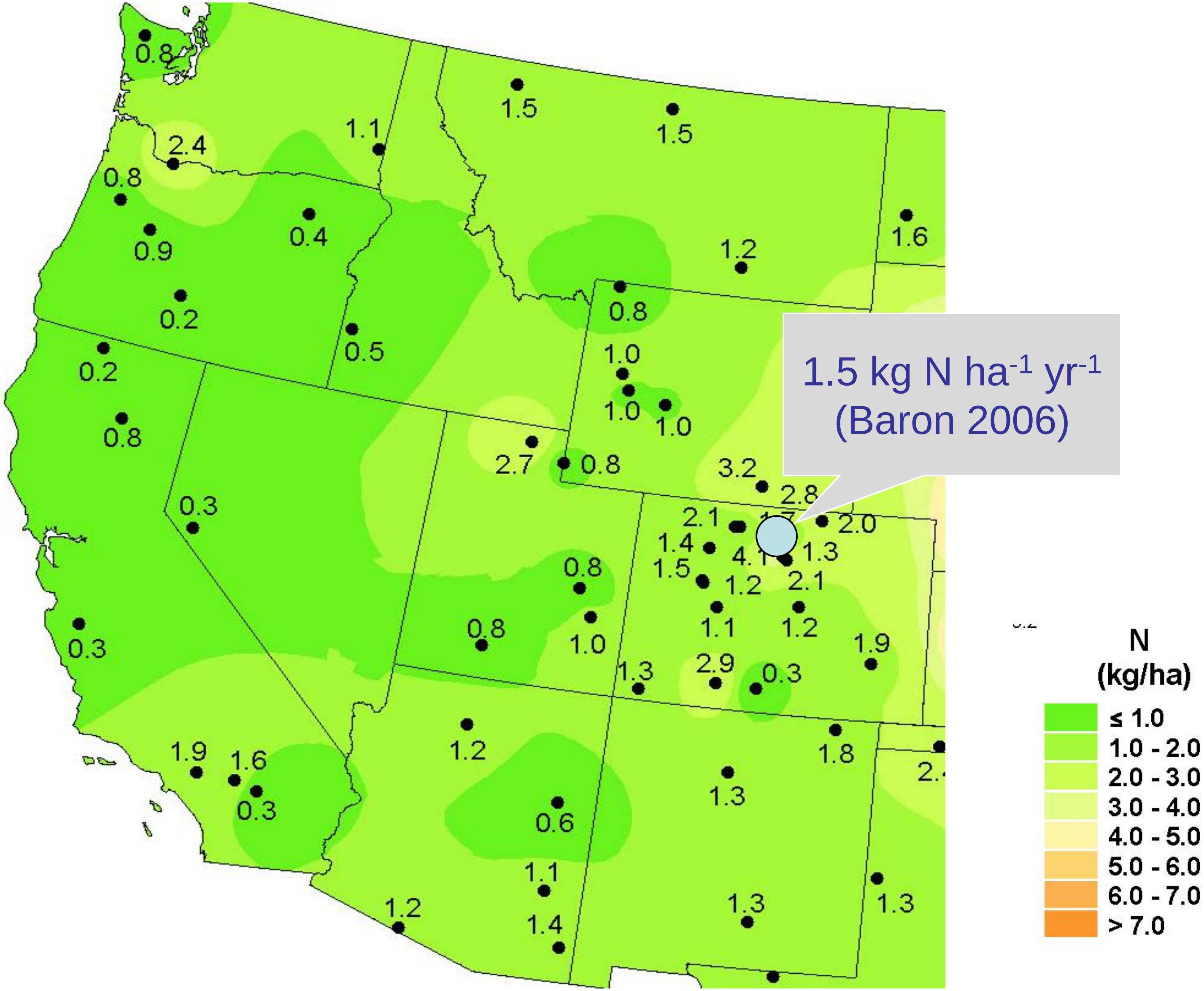




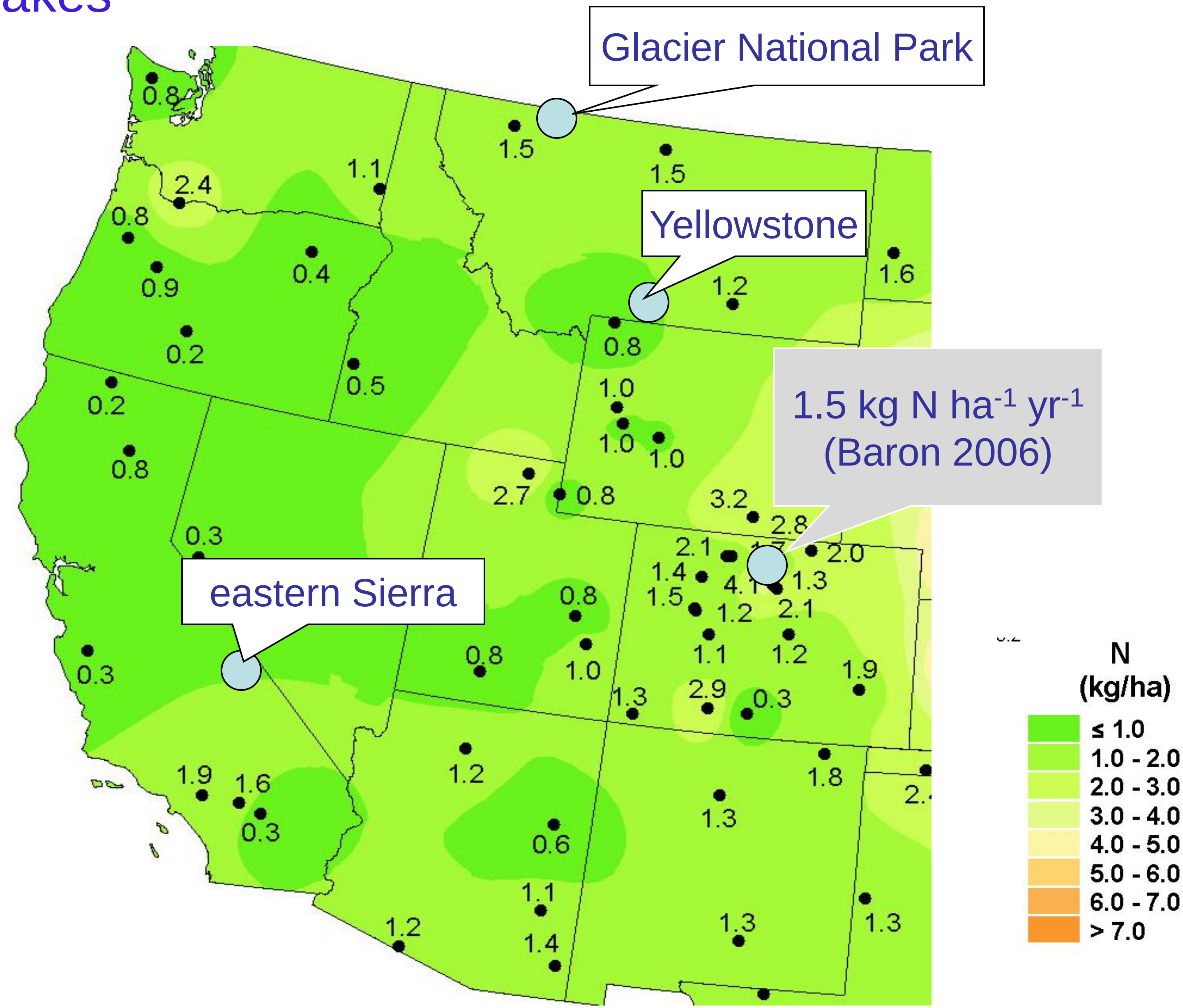


Saros et al. 2005

Fossil diatom profiles used to establish critical N load for high elevation lakes in Rocky Mountain National Park



Establish critical N loads for enrichment effects in high elevation lakes



