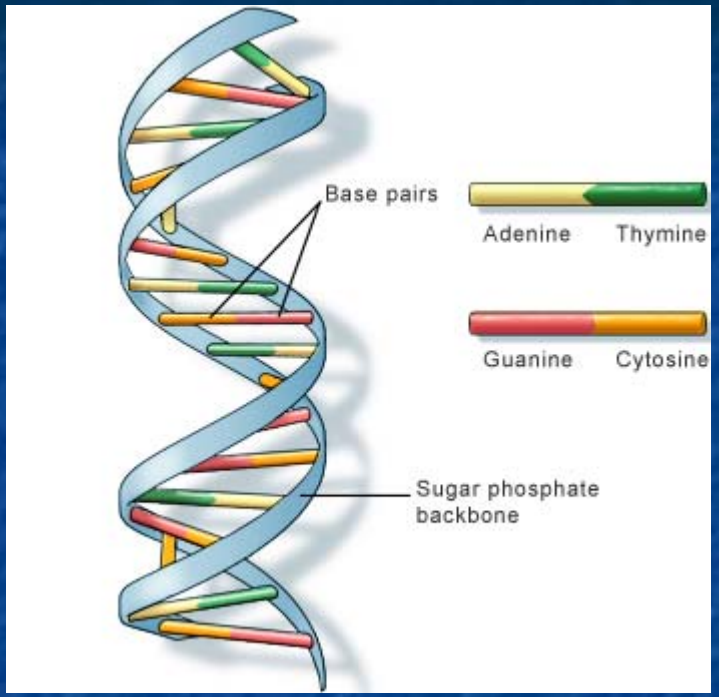
Relationship between phosphorus release & sediment characteristics in Big Platte Lake, Benzie Co., MI

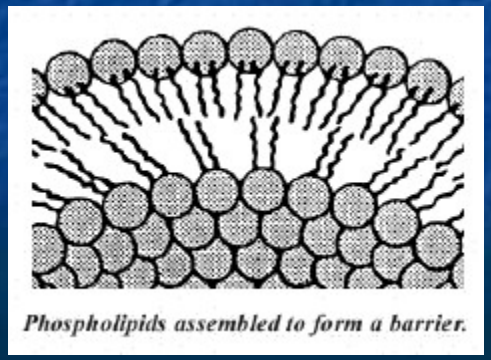
Michael Holmes

Phosphorus

- Essential element in all living organisms
  - Major bone/teeth constituent ($CaPo_4$)
  - Phospholipids
  - DNA/RNA structure
  - ATP



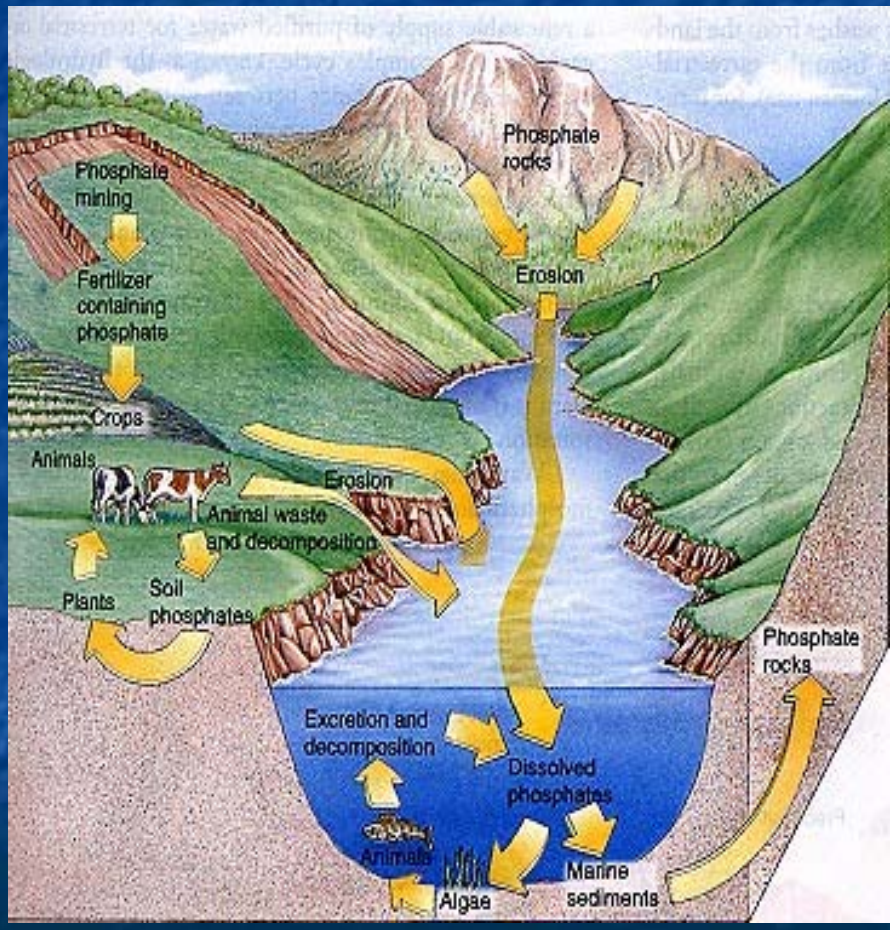
http://ghr.nlm.nih.gov/dynamicImages/understandGenetics



http://www.subtleenergysolutions.com/skincare

Anthropogenic and Natural Sources of Phosphorus

- Detergents
- Fertilizers
- Plant & animal matter
- Rock Minerals
  - Apatite
- Sediments



http://www.ux1.eiu.edu/~cfruf/bio3002/phosphorus_cycle.htm

Effects of Phosphorus Loading

- Limiting nutrient in most freshwater lakes
- ↑phosphorus = ↑productivity/vegetation
- Increased phosphorus reservoir in sediments
  - Oligotrophic=p-sink
  - Eutrophic=p-source

http://www.oberlin.edu

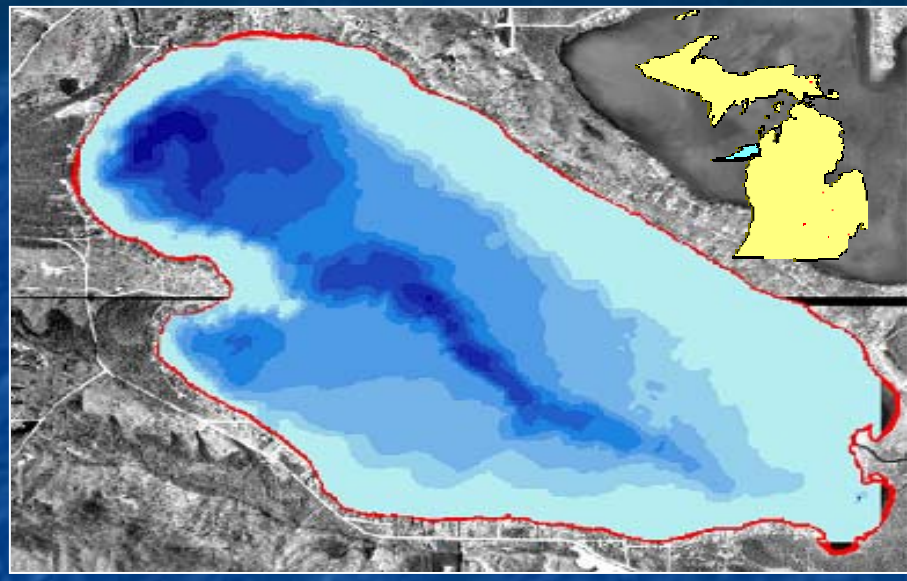
Effects of Phosphorus Loading

- Limiting nutrient in most freshwater lakes
- ↑phosphorus = ↑productivity/vegetation
- Increased phosphorus reservoir in sediments
  - Oligotrophic=p-sink
  - Eutrophic=p-source

http://www.oberlin.edu

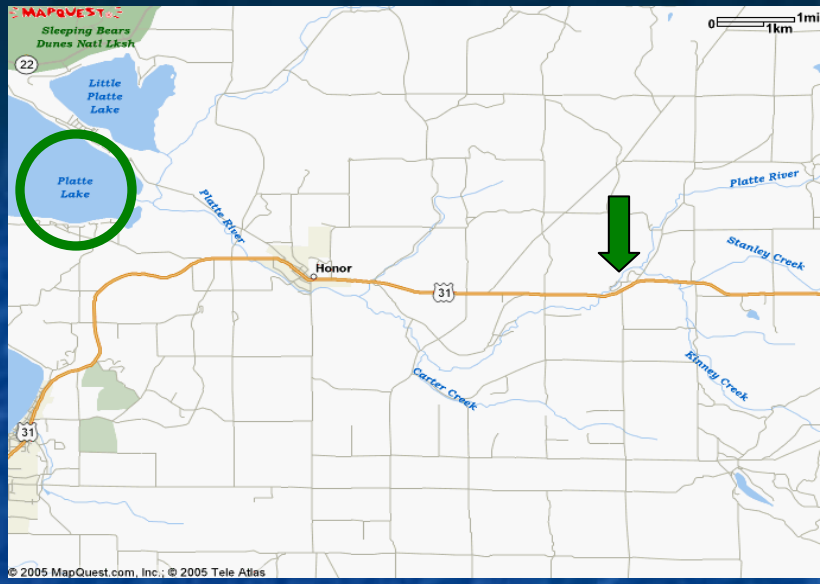
Big Platte Lake

- Benzie County
- Oligo-mesotrophic
- Dimictic
- Hard-water, marl lake
- Anoxic hypolimnion
  ~100 days a year
- Max depth ~30 m



