Water Quality Considerations

Managing Lakes for Preferred Native Plants

William F. James
ERDC Eau Galle Aquatic Ecology Laboratory
W500 Eau Galle Dam Rd
Spring Valley, Wisconsin 54767

Minnesota-Wisconsin Invasive Species Conference
8-10 November, 2010 St. Paul, MN

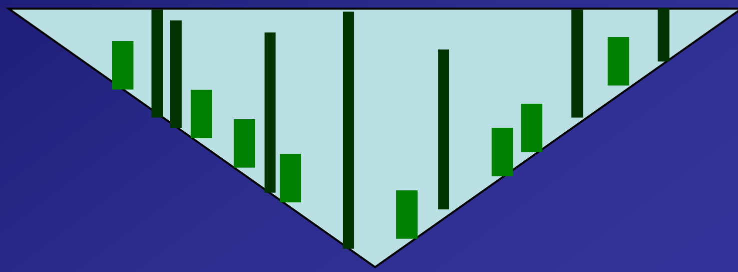
Importance of Submersed Aquatic Plant Communities

- **A diverse, predominantly native, submersed macrophyte community plays an important structuring role in aquatic ecosystems:**
  - Refugia for young fish
  - Habitat for a wide diversity of invertebrates including zooplankton
  - Food supply for waterfowl
  - Stabilization of sediment from resuspension
  - Sequestration and trapping of nutrients
  - Allelopathic impacts on algae
- **These interactions and feedbacks can foster:**
  - Fishery dominated by piscivores
  - Increased grazing pressure on algae
  - Nutrient limitation of algal growth
  - High water clarity and low turbidity
  - Resilience to perturbations

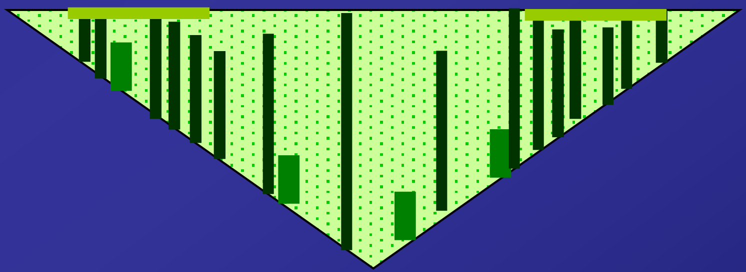
How Can We Manage Lakes to Reduce Exotic Species and Encourage Native Species Growth?

Is Selective Control with Herbicides or Biocontrol Agents Usually Enough?

