Freshwater Responses to Nitrogen and Phosphorus Pollution and a Case Study of Cutler and Dingle Marsh Wetlands

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Department of Watershed Sciences

January 13, 2008

Outline

- **Control of Eutrophication by nutrients**

  - Are Phosphorus, Nitrogen or Both important?

- **Lewis, W.M. Jr. and W.A. Wurtsbaugh. 2008. Control of Lacustrine Phytoplankton by Nutrients: Erosion of the Phosphorus Paradigm. Internat. Rev. Hydrobiol. 93 2008 4–5 446–465**

- **Is nutrient loading effecting Cutler Reservoir?**

  - Analyses from 2007 and 2008 Aquatic Ecology Practicum Course (WATS 4510)

Problems with Eutrophication

Taste & Odor in Drinking Water

Oxygen loss when algae decomposes

Fish Kills

Problems with Eutrophication

Cyanobacteria & other phytoplankton produce toxins to humans & wildlife

Skin rashes in some individuals

Algae toxin blamed in teen's death

Associated Press

The Dane County coroner has concluded that a teenager's death last year was from exposure to a toxin released by algae.

Dane Rogers, 17, of Cottage Grove, went into shock and suffered a seizure

Stanley said he decided to release the report to make the public aware of the potential dangers of algal toxins in small ponds.

"There are a lot of ponds out there with a lot more algae than was in this one," he said. "We wanted the public to know that you should not go swim-

Mortalities in wildlife & occasionally humans

Problems with Eutrophication

Esthetics

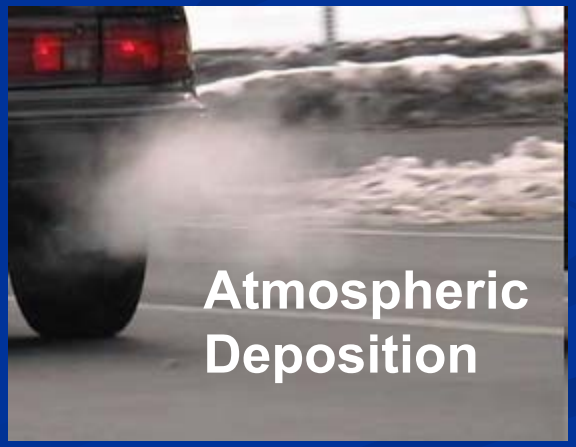
Lake Winnipeg shoreline

Sources of Nutrients Causing Eutrophication

www.oznet.ksu.edu/conservation/livestock.htm

www.ia.nrcs.usda.gov/news/images/Pics/nitrogen1.jpg

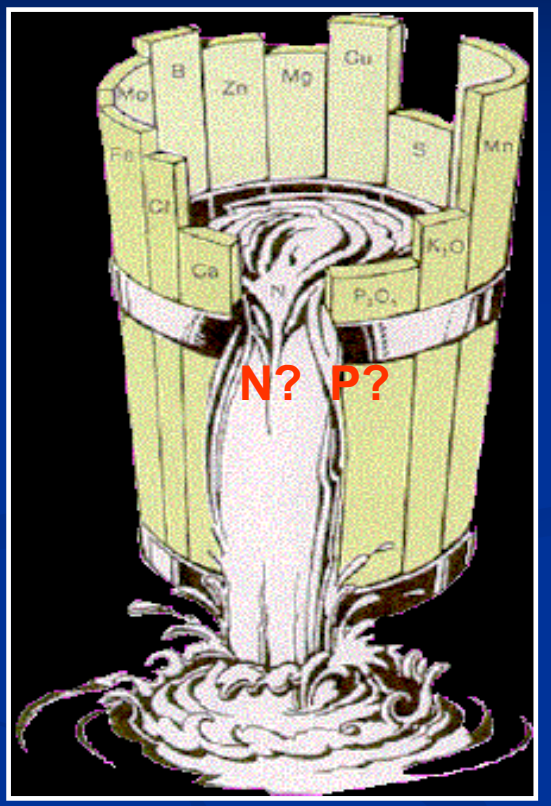
www.winnsystems.com/



www.topnews.in/health/files/

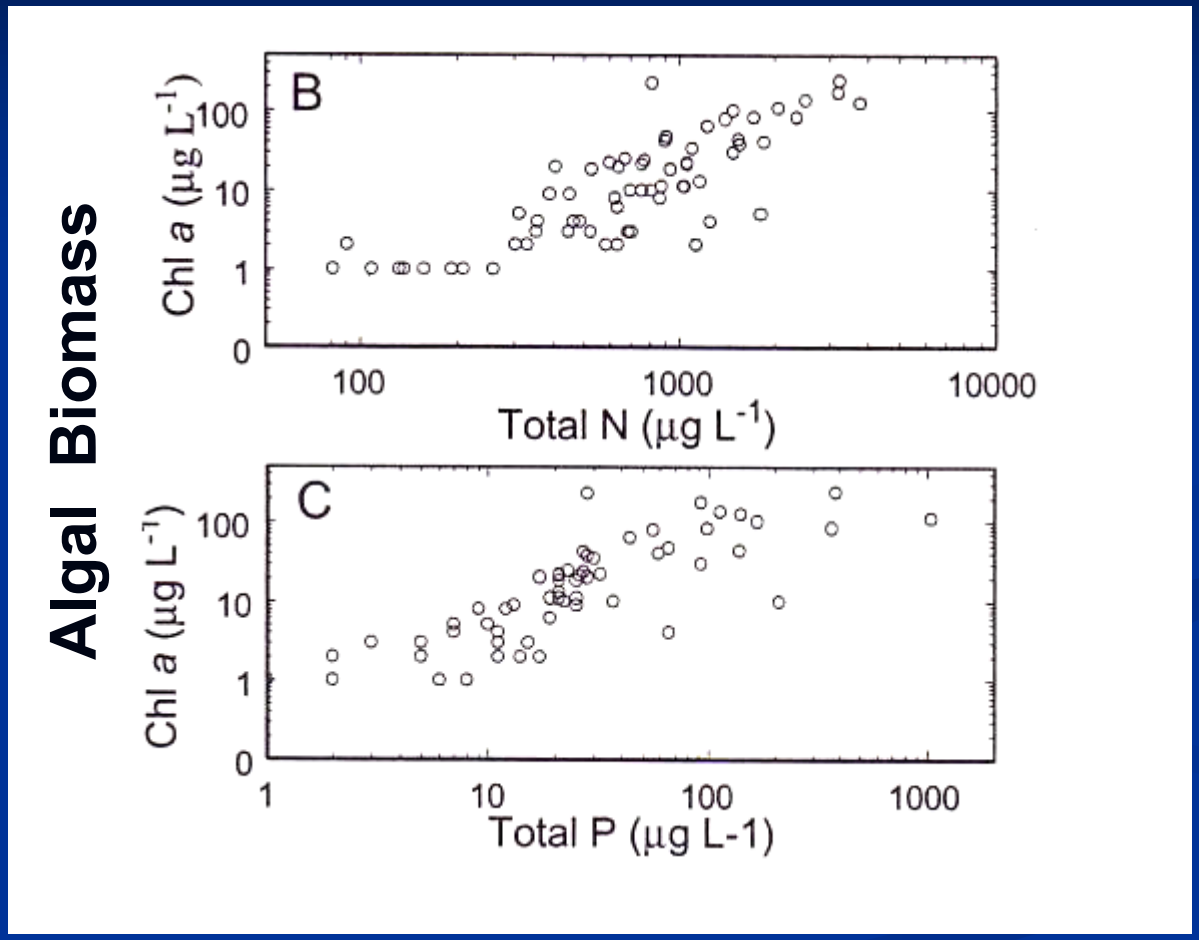
What Nutrient(s) Control Eutrophication?

- **The one in shortest supply relative to algal needs**
- **How do we figure out which nutrient is limiting?**



Liebig's Law of the Minimum

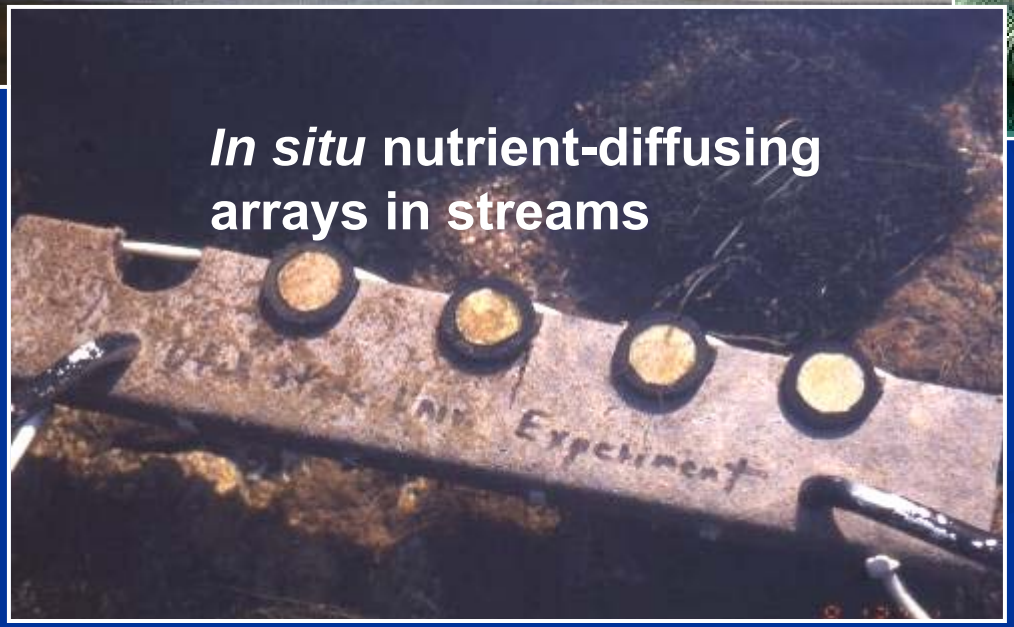
Correlation Analyses



Relationship between total nitrogen and total phosphorus and algal biomass (Chlorophyll a) in Florida Lakes (Bachman et al. 1996)