Defining a critical load from diatom fossils

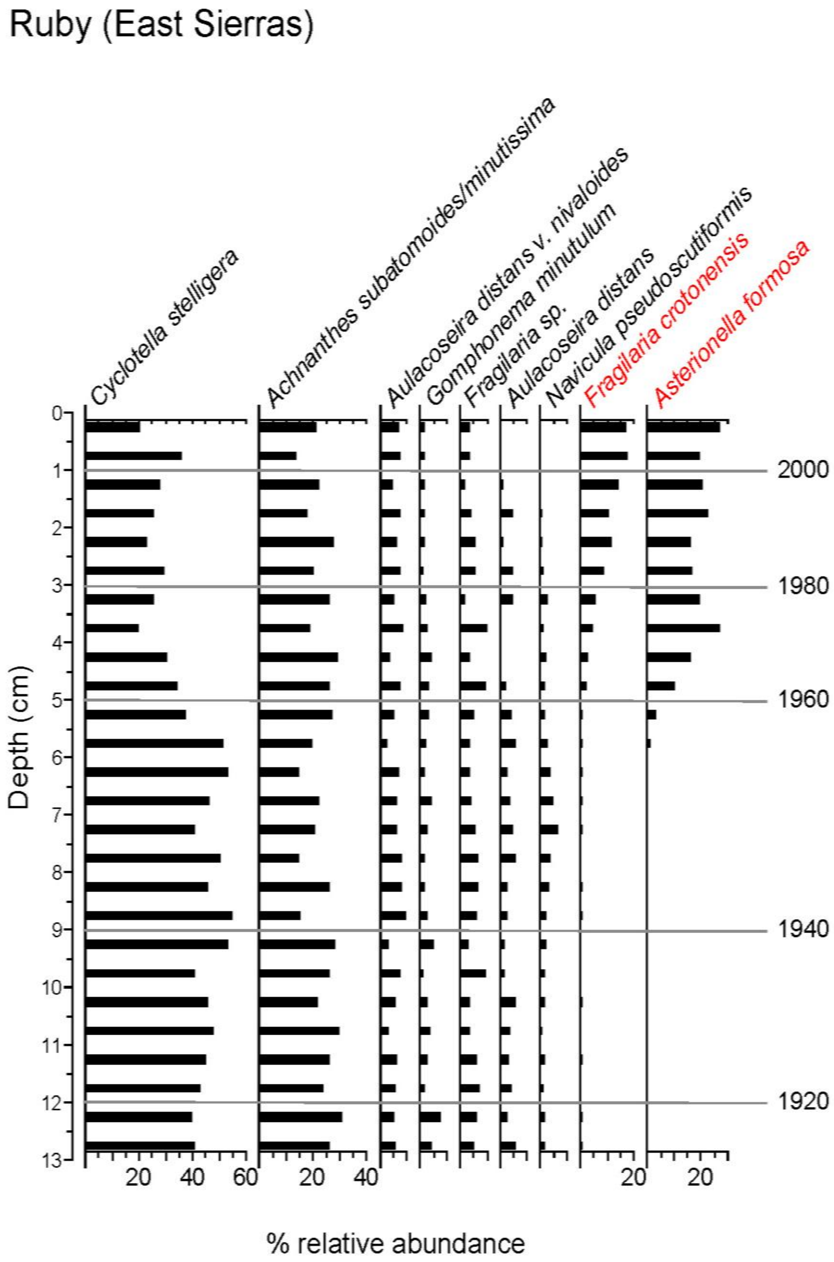
Using the methods of Baron (2006)

1. Determine the time frame in which key diatom taxa changed
   - Here, we used the time frame in which the relative abundances of key diatoms doubled and exceeded 5% of the total assemblage