Platte River Hatchery

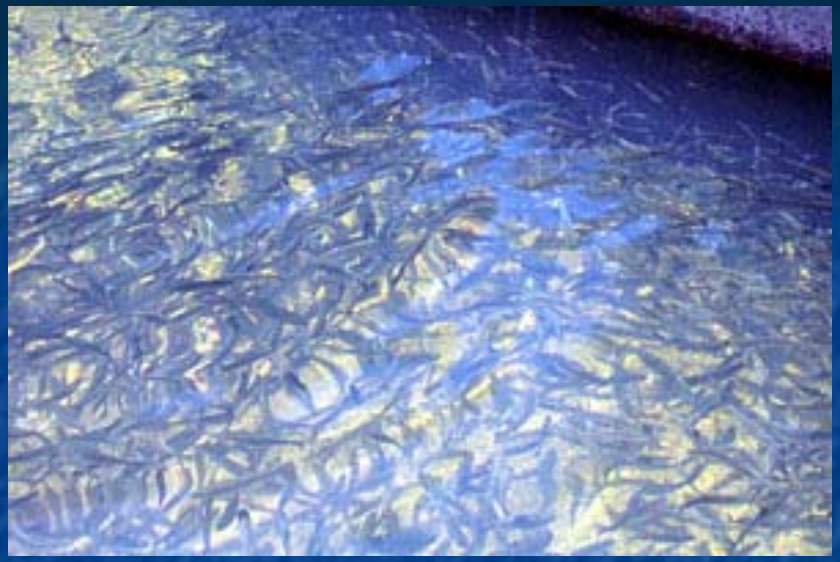
- ~6 miles upstream of Platte Lake
- US 31 Highway; Honor, MI
- Established in 1928
- Michigan's main salmon hatchery since 1972
  - Coho
  - Chinook
- Recently renovated wastewater treatment system



http://www.michigan.gov/dnr

Hatcheries and Phosphorus Loading

- High fish densities
- Significant sources of phosphorus
  - Excess Food
  - Fish Waste
- Wastewater returned to streams



http://www.glenwoodnewmexico.com/fishhatchery08.jpg

http://www.governor.wa.gov/gsro/publications/sosreport/2000/hatcheries.htm

Platte Lake Background & Rationale

- Phosphorus loading during the 1970's & 1980's
- Phosphorus deposited in Platte Lake sediments
- Monitor and describe phosphorus inputs to Platte Lake
  - Streams and hatchery
  - Septic systems and lawns
  - Sediments
- Magnitude of p-release from the sediment was unknown
  - Significant lake to lake variation
  - Most previous studies have focused on highly productive lakes

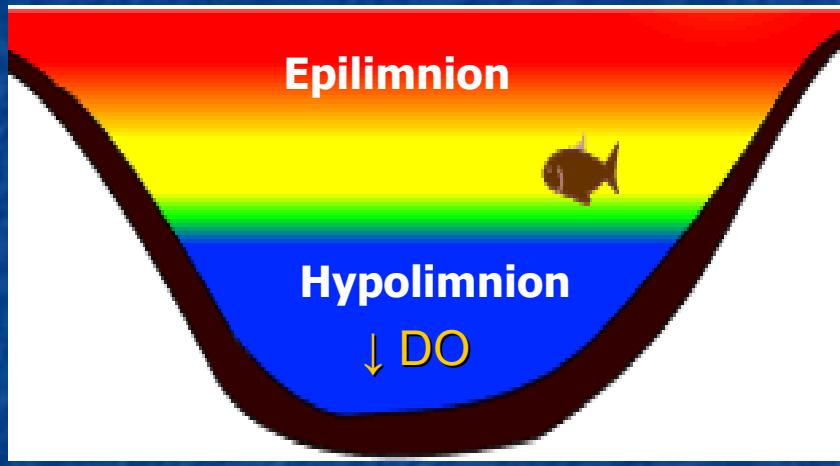
Platte River Hatchery

Discharge into Platte River

Physical & Biological Factors Affecting Sediment P-release

- Temperature
  - Microbial activity
  - Stratification
- Dissolved oxygen (DO)
  - Anoxia (<2 mg O^2/L)
- pH
- Grain size
- Wind/wave action
- Benthic macroinvertebrates
  - Bioturbation
  - Bioexcretion
    - Chironomids, amphipods, mayfly larvae, etc.

Summer Lake Stratification



http://waterontheweb.org/oldSite/under/parameters/art

http://www.jonesctr.org/research

Chemical Factors Affecting Sediment P-release

- ***Inorganic composition***
  - Fe- & Mn- oxides
  - Apatite --- $Ca_5(PO_4)_3(OH, F, CL)$
  - Limestone --- $CaCO_3$
  - Other clay complexes
    - Silicates
    - Aluminosilicates
- ***Organic composition***
  - Quantity (% organic matter)
  - Quality
    - Refractory compounds: Lignin, etc.

Fe w/ O^2

Platte River

Main Factors of Interest Influencing P-release

- Sediment Total Phosphorus (TP)
  - ↑ TP = ↑ p-release (TDP)
- Sediment Oxygen Demand (SOD)
  - decomposition/oxidation = ↓ DO
  - ↑ SOD (↑ Anoxia) = ↑ p-release

http://lakespi.niwa.co.nz/shared/images

Big Platte Lake

Main Objectives

1) Characterize sediment at different depths and locations in Platte Lake

2) Quantify p-release from Platte Lake sediments

3) Compare Platte Lake to other lakes

Research Questions

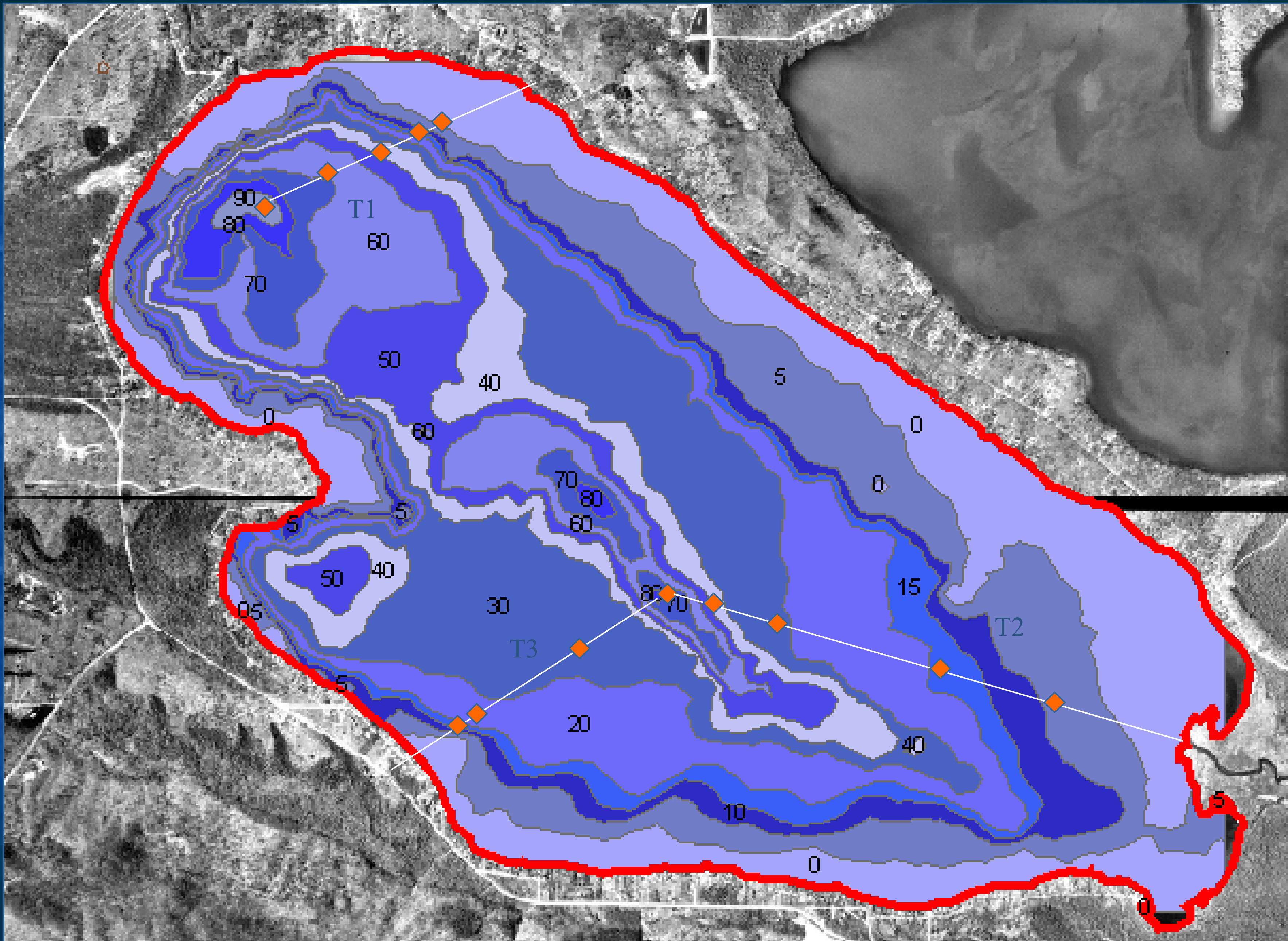
- What factors are influencing p-release?
  - Is oxygen depletion influencing p-release?
  - Are there seasonal differences in SOD & p-release?
  - Do SOD & p-release differ between locations?
  - Do TP & organic matter (OM) influence p-release?