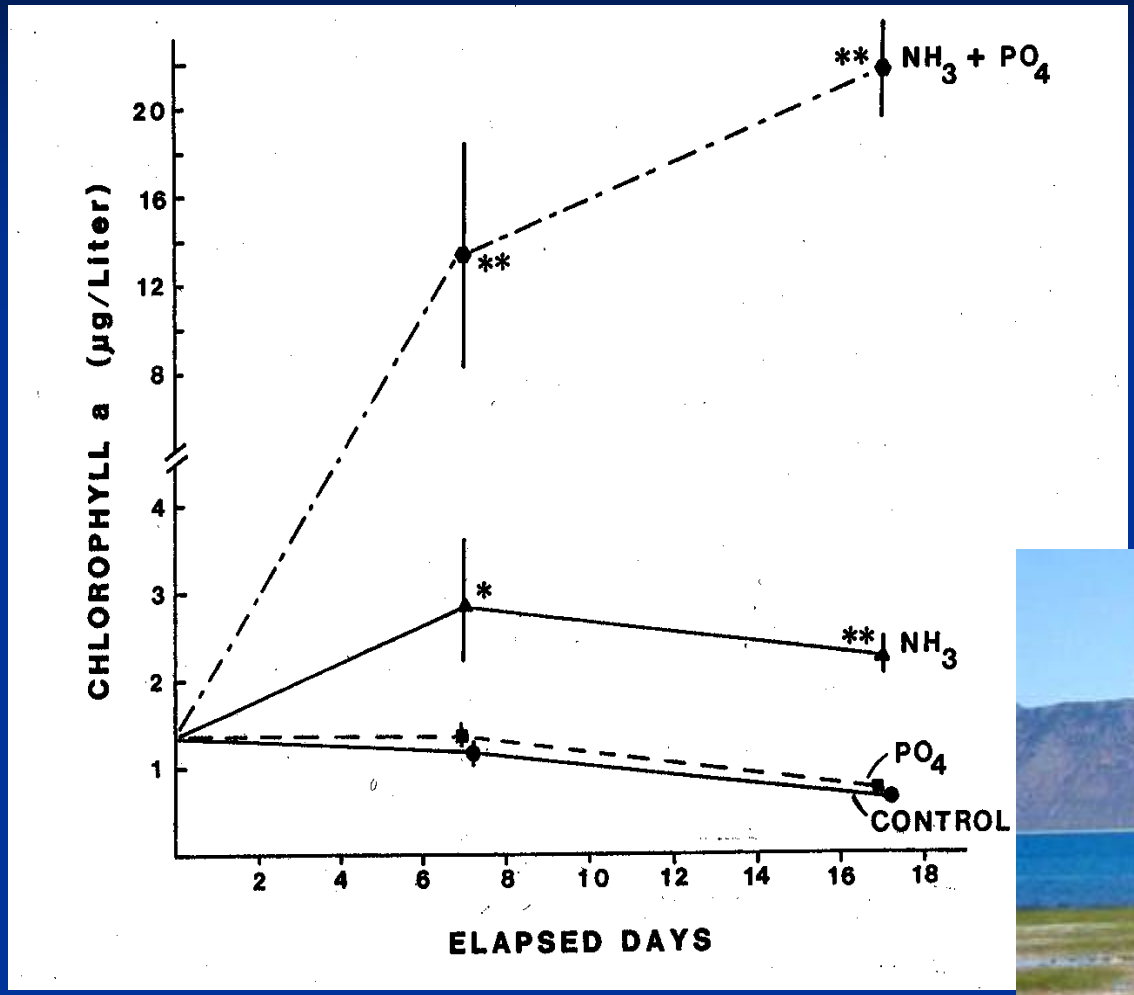
Bioassay Experiments

Lab



Add different nutrients and see which one(s) stimulate algal growth

Chlorophyll *a* Response in Oligotrophic Bear Lake, Utah



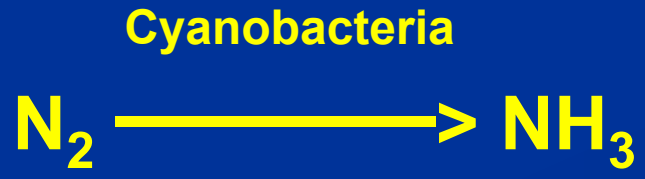
Bottle & Small-Scale Mesocosm Experiments Criticized Because they Do Not Allow Full Range of Biotic Responses

David Schindler (1974, 1977, 2008) promoted whole-lake experiments

Concluded:

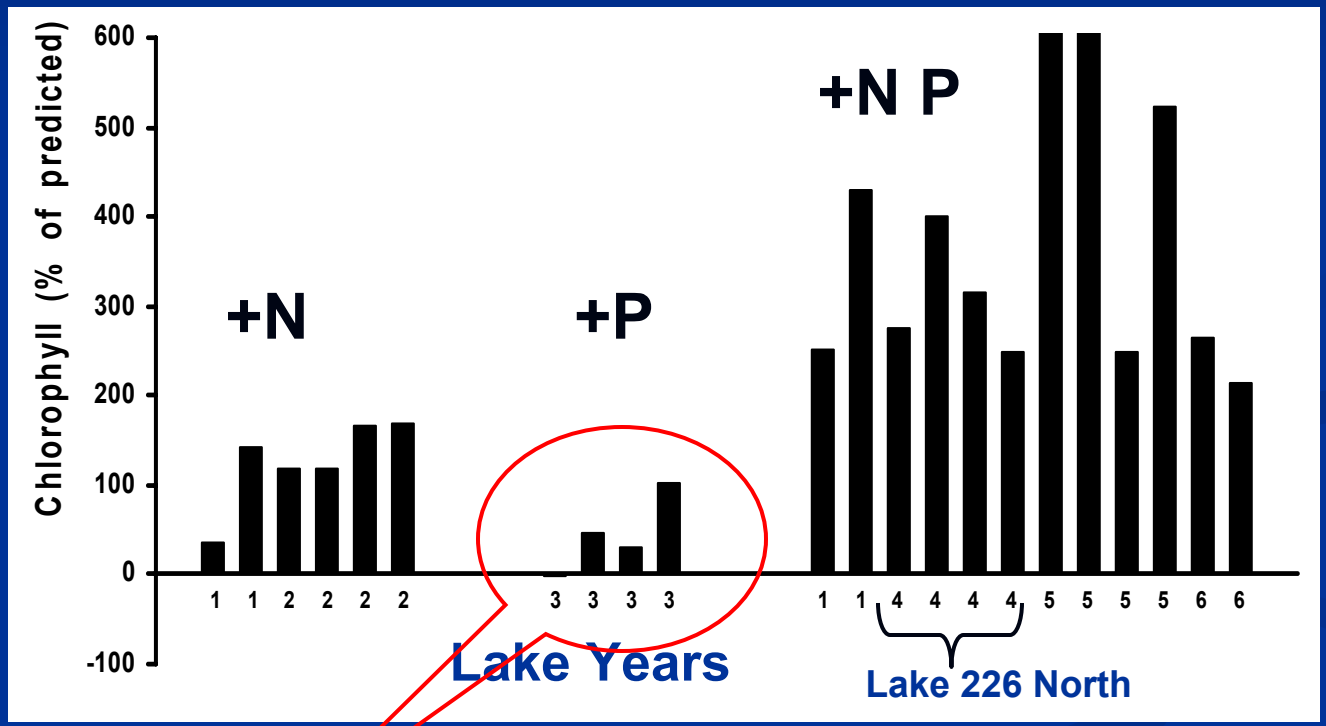
- **Only phosphorus is important**

- **If nitrogen is in short supply, nitrogen fixation by cyanobacteria will make up the nitrogen deficit:**



Schindler (1977) Evolution of phosphorus limitation in lakes, Science

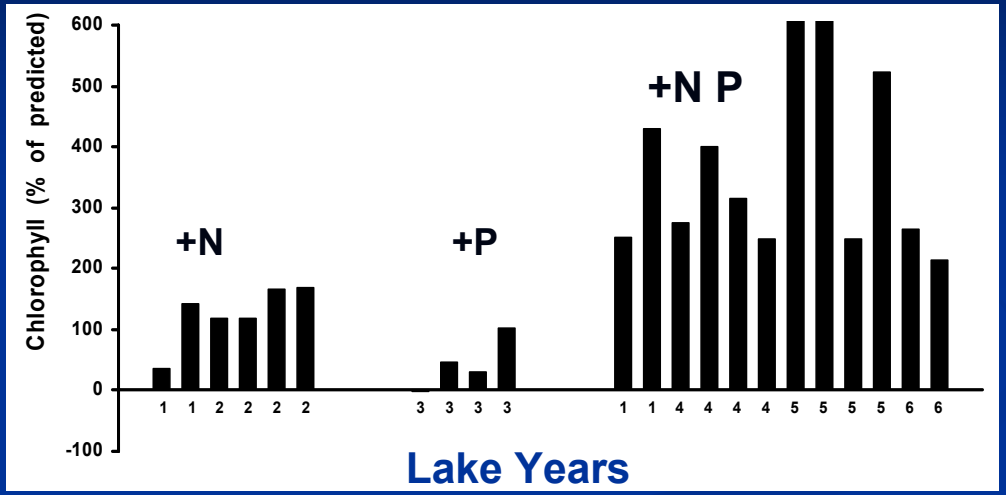
Response to Nutrient Additions in All of the ELA Lakes



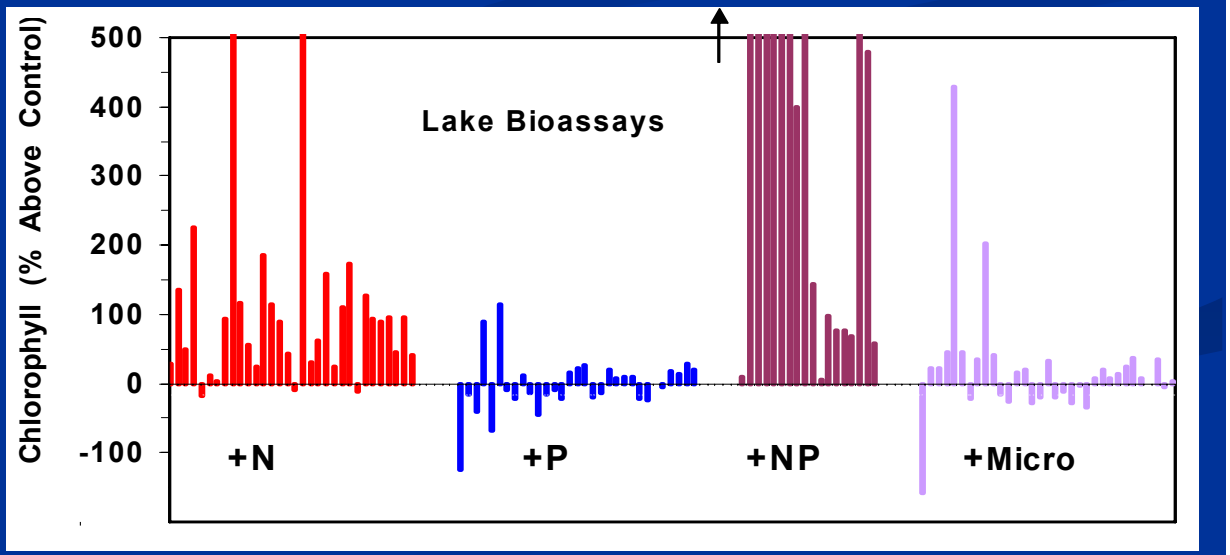
No nitrogen fixation in water column, but some in periphyton

