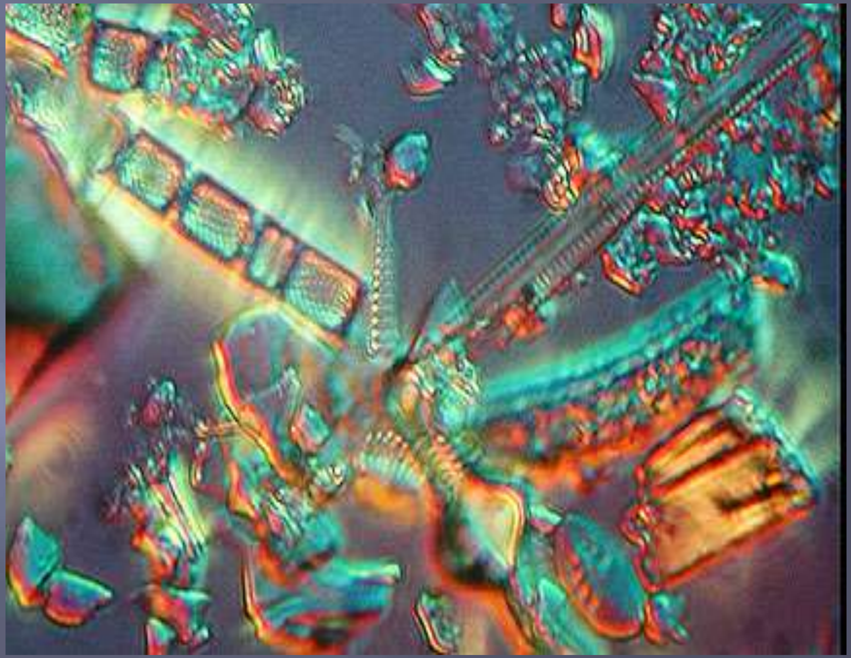
Nutrient Enrichment of Western Montane Lakes: Interactions Between N and P Loading



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Delores Lucero - Environmental Sciences, University of California Riverside
Mark Brenner - Geological Sciences, University of Florida

Presented at:
USFS Western Lakes Monitoring Workshop
March 2-4
Stevenson WA

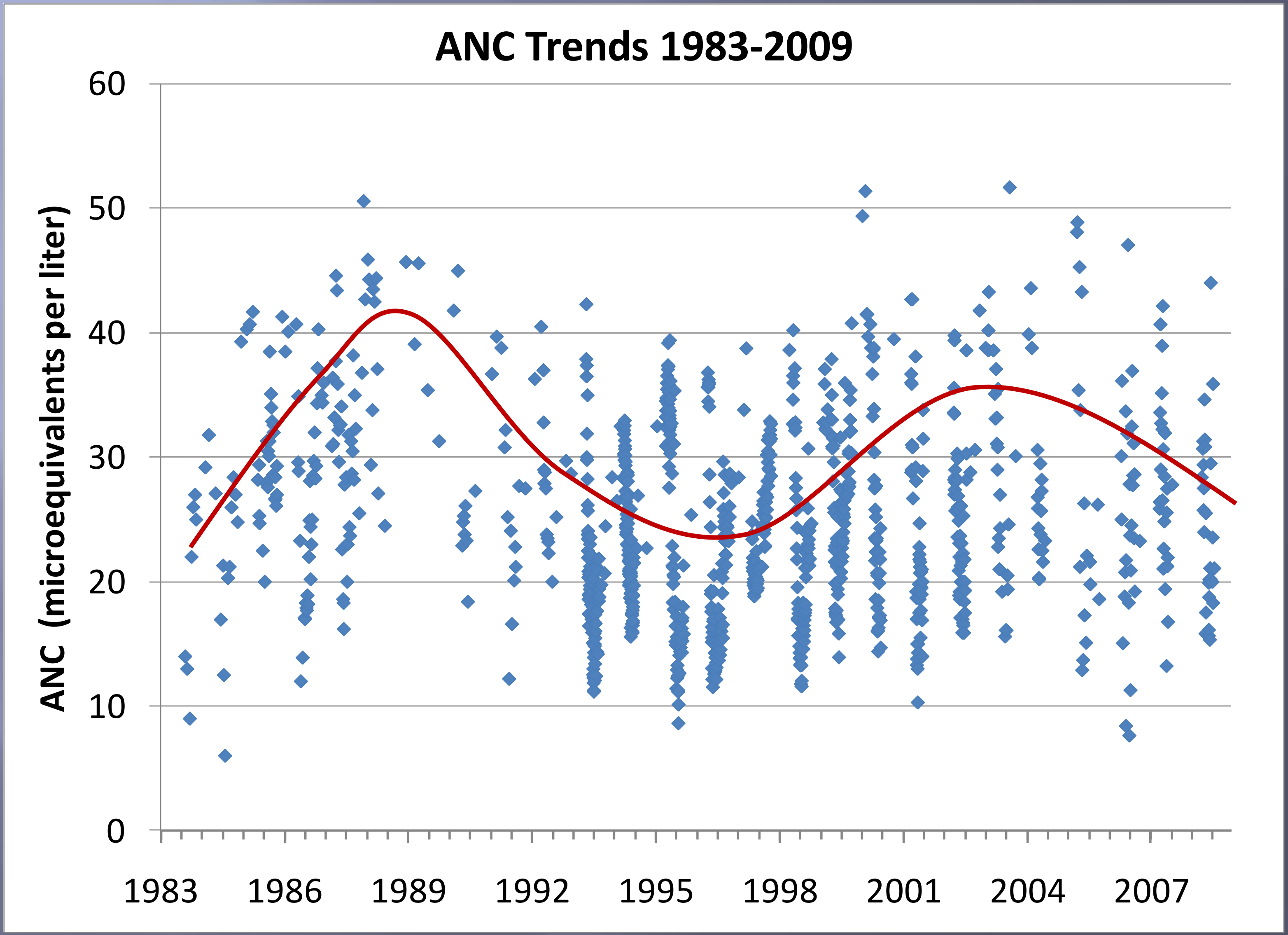
UC RIVERSIDE
UNIVERSITY OF CALIFORNIA

Outline of Today's Talk

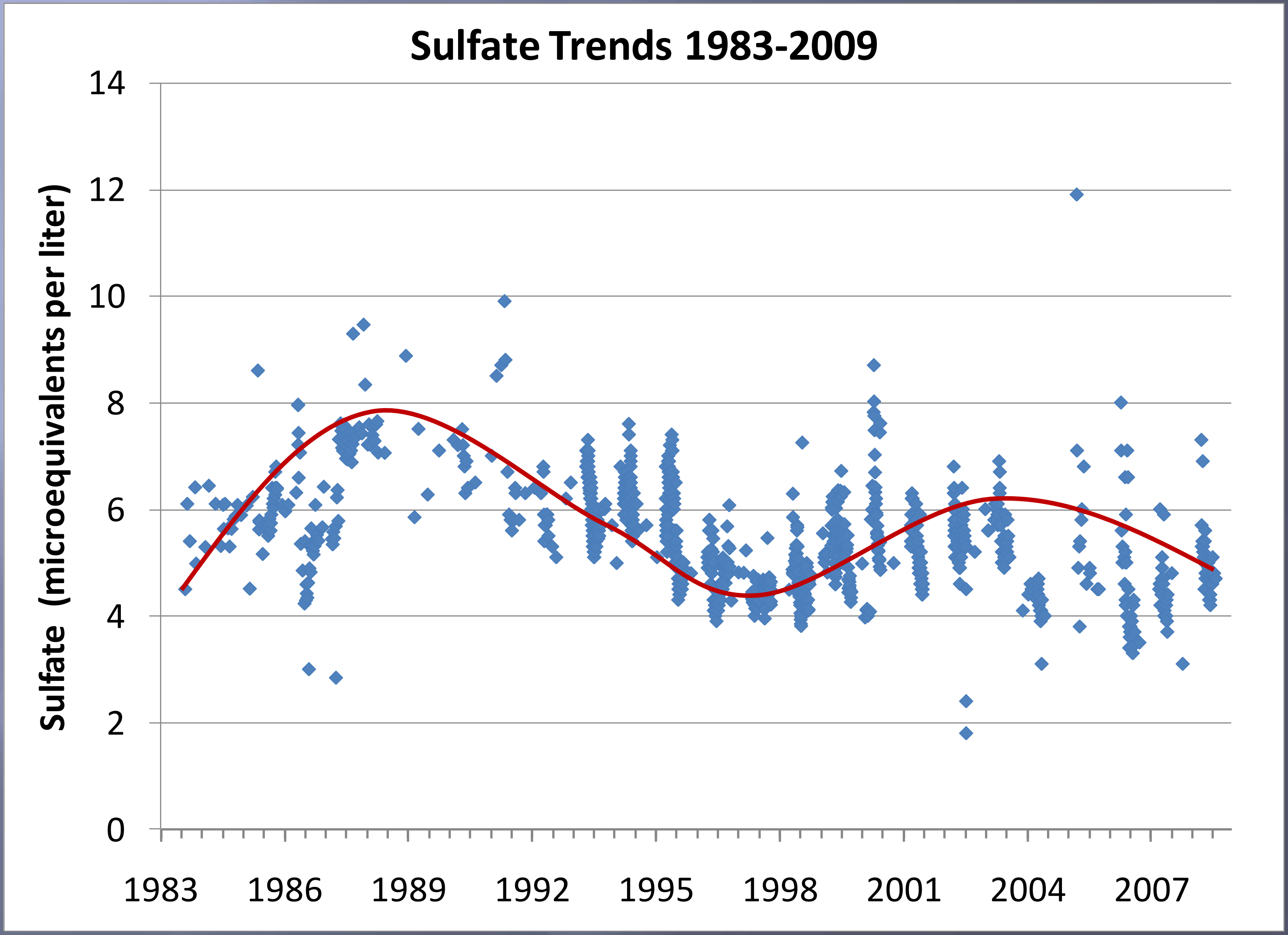
- Examine trends in water quality, deposition and lake changes in the West
- Evaluate Diatom as potential indicators of deposition effects
- Describe ongoing work in the Sierra Nevada incorporating diatoms to establish N critical loads and nutrient criteria