Research Outline

- Initial sediment survey
  - Determine variability between locations
- SOD experiments
  - Measure oxygen uptake rates
  - Compare SOD vs. depth and season
- P-release experiments
  - Compare oxic & anoxic rates
  - Compare anoxic p-release vs. depth and season
  - Compare OM and TP vs. depth

Initial Sediment Survey

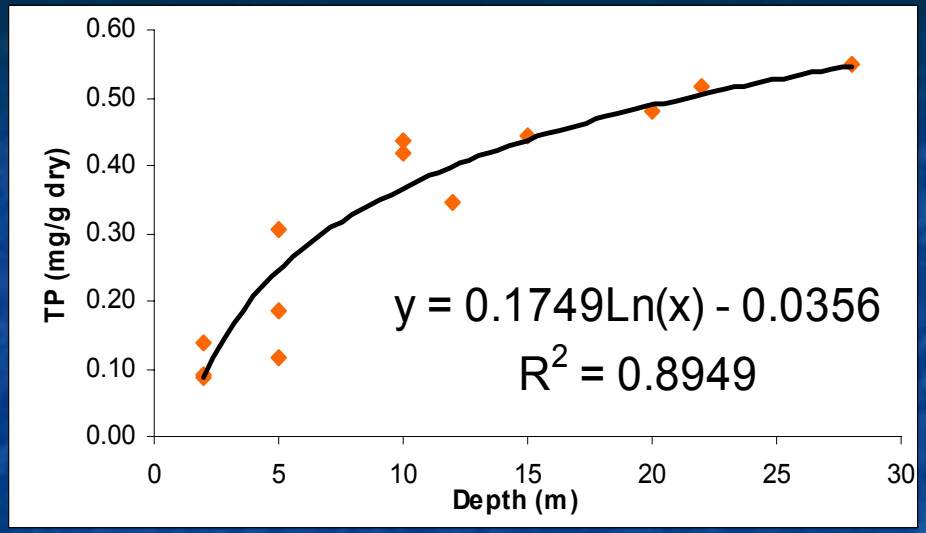
- 13 locations
  - Mini-ponar grab sampler
- Parameters measured:
  - % organic matter
  - Total phosphorus (mg/g dry)
  - Grain size (% sand/ % silt/ % clay)
  - % water
  - COD (chemical oxygen demand)
  - TKN (total kjeldahl nitrogen)



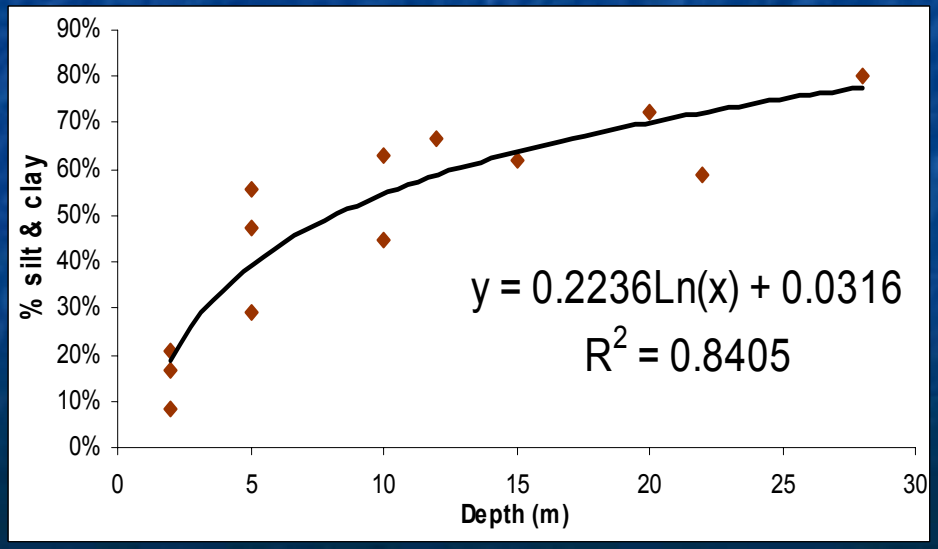
90
80
T1
60
70
50
40
5
0
60
0
0
70
80
60
5
5
50
40
30
15
80
70
T2
05
T3
5
20
40
10
0
5
0

Relationships with Depth

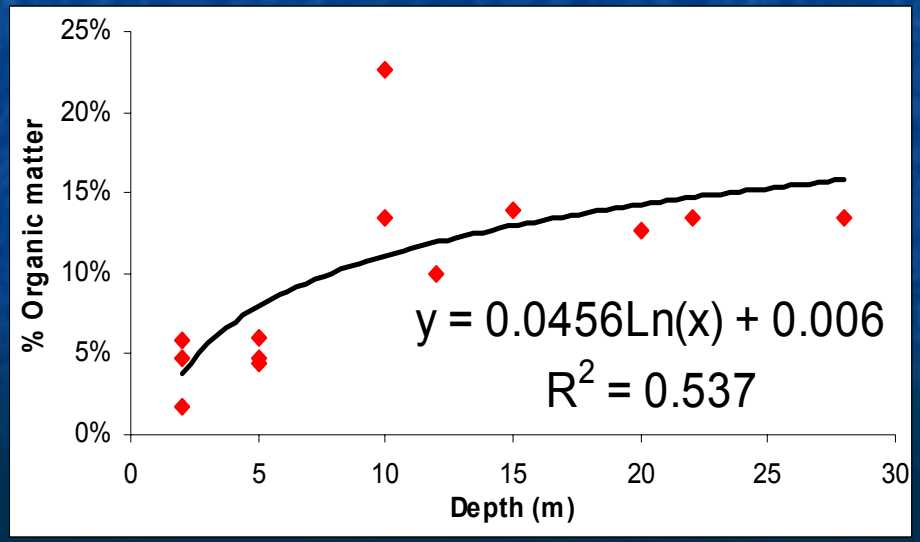
Total Phosphorus



Small Grains (<0.05 mm)



Organic Matter



Initial Conclusions

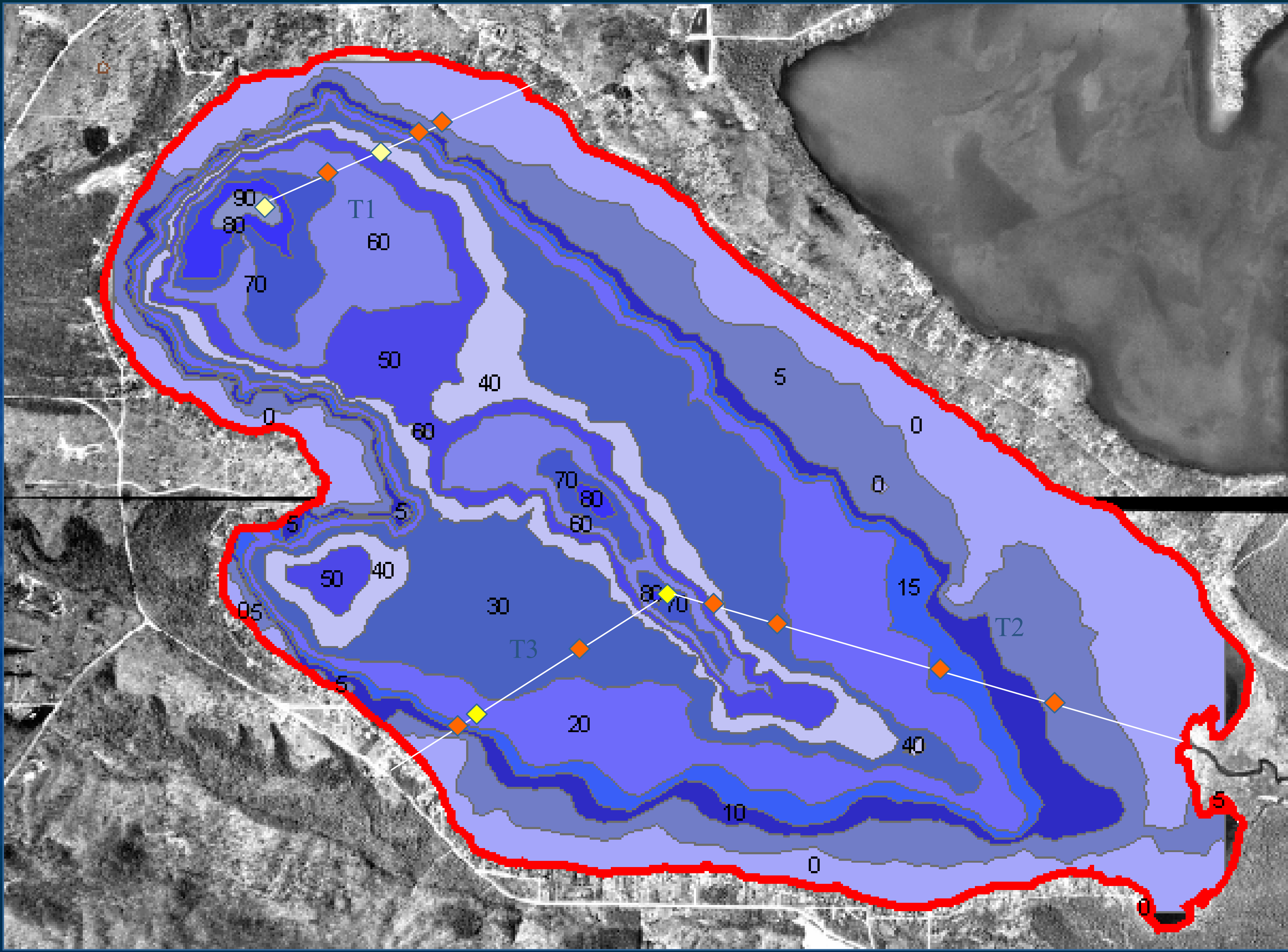
- '% silt & clay' , OM, & TP increase with depth
- TP shows the strongest relationship with depth
- High variability between locations (especially <15 m)