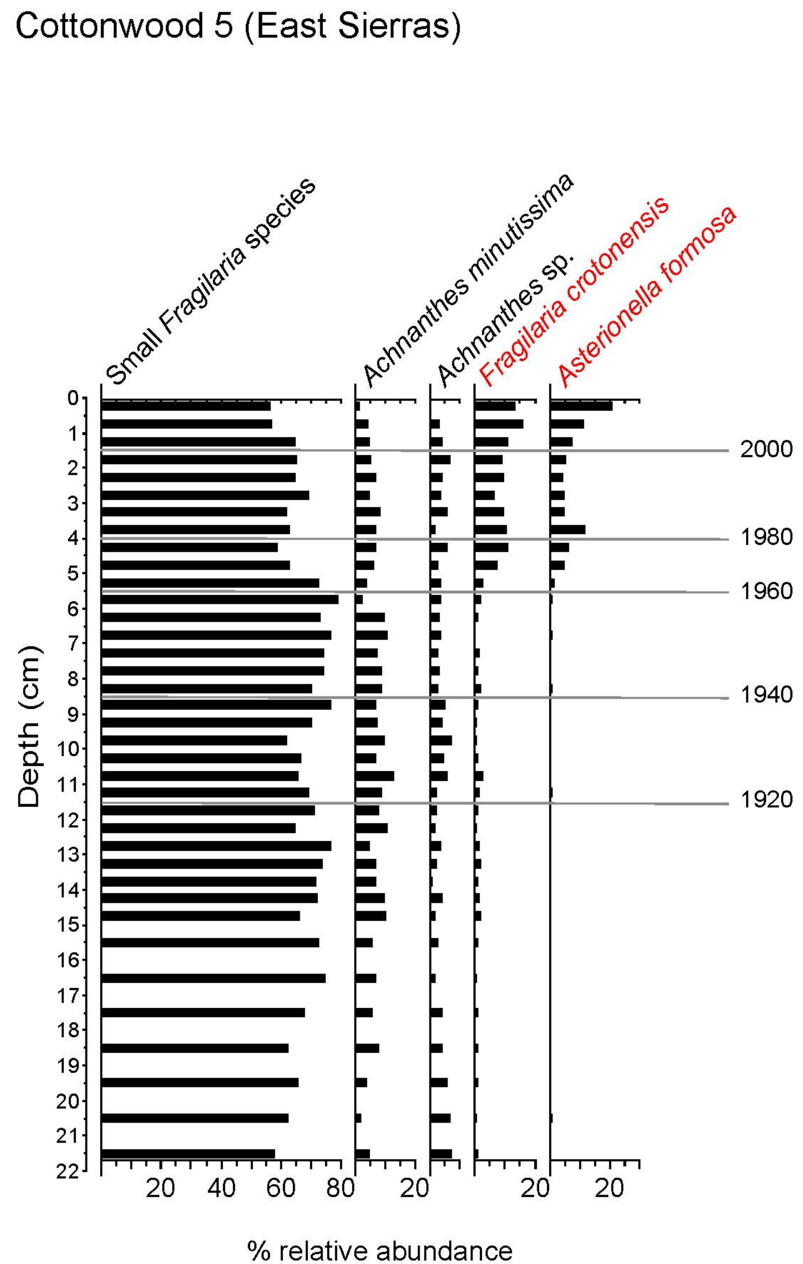
2. Hindcast to time period of interest using NADP data to determine CL
   - We assumed an exponential increase in total wet inorganic N deposition, as in Baron (2006)
   - Note that we only modeled wet deposition

Selected lakes

Region	Lake	Elev (m. a.s.l.)	Surface area (ha)	Alkalinity (ueq L^{-1})	Nitrate (ug L^{-1})
Yellowstone	Island	2901	60.7	116	4
	Heart	3162	16.6	NA	1
Glacier	Old Man	2215	18.2	1574	<1
	Snyder	1585	2.6	162	20
E Sierra	Cottonwood #5	3729	10.7	110	<1
	Ruby	3667	14.5	23	5



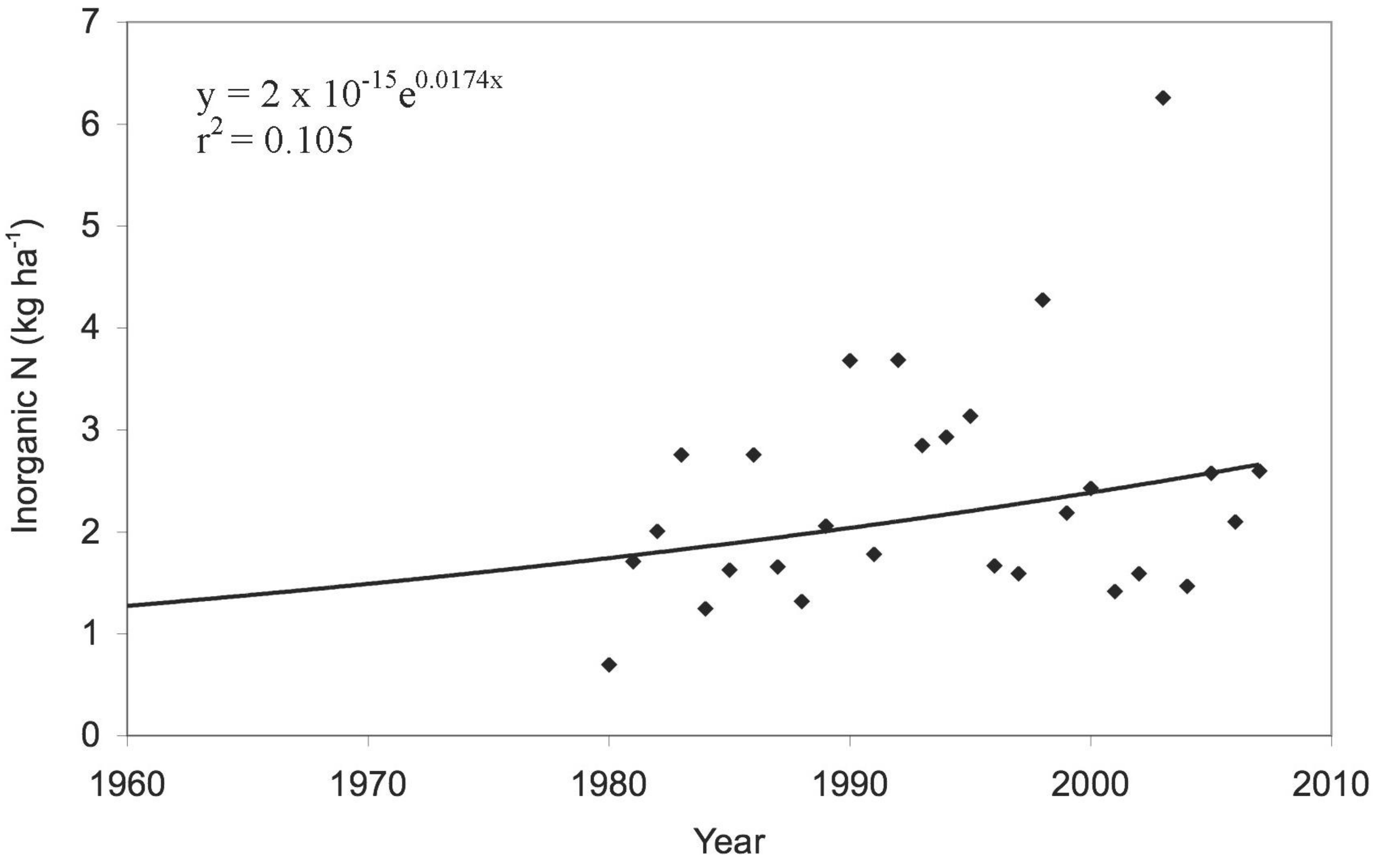
Ruby (East Sierras)
Cyclotella stelligera
Achnanthes subatomoides/minutissima
Aulacoseira distans v. nivaloides
Gomphonema minutulum
Fragilaria sp.
Aulacoseira distans
Navicula pseudoscutiformis
Fragilaria crotonensis
Asterionella formosa
Depth (cm)
2000
1980
1960
1940
1920
% relative abundance



