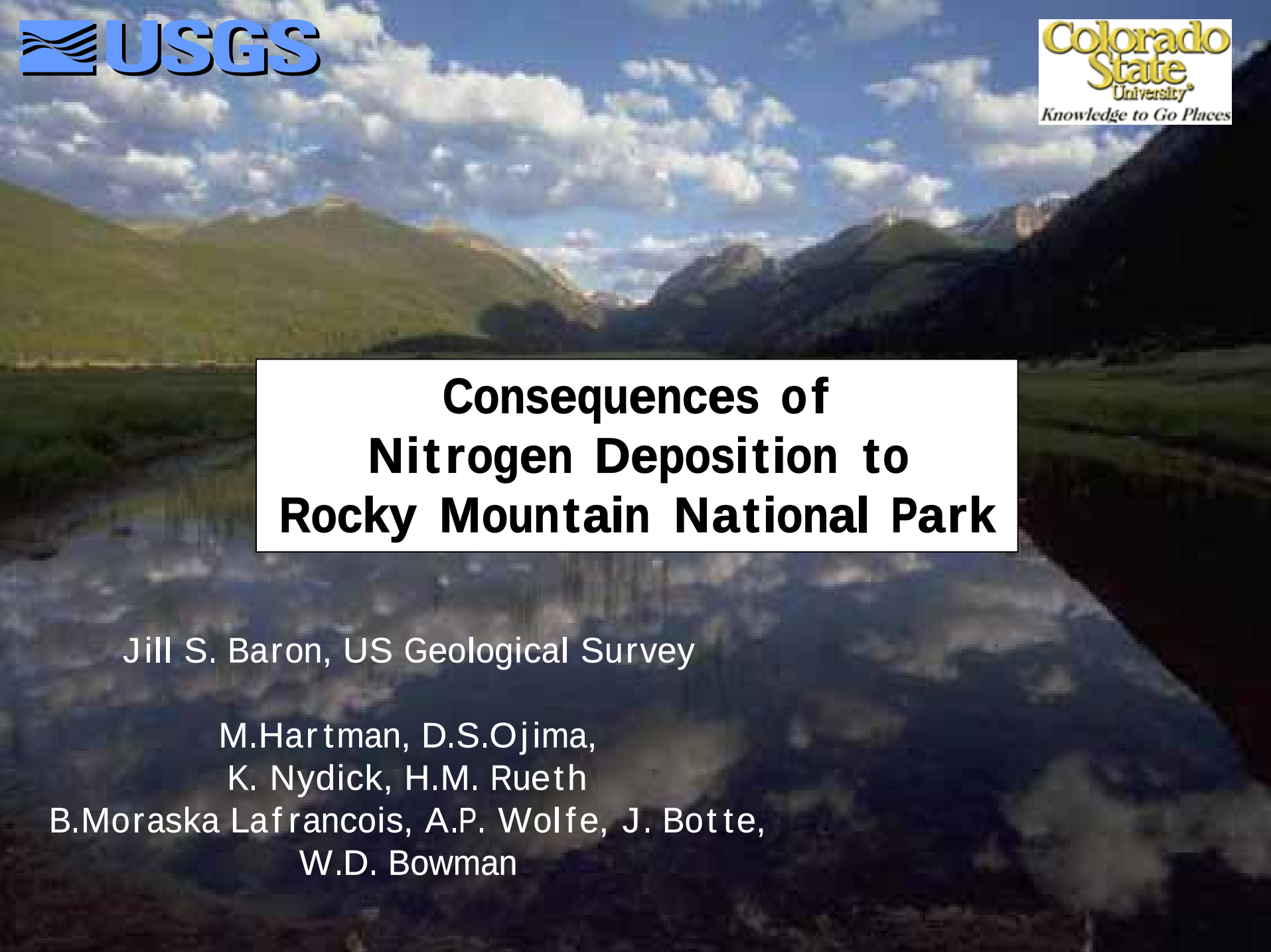
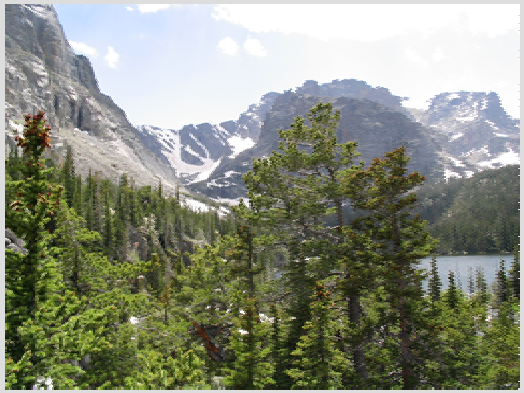


Consequences of Nitrogen Deposition to Rocky Mountain National Park

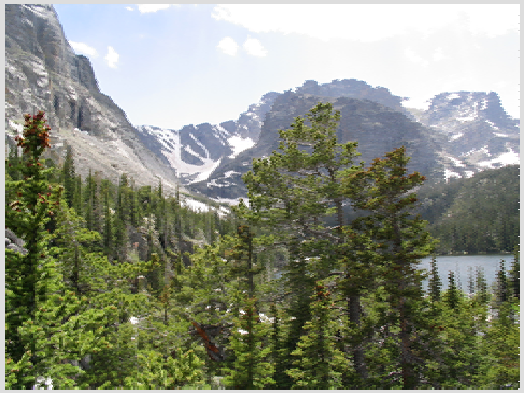
Jill S. Baron, US Geological Survey

M.Hartman, D.S.Ojima,
K. Nydick, H.M. Rueth
B.Moraska Lafrancois, A.P. Wolfe, J. Botte,
W.D. Bowman



Life is Short – Have Conclusions First!

- Nitrogen deposition is higher on the EAST side of Rocky Mountain National Park
- On the east side of the Front Range we have observed:
  - Changes in alpine tundra vegetation
  - Increased uptake of N by trees
  - Faster rates of soil nitrogen cycling
  - High year-round lake and stream N concentrations
  - Large changes in algal composition, beginning ca. 50 years ago



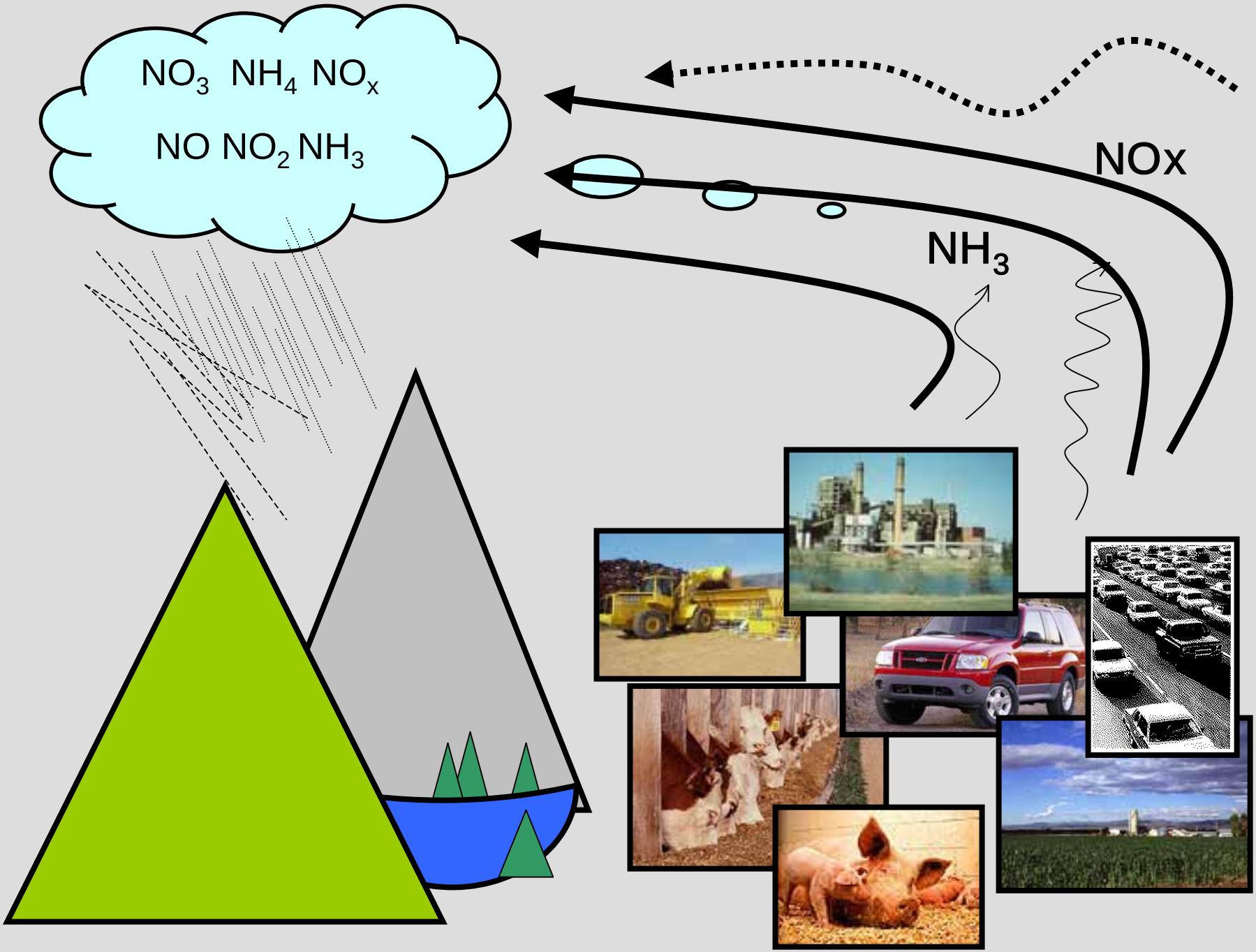
- Context: why care about nitrogen?
- Long-term research in and around Rocky Mountain National Park: how we know what we know
- The cascade of nitrogen deposition effects
- Research results

Why care about nitrogen?