Research Outline

- Initial sediment survey
  - Determine variability between locations
- SOD experiments
  - Measure oxygen uptake rates
  - Compare SOD vs. depth and season
- P-release experiments
  - Compare oxic & anoxic rates
  - Compare anoxic p-release vs. depth and season
  - Compare OM and TP vs. depth

General Methods

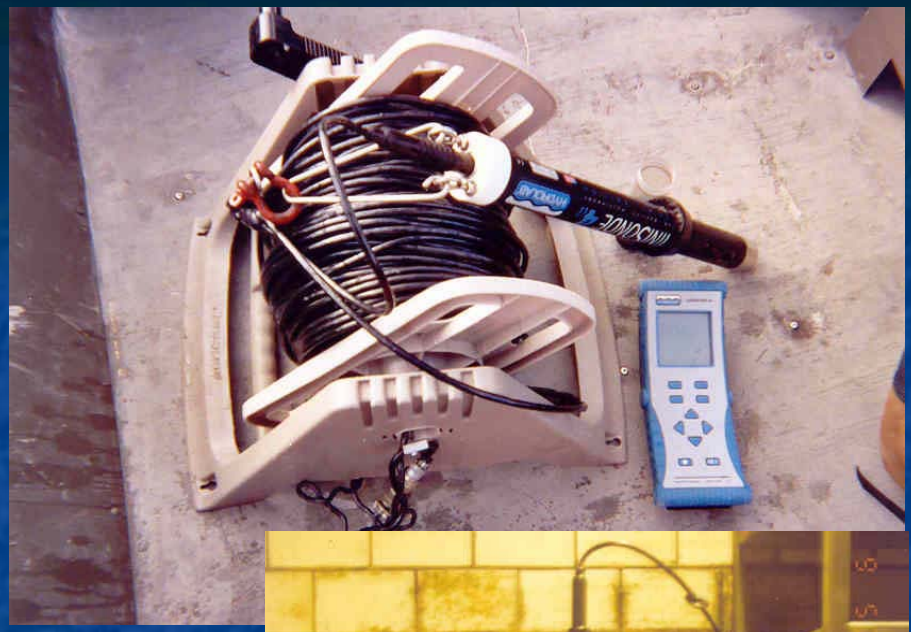
- P-release and SOD
  - 4 locations of different depth
  - Modified Kajak-Brinkhurst corer
  - Collected lake water
    - 0.45 µm Millipore filter
    - FLW=Filtered Lake Water
  - Cores incubated @ at 7.5°C ±2°C
  - Rates determined from multiple samples or measurements
- OM & TP
  - Mini-ponar grab sampler



90
80
T1
60
70
50
40
0
60
5
0
0
70
80
60
5
5
50
40
30
80
70
15
T2
05
T3
5
20
40
10
5
0
0

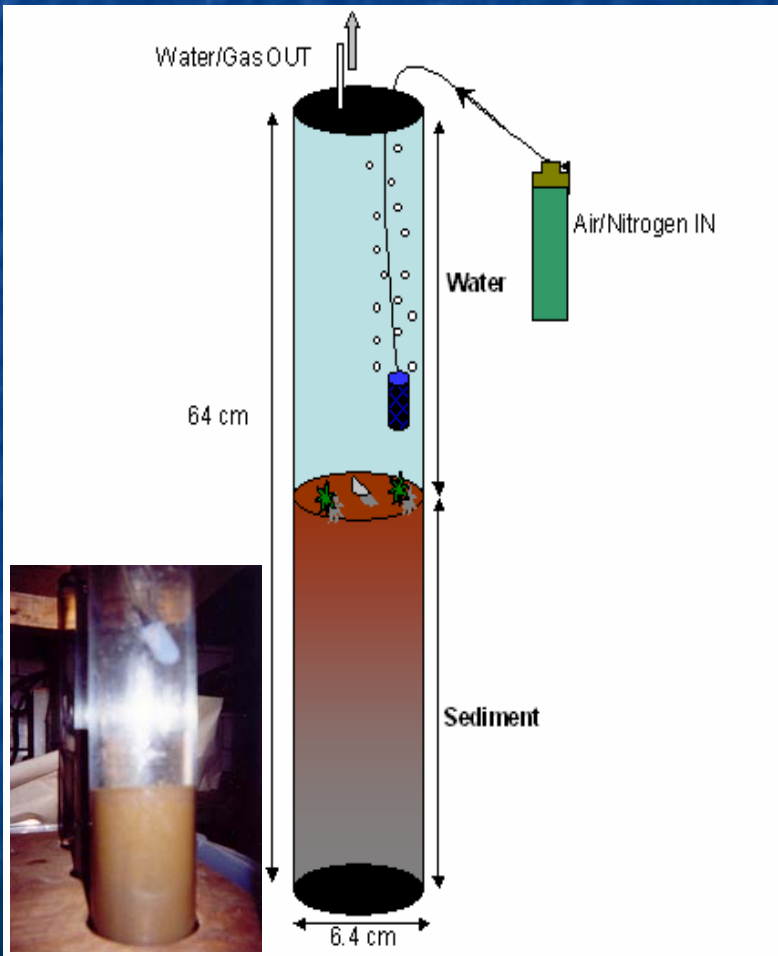
SOD Core Setup

- Bubbled w/ air for 2 hours
- Hydrolab 4a Surveyor and mini-sonde
- D.O. measured every 15 minutes for 8 hours
- FLW Blanks



P-release Core Setup

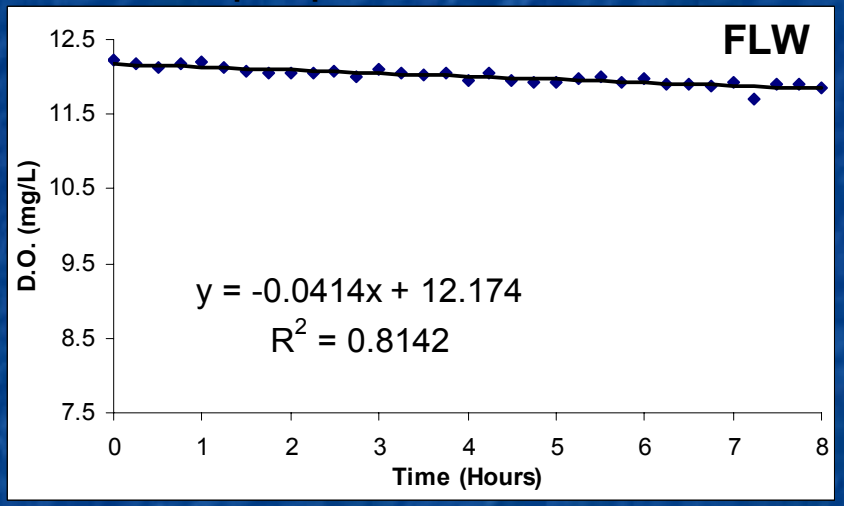
- Anoxic=*Nitrogen*; Oxic=*Air*
  - For duration of experiment
- 50 ml samples removed on alternate days for 10 days
  - Volume replaced with FLW
- TDP measured in overlying water
- FLW Blanks