Similar Response in ELA Lakes as in Small-Scale Bioassays

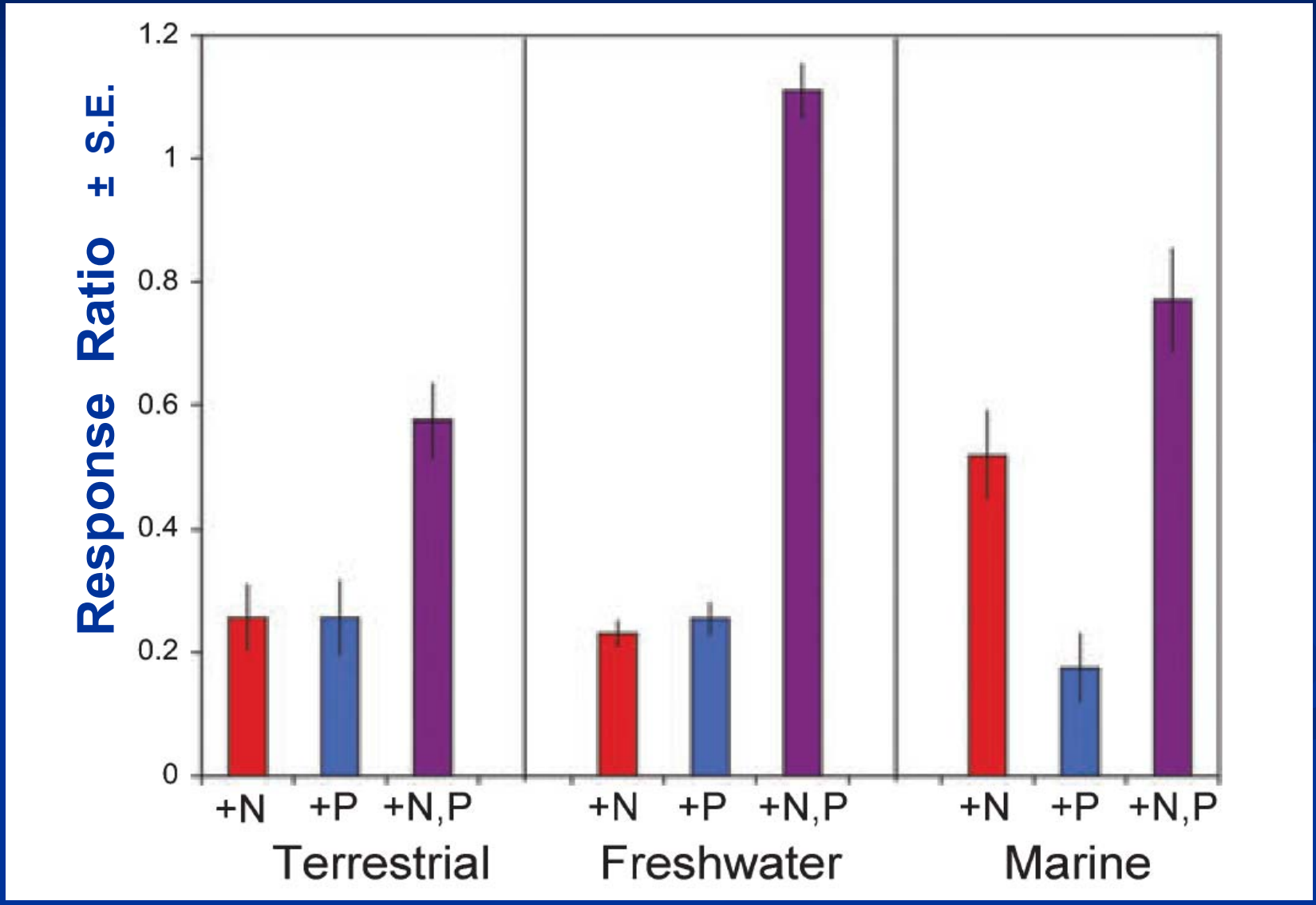
Experimental Lakes Area of Canada
(adapted from Fee 1979)



Summary of 32 Bioassays in 8 Widely-different Lakes in western US, Spain, Peru (W. Wurtsbaugh)



Elser et al. 2007. Global analysis of nitrogen and phosphorus limitation of primary producers in freshwater, marine and terrestrial ecosystems.
Ecology Letters 10: 1-8



Can nitrogen fixing cyanobacteria make up the N-deficiency?

For eutrophic lakes showing N fixation in the plankton, the median contribution to total load that could be attributed to N fixation is near 22%, and the median fixation as a proportion of the total N necessary to support primary production is less than 5%, according to the data compiled by HOWARTH et al. (1988). **-- Lewis & Wurtsbaugh (2008)**

- Limited by some other nutrient
  (e.g. Fe, Wurtsbaugh and Horne 1983)
- Light limitation (energetic constraints)
- Turbulence
- Grazing losses

37 Whole-Lake Bioassay Experiment (Schindler et al. 2008)

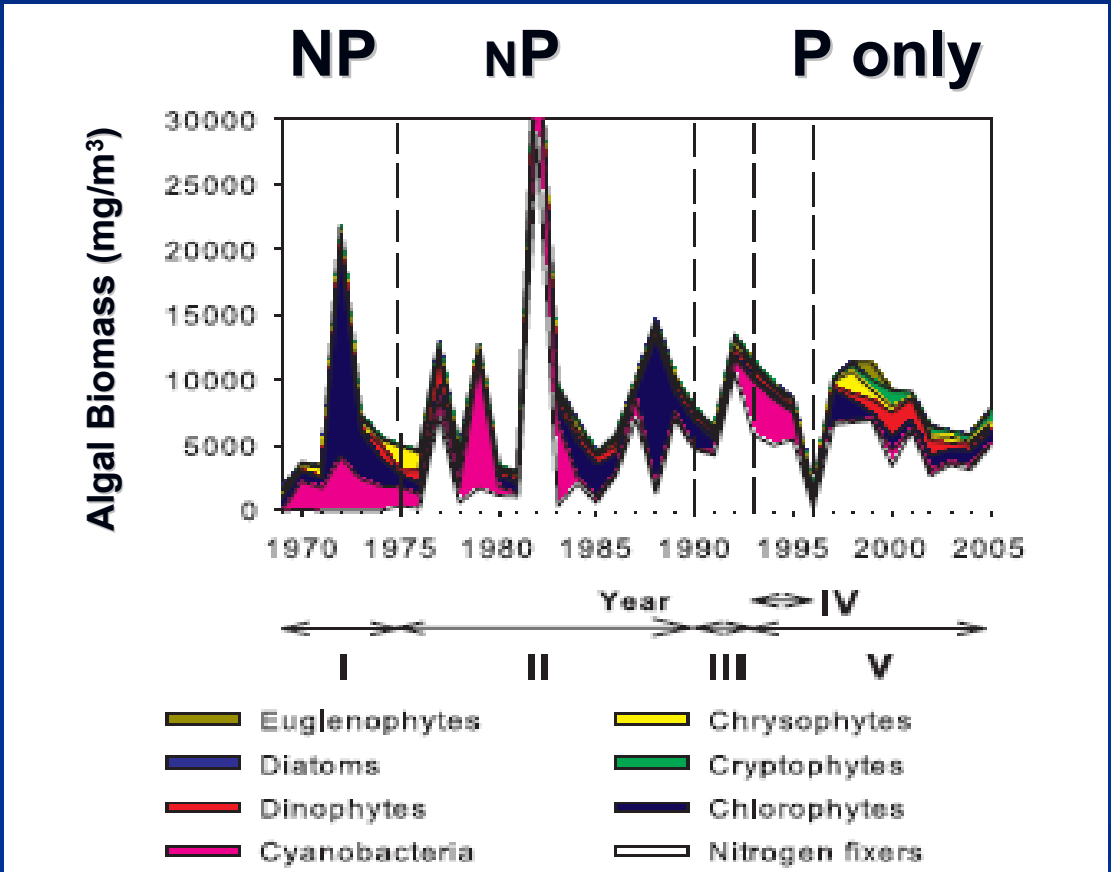
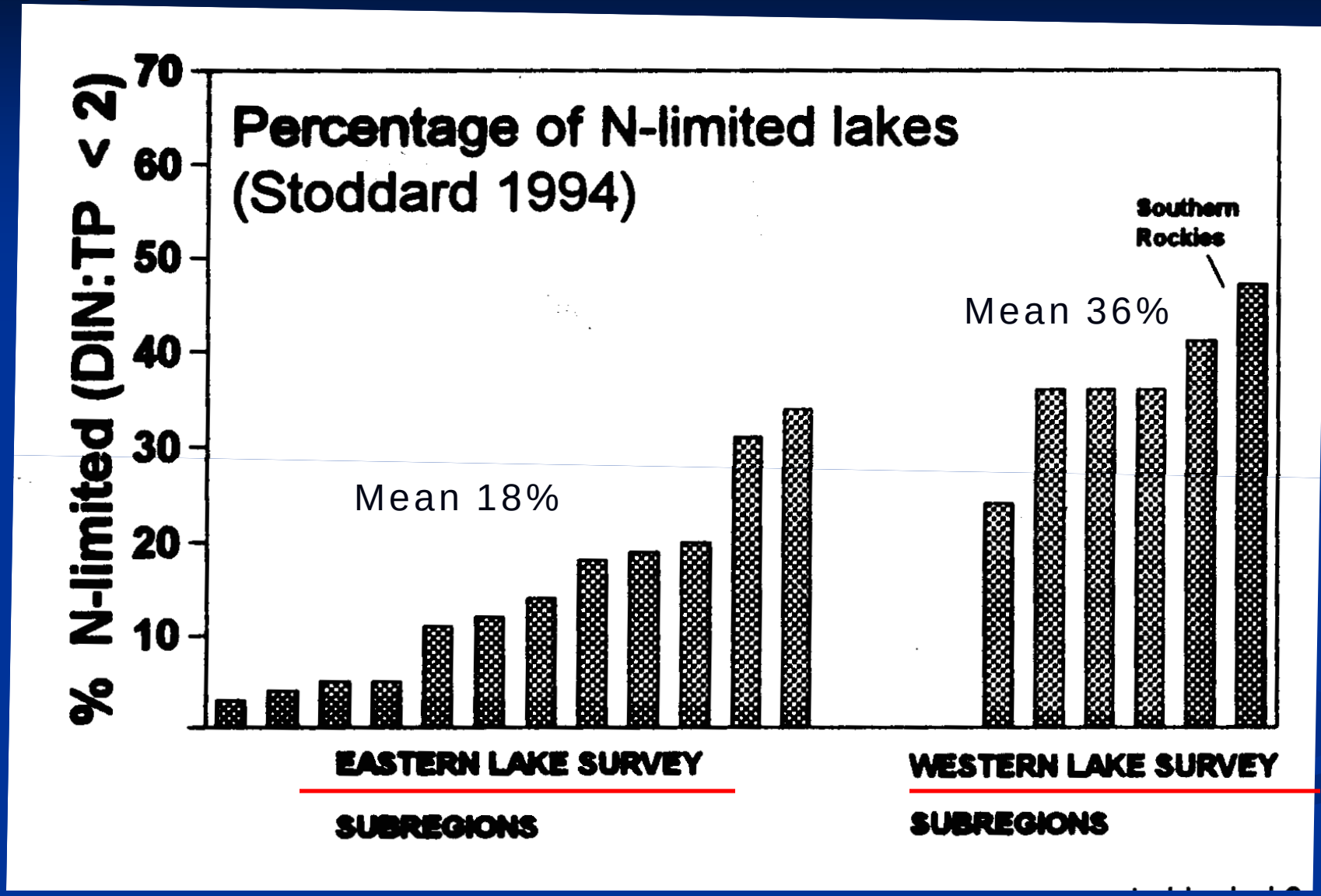


Fig. 3. Phytoplankton biomass in the epilimnion by algal group, 1969–2005. Vertical dashed lines were as in Fig. 2. In the Legend, "cyanobacteria" refers to cyanobacteria species that are not known to fix nitrogen. "Nitrogen fixers" refers to N-fixing species of cyanobacteria.