NASA

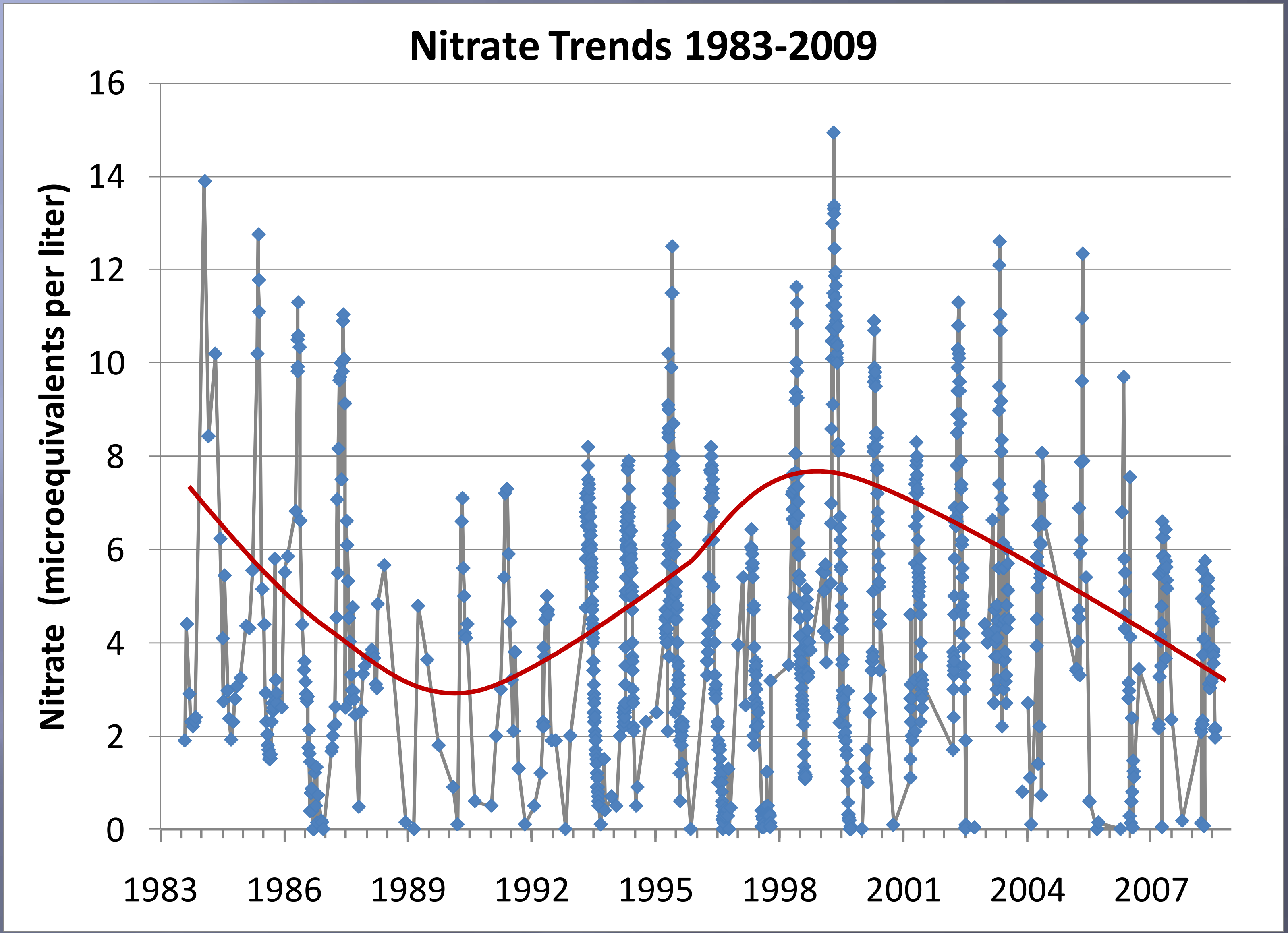
Emerald Lake 1983-2009



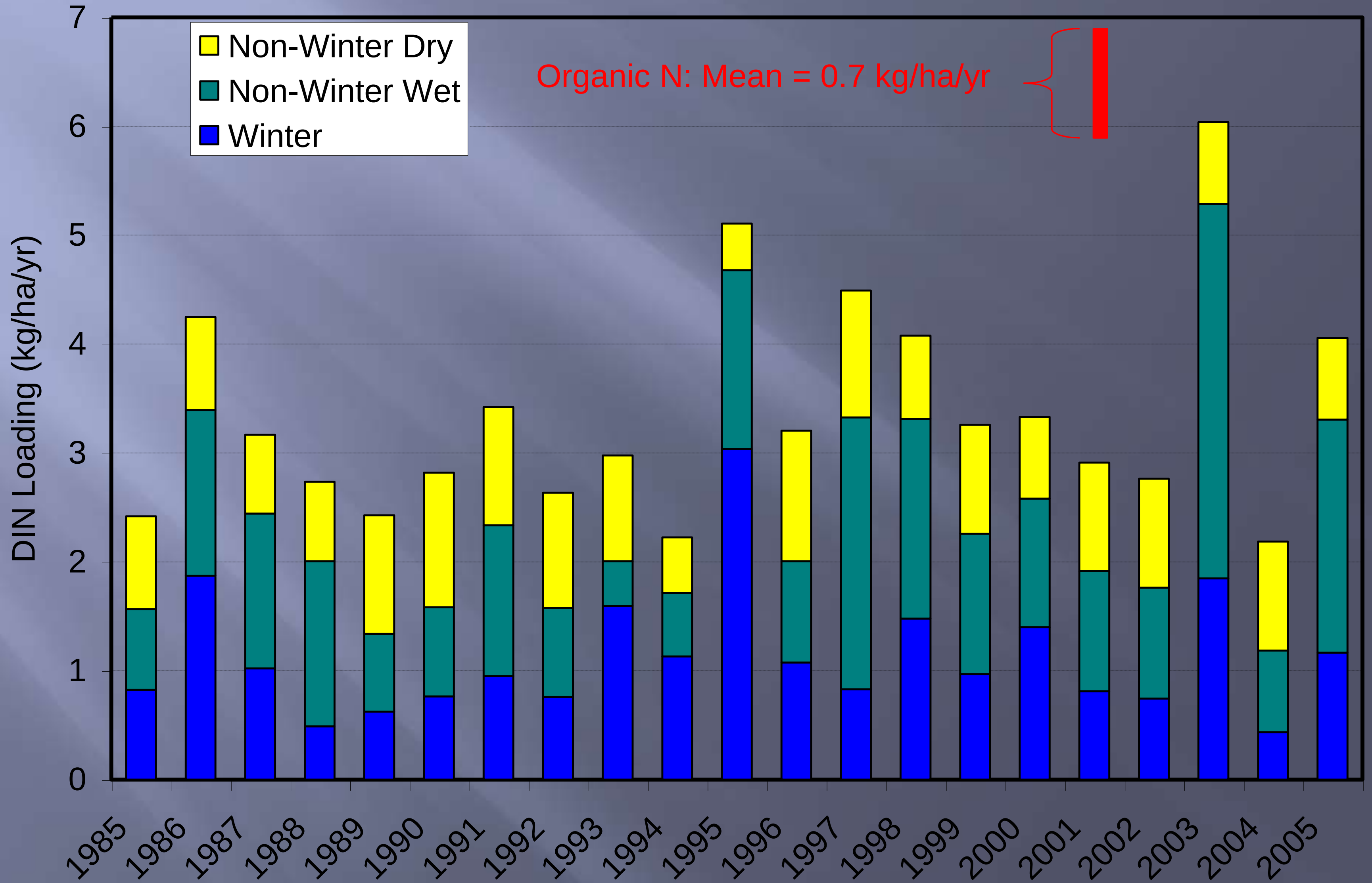
Emerald Lake 1983-2009



Emerald Lake 1983-2009



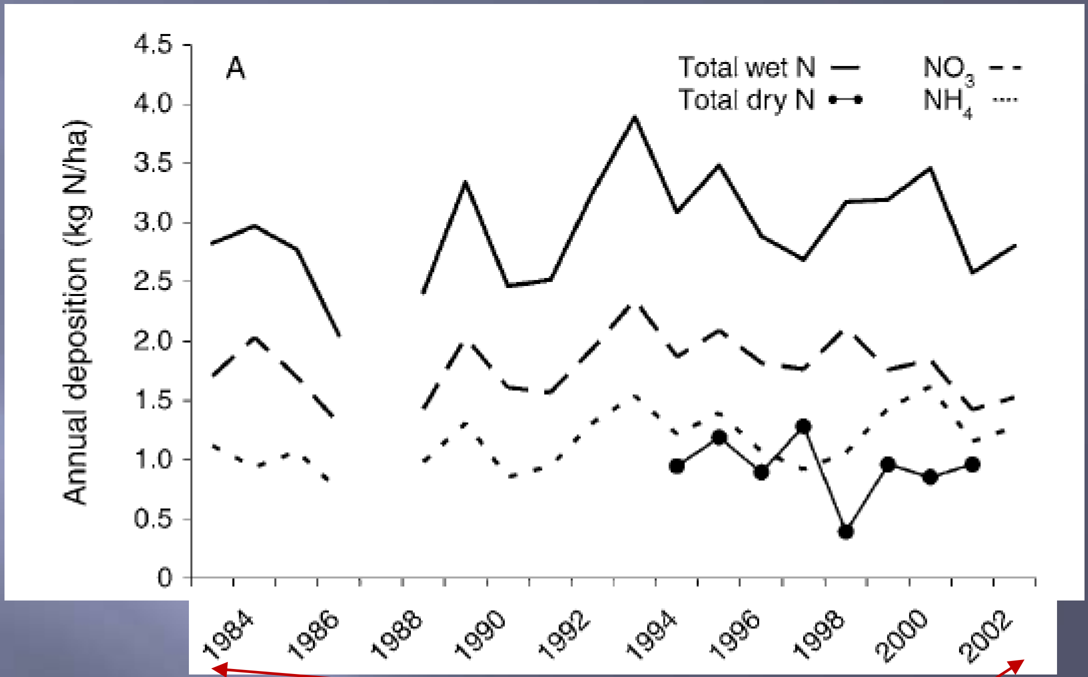
N Deposition to High Sierra Nevada Emerald Lake: 1985-2005



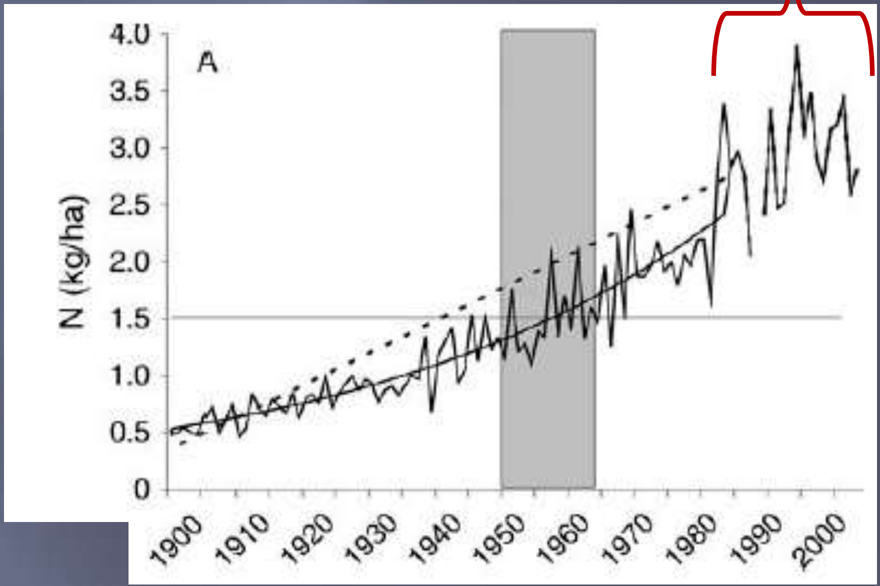
Temporal Patterns:
Loch Vale, Colorado

Baron 2006:

Ecological Applications



- N deposition stable over past 20-25 yrs
- N deposition ++ over past 100+ yrs

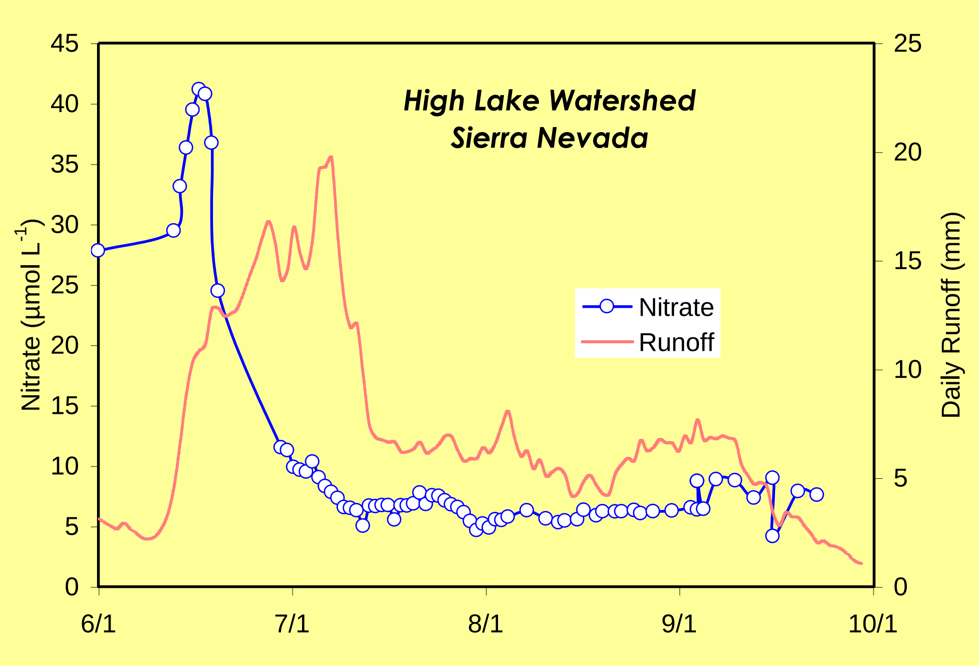


"anchor" deposition

Evidence of Depositional Effects

- N saturation of alpine watersheds in the Sierra Nevada
- Eutrophication of Emerald Lake