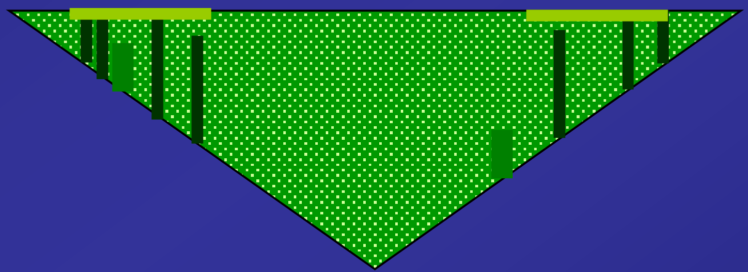
Alternate Stable States Theory



Clear-water native macrophyte-dominated state



Invasive, canopy-forming, macrophyte dominated state

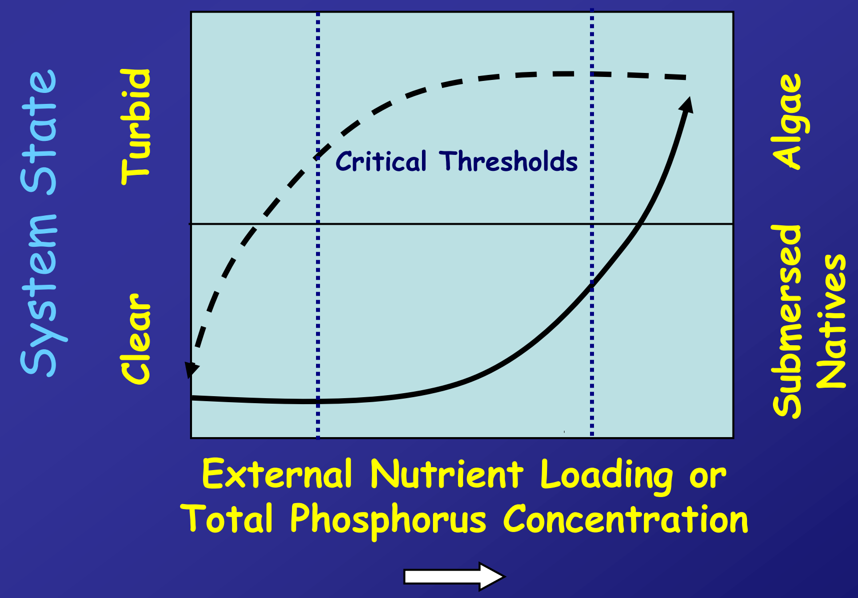


Algal-dominated state

Scheffer (1998)

Alternate Stable States are Resistant to Change or Management

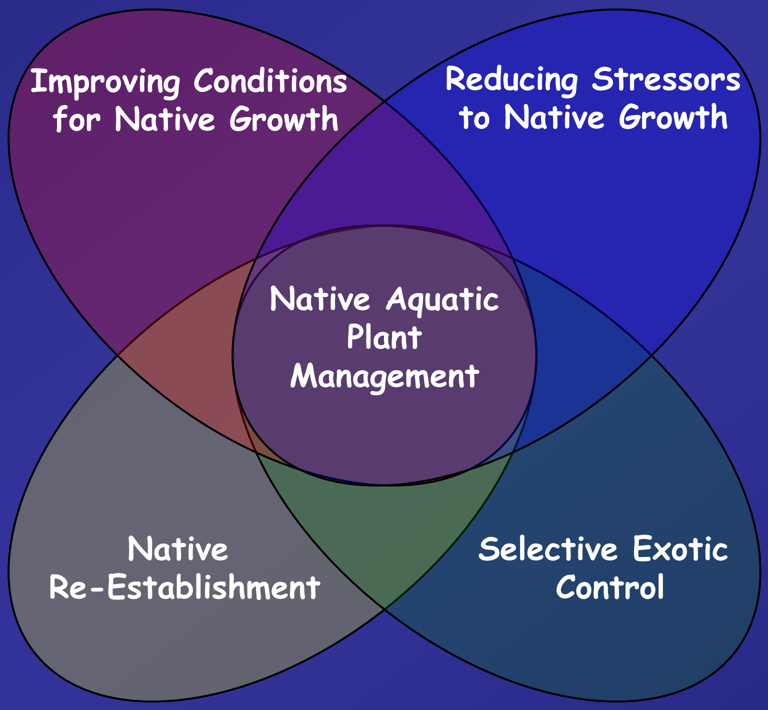
- Tremendous efforts are often required to drive systems from one state to another
  - Costly
  - Labor-intensive
  - Societal impacts
- Hysteretic effects complicate restoration efforts
  - Delayed response to restoration
  - Example: nutrient retention in sediment and internal recycling



Widespread Loss of Native Submersed Vegetation

- Eutrophication and changes in light regime
- Invasion by canopy-forming exotic species
- Unchecked benthic fish growth
- Catastrophic events
- Changes and management of pool elevation

Native Aquatic Plant Management Strategy



Management Strategies

- Strategies to limit algal growth, algal-induced light attenuation, and improve light condition
  - External phosphorus loading reduction
  - Internal phosphorus loading reduction
  - Manipulation of fish communities
- Strategies to reduce nonalgal turbidity
  - Fetch reduction
  - Sediment consolidation
  - Sediment dredging
  - Benthic fish eradication
- Selective control of exotic species
  - herbicides
  - biocontrol
  - mechanical