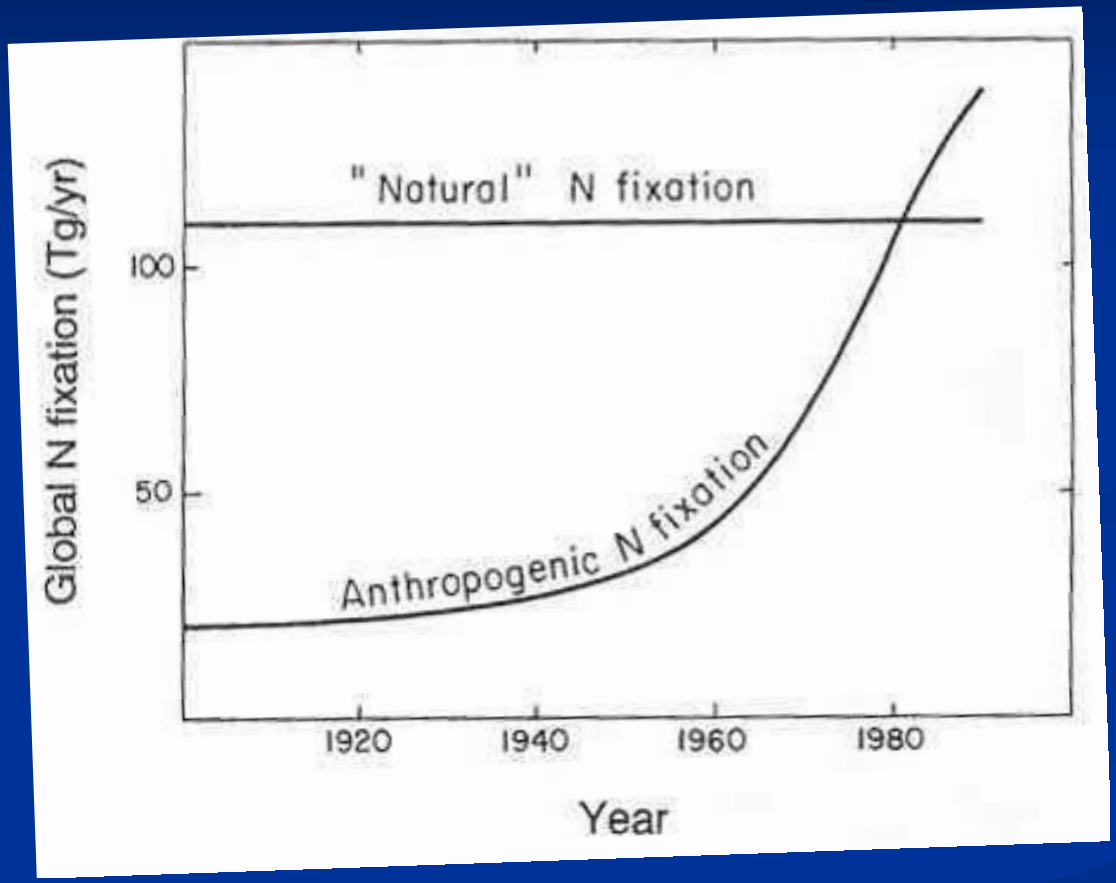
Once eutrophic, adding P only maintained high algal levels

Lake 227, ELA

Regional Differences in N vs P limitation



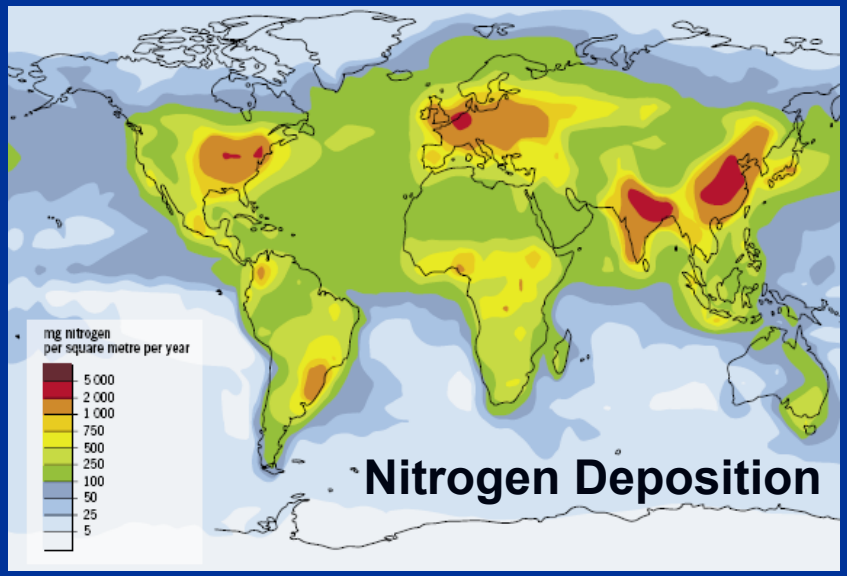
Stoddard, J. L. 1994. Long-term changes in watershed retention of nitrogen. Environmental Chemistry of Lakes and Reservoirs. American Chemical Society: 223-284.



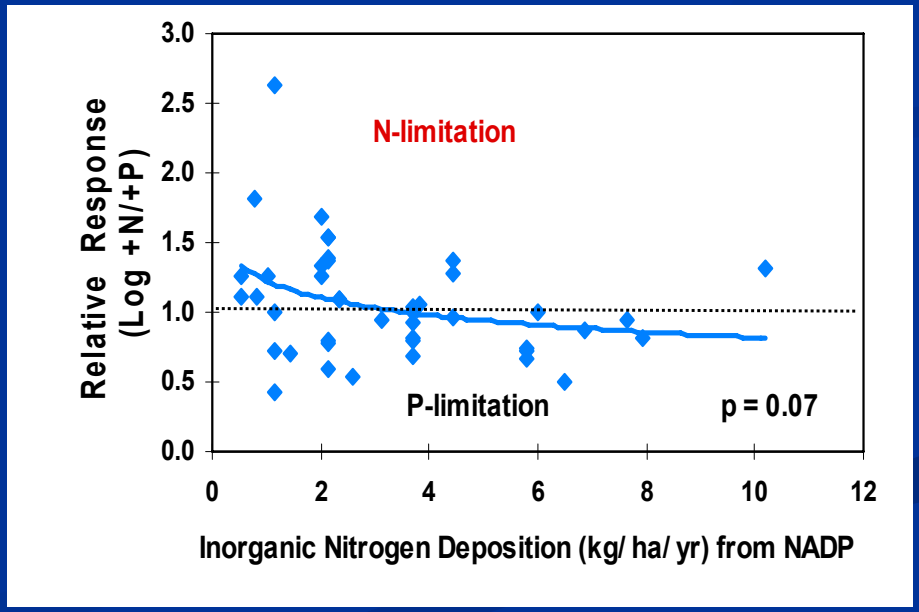
Vitousek 1994

Why are Some Waters Limited by N, others by P, and Still Others Need Both Nutrients?

- Geological Differences in Edaphic Factors (mineralogy, soil development, fires)
- Atmospheric pollution with N?



From Galloway et al. 2004



Derived from Elser et al. (1990) & National Atmospheric Deposition Program (EPA)

Think Globally, Act Locally

Valley environment

Cleanup needed but at what cost?

Regulations put Logan in pickle over Cutler Reservoir phosphorous levels

By Karen Lambert
staff writer

For four years, Logan and the state of Utah have discussed the city's role in cleaning up excess phosphorous in Cutler Reservoir.

So far, they've struggled to conjoin competing interests — with one entity saying it's most concerned about people's pocketbooks and the other indicating it's most worried about the health of a lake.

The Utah Division of Water Quality thinks Logan needs to reduce its phosphorous output into Cutler Reservoir by 50 percent. According to a state-funded study, the levels of phosphorous being released into Cutler Reser-

Environmental Department, said the threat to fish is not large enough to require residents to pay $100 to $200 million for a new water treatment plant.

But Mike Allred with the Utah Division of Water Quality said the phosphorous levels are getting to the point they could hurt fish if measures aren't taken. Allred said he also doubts the city would need such an expensive plant and believes there are less expensive alternatives.

Logan agrees — as long as the state will allow it to utilize those options. The city, among other things, is looking into removing the algae from the lake and using it to create biodiesel fuel, using

Eli Lucero/Herald Journal

Tim Lindsay takes a water sample out Thursday of one of the Logan city sewage lagoons.

"People don't realize the impact. That's astronomical. That's the average hom-

Herald Journal, October 5, 2008

Aquatic Ecology Practicum (WATS 4510)

Capstone course with students doing individual research projects focused around a common limnological problem

4510 Students

2007

Baillie, Marshall
Dees, Travis
Jensen, Kirt
Low, Chad
Reilly, Robert
Stoller, Jacob