Cottonwood 5 (East Sierras)
Small Fragilaria species
Achnanthes minutissima
Achnanthes sp.
Fragilaria crotonensis
Asterionella formosa
Depth (cm)
2000
1980
1960
1940
1920
% relative abundance

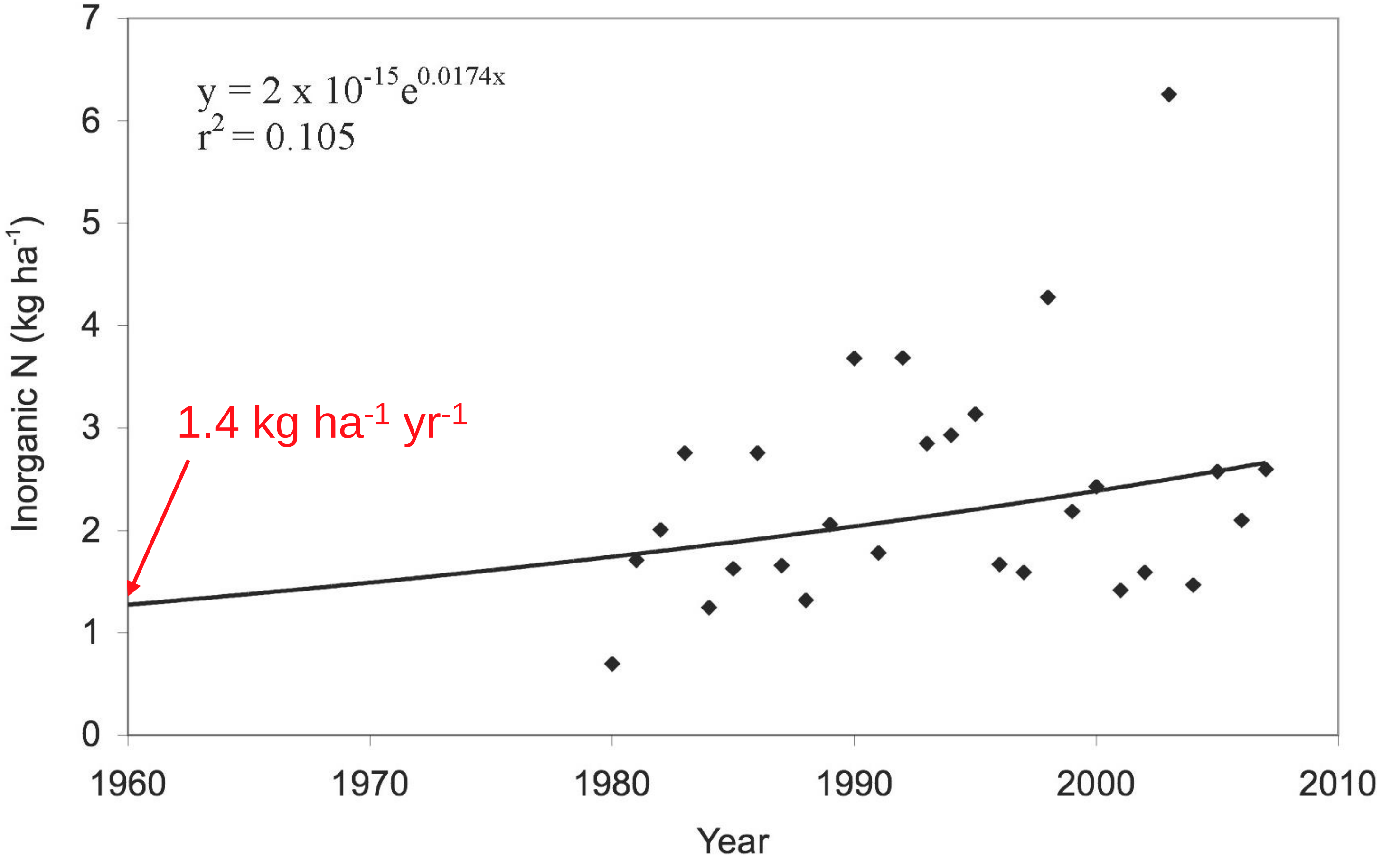
NADP data used to hindcast N deposition rates during period of diatom shifts