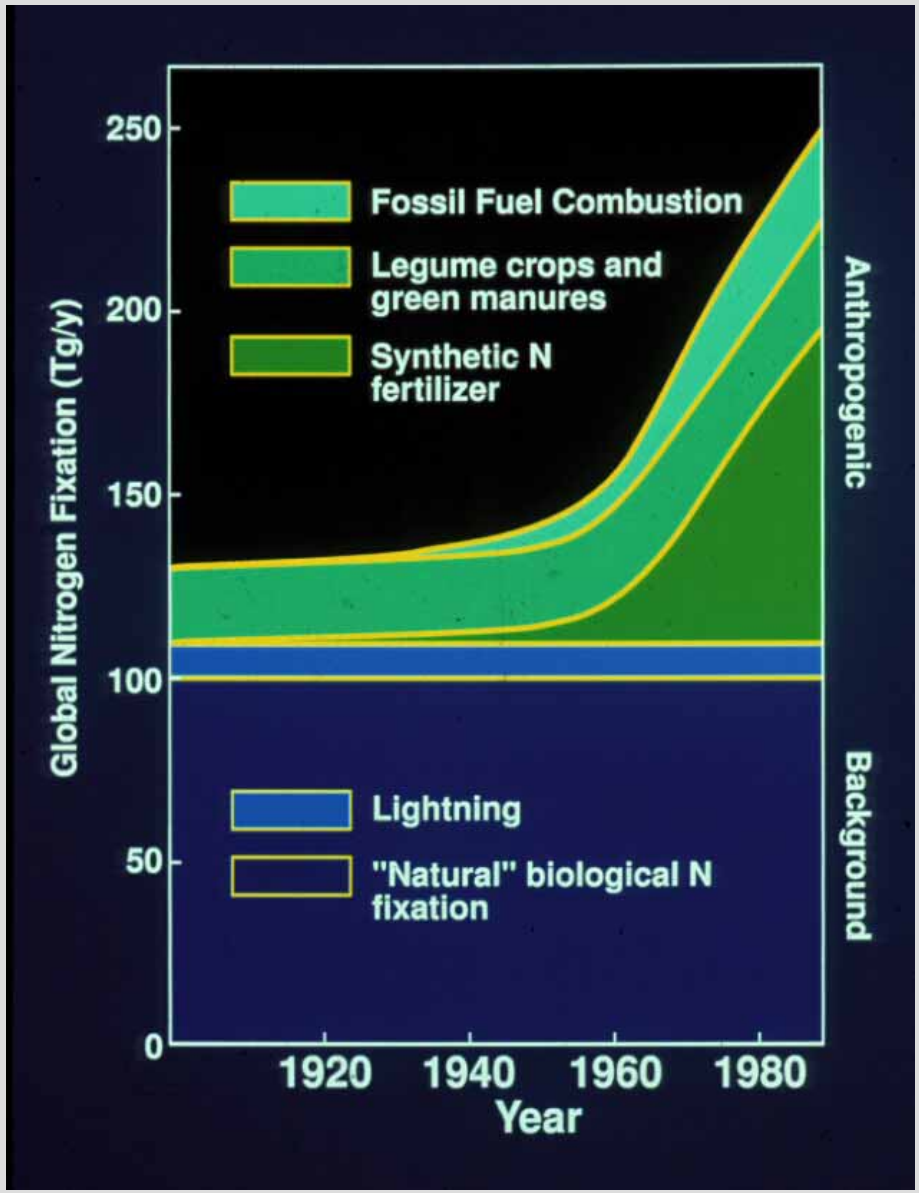
- Nitrogen is necessary for life
- Most N on Earth is in a form unusable by living organisms
- The Green Revolution occurred largely due to synthetic N fertilizers
- Humans depend on fossil fuels for transportation and energy
- Thus, to sustain human life, we convert unusable N to reactive forms.

Nitrogen in the environment

- All of the reactive N created by fossil fuel combustion enters the environment.
- Ammonia from agriculture, especially animal feedlots, enters the environment
- Nitrogen is accumulating in the environment

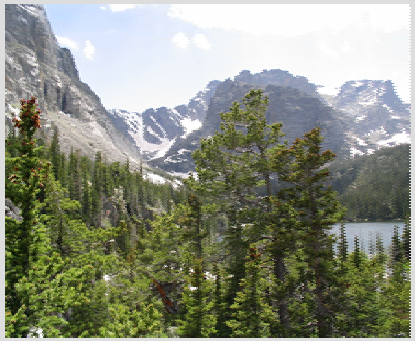

NO_3 NH_4 NO_x
NO NO_2 NH_3
NOx
NH_3

More nitrogen is now fixed by human activities than by natural processes



Vitousek et al.

Nitrogen accumulation contributes to:

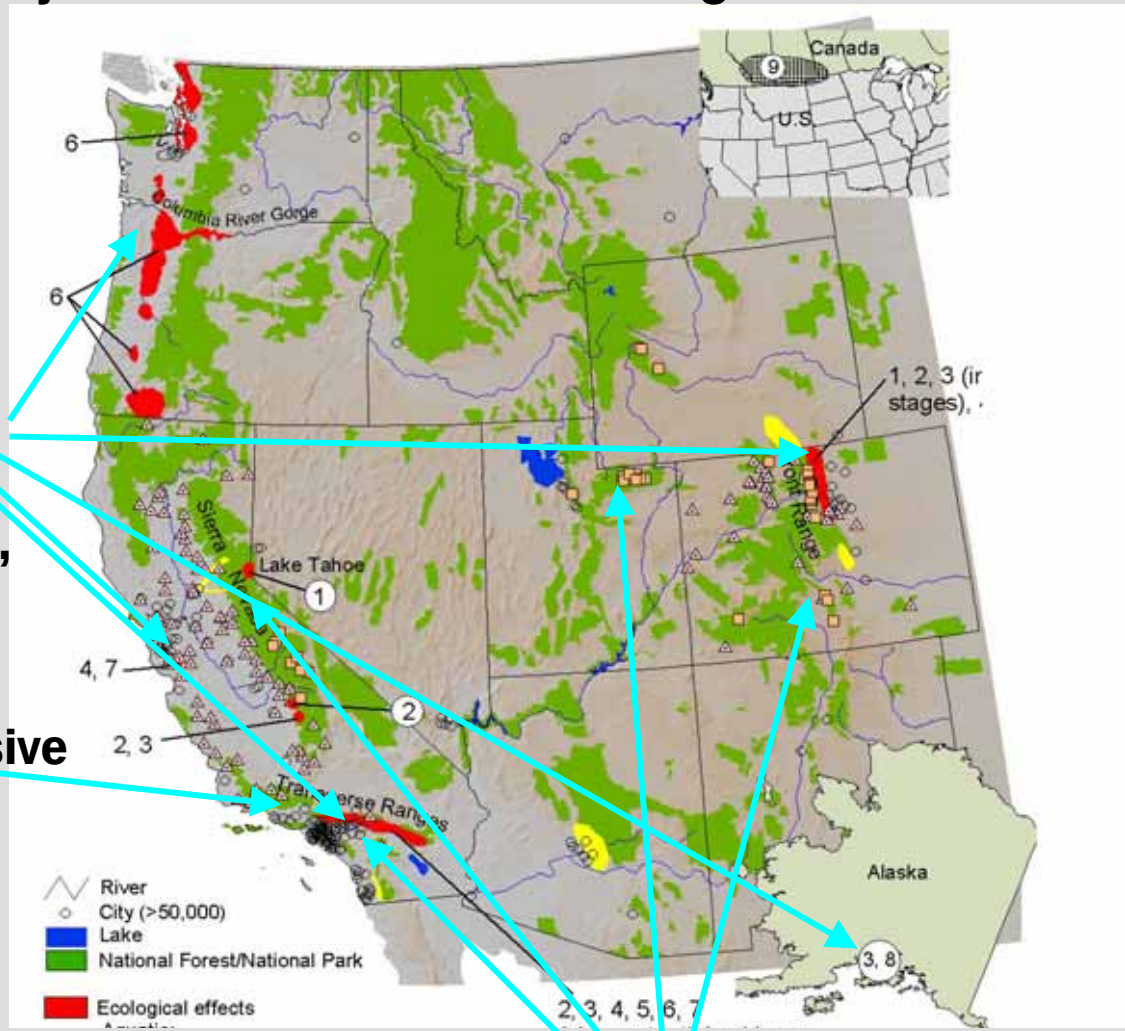


- Acid deposition
- Coastal dead zones
- Lake and river eutrophication
- Unnatural rates of forest growth
- Loss of biodiversity
- Smog
- Greenhouse effect
- Stratospheric ozone depletion