TA Ryan Lockwood

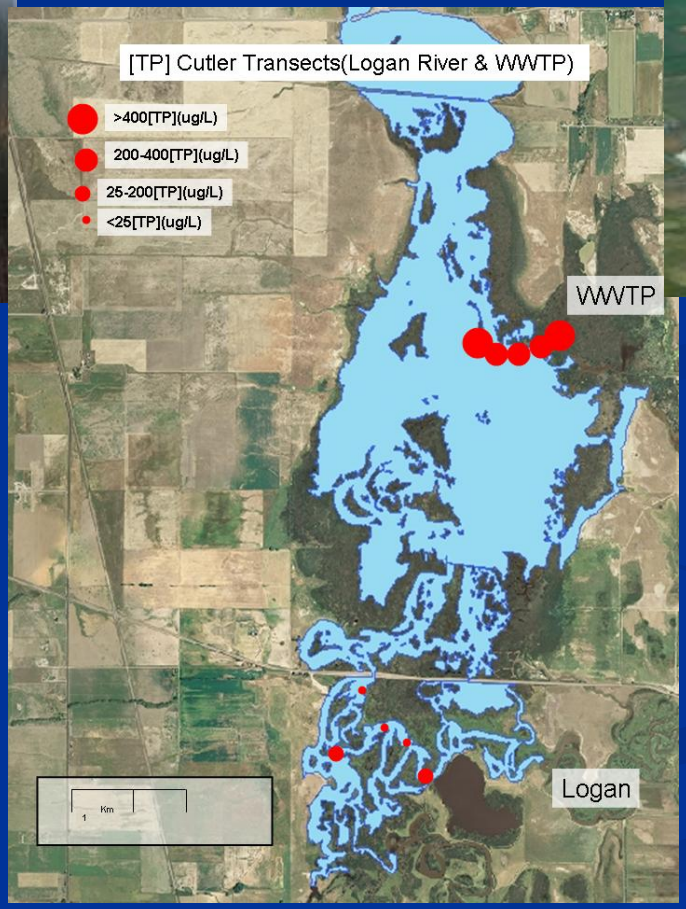
2008

Abbott,Ben
Braithwaite,Nic
Elsner, Justin
Mason,Paul
Randall,Jared

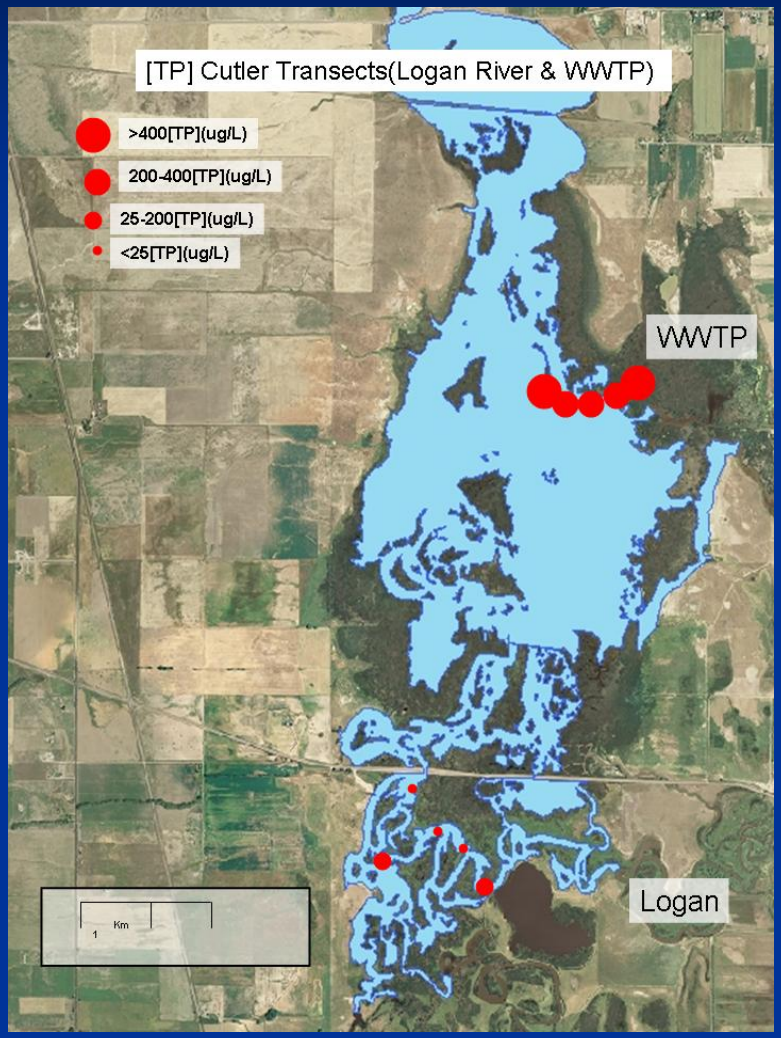
TA Dave Epstein

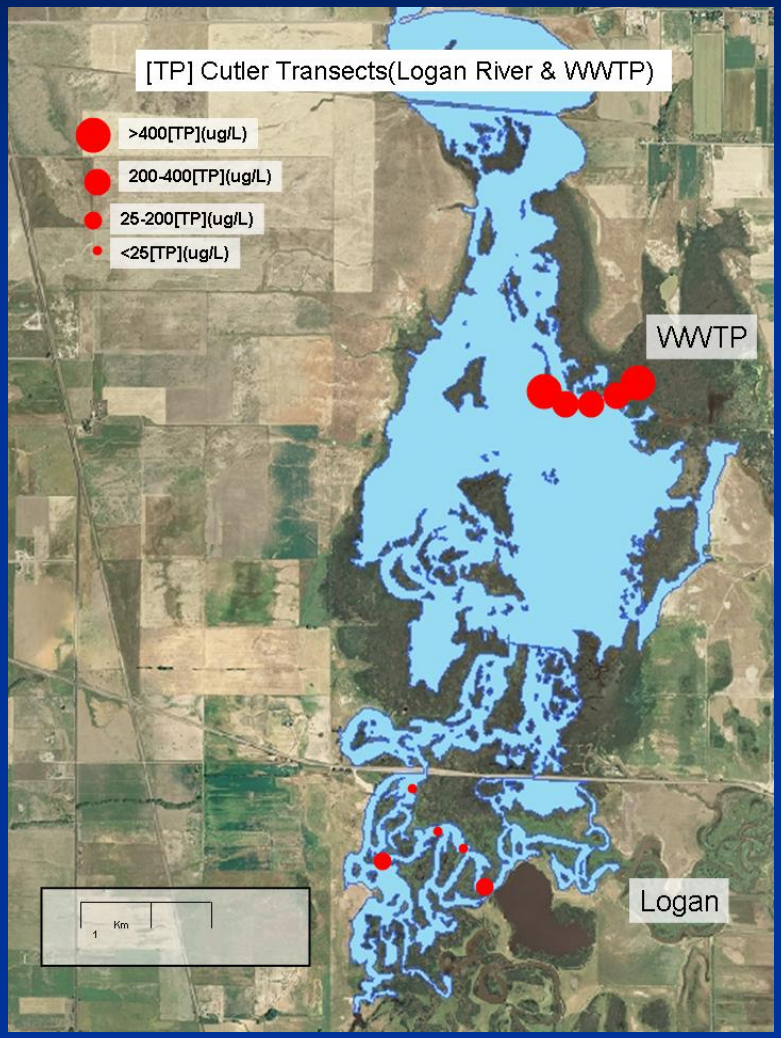
Cutler Reservoir Eutrophication

Total Maximum Daily Load (TMDL) Process



2007 Work


[TP] Cutler Transects(Logan River & WWTP)
>400[TP](ug/L)
200-400[TP](ug/L)
25-200[TP](ug/L)
<25[TP](ug/L)
WWTP
Logan
1
Km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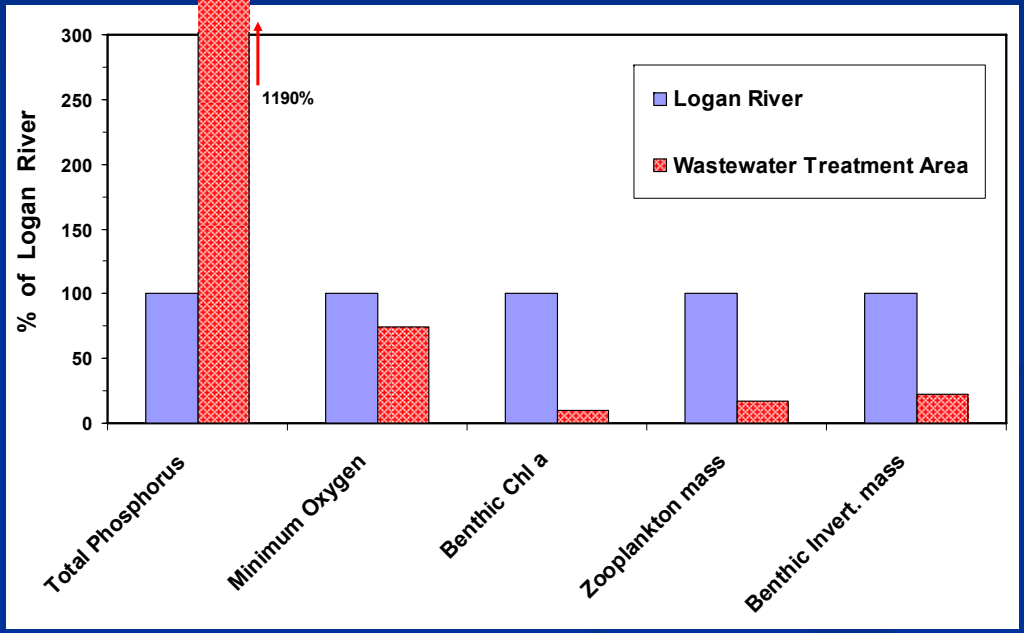
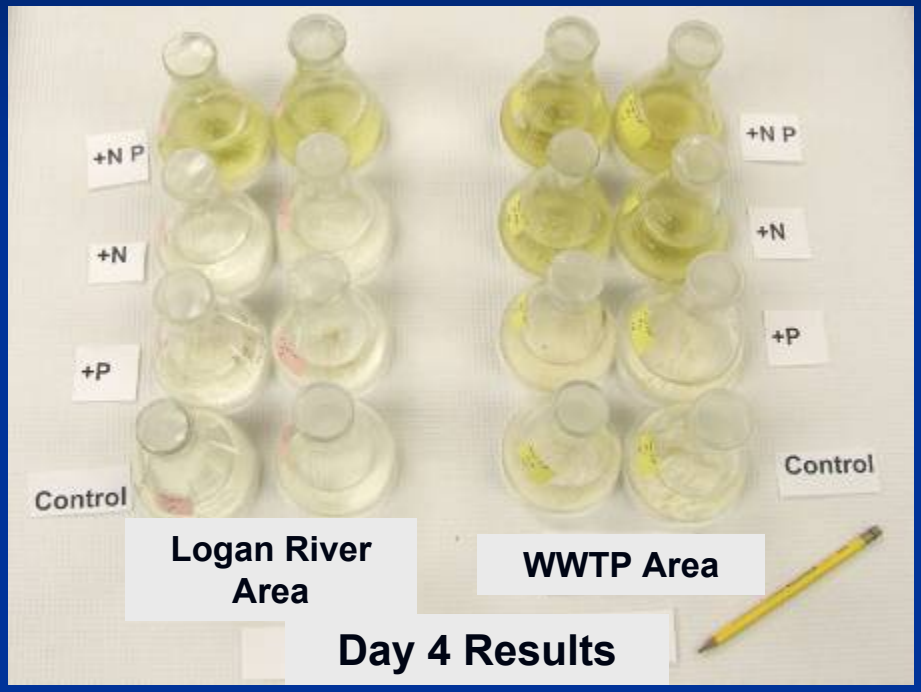
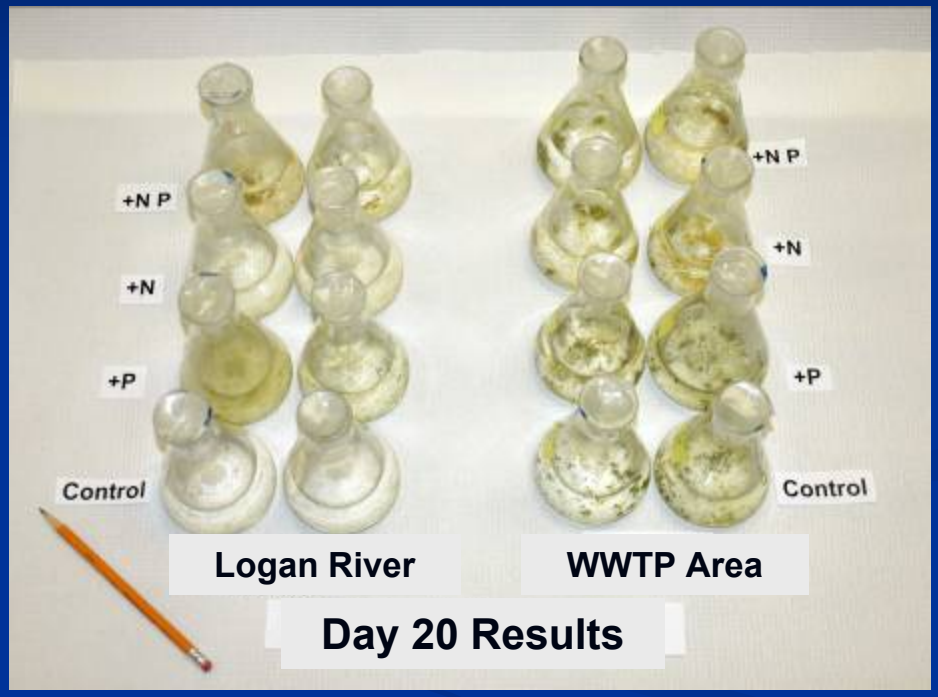
Logan
1
Km