Some Sierra Nevada Watersheds Are Nearing N-Saturation



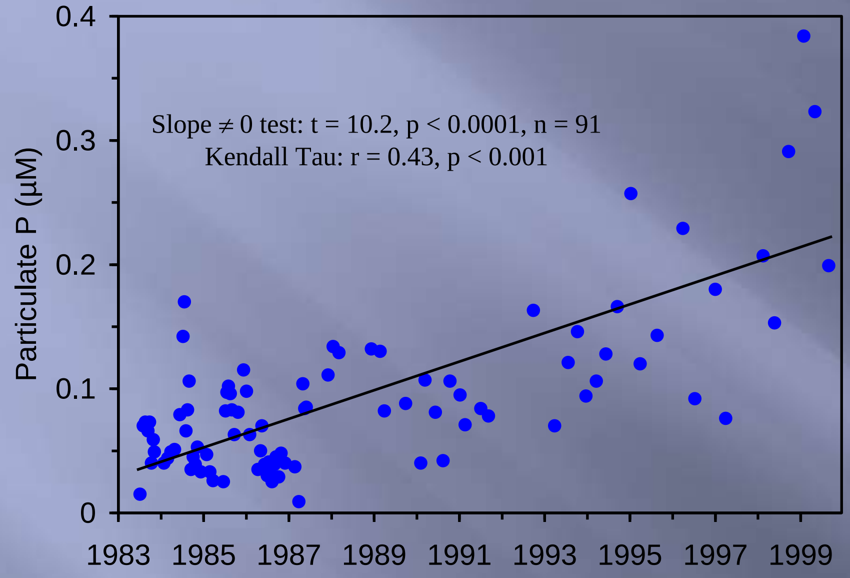
	Elevation (m)	Mean NO_3^- (µM)	Catchment % DIN Retention	N-Saturation Stage
High Lake	3603	13	-24%	3
Low Lake	3444	9.6	-7%	3
Mills	3554	9.3	0%	2
Treasure	3420	8.9	27%	2

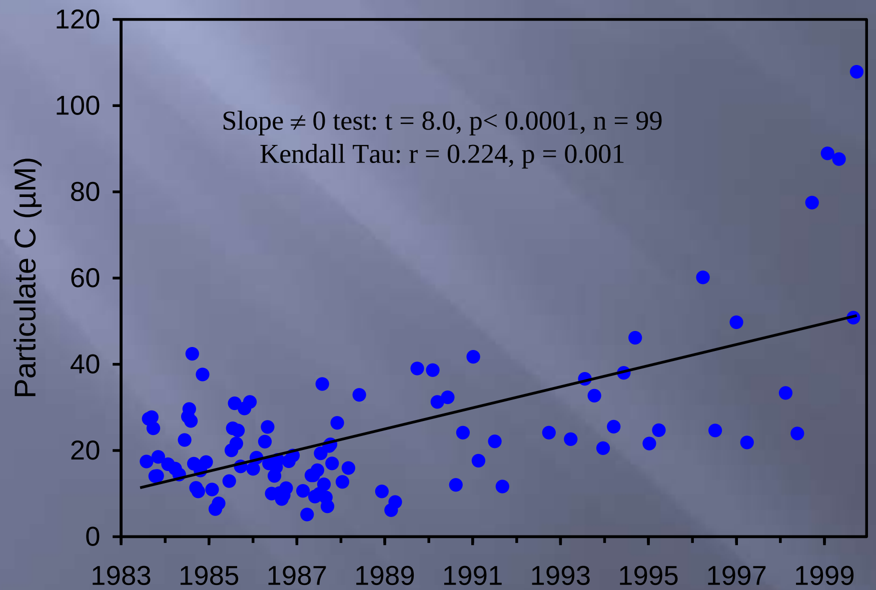
Stage 2: Elevated nitrate concentration in growing season

Stage 3: Catchment net source for N

Sickman et al. 2002

Long-term Changes at Emerald Lake





Trends detected at Emerald Lake:

- ❖ TP and PP increase
- ❖ Increased phytoplankton biomass

- *Trends suggest affects of both N and P deposition*

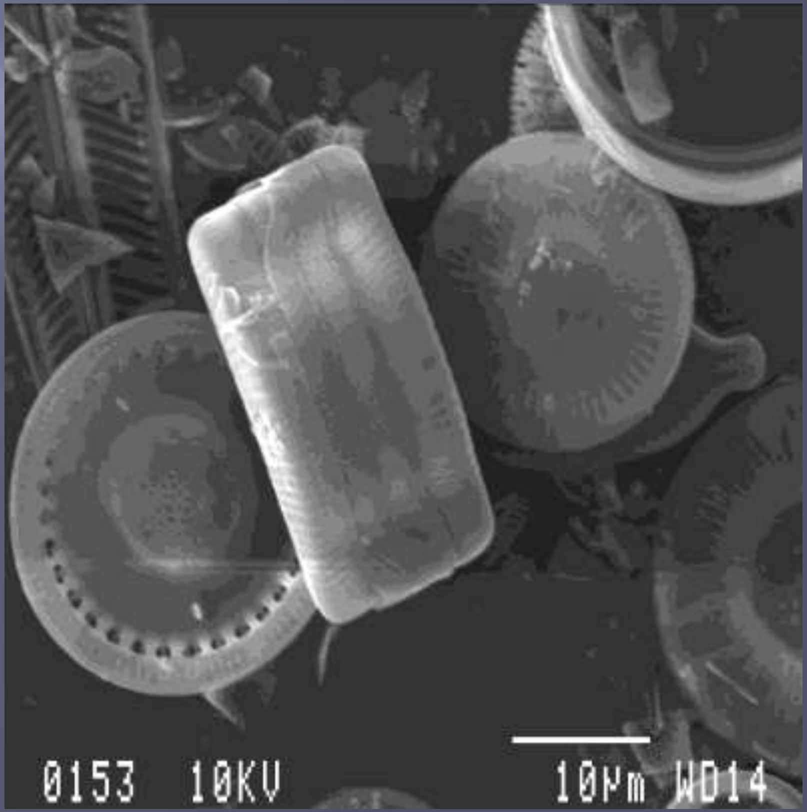
Sickman et al. 2003

Diatom Indicators of Atmospheric Deposition: Three Case Studies

- Background
- Case Studies in high elevation lakes:
  - Diatom proxies of pH
    - Emerald Lake (Holmes et al. 1985)
  - Diatom proxies of N deposition:
    - RM National Park (Baron et al. 2000 Wolfe et al. 2001)
    - Wyoming Lakes (Saros et al. 2003)

Diatoms are excellent indicators

- High species diversity (pelagic & benthic types in lakes)
- Well-defined ecological requirements
- Respond quickly to environmental change
- Cell walls composed of silica are well preserved in sediments