West Sierra deposition station data

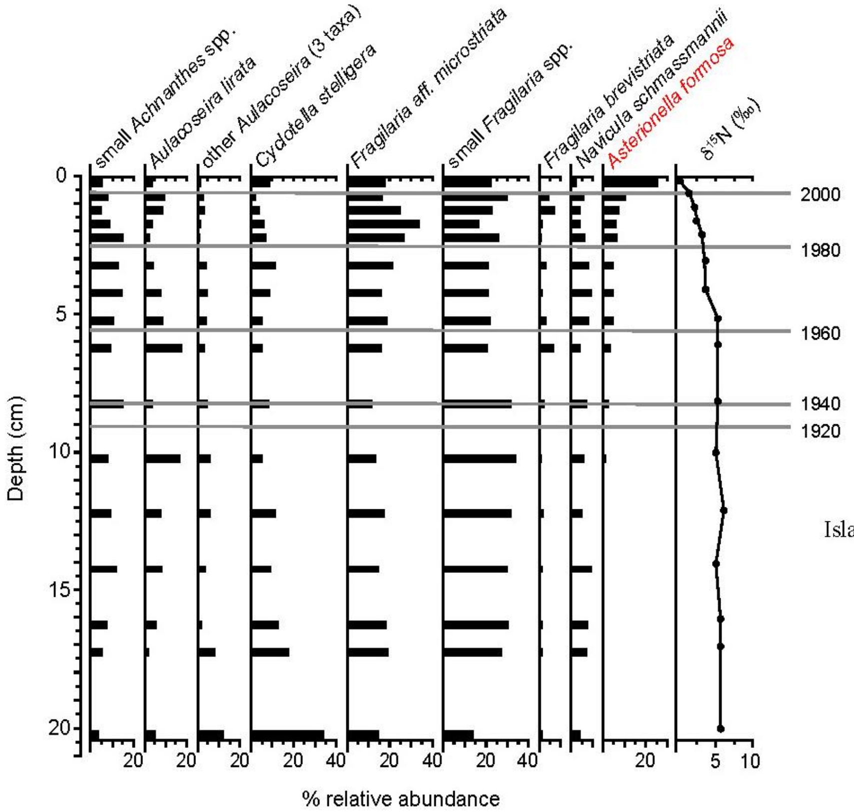


Determined a critical load of 1.4 kg ha^{-1} yr^{-1} total wet N deposition

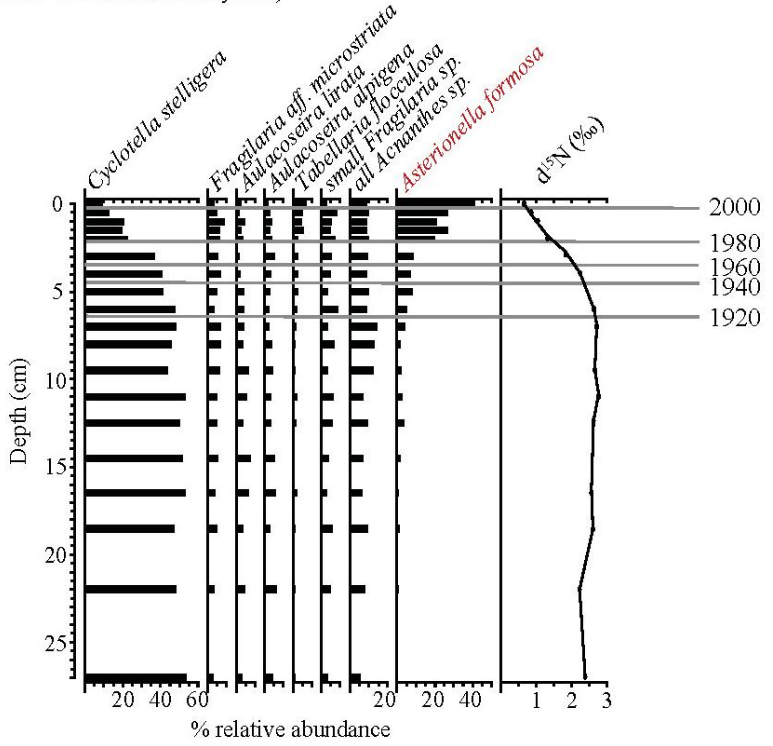
West Sierra deposition station data

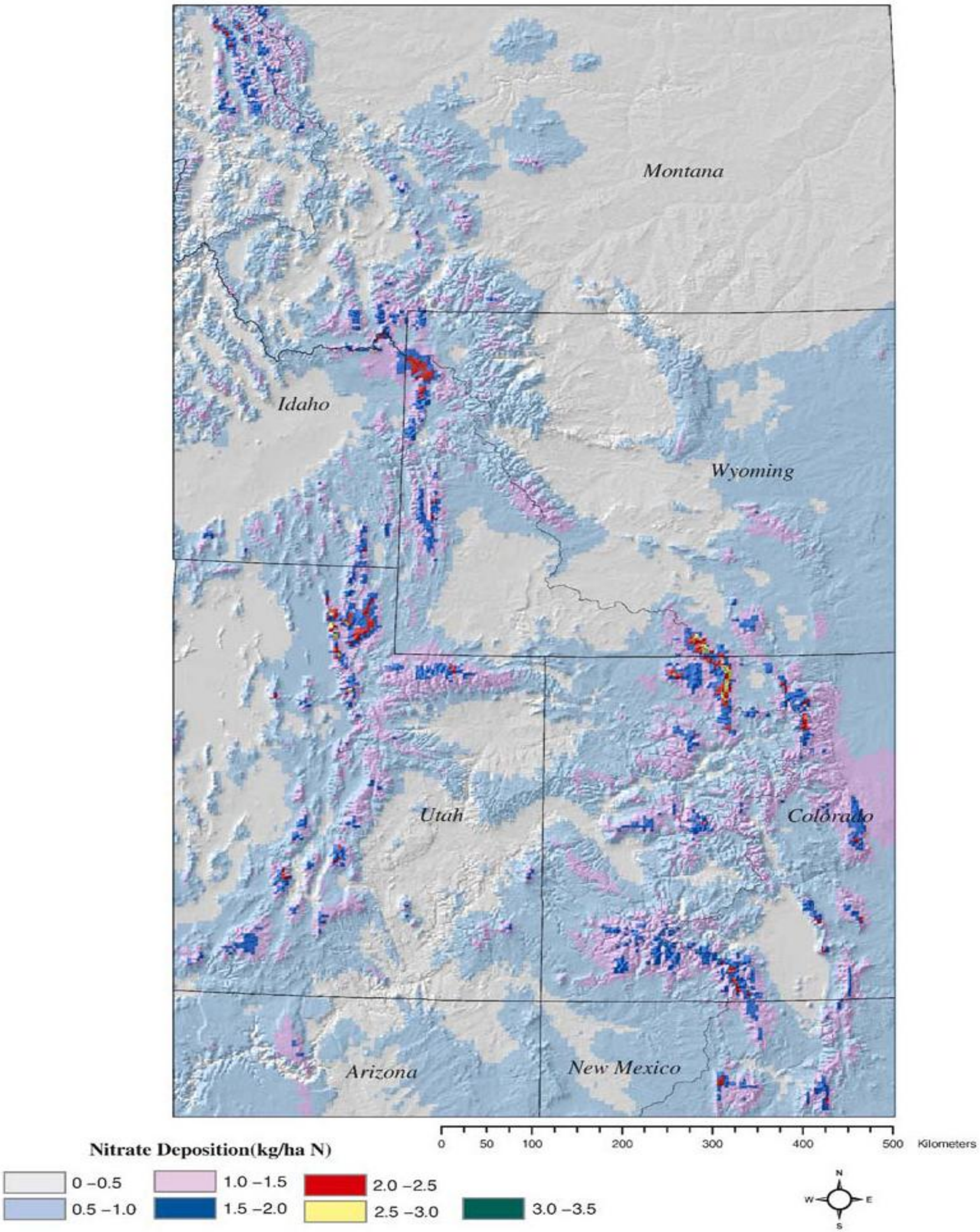


Heart Lake (Greater Yellowstone Ecosystem)