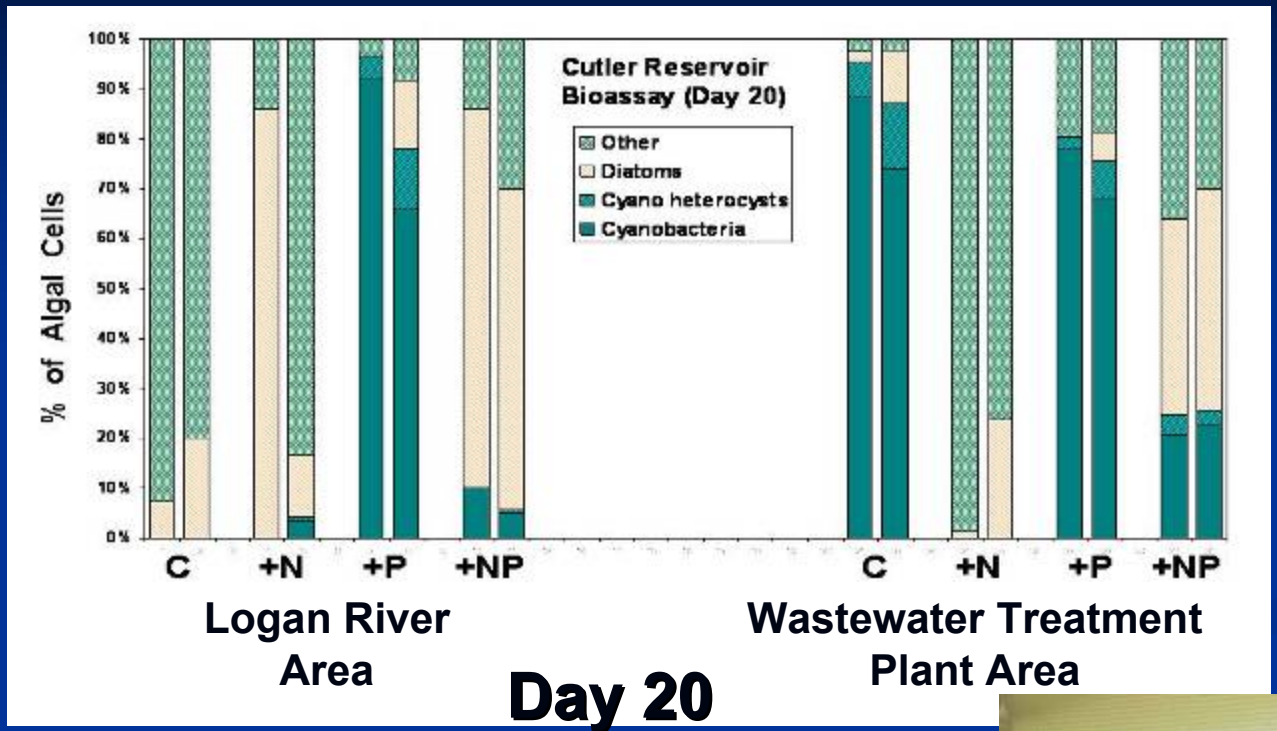

% of Logan River
300
250
200
150
100
50
0
1190%
Logan River
Wastewater Treatment Area
Total Phosphorus
Minimum Oxygen
Benthic Chl a
Zooplankton mass
Benthic Invert. mass

Nutrient Addition Bioassay Results





Bioassay Results: Algal Counts

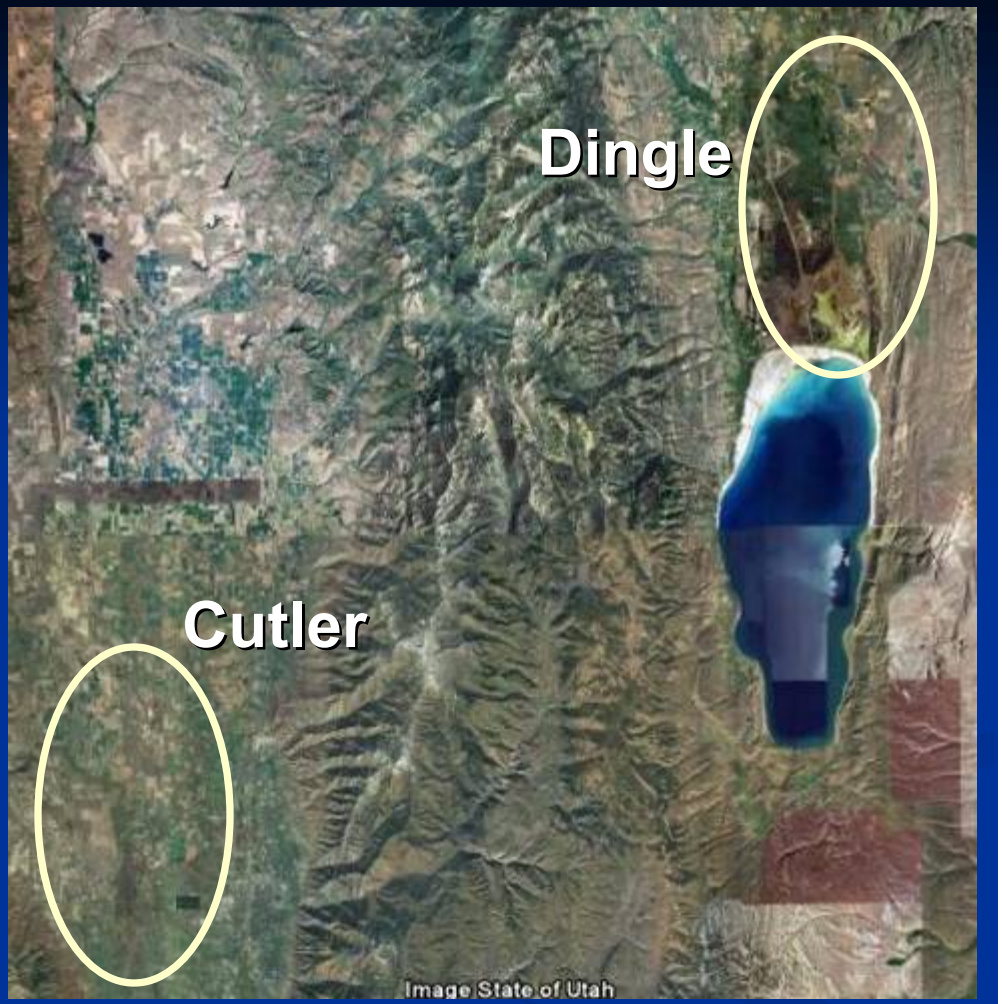


Day 20

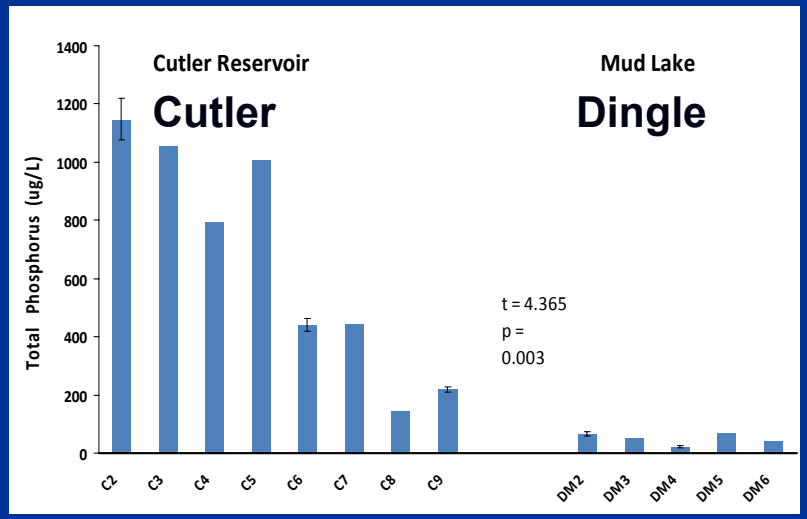
Cyanobacteria associated with "benthic" walls of flasks

2008 Class Project

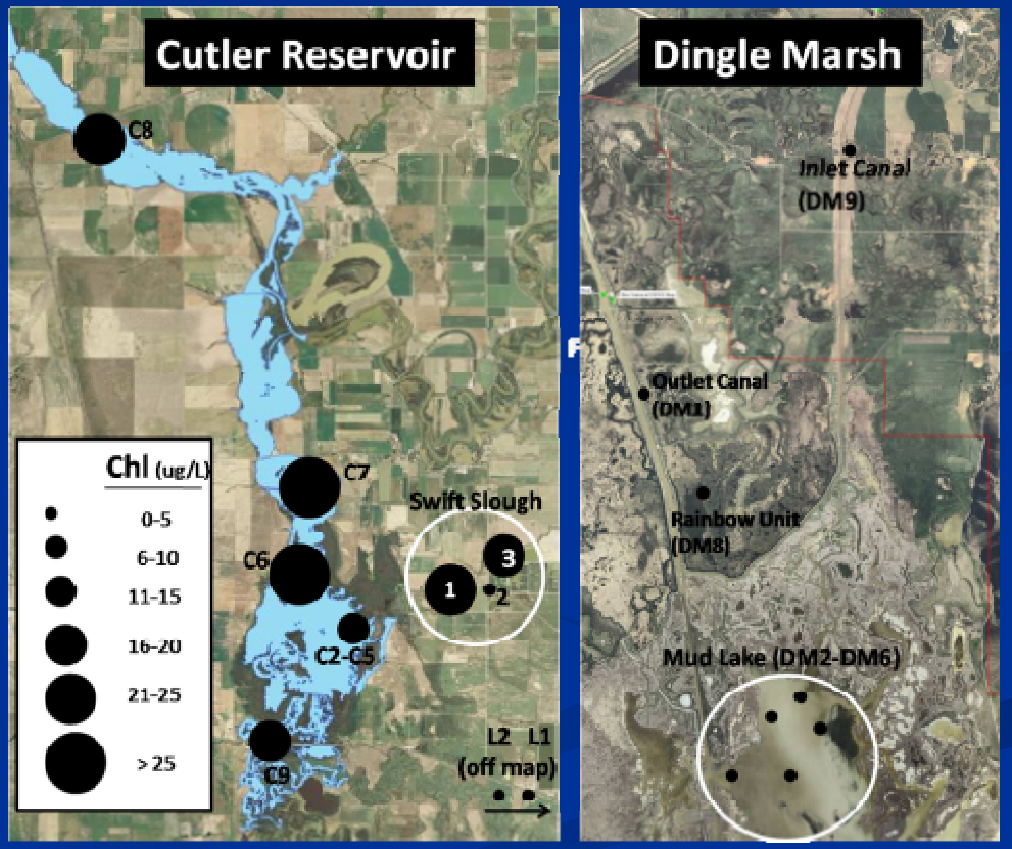
Comparison of Cutler and Dingle Marsh (Control)



Phosphorus & Chlorophyll much higher in Cutler than in Dingle (Nic Braithwaite)