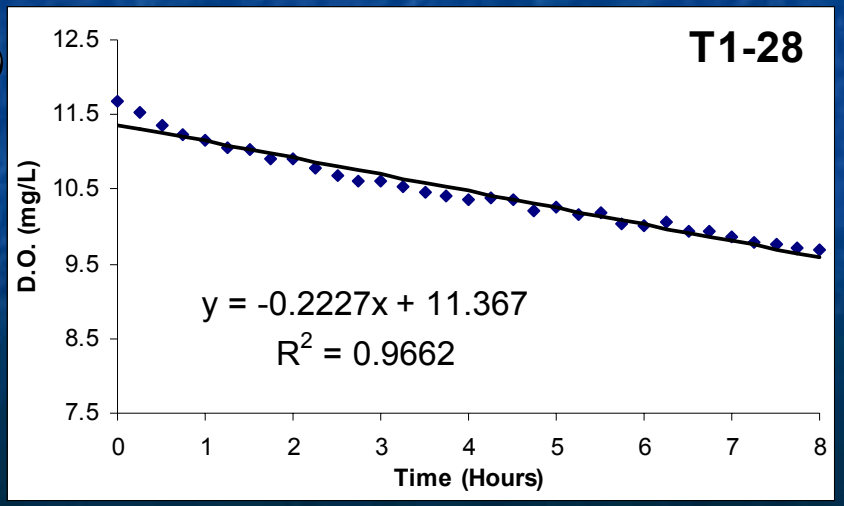


Determination of SOD Rates

- Slope of best fit line (mg O^2/L/hour)
  - Corrected for slope of blank (FLW)
  - Corrected for ratio of overlying water volume (L) to sediment surface area (m^2)
  - SOD (g O^2/m^2/day)

Example plots from 11-14-04

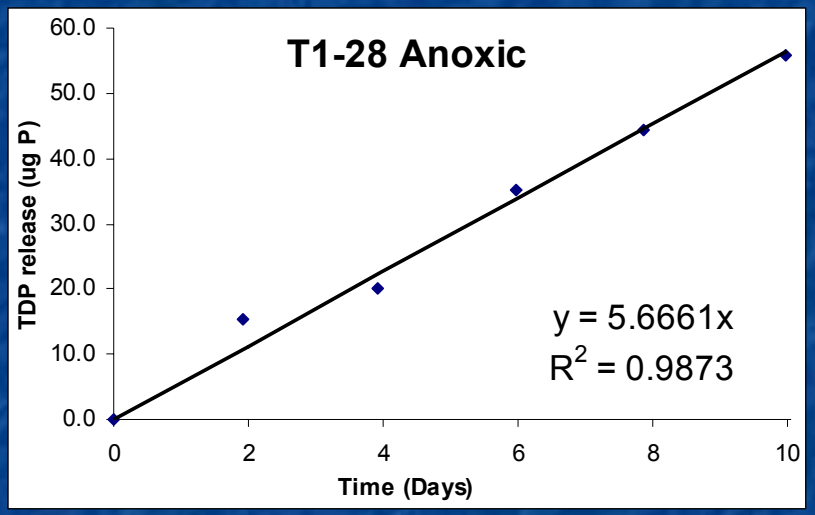


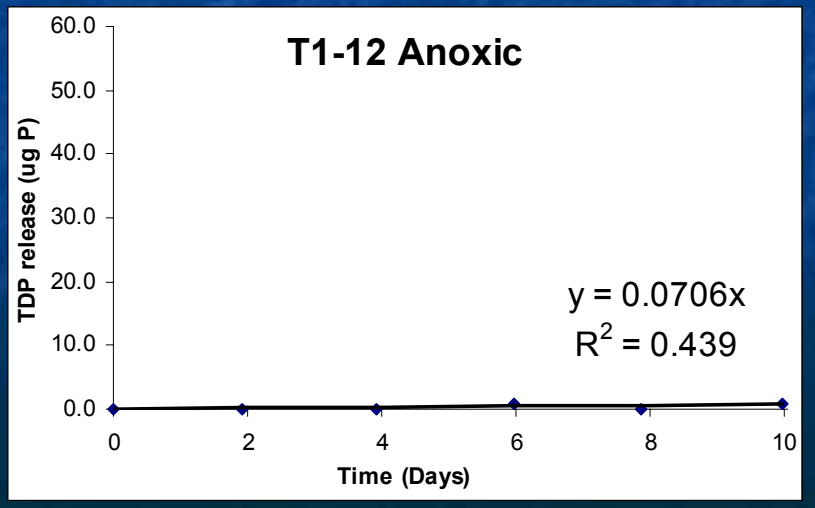


Determination of P-release Rates

- Slope of best fit line (µg P/ day)
  - Cumulative TDP release
  - Corrected for TDP in replacement water (FLW)
  - Final rate (µg P/ m^2 /day) related to sediment surface area (m^2)
  - Final rates not corrected for release rates in blank cores

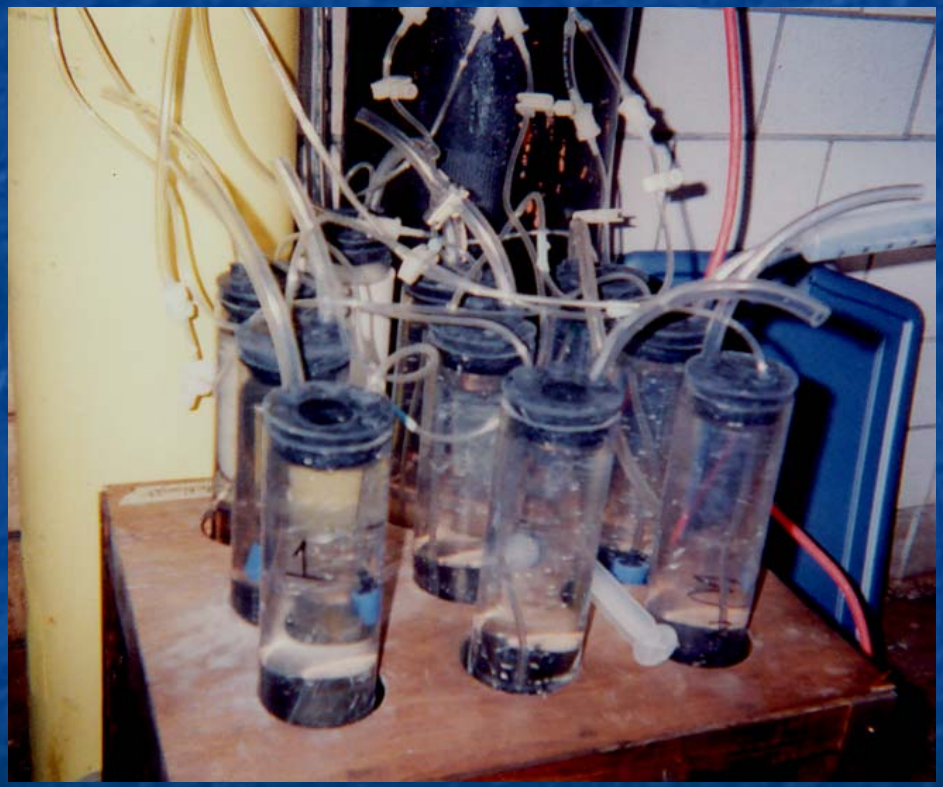
Example plots from 11-14-04





Typical SOD and P-release Rates

- SOD
  - Oligotrophic-
    - **<1** g O^2/m^2/day
  - Eutrophic/hypereutophic-
    - **>5** g O^2/m^2/day
- Anoxic p-release
  - Oligotrophic
    - **<1,000** µg P/m^2/day
  - Eutrophic
    - **>10,000** µg P/m^2/day
  - Hypereutrophic
    - **>20,000** µg P/m^2/day