Island Lake (Greater Yellowstone Ecosystem)

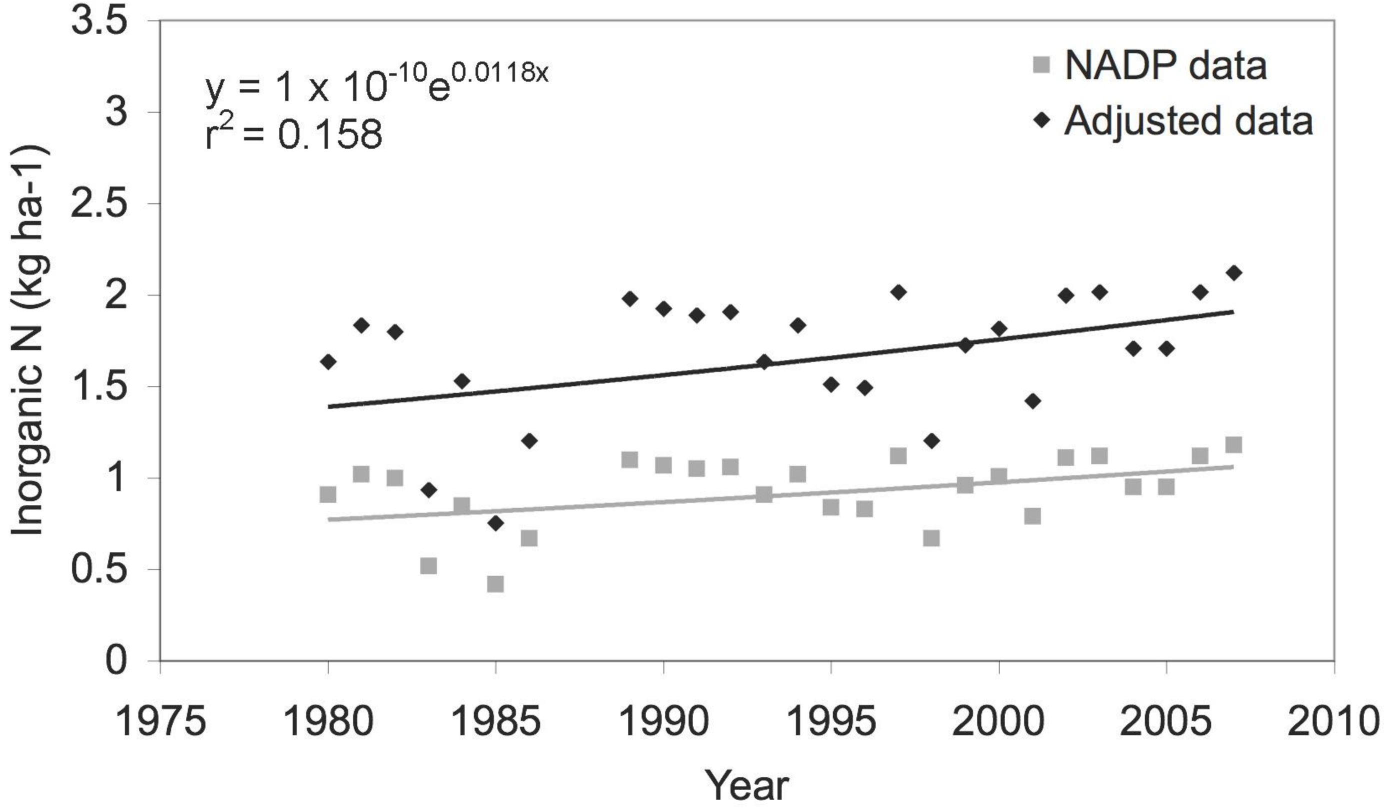




Nanus et al. 2003

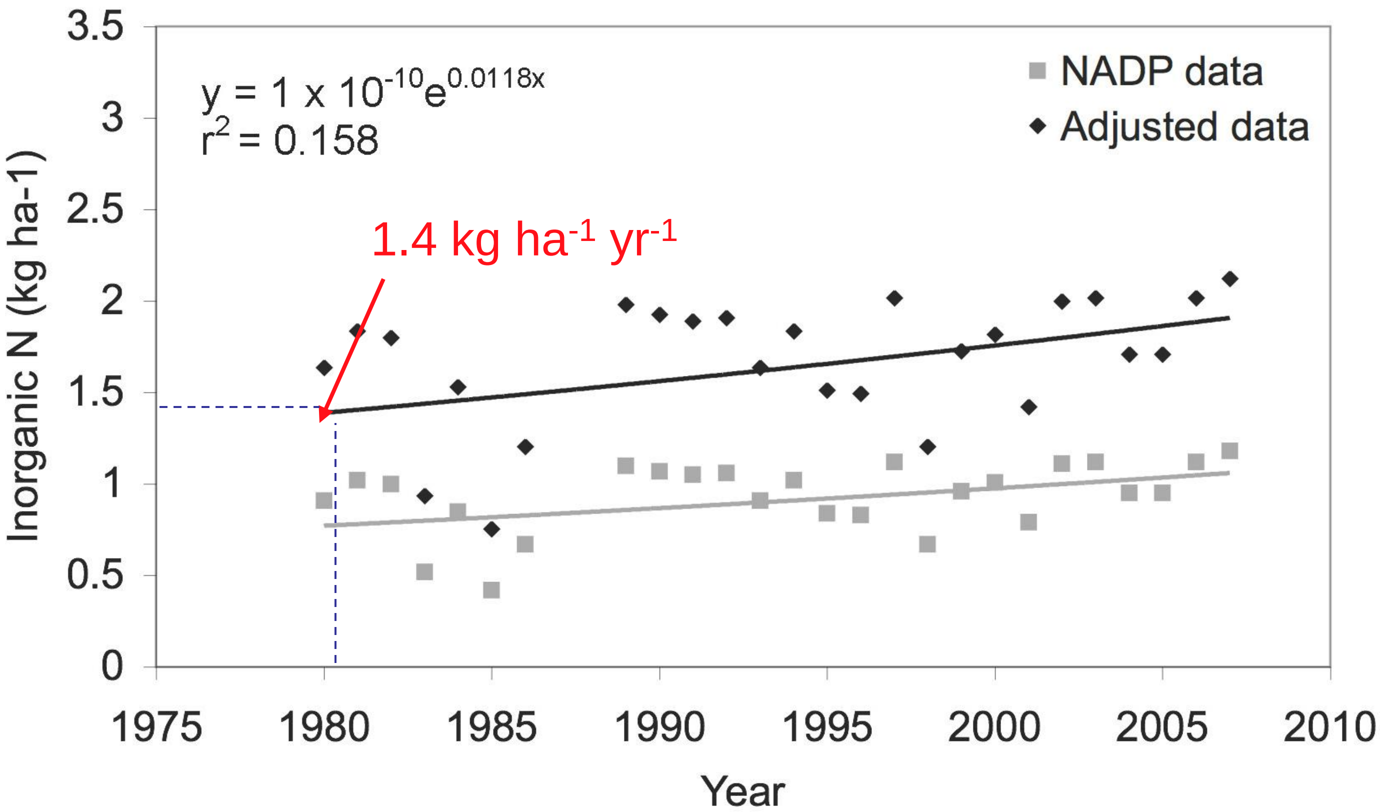
NADP data used to determine N deposition rates during period of diatom shifts