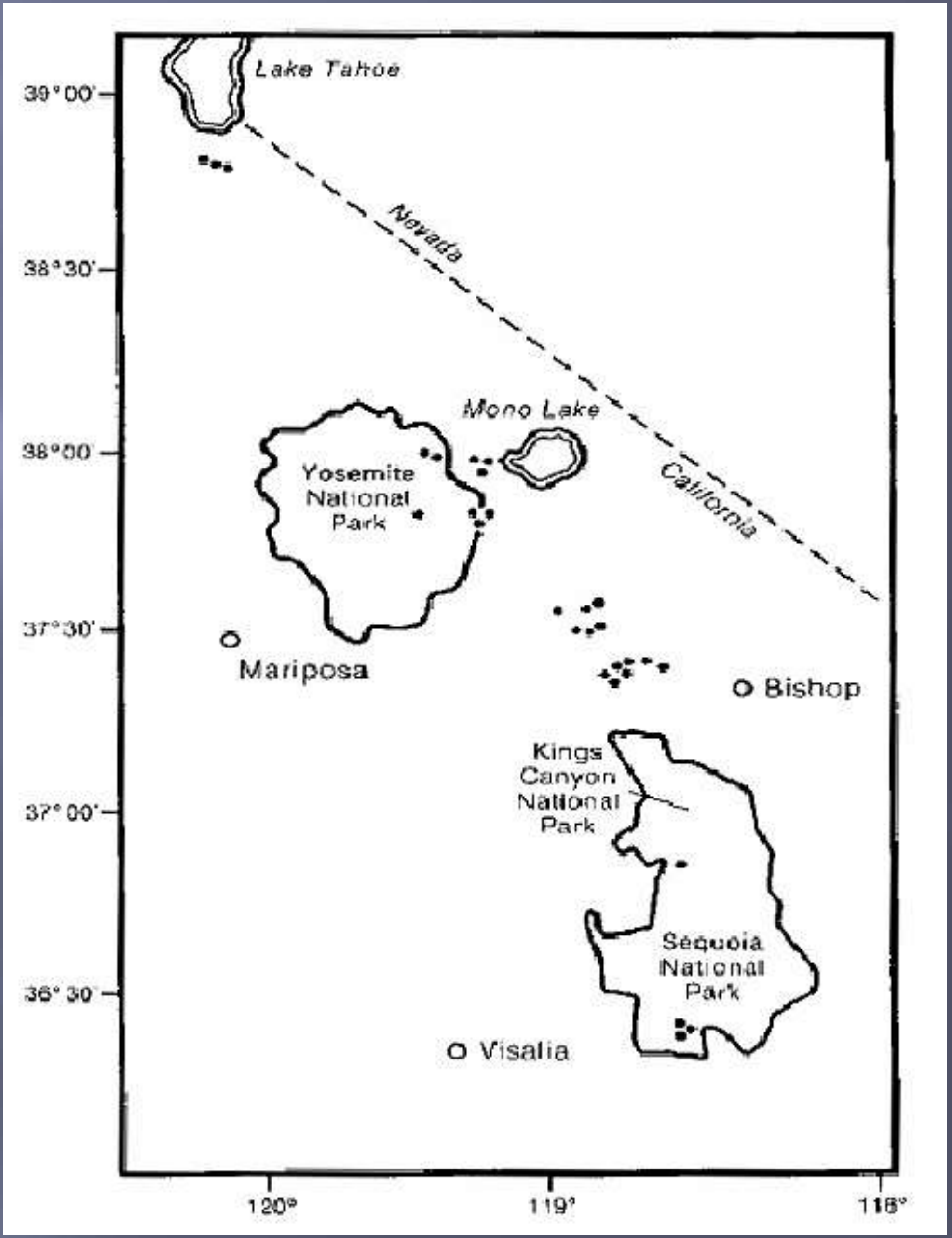


Case Study 1

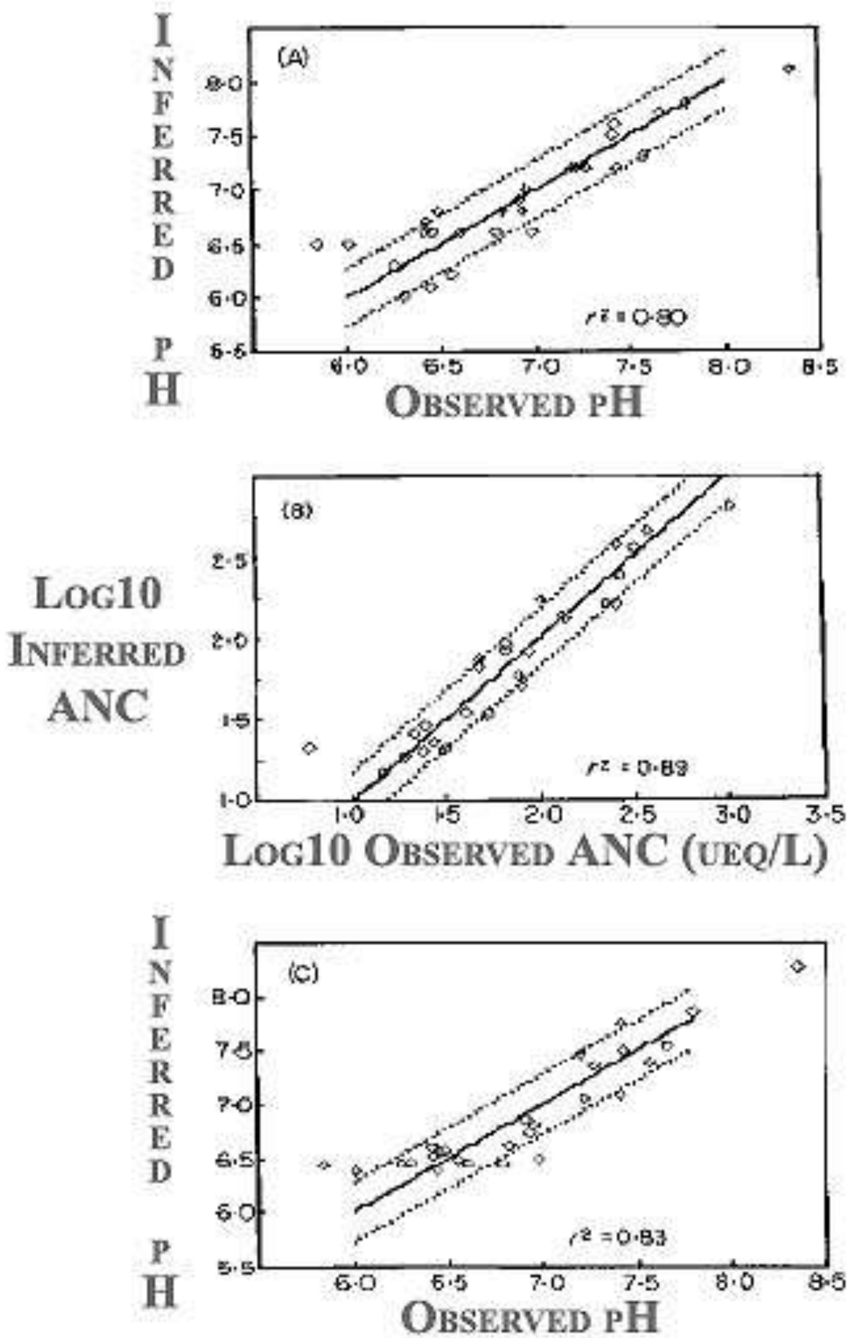
Holmes et al. (1989)

Study of
Emerald Lake to
reconstruct
pH and ANC history
from sediment
diatoms

A calibration set
of 27 lakes was
used to develop
diatom predictive
models



Holmes *et al.* 1989



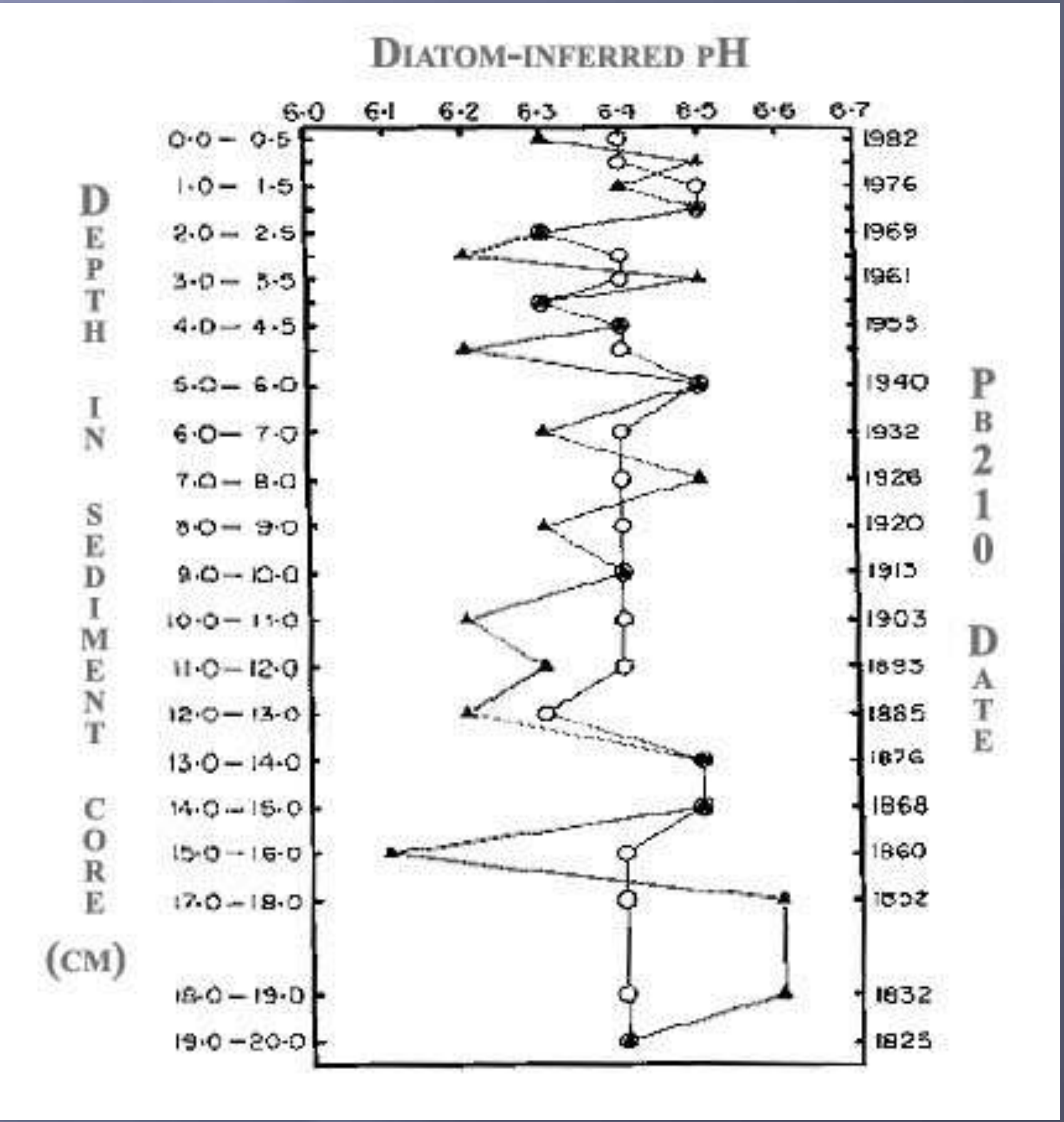
Predictive model based on a ratio of pH preference categories

ANC predictive model based on multiple regression of 4 new ANC preference categories for diatoms

pH predictive model based on multiple regression Of pH preference categories

pH inferences for Emerald Lake

Holmes *et al.* 1989



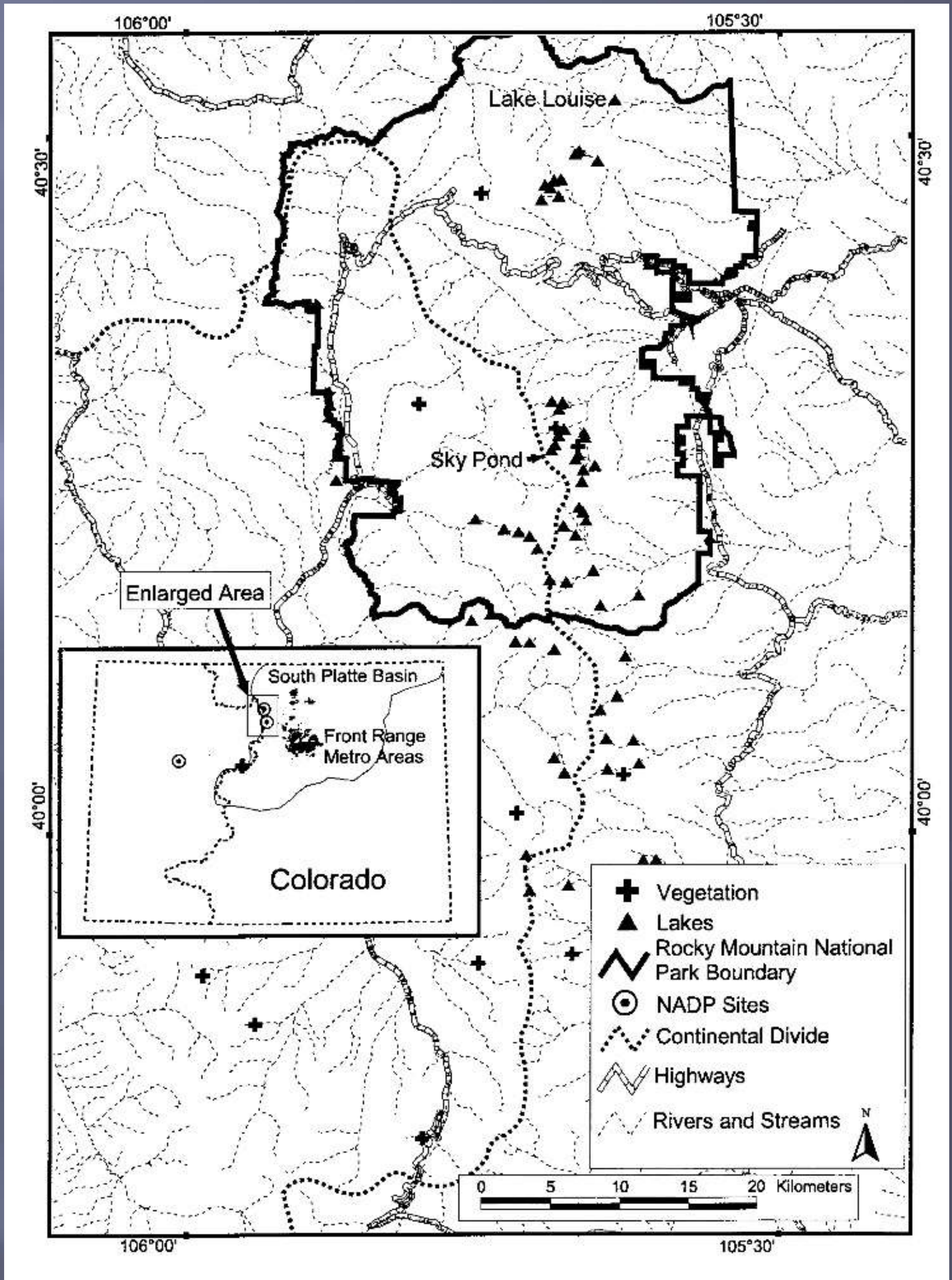
Study demonstrated no pH changes from acid deposition

Case Study 2

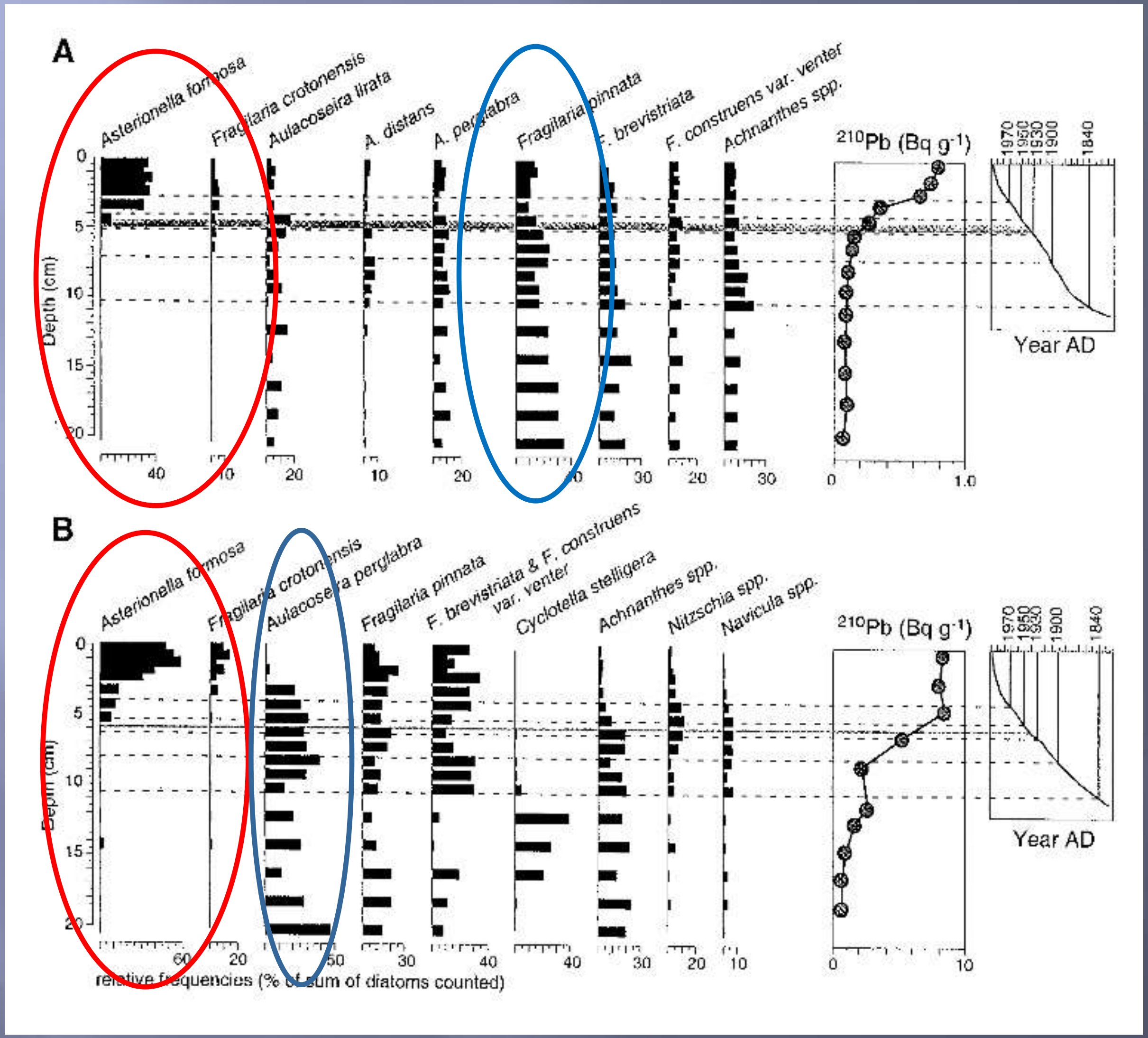
Baron et al. (2000)
Wolfe et al. (2001)