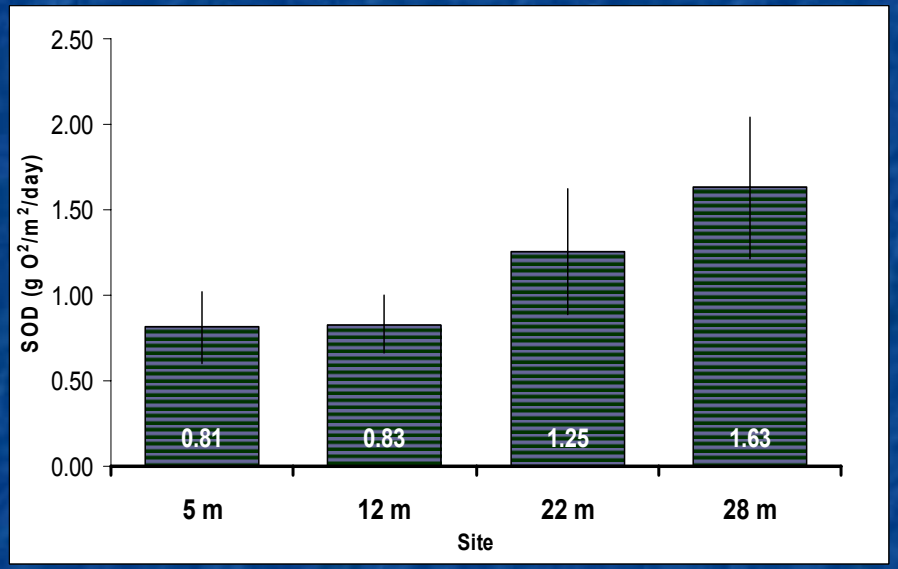


Statistics

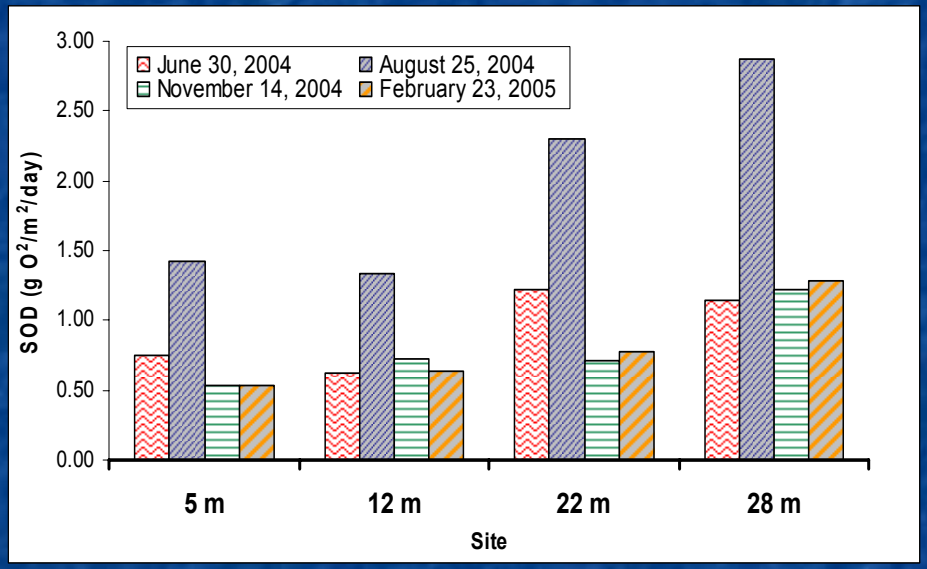
- Randomized Block ANOVA
  - Response: % OM; TP (mg/g dry); P-release (µg $P/m^2/day$); SOD (g $O^2/m^2/day$)
  - Treatment Factor: Location/Depth
  - Blocking Factor: Date
  - Tukey Pairwise Comparisons

Sediment Oxygen Demand

Overall Results



Seasonal Comparison



Date: p=0.000, Depth: p=0.005 (RB-ANOVA)

28 m site higher SOD than 5 m & 12 m sites (Tukey P-C)

August: higher SOD than other 3 dates (Tukey P-C)

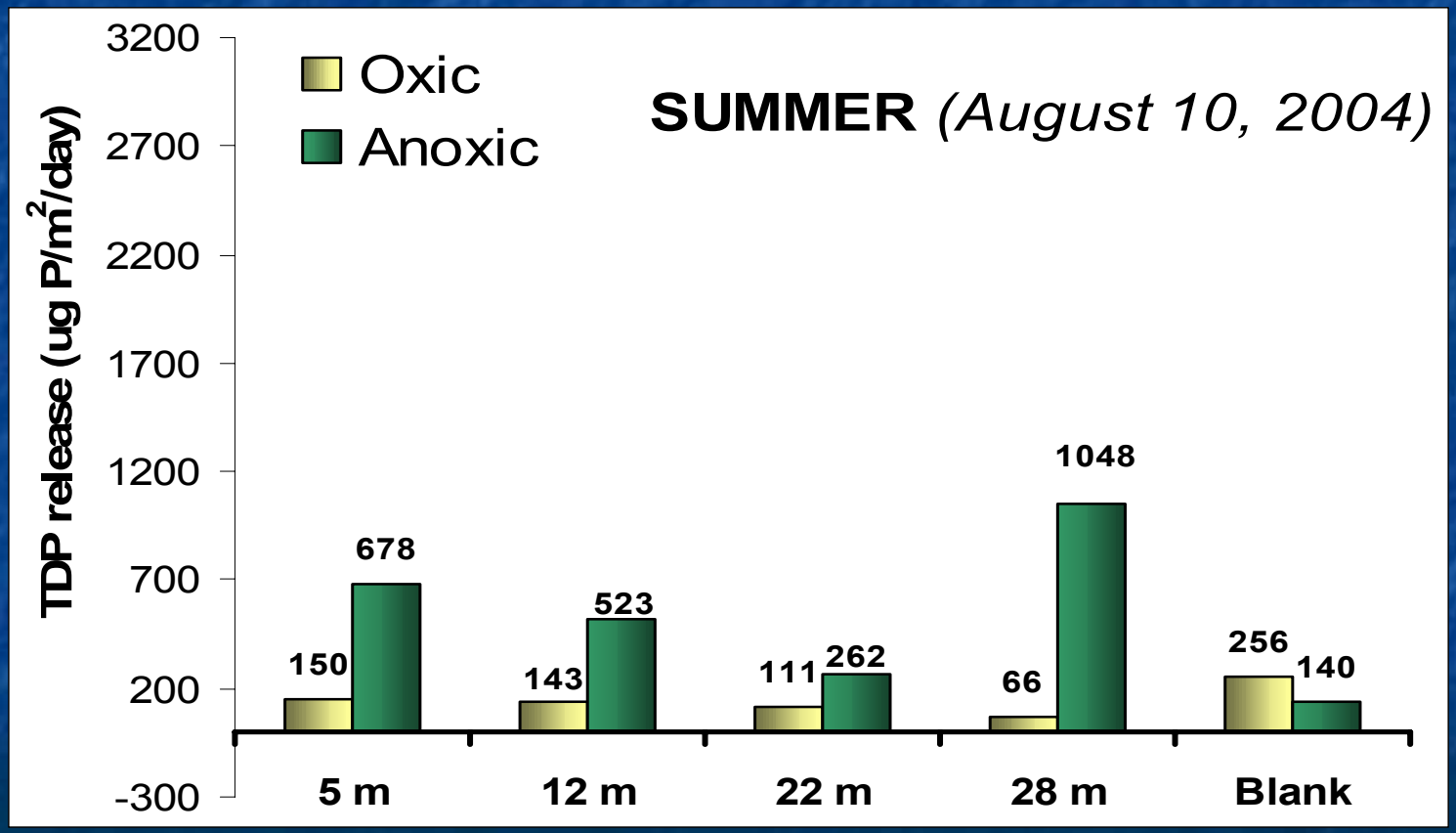
Oligotrophic:

<1 *g O^2/m^2/day*

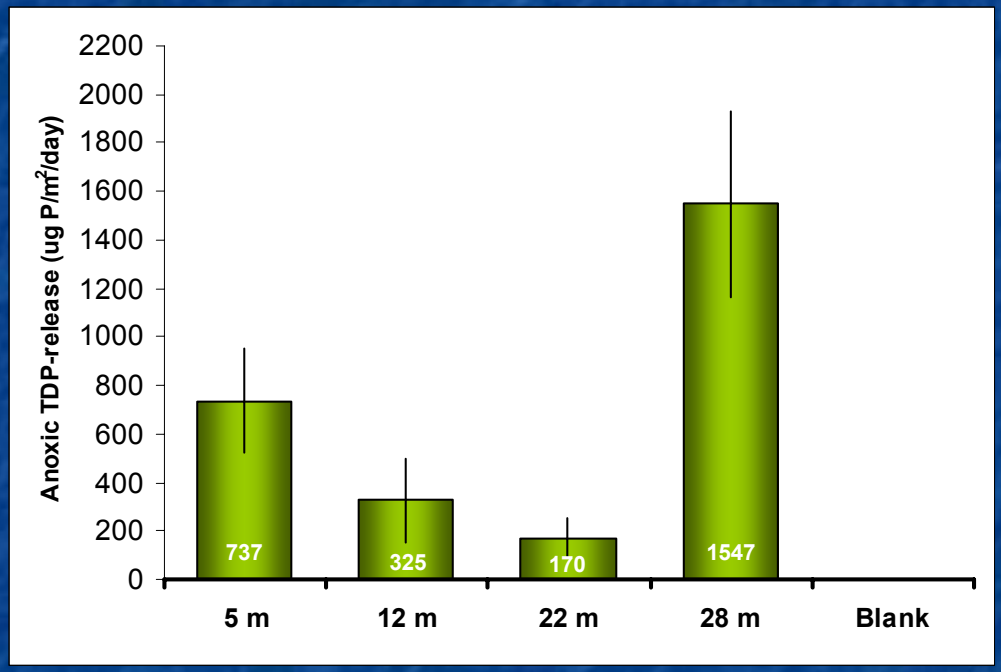
Eutrophic:

>5 *g O^2/m^2/day*

Oxic/Anoxic P-release Comparison



Summary of Anoxic P-release



Depth: p=0.000, Date: p=0.295 (RB-ANOVA)

28 m site higher anoxic p-release than 12 m & 22 m sites (Tukey P-C)