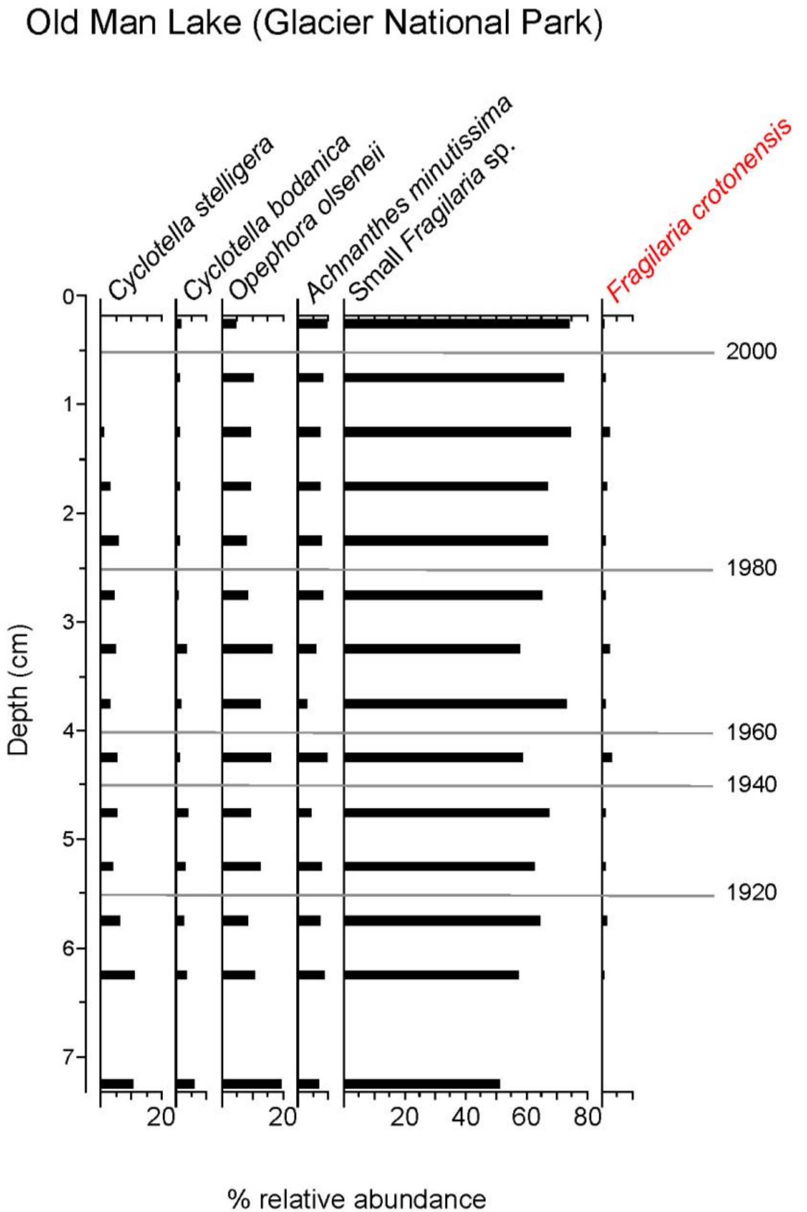
Yellowstone deposition station data



Determined a critical load of 1.4 kg ha^{-1} yr^{-1} total wet N deposition

Yellowstone deposition station data




Old Man Lake (Glacier National Park)
Cyclotella stelligera
Cyclotella bodanica
Opephora olseneii
Achnanthes minutissima
Small Fragilaria sp.
Fragilaria crotonensis
Depth (cm)
2000
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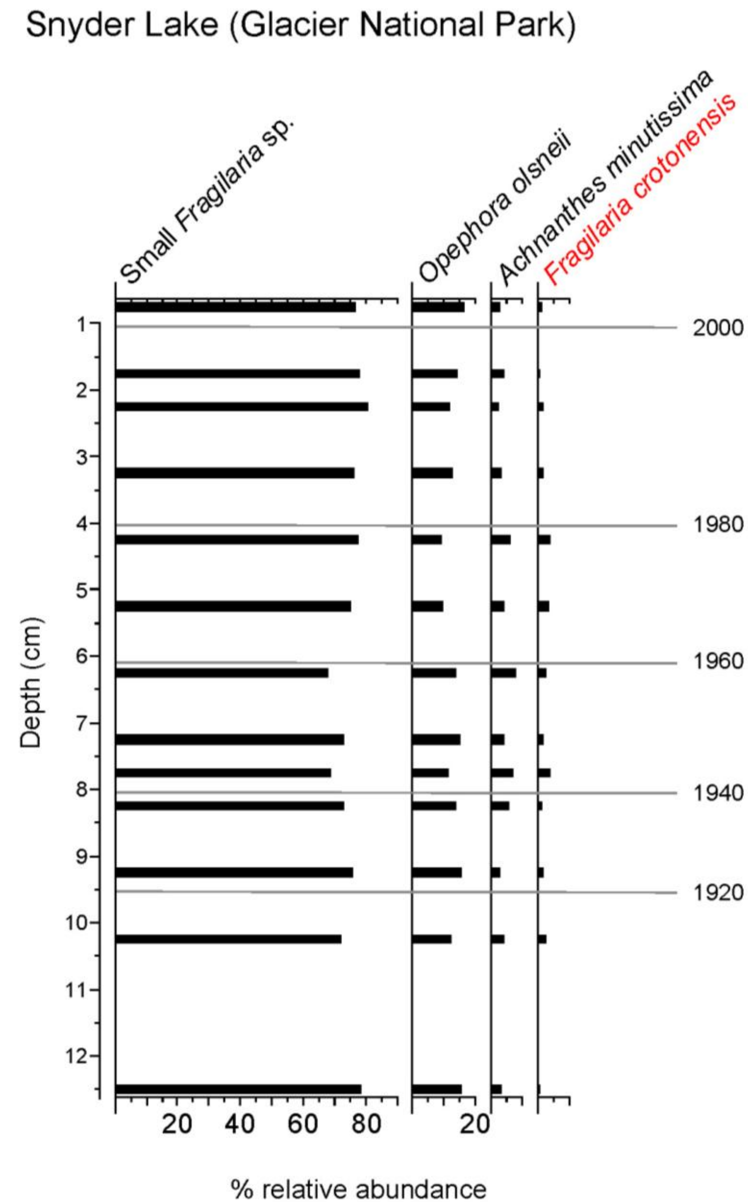
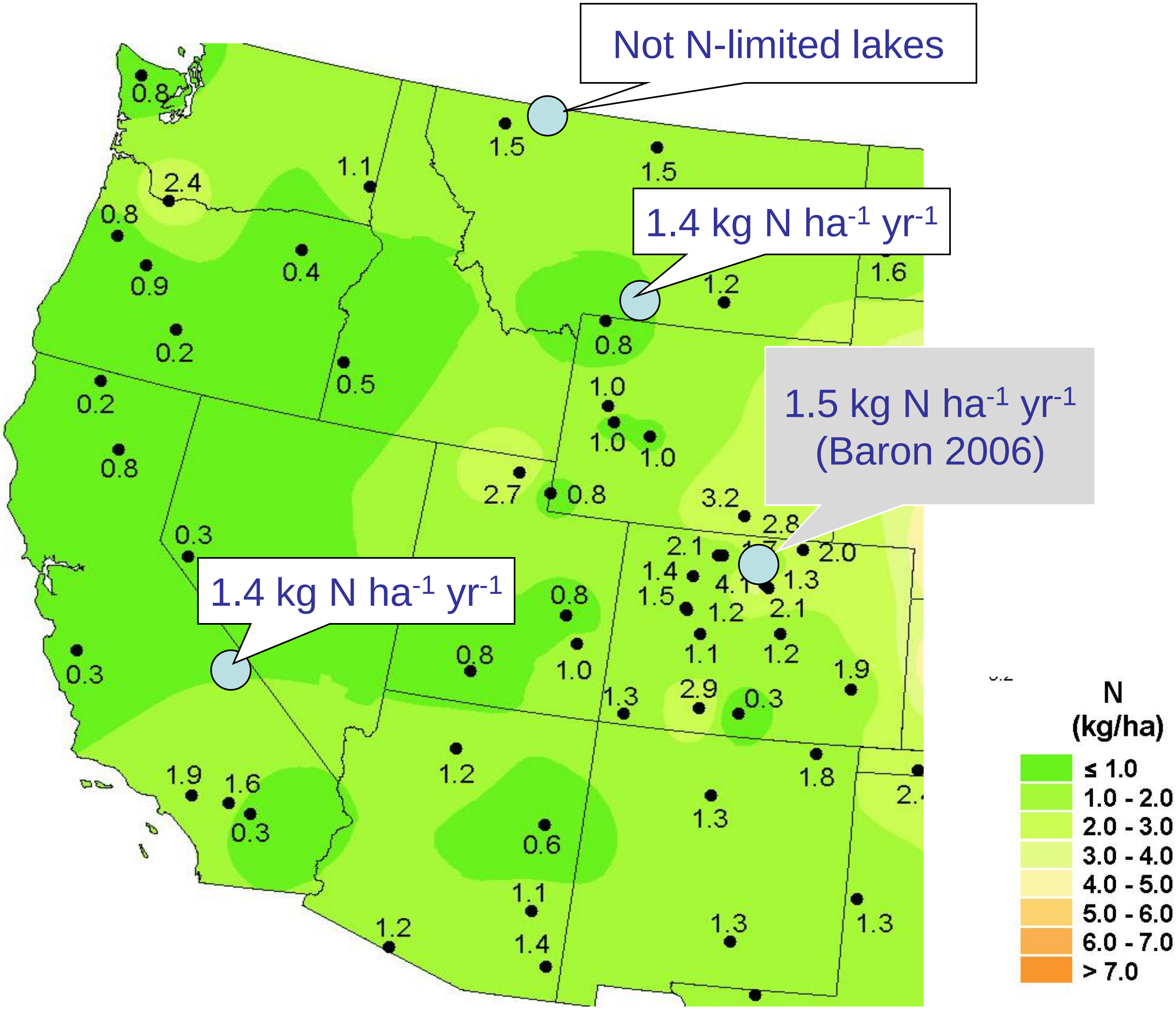
% relative abundance


Snyder Lake (Glacier National Park)
Small Fragilaria sp.
Opephora olsneii
Achnanthes minutissima
Fragilaria crotonensis
Depth (cm)
2000
1980
1960
1940
1920
% relative abundance

Critical N loads for enrichment effects in high elevation lakes



Conclusions

- Critical loads of 1.4 kg ha^{-1} yr^{-1} of total wet N deposition were found for both the eastern Sierra Nevada and the Greater Yellowstone Ecosystem
- Lakes in Glacier National Park are P-limited, and do not respond to N enrichment
    - These lakes are also generally high in ANC, suggesting that they are likely fairly resilient to N deposition effects
- While the similar critical N loads defined here and by Baron (2006) suggest a common response across N-limited ecosystems, the results from Glacier NP underscore the importance of understanding nutrient limitation patterns in each region
- The high sensitivity of diatoms to N deposition may provide critical loads that are broadly protective across aquatic and terrestrial ecosystems in a region

Acknowledgements

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