Diatoms used to assess lake responses to N Deposition in the Colorado Front Range

Diatom analyses in Sky Pond and Lake Louise



Diatoms and ^{210}Pb dates from 2 sediment cores



Sky Pond

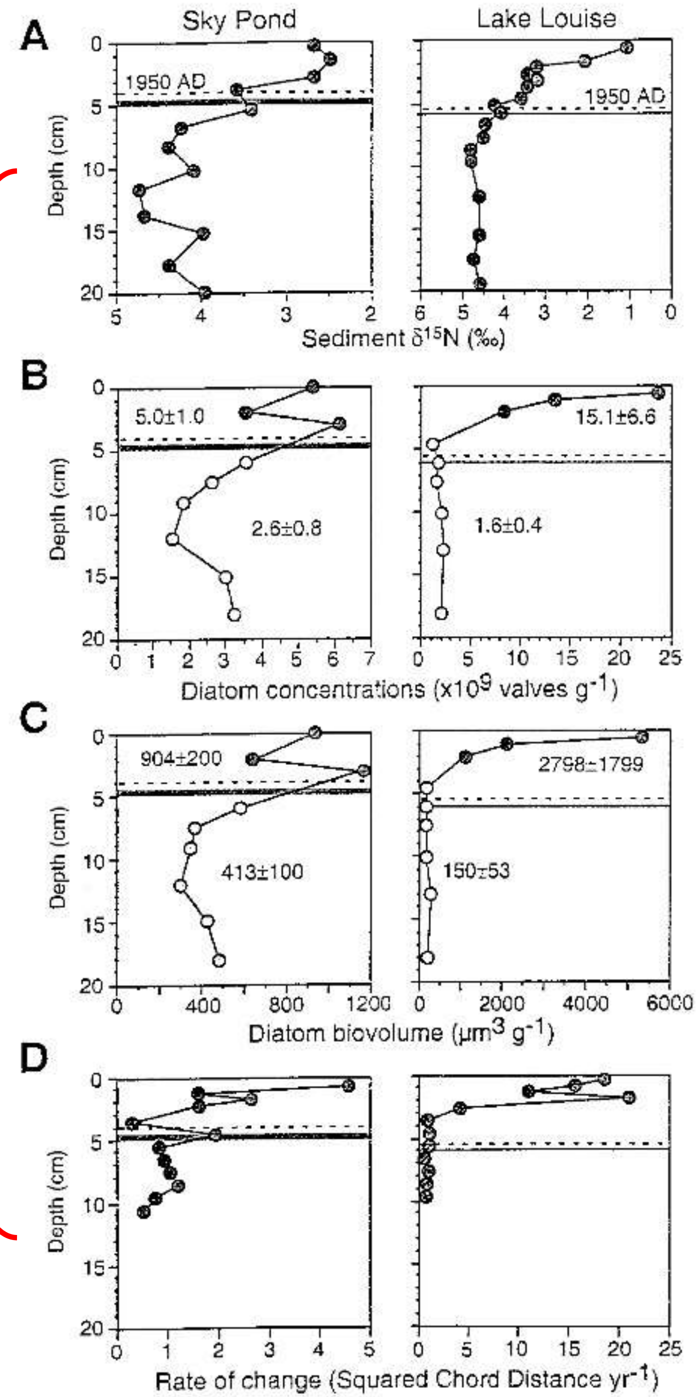
Baron et al. (2000)
Wolfe et al. (2001)

Lake Louise

Shift from oligotrophic to mesotrophic diatom species c. 1950-1970 suggests a trophic shift occurred in the lakes

Baron et al. (2000)
Wolfe et al. (2001)

Linkages to N deposition



Change in $\delta^{15}N$ signatures suggest a new source of N

Increase in diatom productivity suggests greater nutrient input

An increase occurred in the volume of diatoms deposited in sediments

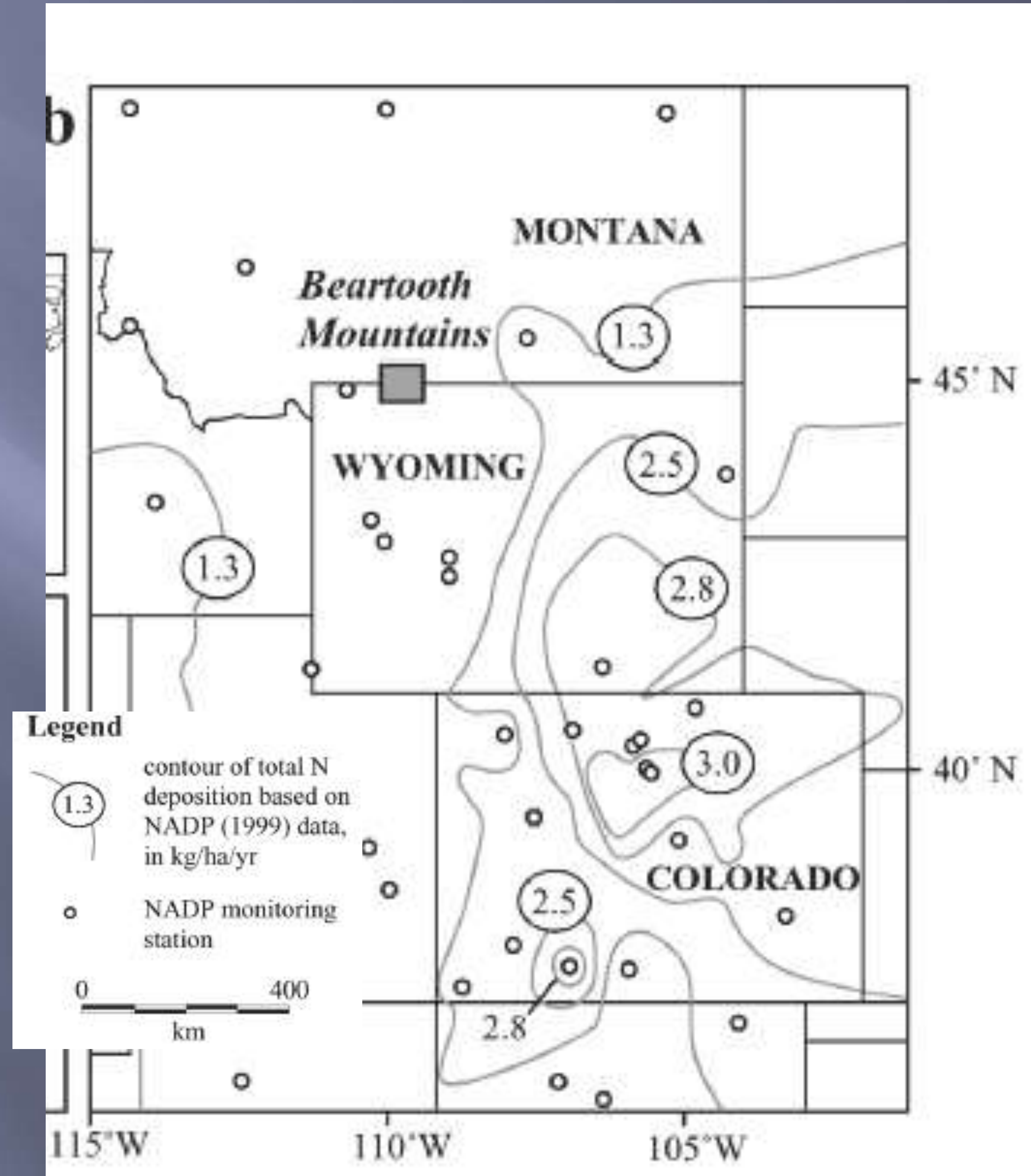
Recent diatom communities changed more rapidly than at any time in past

Case Study 3

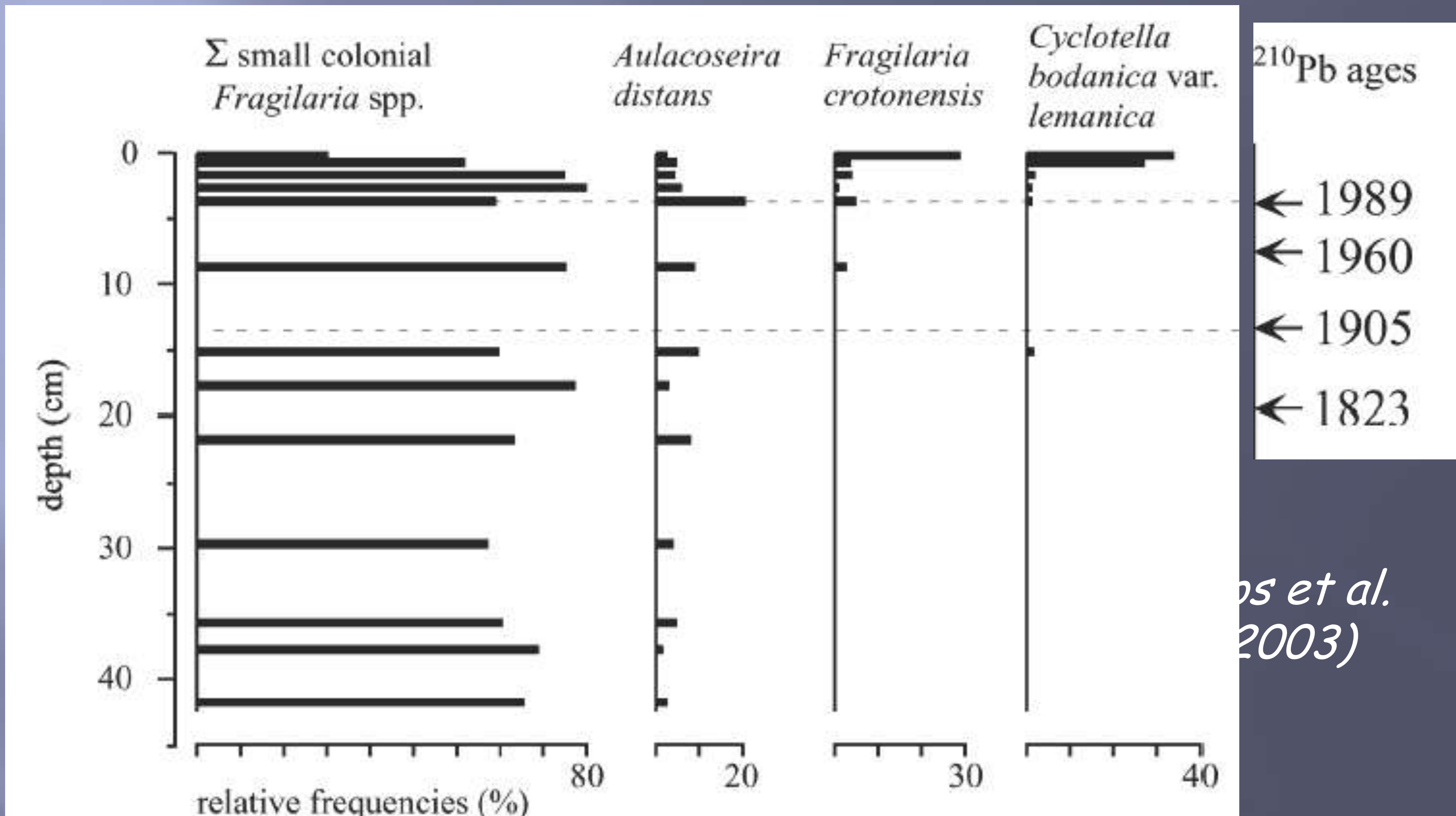
Saros et al. (2003)