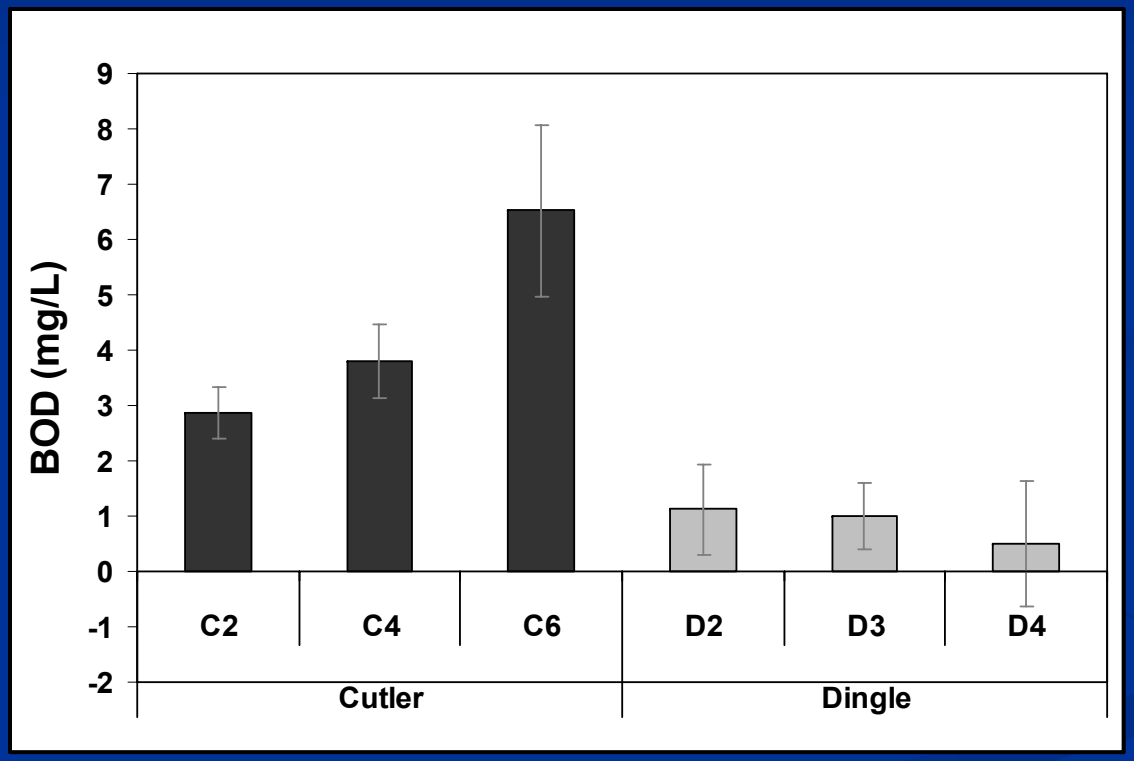


Total Phosphorus (ug/L)

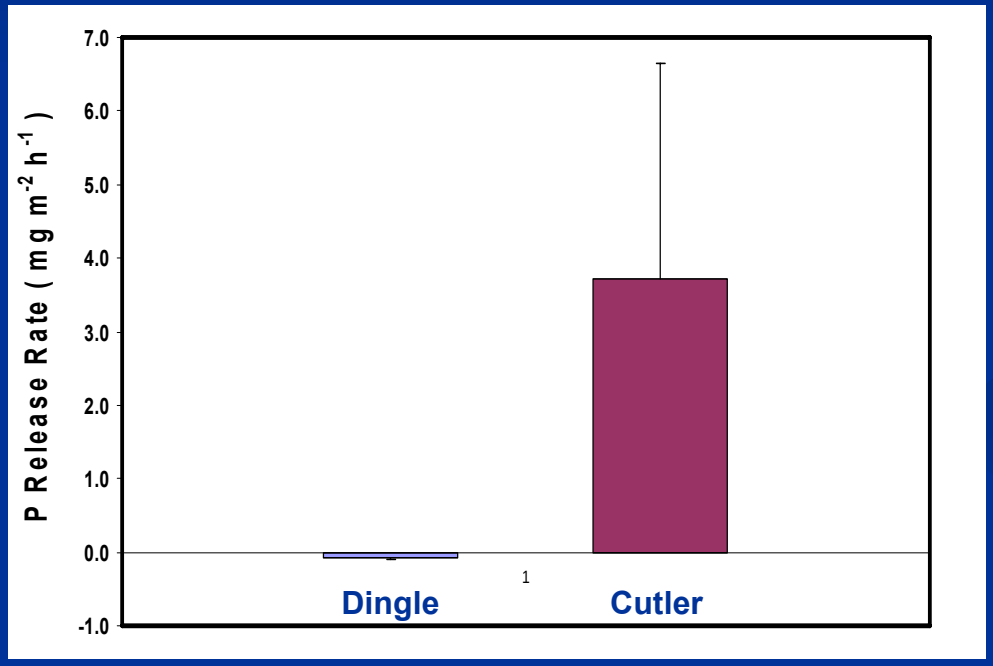


Algal Biomass (Chlorophyll *a* ug/L)

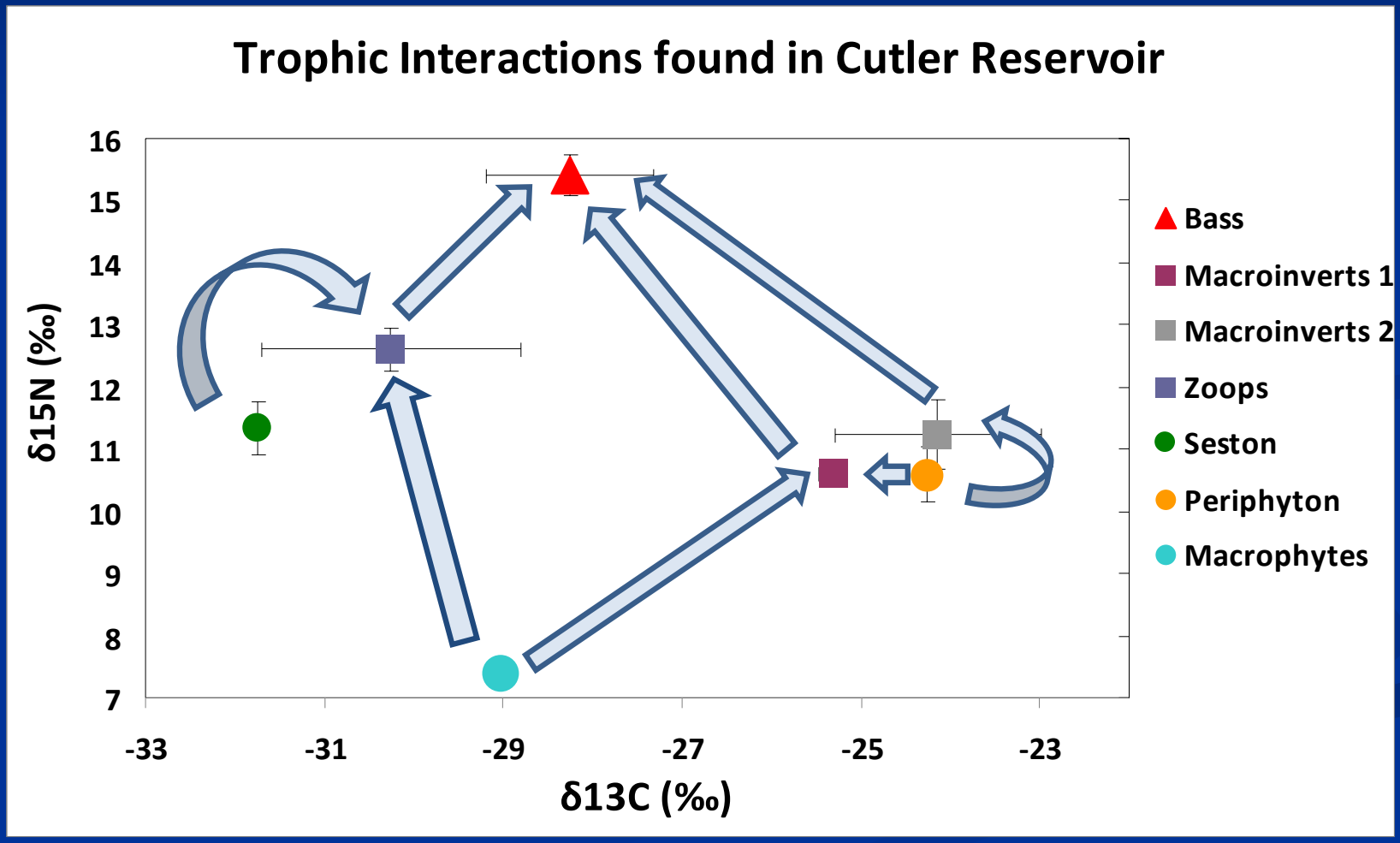
Biochemical Oxygen Demand Much Higher In Cutler than in Dingle Marsh (Paul Mason)



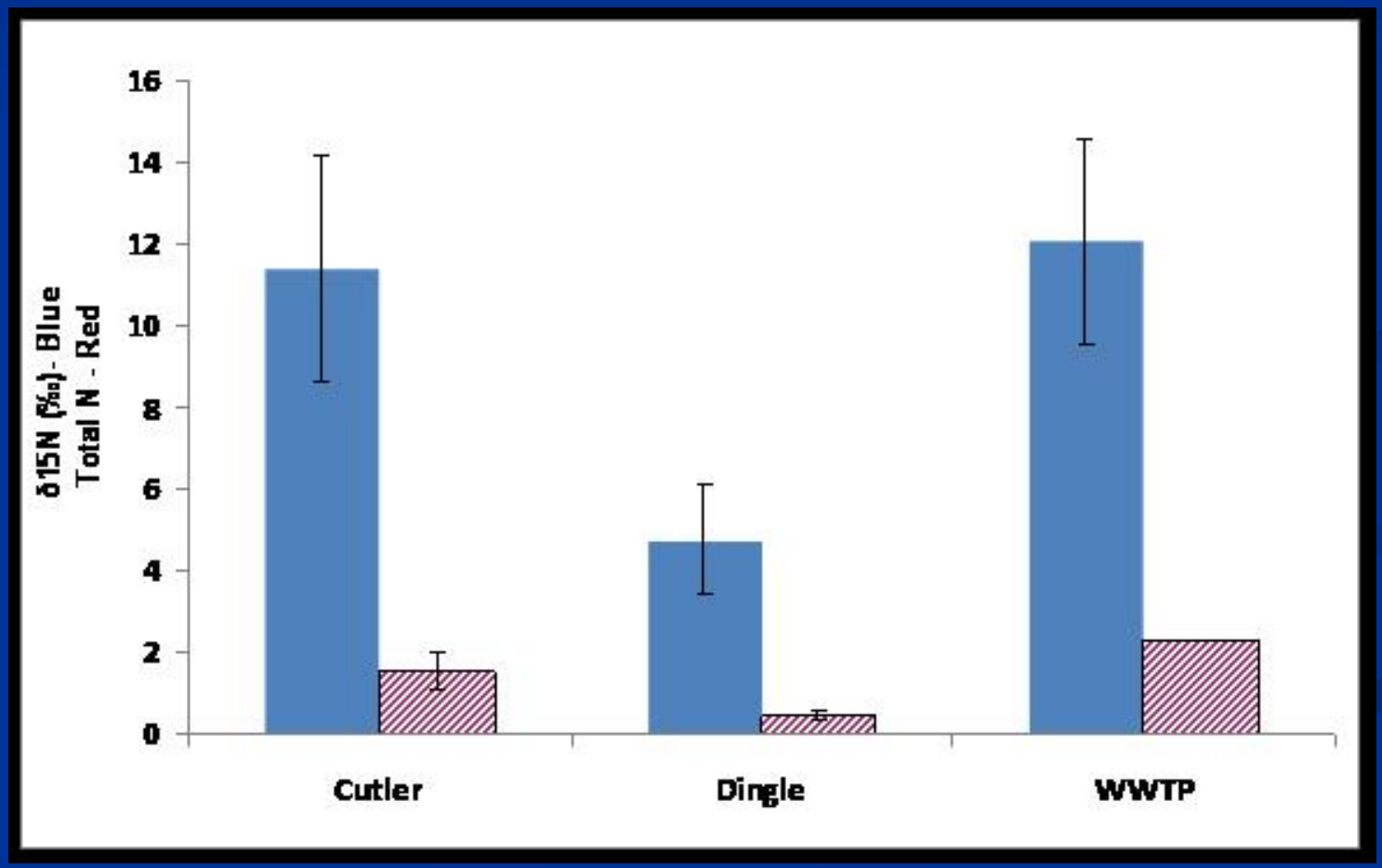
Phosphorus Release from Sediment Cores Far Higher in Cutler (Justin Elsner)