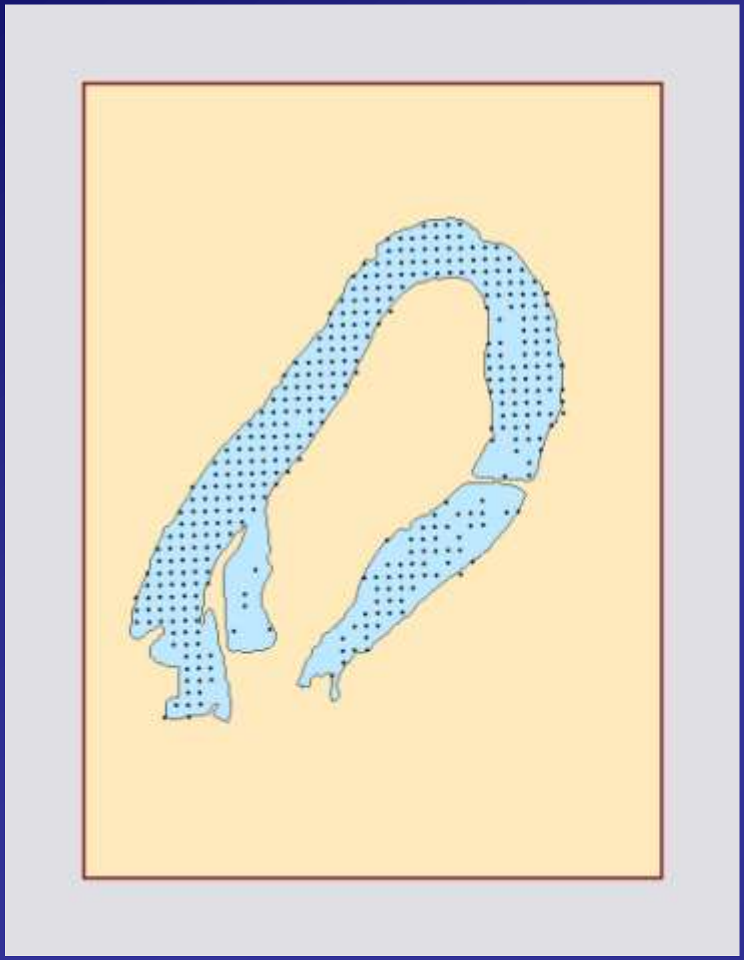
Problem Identification
Half Moon Lake, Wisconsin

- Invasive *Potamogeton crispus* and *Myriophyllum spicatum*

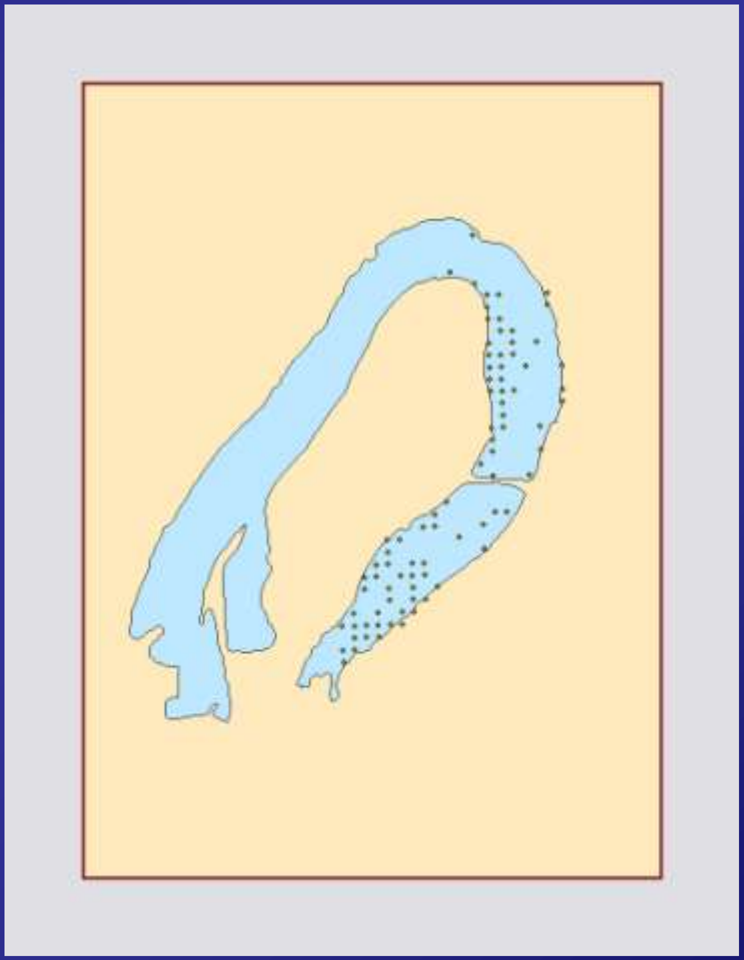
- Eutrophic
  - TSI = 74
  - > 0.10 mg L^{-1} phosphorus
  - > 80 mg m^{-3} chlorophyll
  - < 1.0 m Secchi transparency