Study examined sediment and diatom records in four lakes in the Beartooth Mountains

NADP data indicate the study area receives N deposition <1.5 kg/ha/yr



Diatoms and ^{210}Pb dates from Beartooth Lake



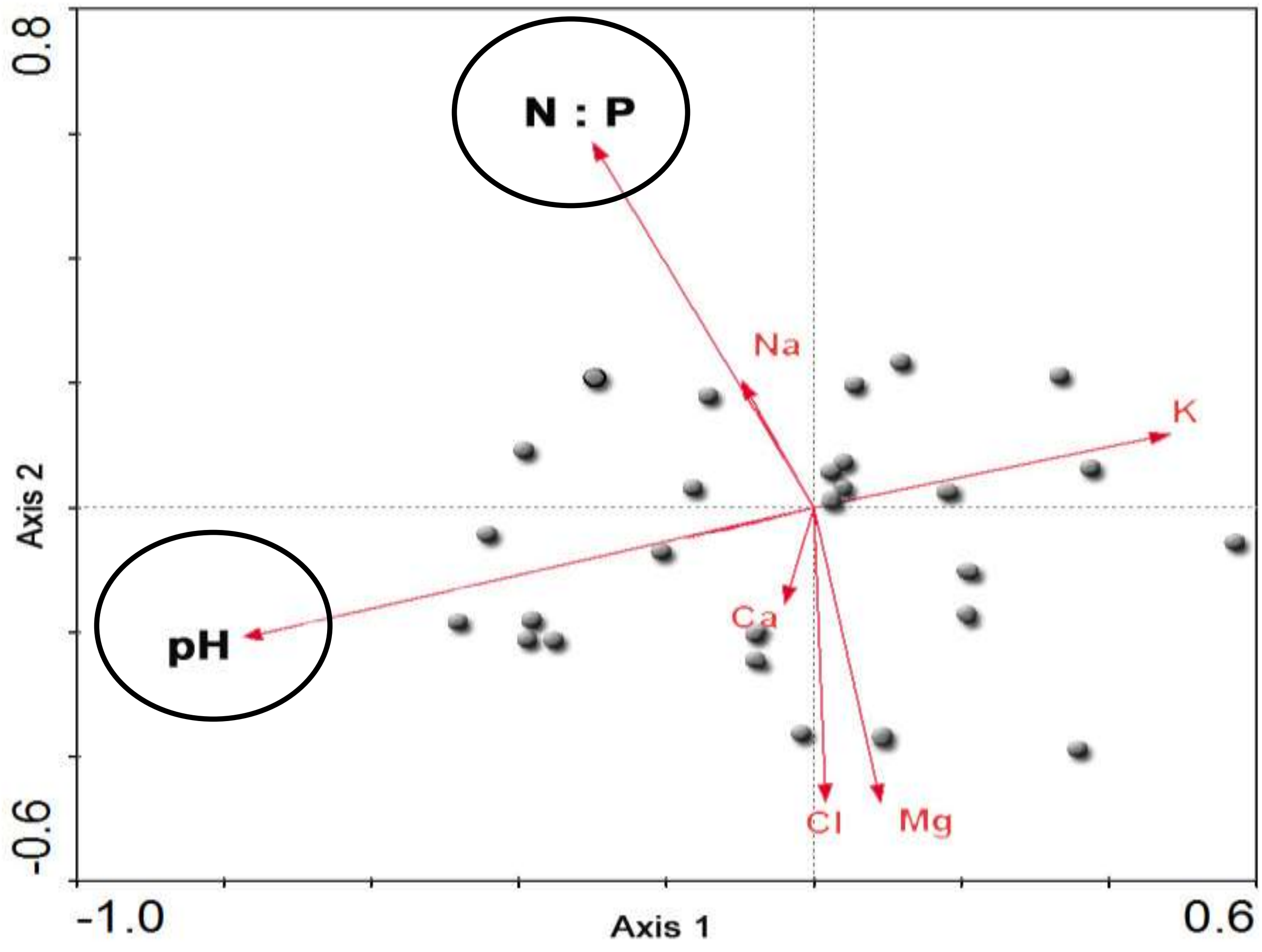
Diatom record indicates a community shift occurred within last two decades

Current Research in Sierra Nevada

Selected for large variation in nitrate concentrations

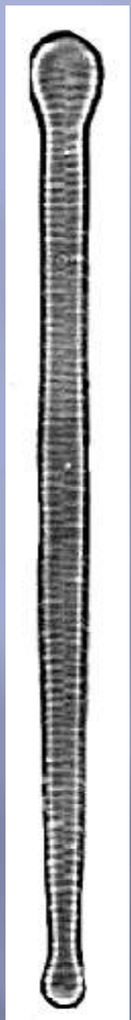
Selected for low variation in pH, ANC

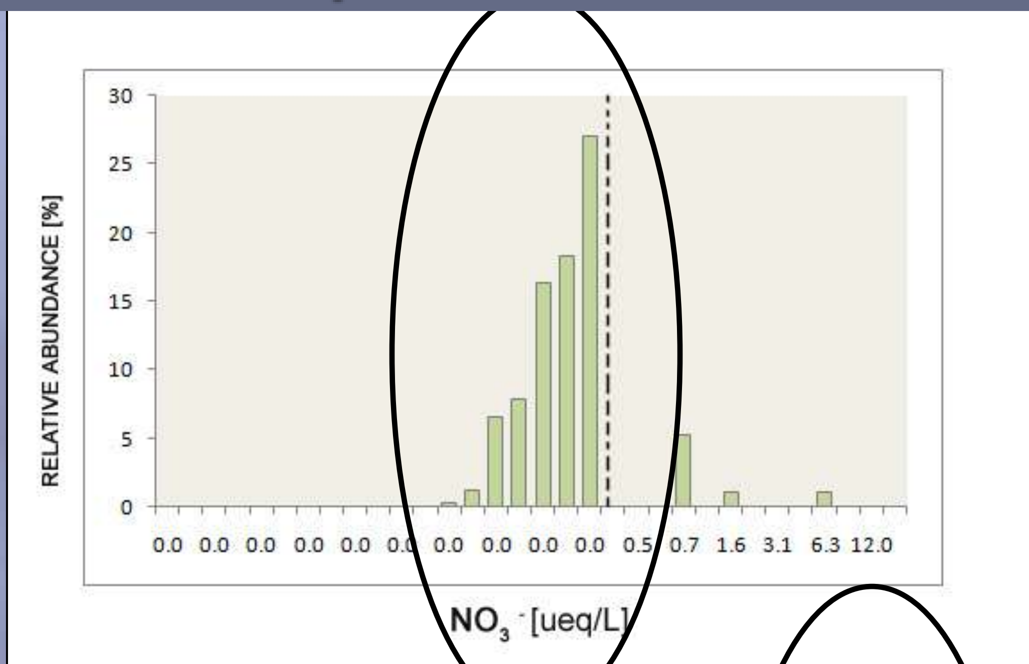
Environmental variables (CCA)

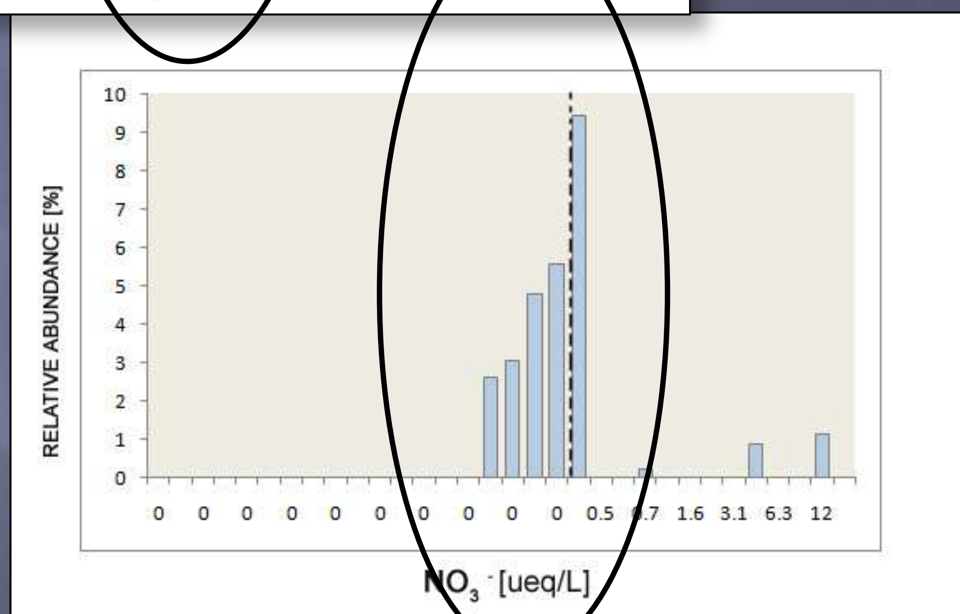


RM Indicator Species: More Abundant in Low N Lakes

Asterionella formosa Hassall





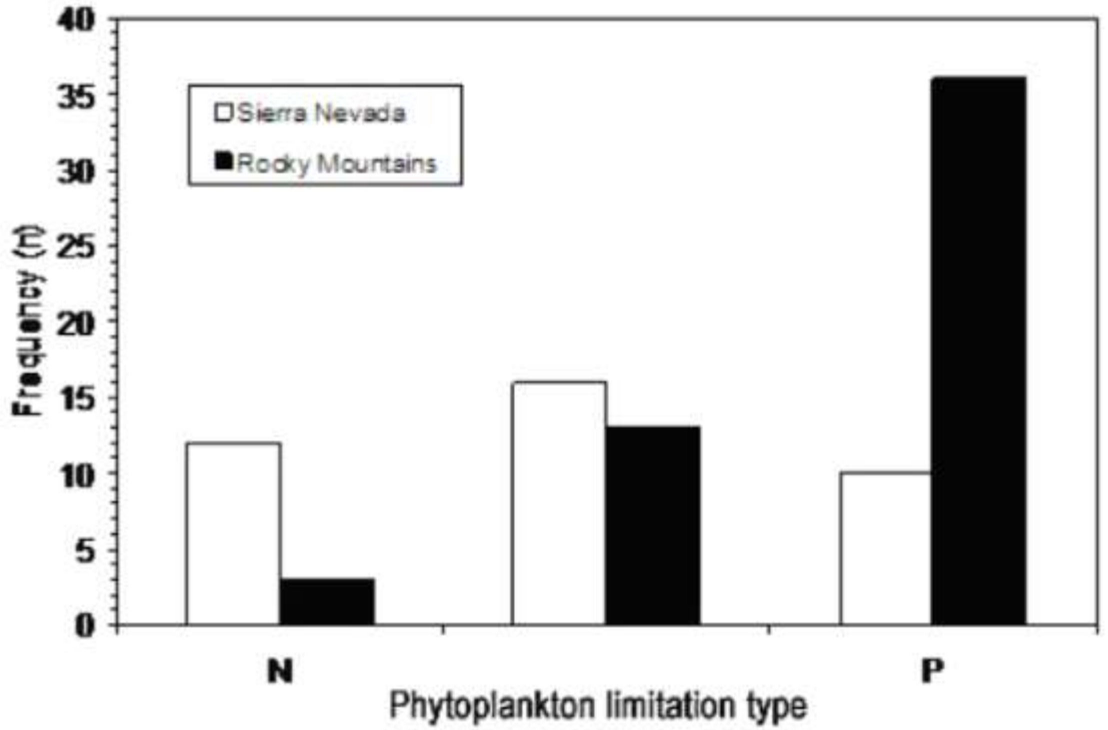


Fragilaria crotonensis Kitton

Observations

1. High elevation regions receive elevated atmospheric deposition relative to 100+ years ago
2. Aquatic ecosystems are very nutrient deficient and are responding to deposition of N and P
3. But responses are different in Rocky Mountains and Sierra Nevada……