In the West, Ecological Effects are Found Adjacent to Urban and Agricultural Areas

Altered plant communities (plants, lichens, fungi)

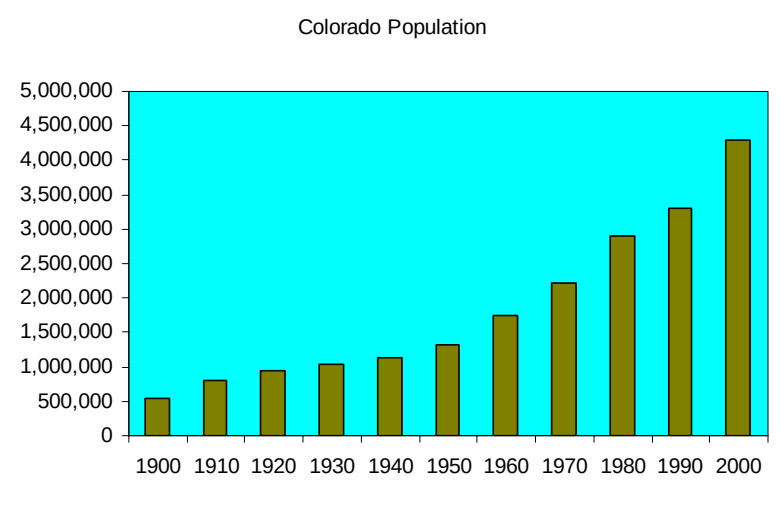
Increased Invasive Species and Altered Fire Regime



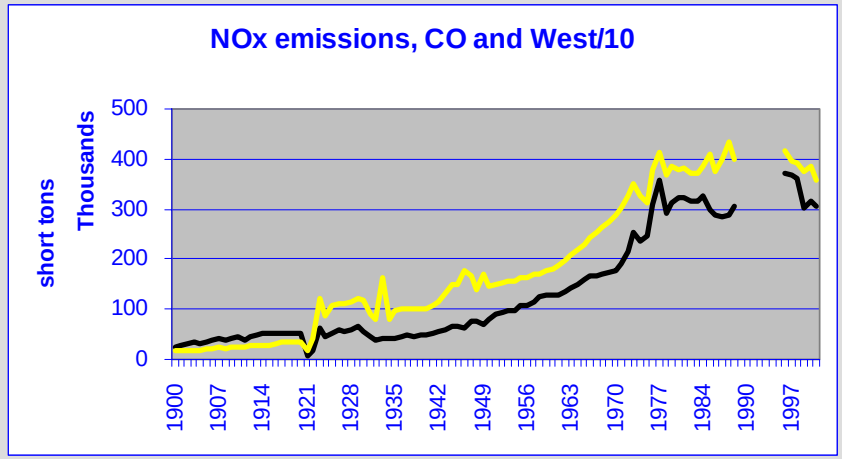
High N waters

Fenn et al. 2003

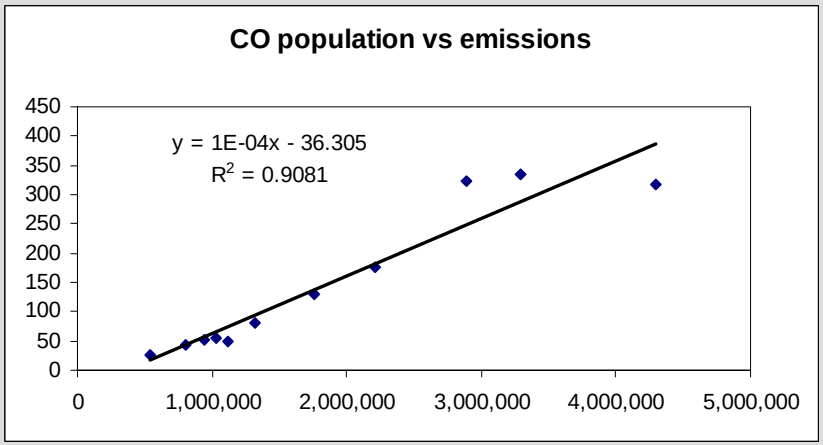
Colorado population and emissions trends