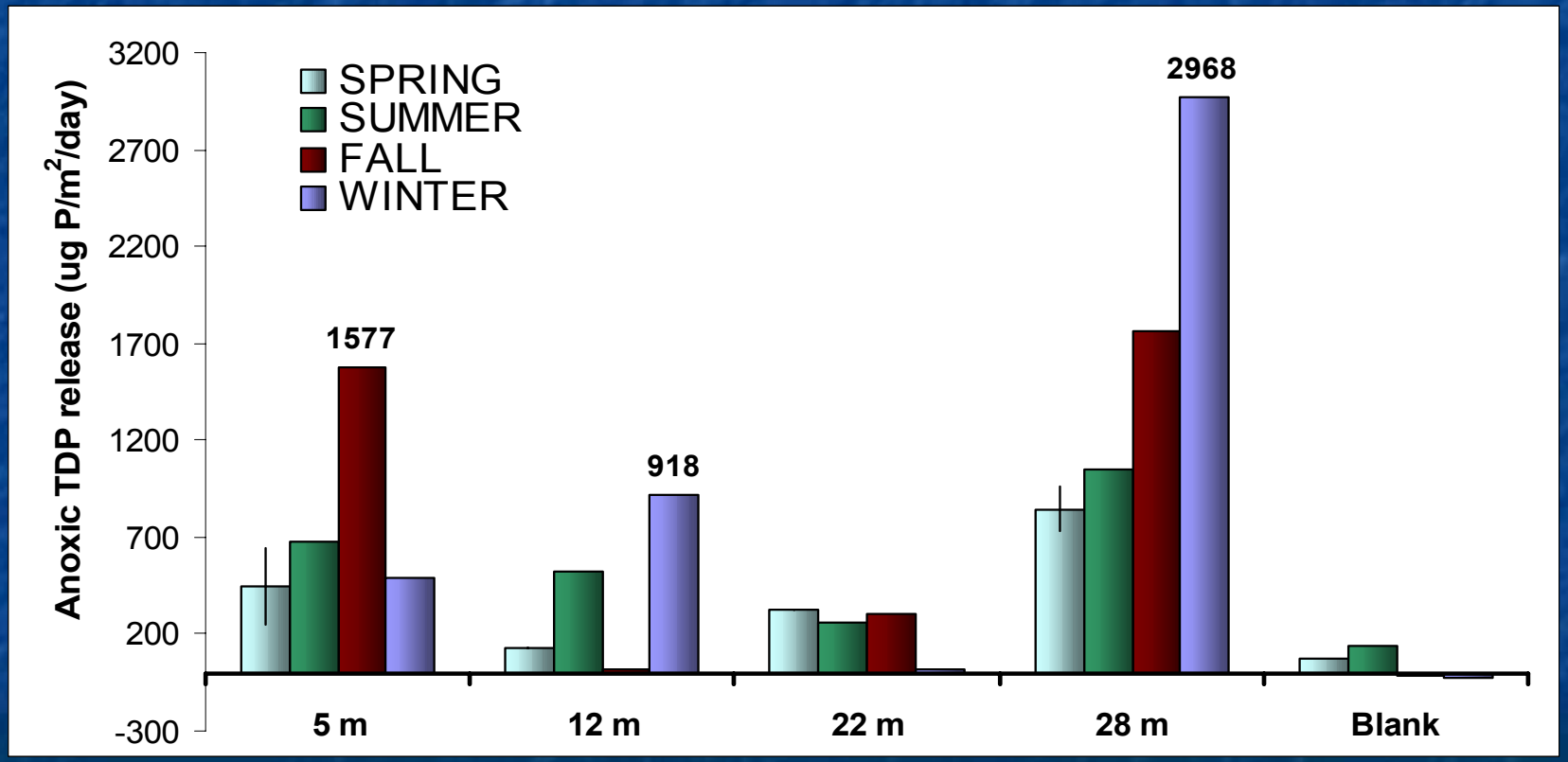
Oligotrophic:

<1,000 µg P/m²/day

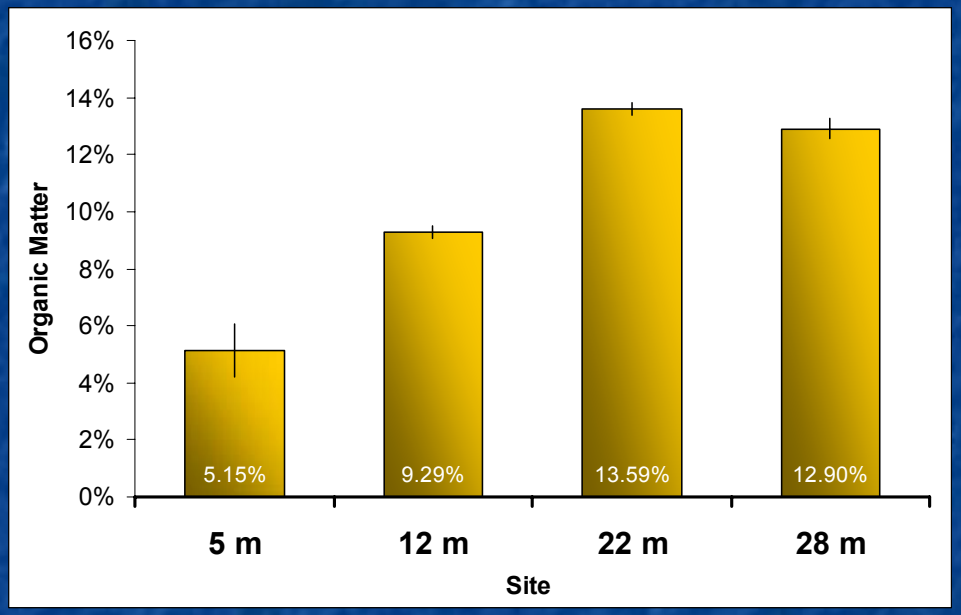
Eutrophic:

>10,000 µg P/m²/day

Seasonal Comparison of Anoxic P-release



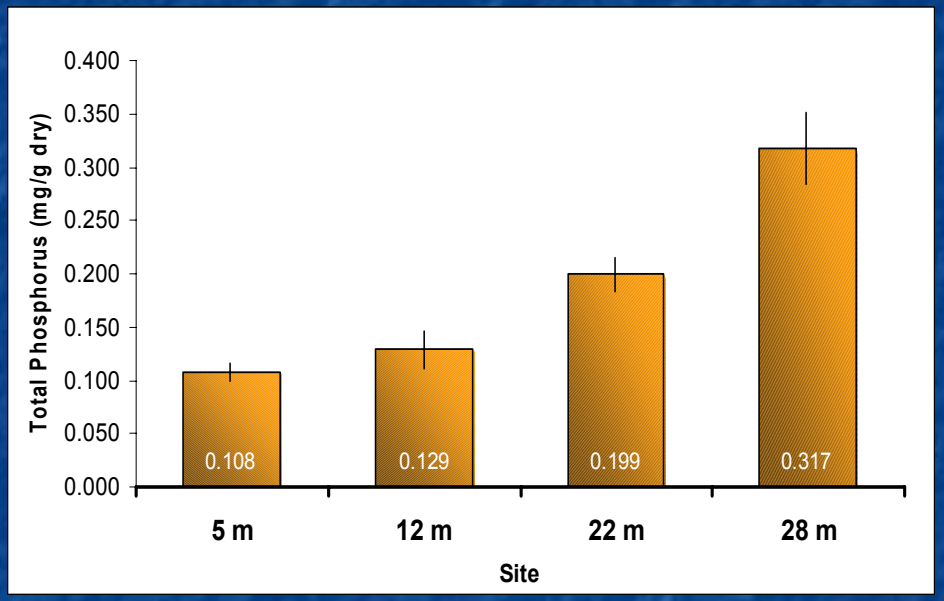
Organic Matter Content



Depth: p=0.000 (RB-ANOVA)

All 4 sites were significantly different from one another, with the exception of 28m-22 m (Tukey P-C)

Total Phosphorus Content



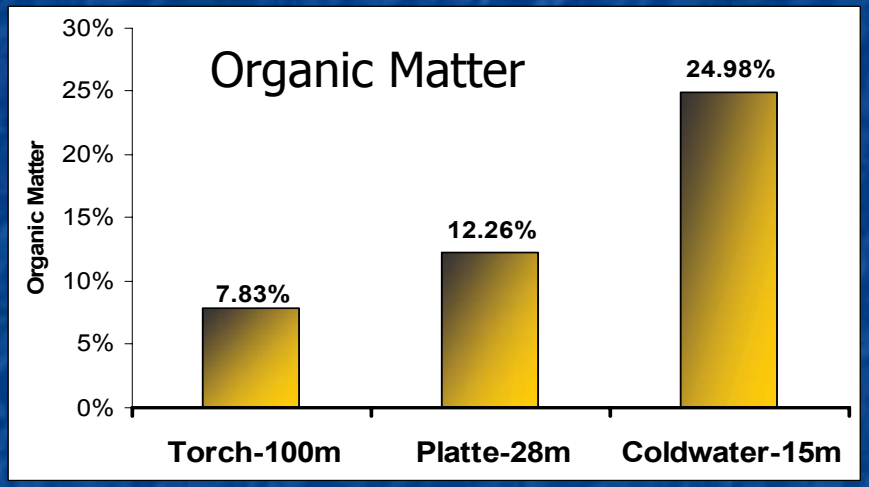
Depth: p=0.000 (RB-ANOVA)