- Phosphorus budget
  - Sediment internal loading (42%)

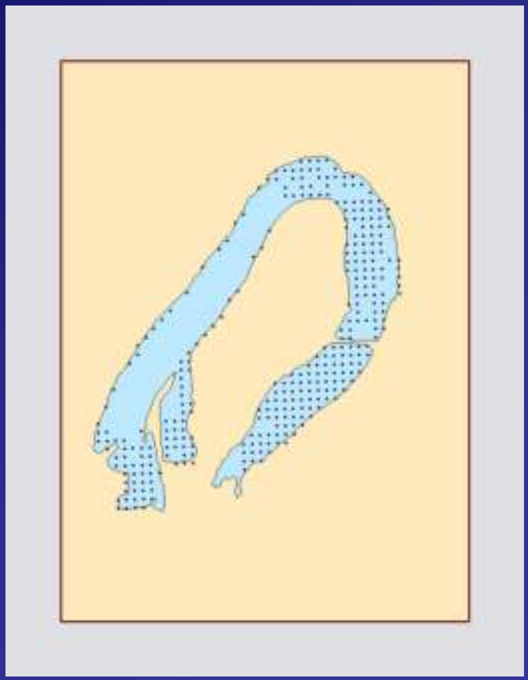
P. crispus



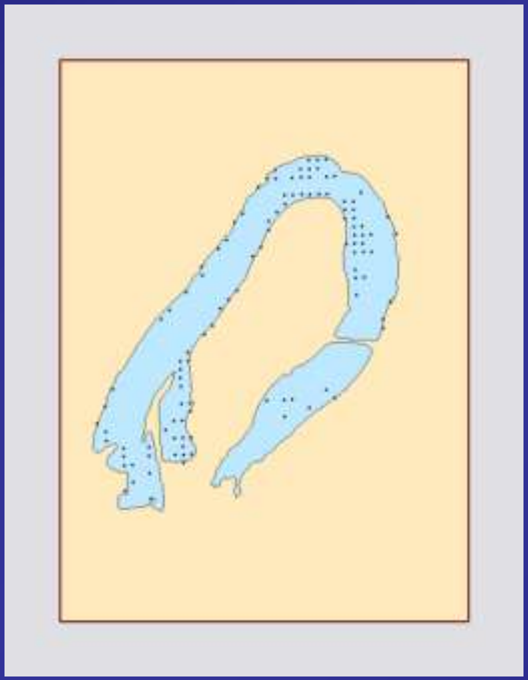
M. spicatum



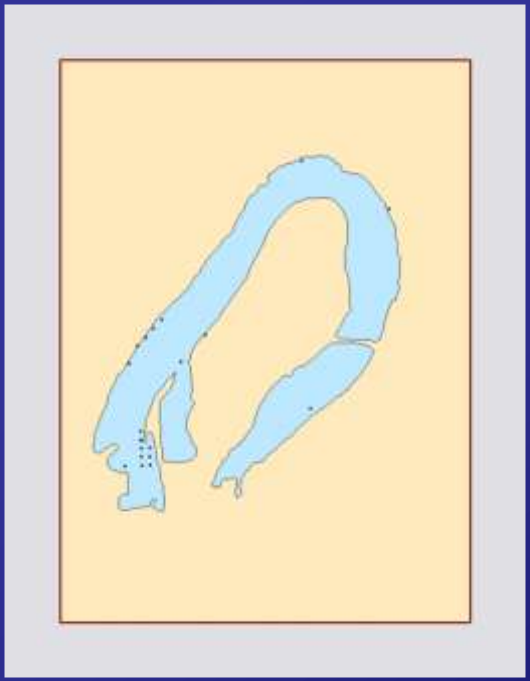
C. demersum



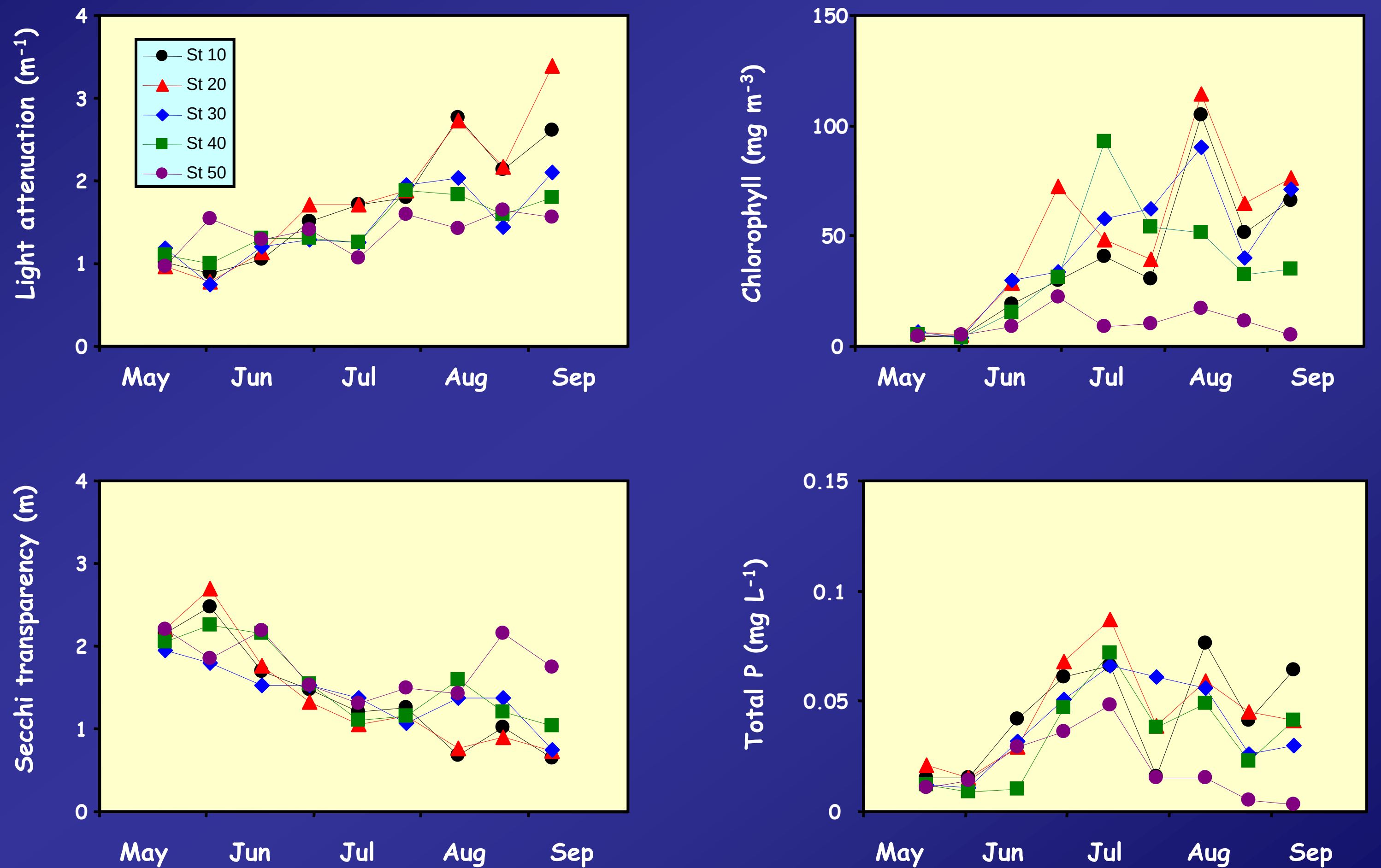
E. canadensis