US Census Bureau

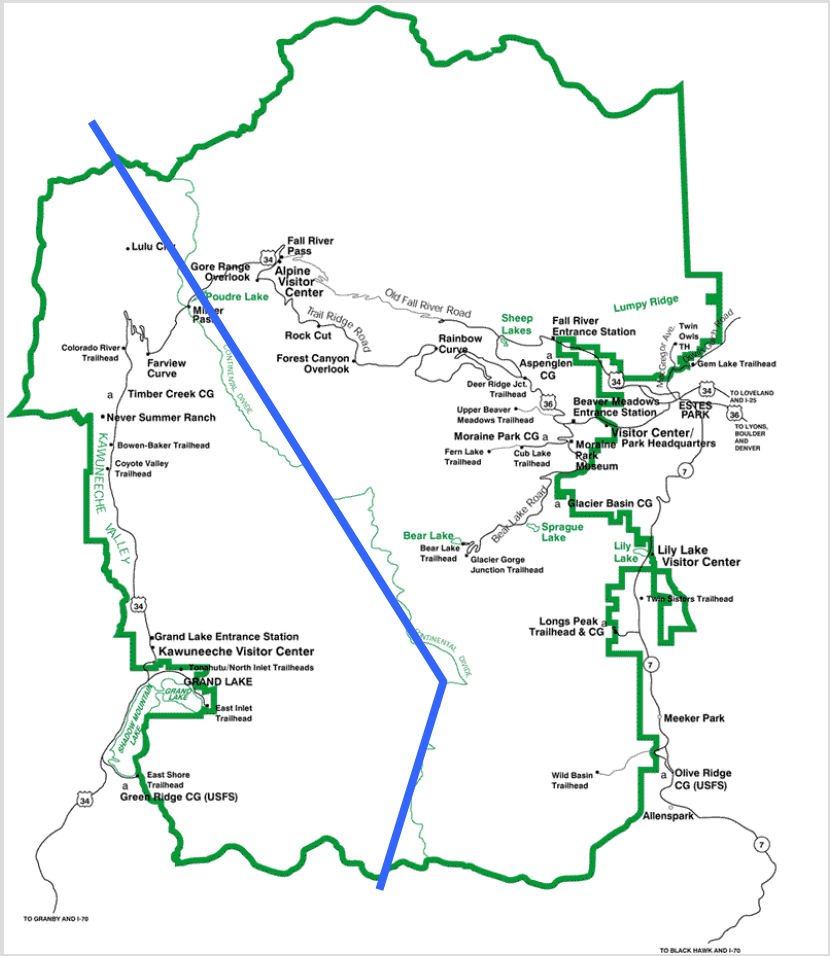


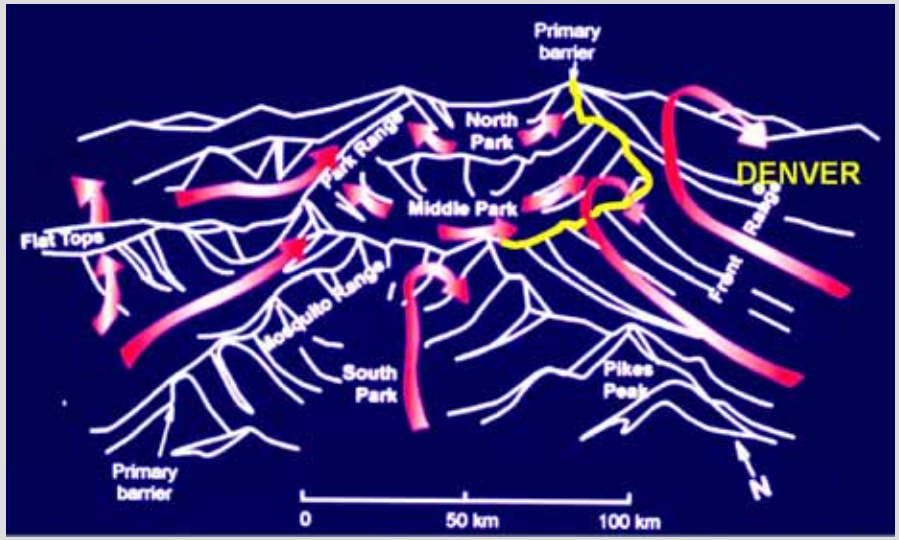
US EPA



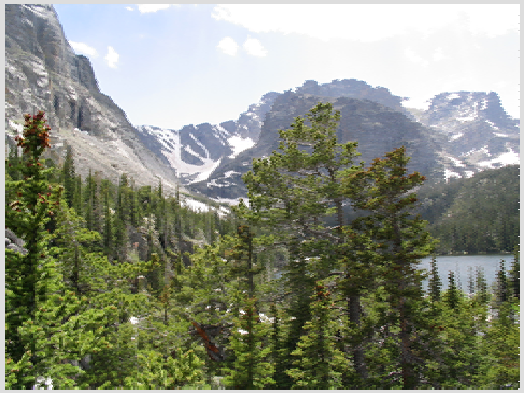
Nitrogen oxide emissions are very tightly related to population.

The Continental Divide separates airsheds in Rocky Mountain National Park





Spring/summer upslope winds move
Front Range air to mountains



- Context: why care about nitrogen?
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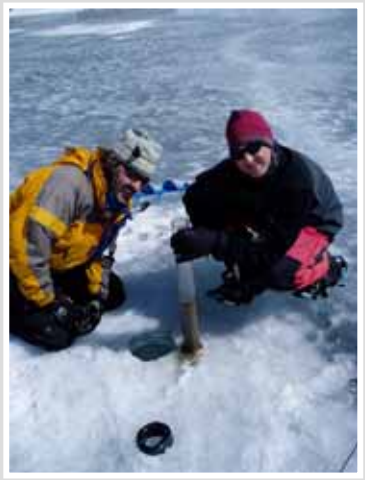
Foundations



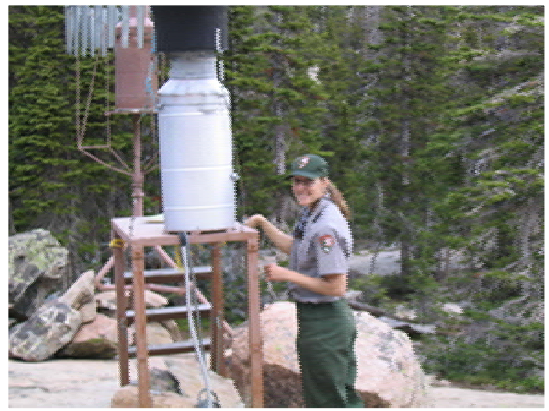
- 23+ years of long-term monitoring in Loch Vale Watershed
- Experiments in field and lab to test cause and effect
- Modeling of ecosystem processes and “what-if” scenarios
- Spatial comparisons in Colorado and across western US

Long-term Program Objectives

- To understand and differentiate natural processes from unnatural, human-caused drivers of change
- To understand and quantify the effects of atmospheric deposition on high elevation ecosystems
- To share knowledge with managers so they are better informed

Our equipment is sturdy and Park Service Brown

Rain Gages



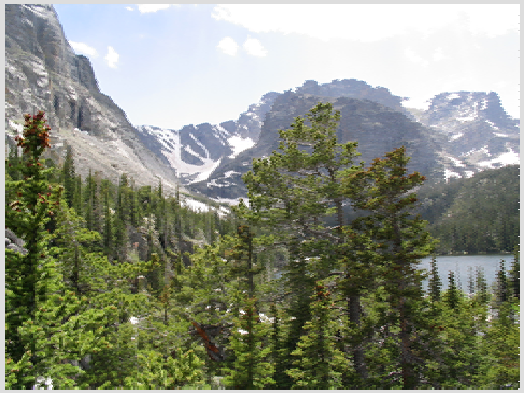
NADP Buckets

Stream Gage

Soil Lysimeter

Loch Vale Research has been widely reviewed and published

- 78 Journal Papers
- 26 Graduate Degrees
- 1 Loch Vale Book
- 1 Special Journal Section
- 9 Methods and QA Reports
- 154 Total Publications



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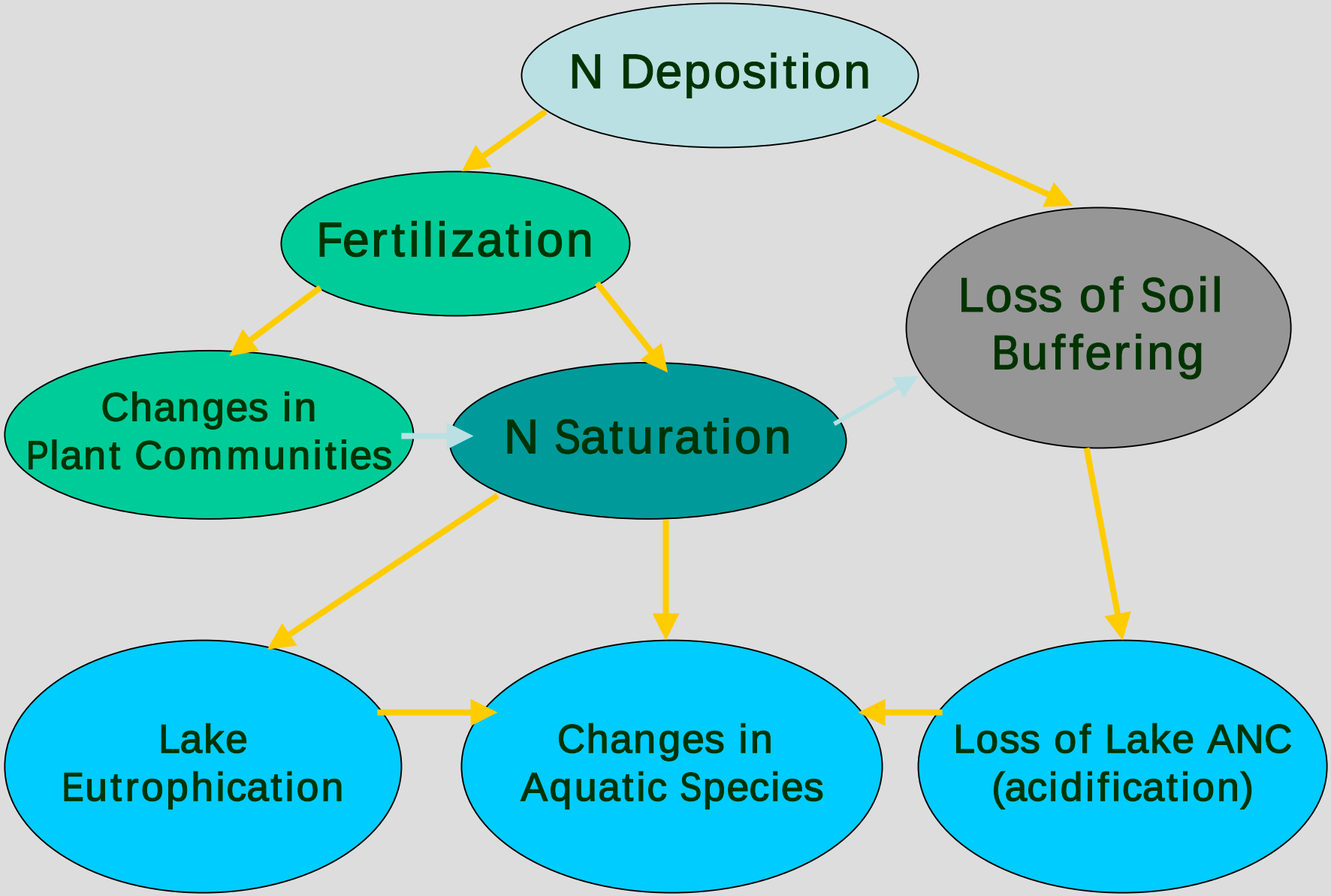
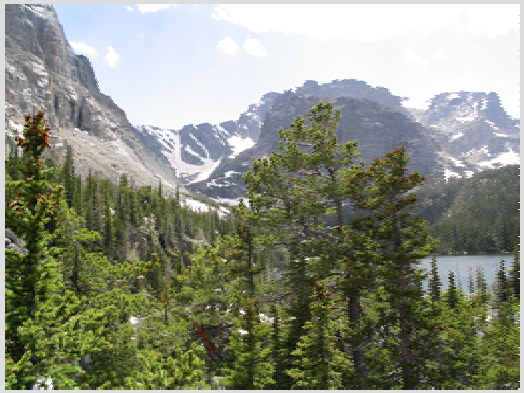
Pathways and Effects of Excess Nitrogen Deposition