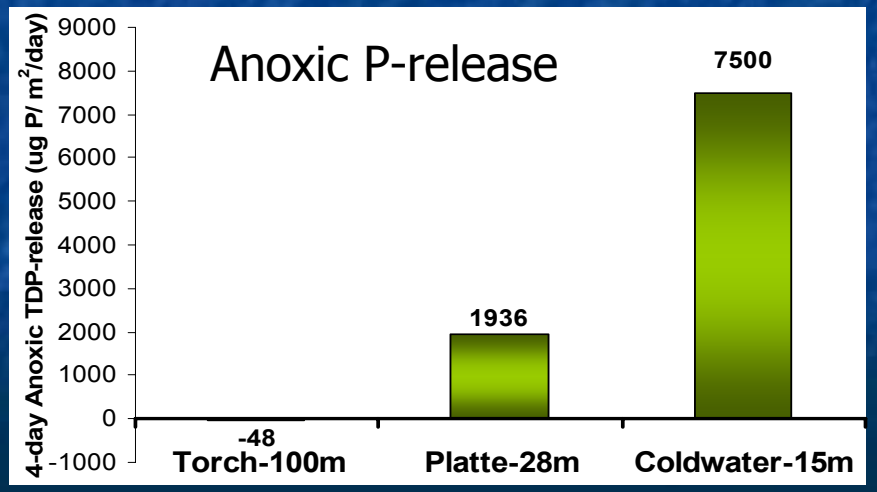
28 m site greater than other 3 sites (Tukey P-C)

22 m site greater than 5 m site (Tukey P-C)

Comparisons to Other Lakes

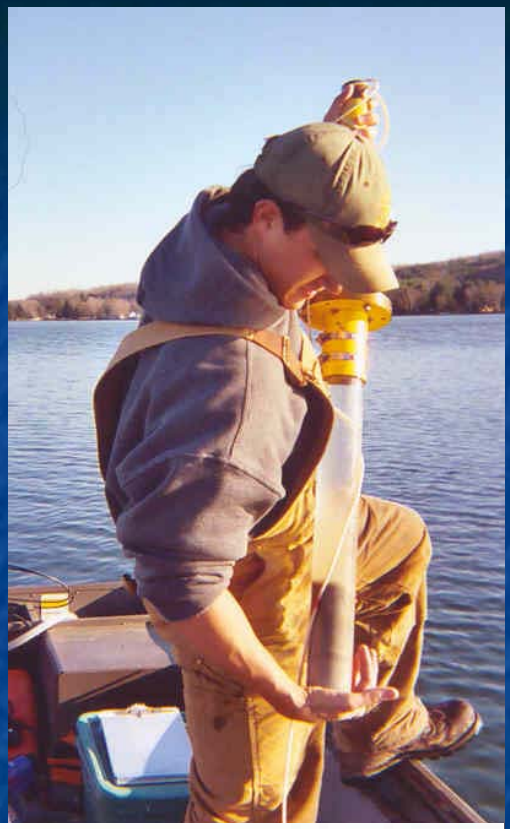
- Torch Lake ~100 m
  - *Low productivity*
  - Low OM & TP
  - Low Anoxic p-release
- Coldwater Lake ~15 m
  - *Moderate-high productivity*
  - High OM & TP
  - High Anoxic p-release





P-release Conclusions

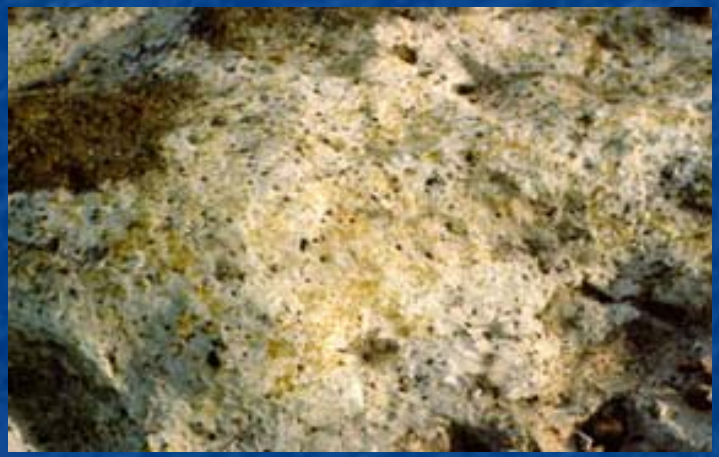
- Oxic p-release was low or negative for all sites
- Deepest site (28 m) showed greatest anoxic p-release
  - Highest TP
  - Oxic microlayer
- Low anoxic p-release at 22 m site
  - More P bound to organics?? (High OM)
  - Higher carbonates??
  - TP threshold for p-release??
- Potential for anoxic p-release from shallow sites (5 m)
  - Anoxia unlikely under *in situ* conditions
  - Bioturbation?? Bioexcretion??
    - Amphipods; mayfly larvae



Oxic Microlayer

P-release Conclusions

- Oxic p-release was low or negative for all sites
- Deepest site (28 m) showed greatest anoxic p-release
  - Highest TP
  - Oxic microlayer
- Low anoxic p-release at 22 m site
  - More P bound to organics?? (High OM)
  - Higher carbonates??
  - TP threshold necessary for p-release??
- Potential for anoxic p-release from shallow sites (5 m)
  - Anoxia unlikely under *in situ* conditions
  - Bioturbation?? Bioexcretion??
    - Amphipods; mayfly larvae



http://www.chesterfieldlodge.fsnet.co.uk/

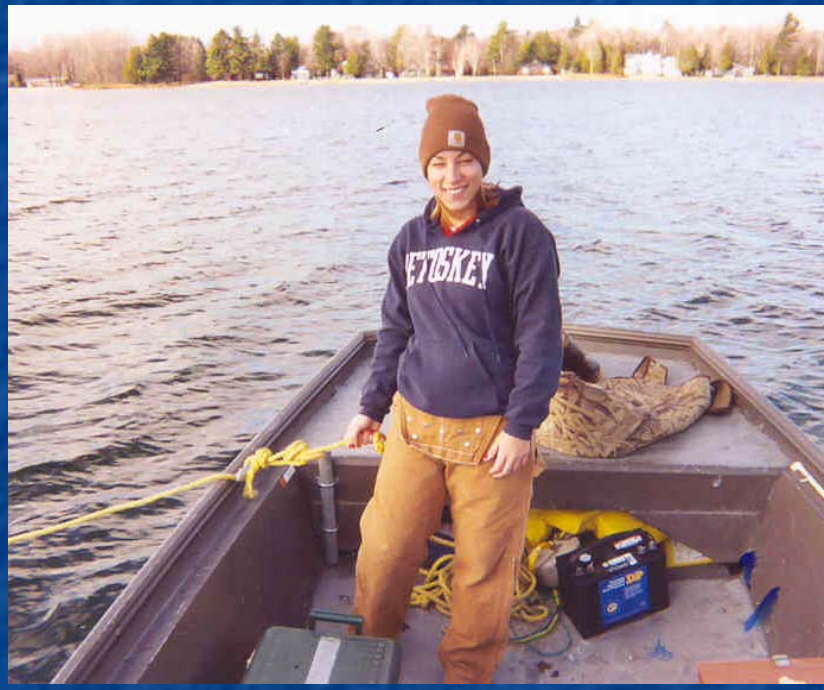
http://www.glerl.noaa.gov/seagrant/GLWL/Benthos

Overall Conclusions

- TP & OM increase with depth
- Highest SOD in late summer
  - Prolonged anoxia
- Major contribution of phosphorus from Platte Lake sediments occurs during anoxia primarily @ deepest location
- Overall contribution of phosphorus from sediments is minor in comparison to more eutrophic lakes

Suggestions for Future Work

- Differential p-extractions
  - P bound to $CaCO_3$, Fe, organics, etc.,
  - May explain low p-release at 22 m site
- More focus on sediment near 28 m site
  - What depth is anoxic p-release reduced?
    - -25 m ??
    - -20 m??
  - Are long-term anoxic p-release rates decreasing?



Acknowledgements

- Graduate Committee
  - Scott McNaught
  - Doug Valek
  - Greg Colores
- CMU Department of Biology
- Michigan Department of Natural Resources--- Platte River Hatchery
  - Aaron Switzer
  - Ed Eisch
  - Gary Whelan
- Platte Lake Improvement Association
  - Ray Canale
  - Will Swiecki
- Others
  - Jenny Estabrook
  - Erica Francis
  - Devin Millions
  - Keith Tollenaere
  - Trisha Schales
  - Clay Wilton
  - Ray Clark
  - Jeff Scofield
- Other grad students, family, & friends


Big Platte Lake
Questions??
Sleeping Bear Dunes
National Shoreline
Lake Michigan