Nutrient Limitation



Sickman, 2001

HOW DIATOM RESPOND TO ELEVATED ATMOSPHERIC DEPOSITION

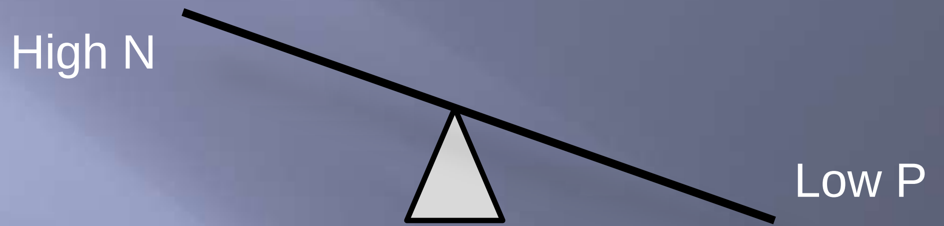
ROCKY MOUNTAINS

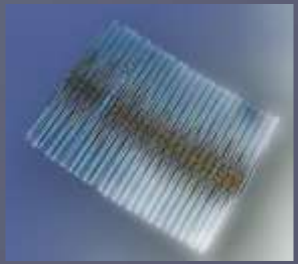
Diatom communities in lakes may be more responding to elevated N deposition, due to their initial N limitation (Saros et al.2003).

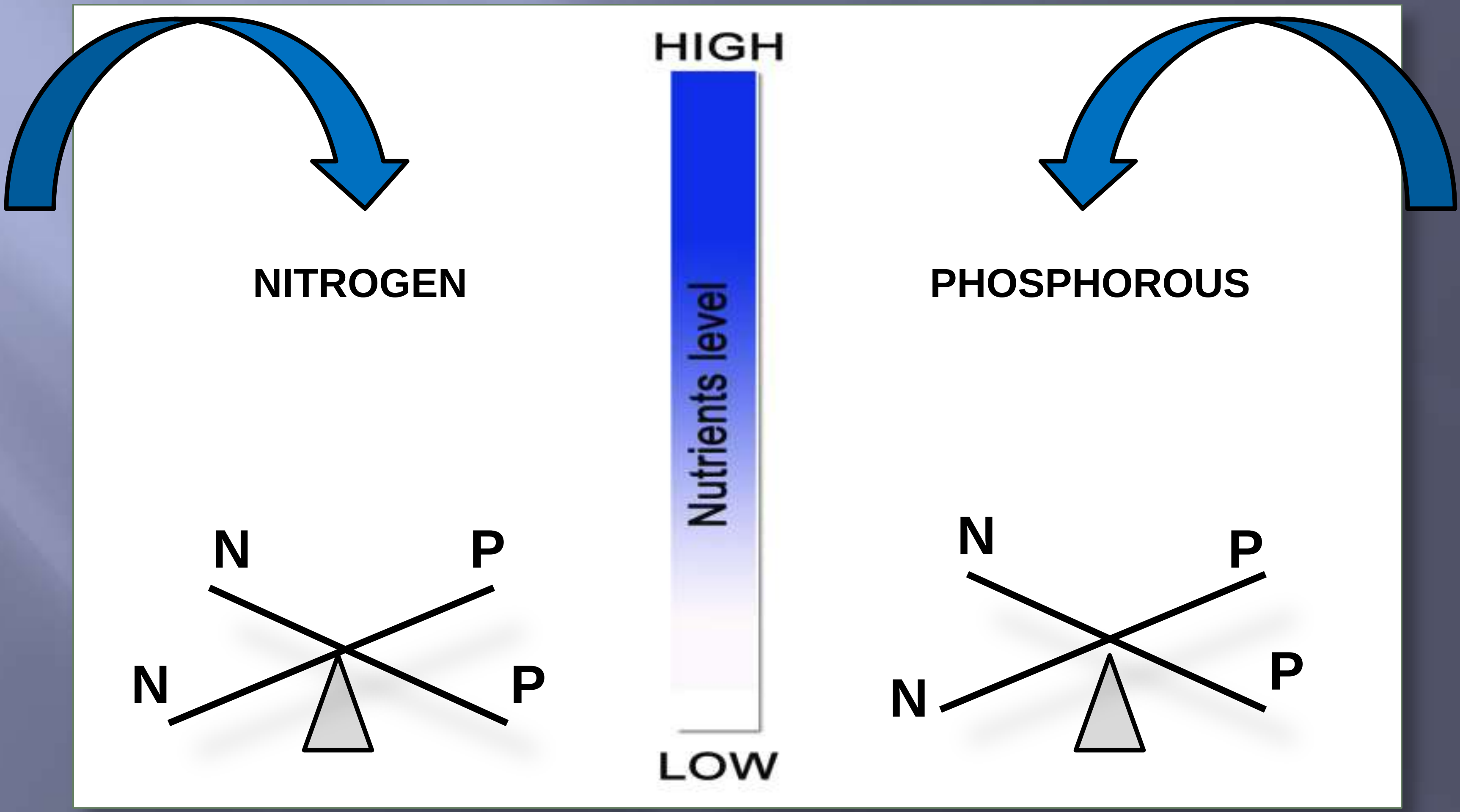
SIERRA NEVADA

Diatom communities respond to both higher rates of N and P deposition, but the P deposition has strongest impact, because lakes were predominantly P limited .

N:P ratio


High N
Low P

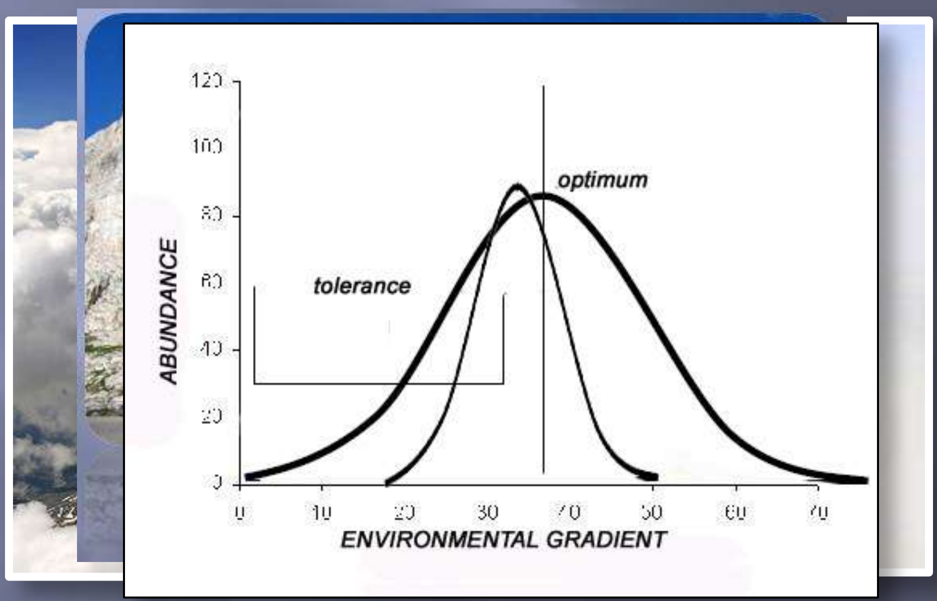



HIGH
Nutrients level
LOW
NITROGEN
N
P
N
P
PHOSPHOROUS
N
P
N
P

CAN WE USE DIATOMS AS INDICATOR OF ATMOSPHERIC DEPOSITION?

Yes…but

1. acknowledge differences between systems (source and type of deposition)
2. incorporate differences between types of initial nutrient limitations through time
3. interpret species tolerances in relation to broad environmental gradients



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QUESTIONS?

Ongoing NPS & USFS-Funded Study: Determining critical N loads and nutrient criteria in the Sierra

Questions to answer:

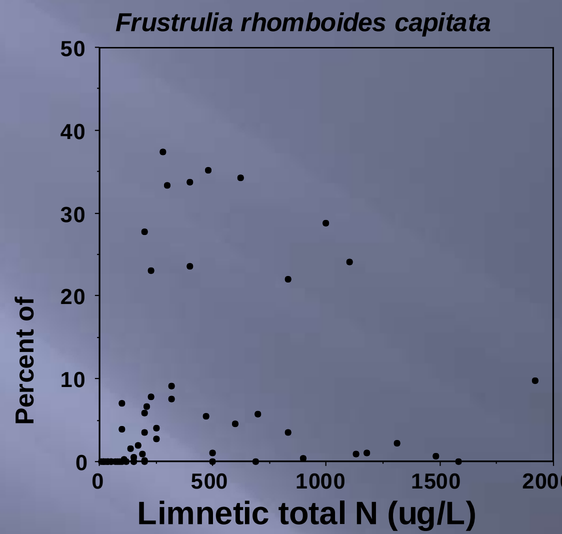
- *Has the trophic status of lakes in the Sierra Nevada changed?*
- *If so, is there a dose-response relationship between atmospheric deposition and trophic status?*
- *If yes, is there a threshold for depositional effects on aquatic ecosystems?*

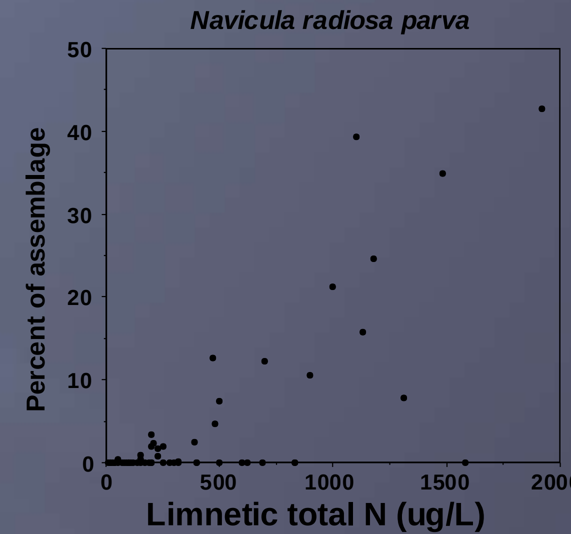
Examples !!!