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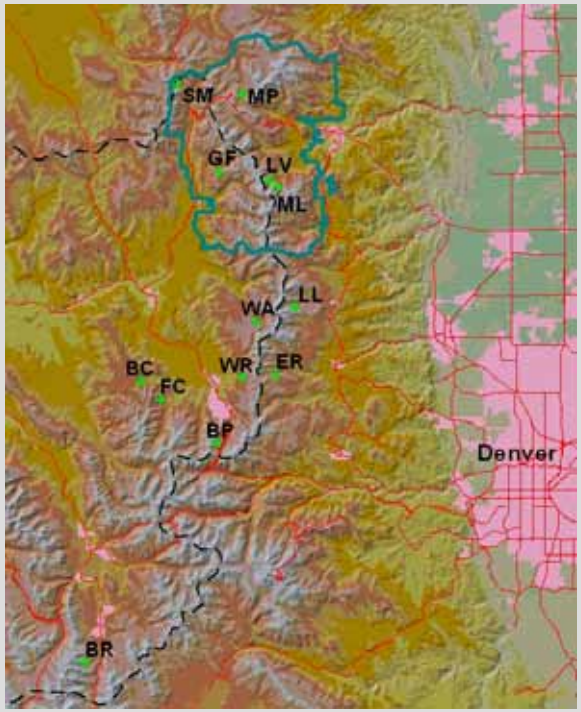
In the alpine nitrogen favors sedges and grasses over flowering plants

Niwot Ridge research shows sedges and grasses grow better with N than flowering plants in both experiments and surveys

(Korb and Ranker 2001; Bowman et al. in review)



East-side forests are closer to N saturation

Six pairs of sites were similar in all characteristics except for N deposition amount

East side stands differed <u>significantly</u> from west side forests:

- higher needle and soil N,
- lower C:N ratios,
- higher soil N cycling rates

Experimental Fertilization of Small Forest Plots

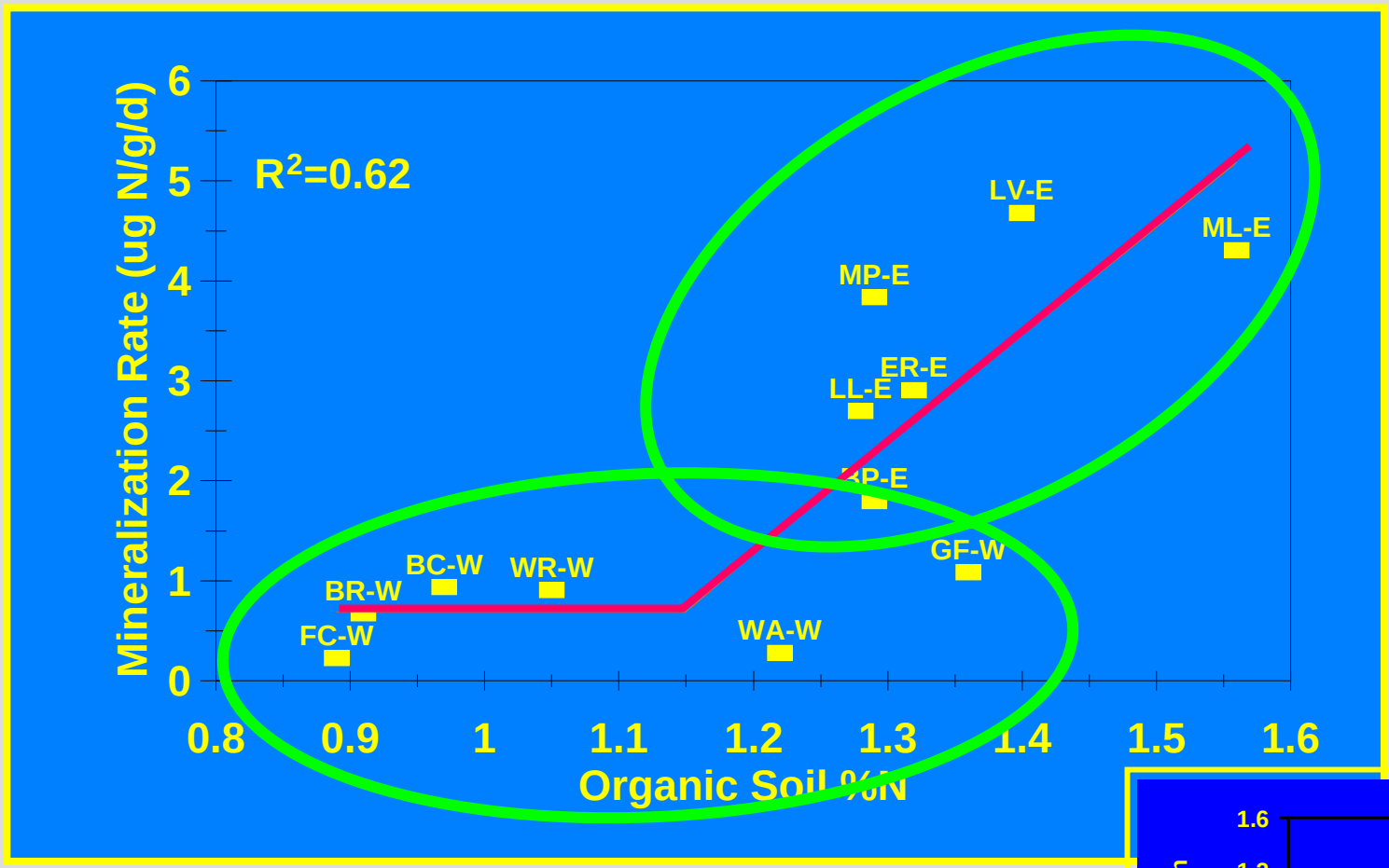
Effects

- nitrate leached from soils => symptom of saturation

- base cations leached from soils => depletes soil buffering capacity and fertility

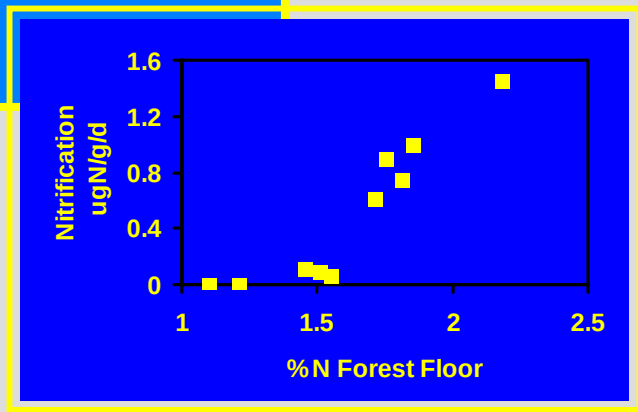
Rueth et al. 2001, Geick et al. in prep

As soils accumulate N, microbial activity increases



Colorado Front Range
Baron et al. 2000
Rueth & Baron 2001

Similar patterns in
New England, USA
McNulty et al. 1991

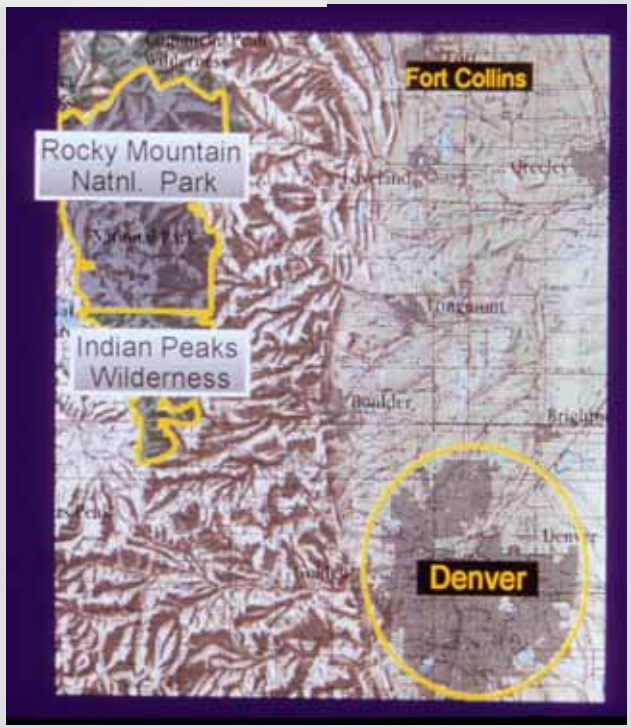


East-side lakes have higher N concentrations

Means (ueq/L)