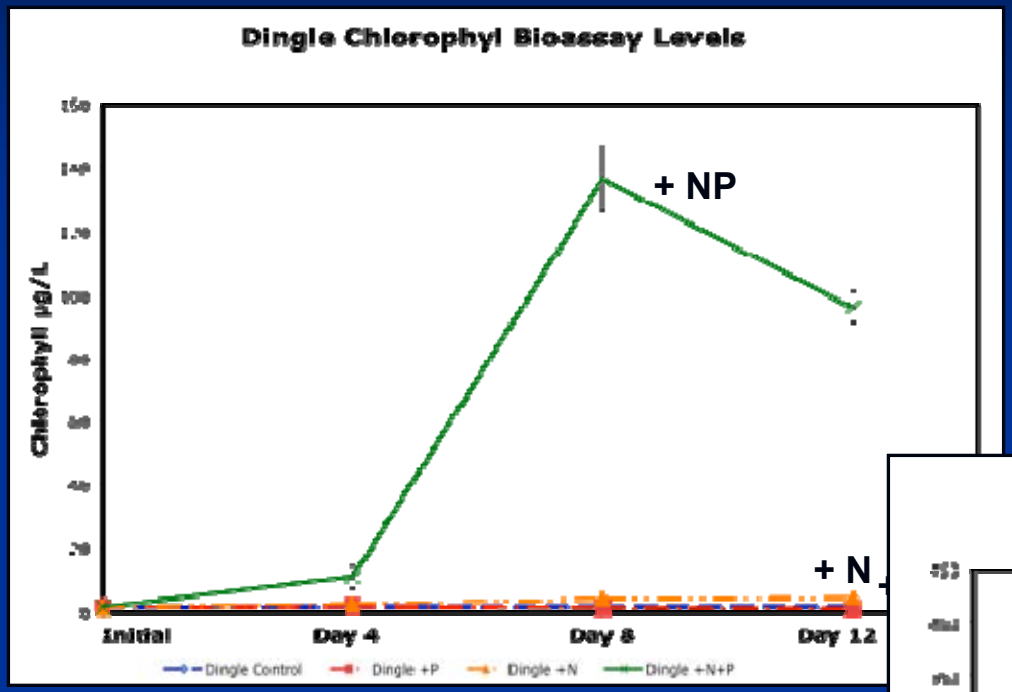
Trophic Interactions in Cutler Driven not only by Phytoplankton (seston), but also by Periphyton and Macrophytes (Jared Randall)

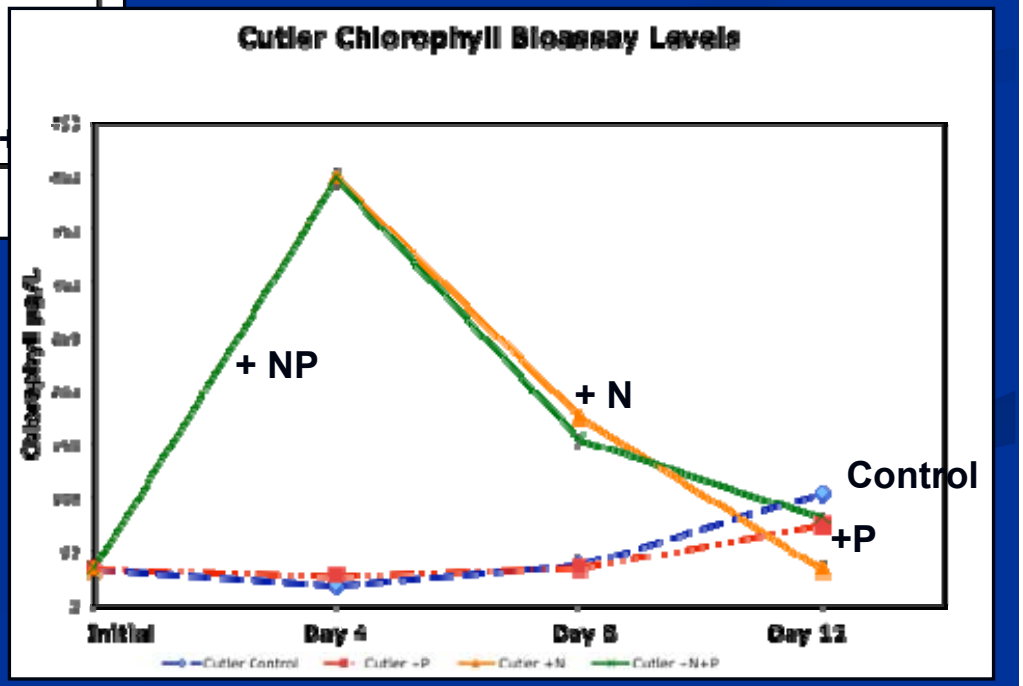


Nitrogen Isotopes in Flora & Fauna of Cutler Reservoir & Wastewater Treatment Plant Indicative of Anthropogenic Sources (Jared Randall)

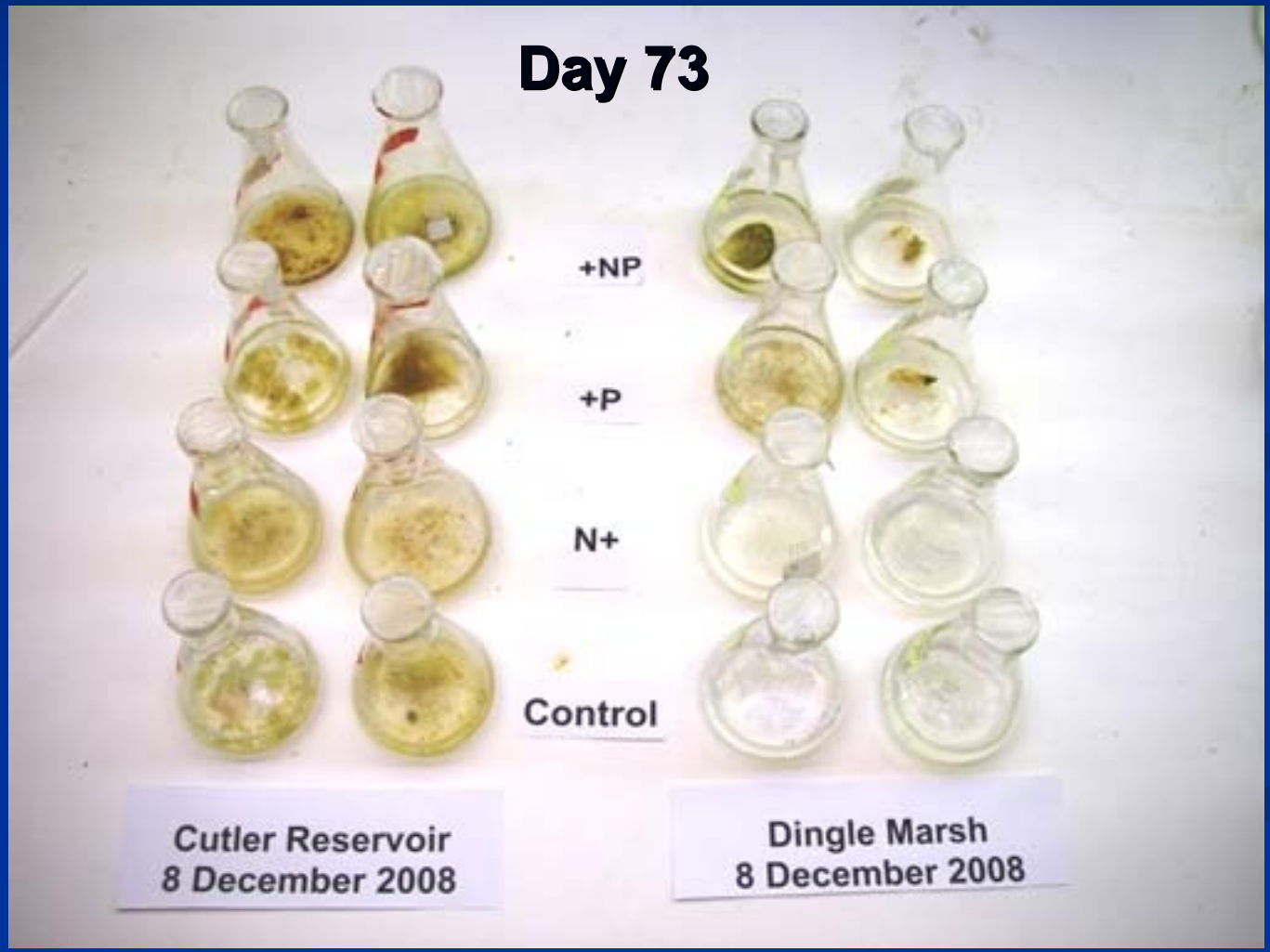


Short-Term Bioassays showed N or N+P Limitation of Phytoplankton (Ben Abbott)





Long-Term (untended) results indicate P more important in Dingle



Conclusions

- Capstone Practicum is very effective in teaching prospective graduate students real-life research skills
- Beneficial to managers in Utah

Conclusions

- Both N and P can be important in controlling eutrophication
- P may be more effective in promoting N-fixation in eutrophic situations (eutrophic lakes, "eutrophic" benthic areas of lakes or flasks)
- If so, eutrophication and oligotrophication may not be symmetrical:

N and P

Oligotrophic ----------→ Eutrophic

Remove only P?

Oligotrophic <---------- Eutrophic

Conclusions

- Management of eutrophication must consider:
  - Current limiting nutrient in system
  - Cost-effectiveness of removing P, N
  - May be most efficient to make a nutrient limiting by removing it from effluents, even though it might not initially be limiting


Thanks