Step 2:

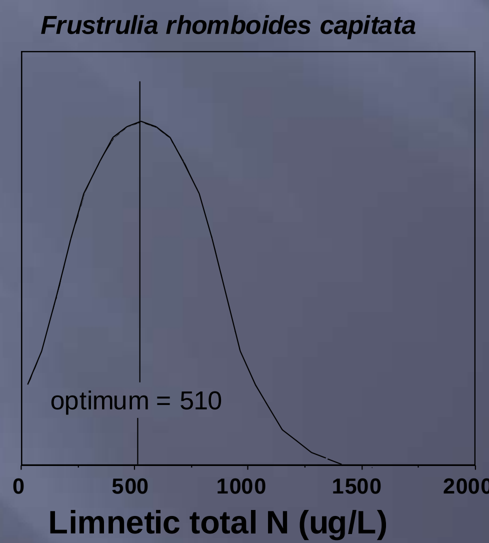
Quantify relationships between diatoms & environmental variables

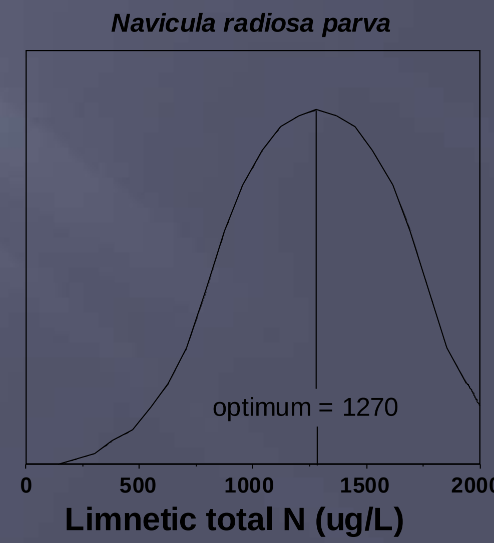
Optima are calculated for each species based on their occurrence in calibration lakes





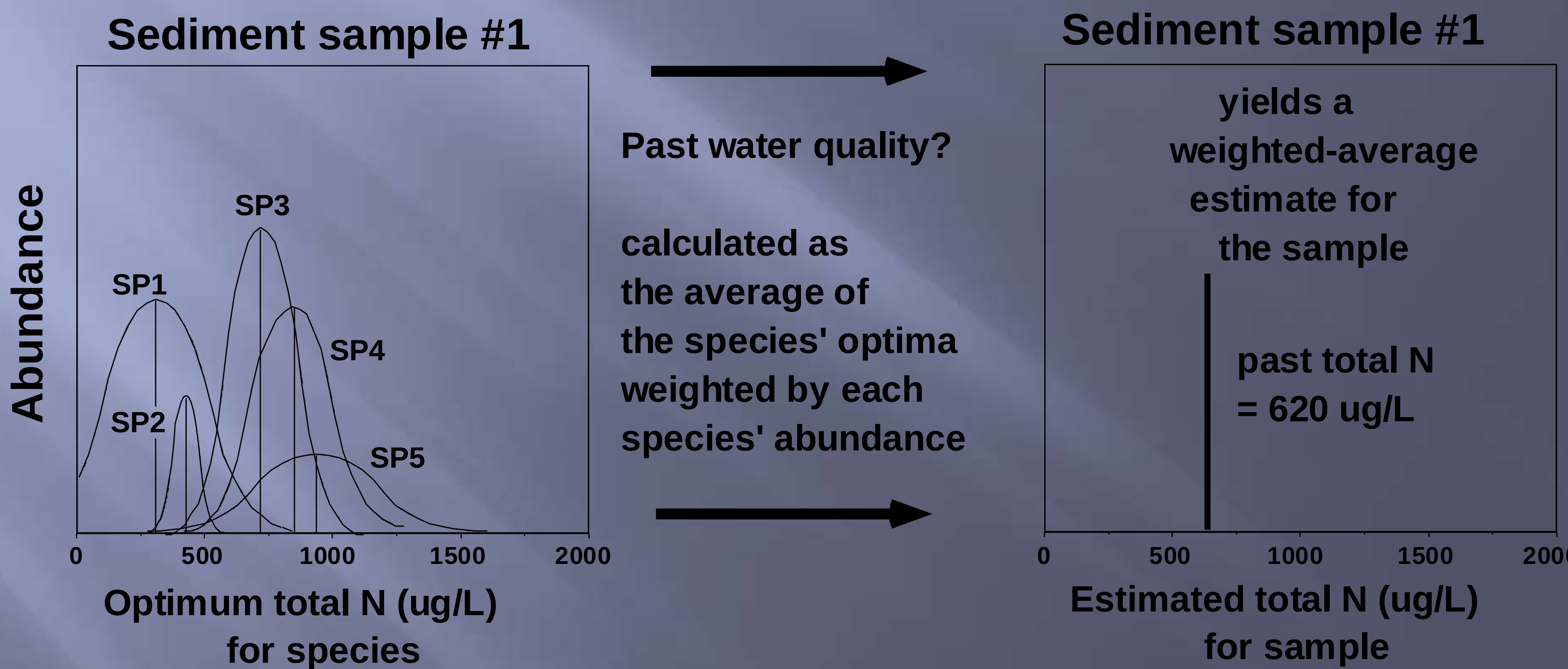
optimum and tolerance of each species is calculated in a regression step





Step 3: Develop Trophic Index Models (TIMs)

Reconstruct trophic conditions of the lakes using weighted-average approach

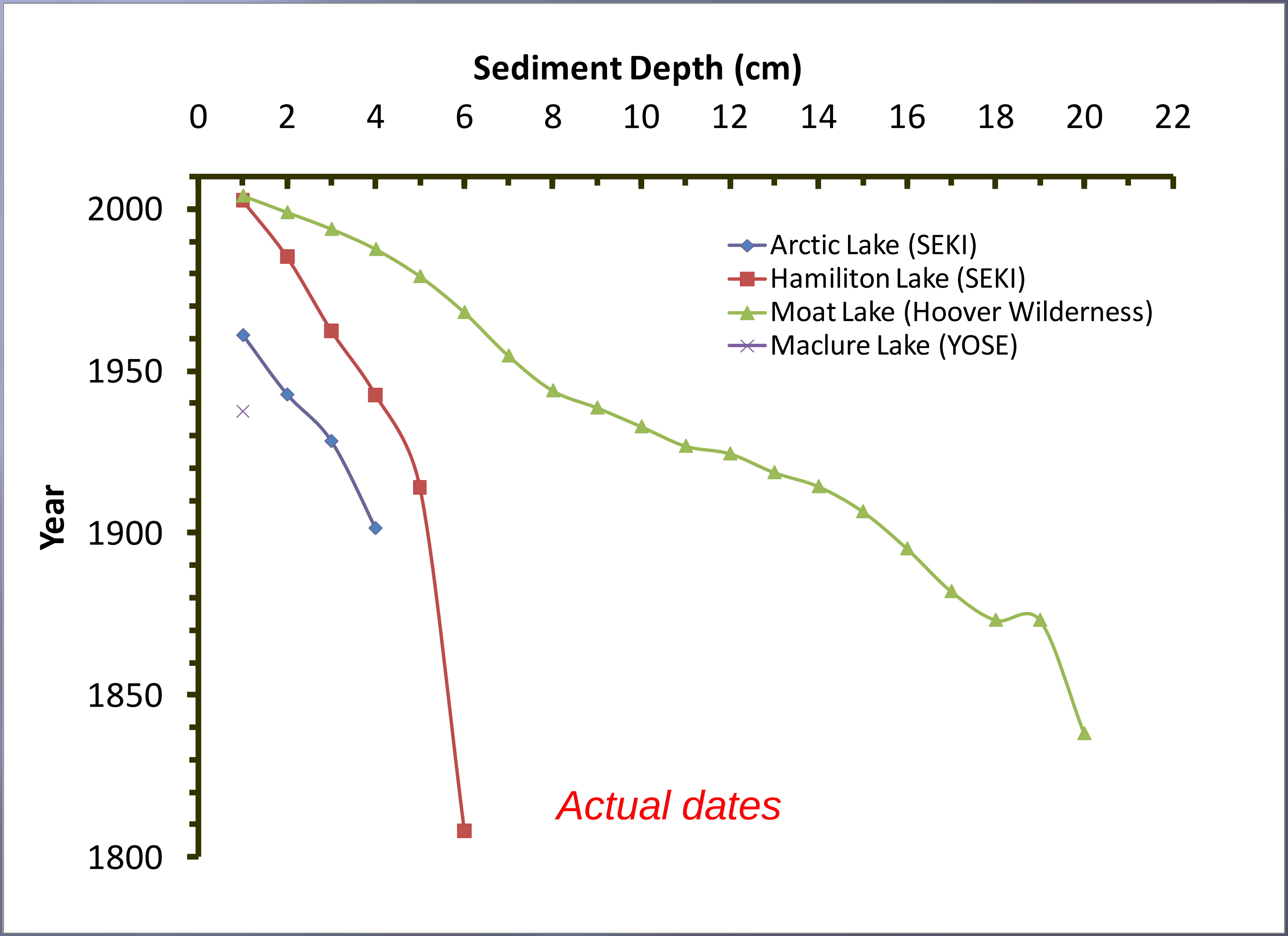


Optimum total P (ug/L

Estimated total P (ug/L

Examples !!!

Step 4: Apply SN-TIMs to Long Cores

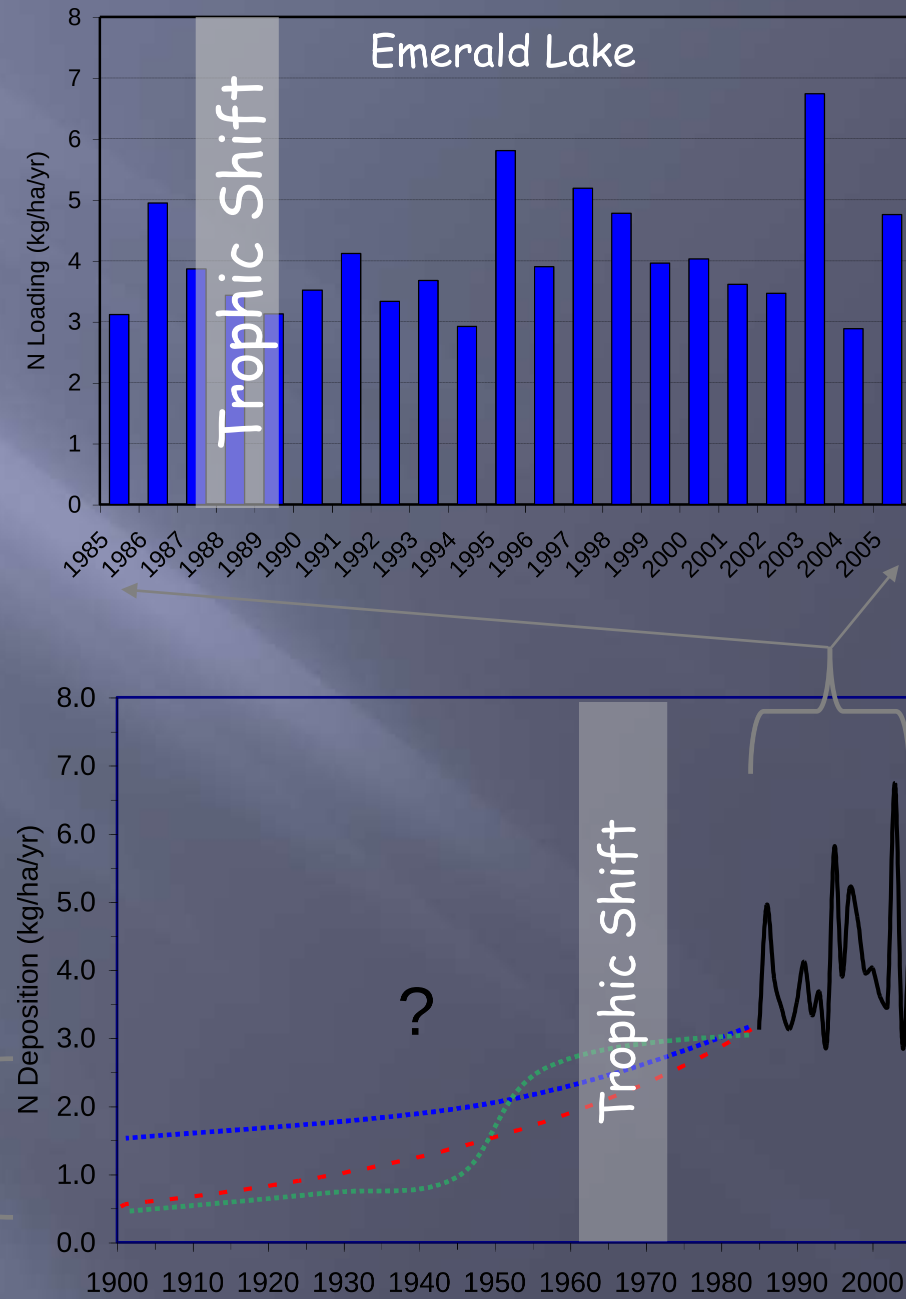


Step 5: Estimate the Critical Nitrogen Load

- If trophic shifts are observed in last 25 years, estimate deposition from instrument records
- If shifts are observed >25 years ago, use the hindcasting method of Baron 2006 and demographic/emission data from California

''anchor'' deposition?

Examples !!!



Step 6: Complementary Research-2009

- Gradient of nutrient additions (0-50 μM N, 0-10 μM P)

- Moat and Hamilton Lakes (N-limited & P-limited)
- Logistics modeling to identify "Dose-Response" and nutrient criteria