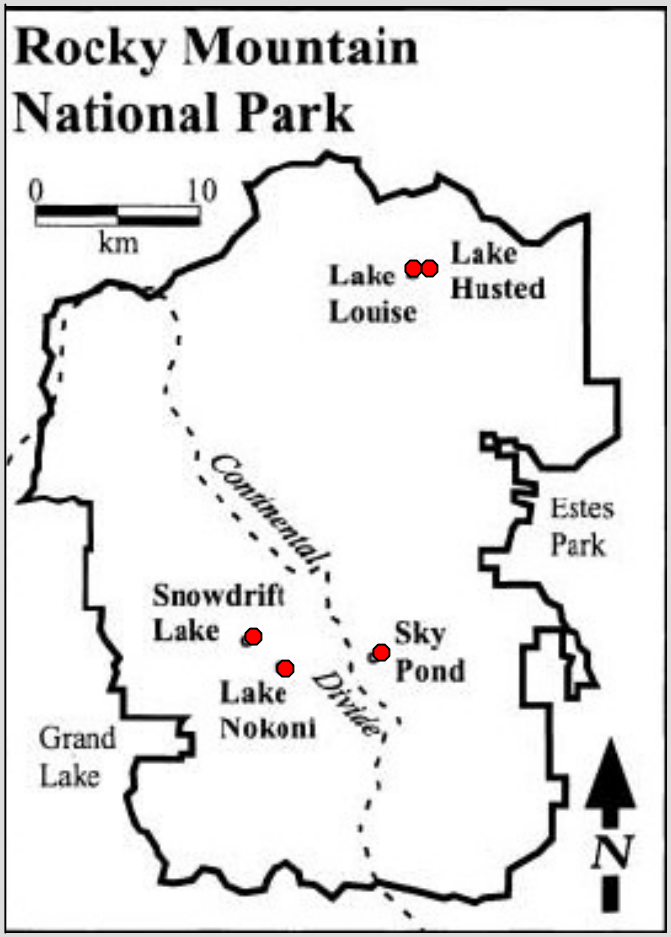
East **10.5** (5.0)
West **6.6** (4.3)

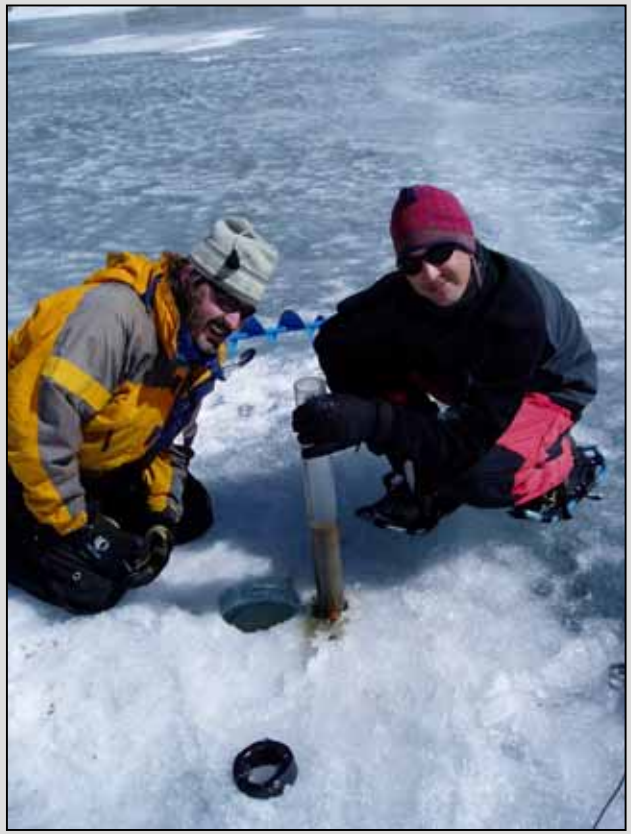
n=44, p = 0.02



Baron et al. 2000

Lake Sediments serve as Proxies for Past Environmental Change

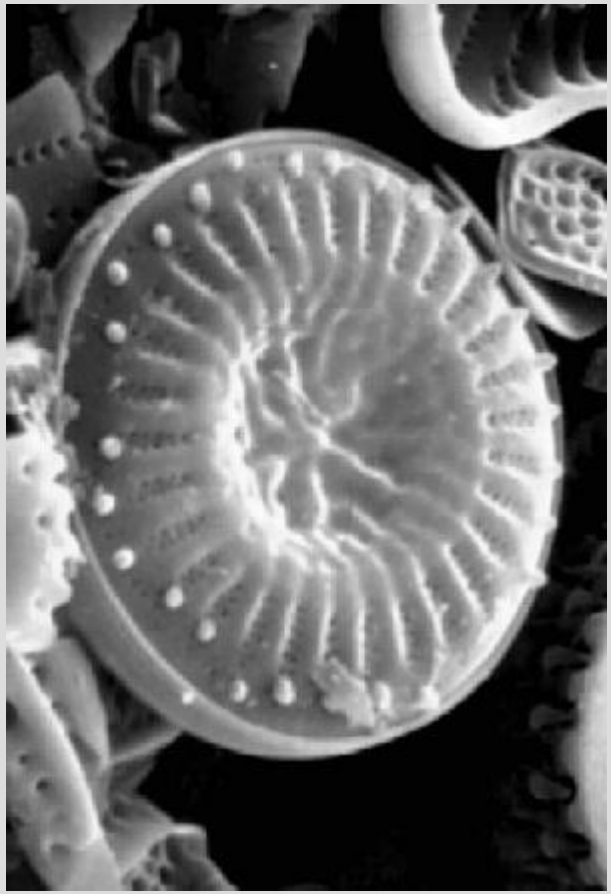




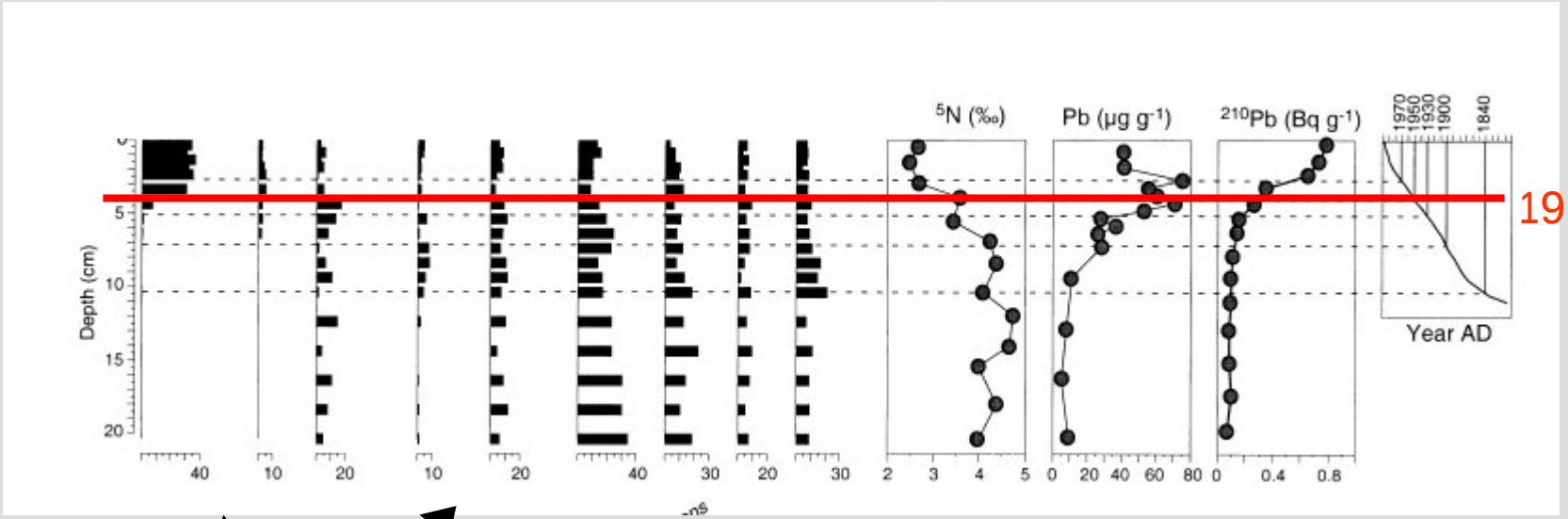
Wolfe et al., 2001, 2003, Baron et al. 1986

Diatoms are good indicators of environmental change

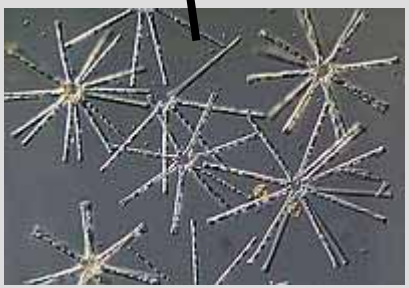
- Diatoms are algae: single-celled aquatic plants
- Species are very sensitive to water chemistry
- Glass (silica) cell walls do not decompose
- Each species has unique cell walls



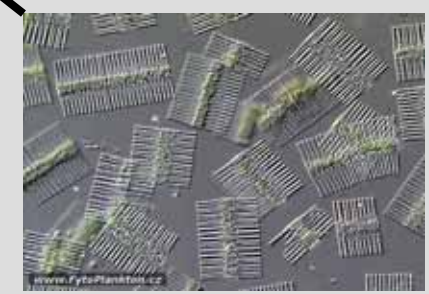
Diatom Indicators of Disturbance Increased Abruptly in east-side lakes ca. 1950-1960



Sky Pond



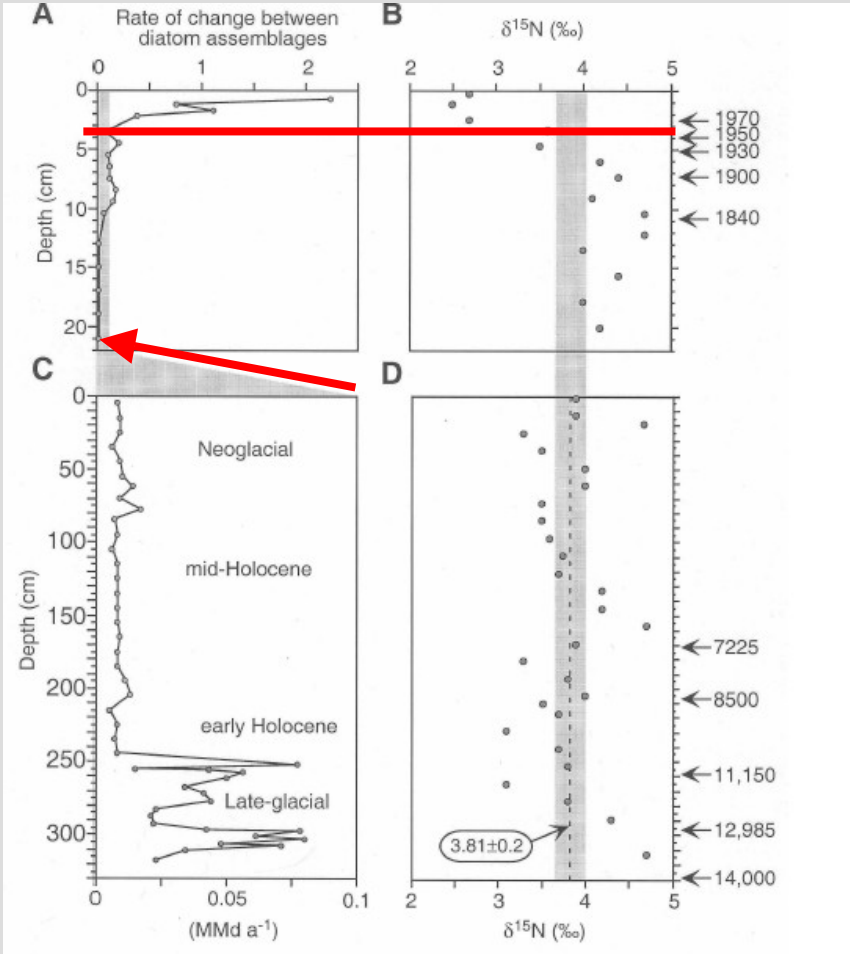
Asterionella formosa



Fragillaria crotonensis

Aulacoseira spp.

Lakes Have Changed More Since 1950 than Previous 14,000 Yrs



The <u>rate of change</u> in diatoms post-1950 is an order of magnitude greater than any change since Pleistocene.

The <u>abundance</u> of diatoms is 8-25x greater post-1950.

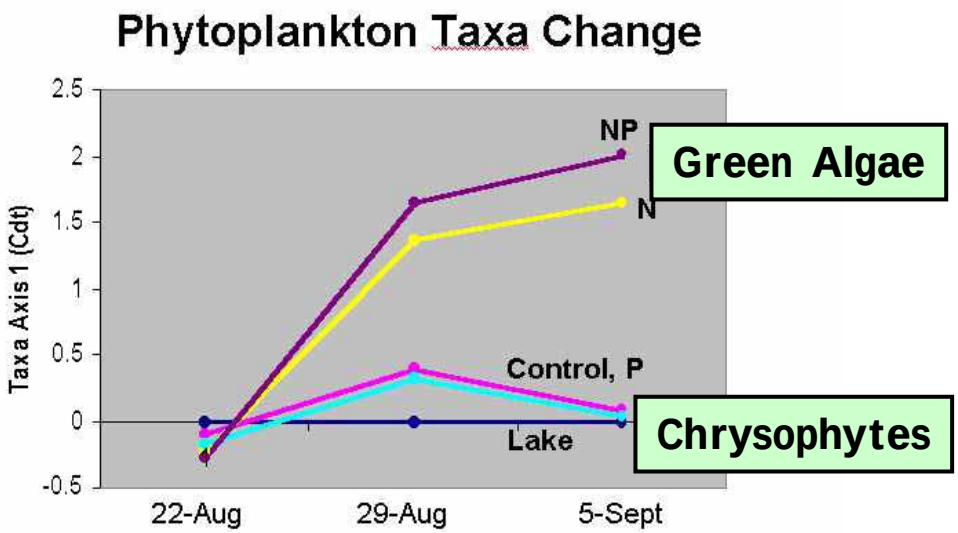
Caused by dominance of 2 disturbance species: *Asterionella formosa* and *Fragilaria crotonensis.*
>40% of total diatoms since 1950

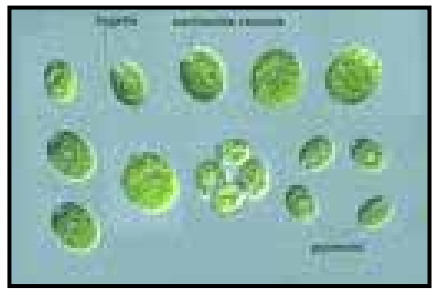
***A. formosa* and *F. crotonensis* are indicators of nutrient-rich waters**

Experiments with Bioassays (Bottles), Mesocosms (Hula Hoops), and Lakes

Lafrancois et al. 2003, 2004,
Nydick et al. 2003, 2004a, b

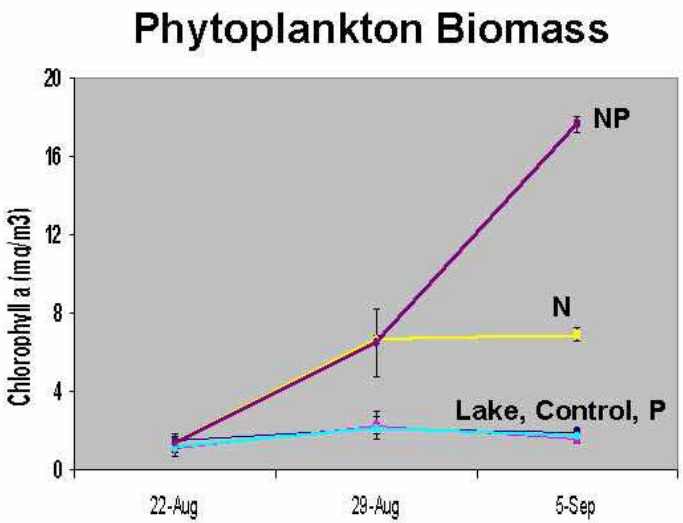
Experiments:
Productivity increased with added N and N+P.
Communities changed to nutrient-loving algae.





Chlamydomonas sp.

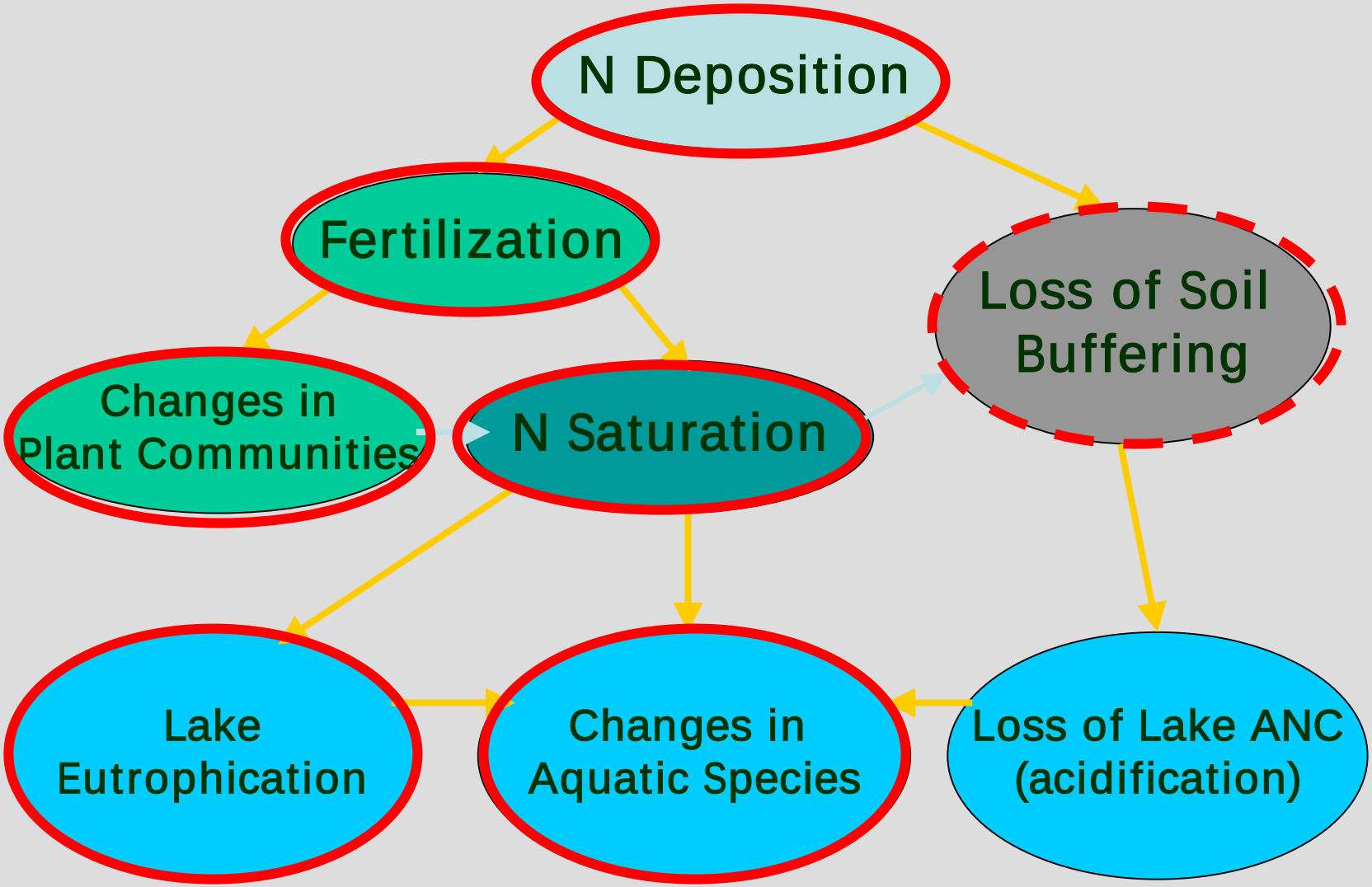
Dinobryon sp.

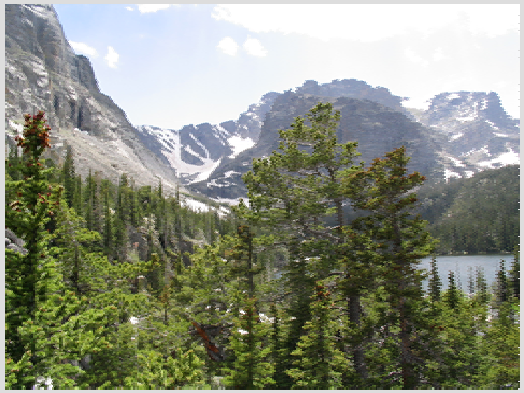


N Additions = Eutrophication

increased productivity
changed algal community

Summary of Research Results





Phew! We made it! Conclusions

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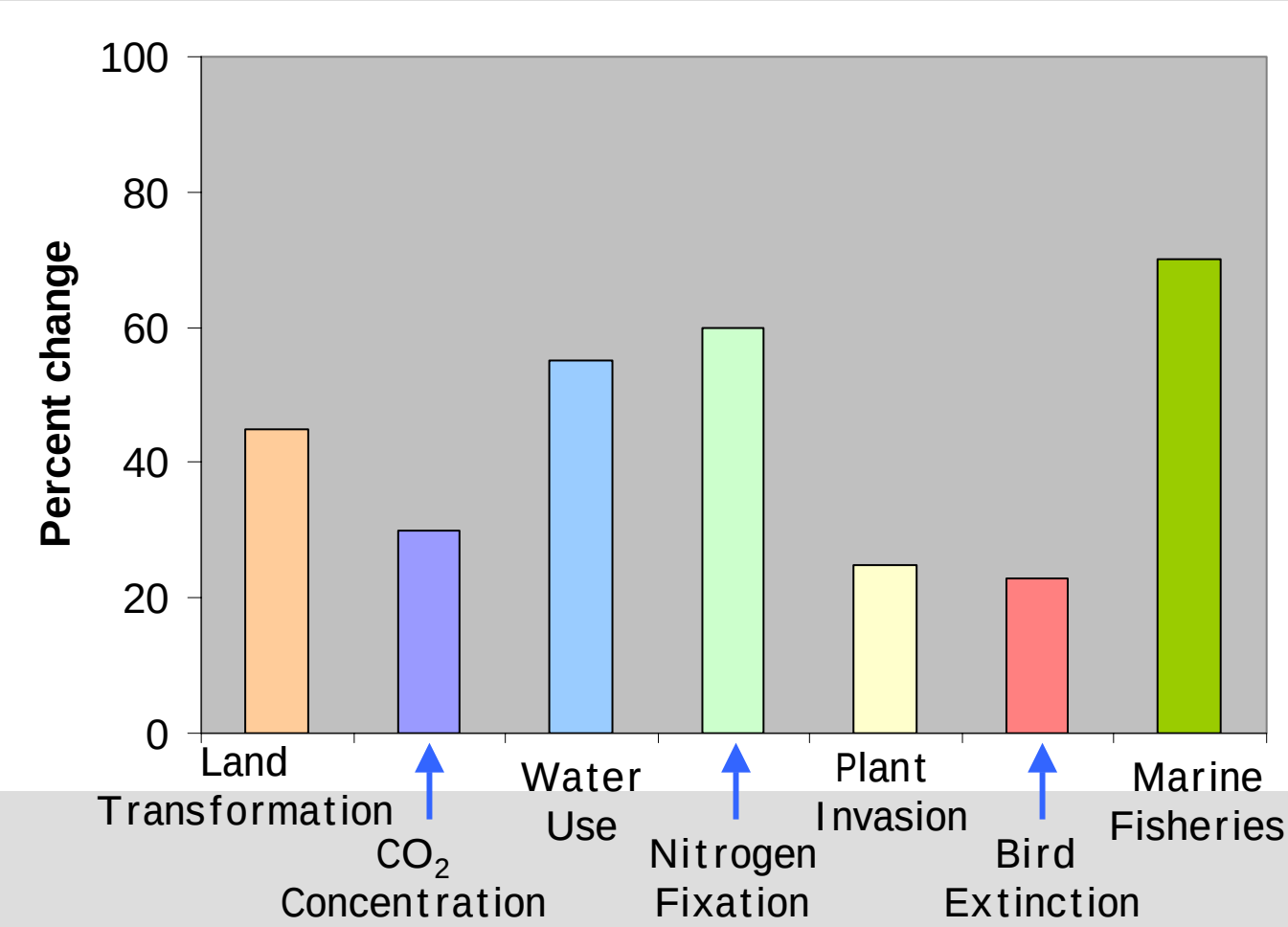
- On the east side of the Front Range we have observed:
  - Changes in alpine tundra vegetation
  - Increased uptake of N by trees
  - Faster rates of soil nitrogen cycling
  - High year-round lake and stream N concentrations
  - Large changes in algal composition, beginning ca. 50 years ago
  - Acidification has not yet occurred


http://www.nrel.colostate.edu/projects/lvws/

Human Dominance of Earth System



Vitousek et al. 1997