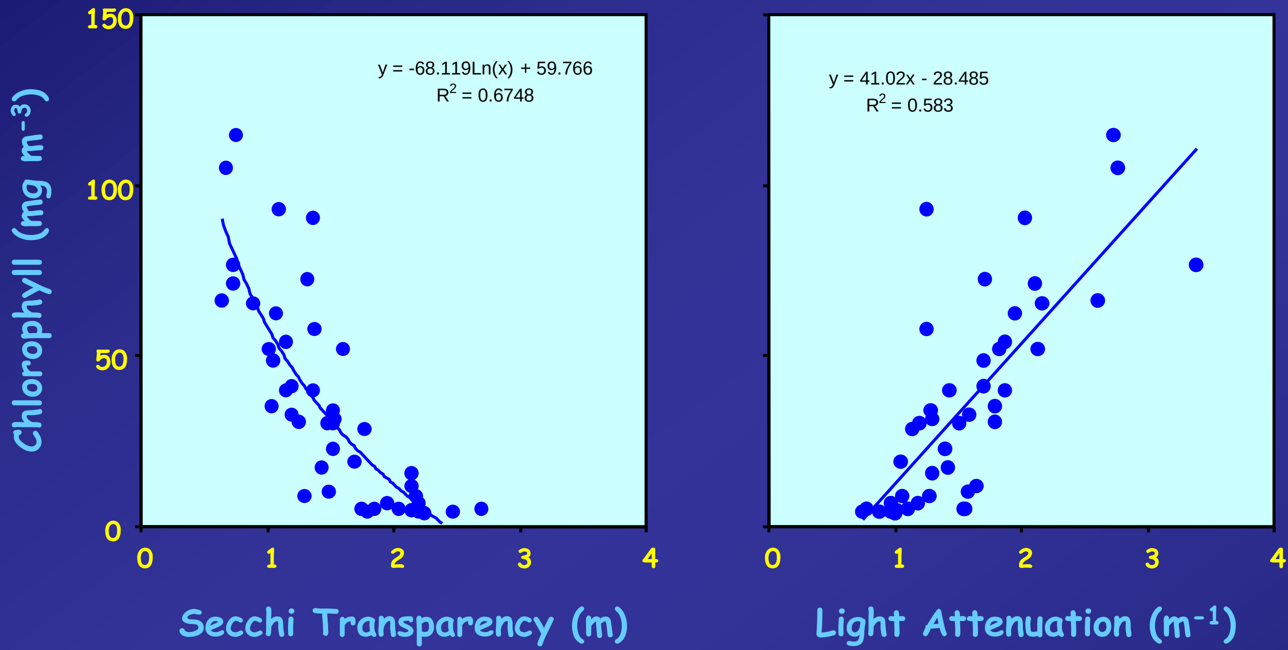
V. americana

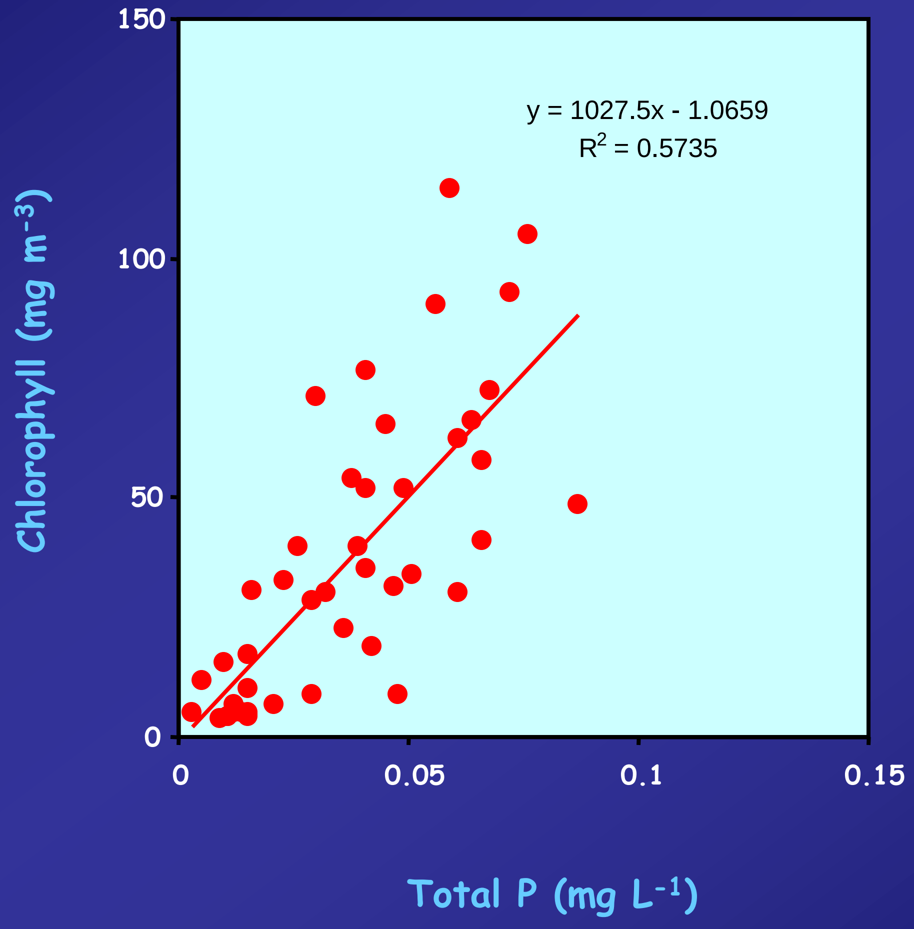


Current Water Quality



2008


Chlorophyll (mg m-3)
150
100
50
0
y = -68.119Ln(x) + 59.766
R2 = 0.6748
0
1
2
3
4
Secchi Transparency (m)
y = 41.02x - 28.485
R2 = 0.583
0
1
2
3
4
Light Attenuation (m-1)


150
100
50
0
0
0.05
0.1
0.15
y = 1027.5x - 1.0659
R2 = 0.5735
Chlorophyll (mg m-3)
Total P (mg L-1)

Projecting Changes in Light Habitat

Scenario	Total P ($mg\ L^{-1}$)	Chlorophyll ($mg\ m^{-3}$)	Secchi Transparency (m)	Light Attenuation (m^{-1})	Z_{max} (m) Caulescent	Z_{max} (m) Rosette	Light Intensity (% Surface) Caulescent	Light Intensity (% Surface) Rosette	Light Habitat (% Total Area) Caulescent	Light Habitat (% Total Area) Rosette
Current conditions	0.109	82	1.1	1.9	1.9	0.8	0.2	2.6	38	16
Post internal P loading reduction conditions	0.038	17.7	3.8	0.3	4.8	2.5	8.0	26.3	100	56

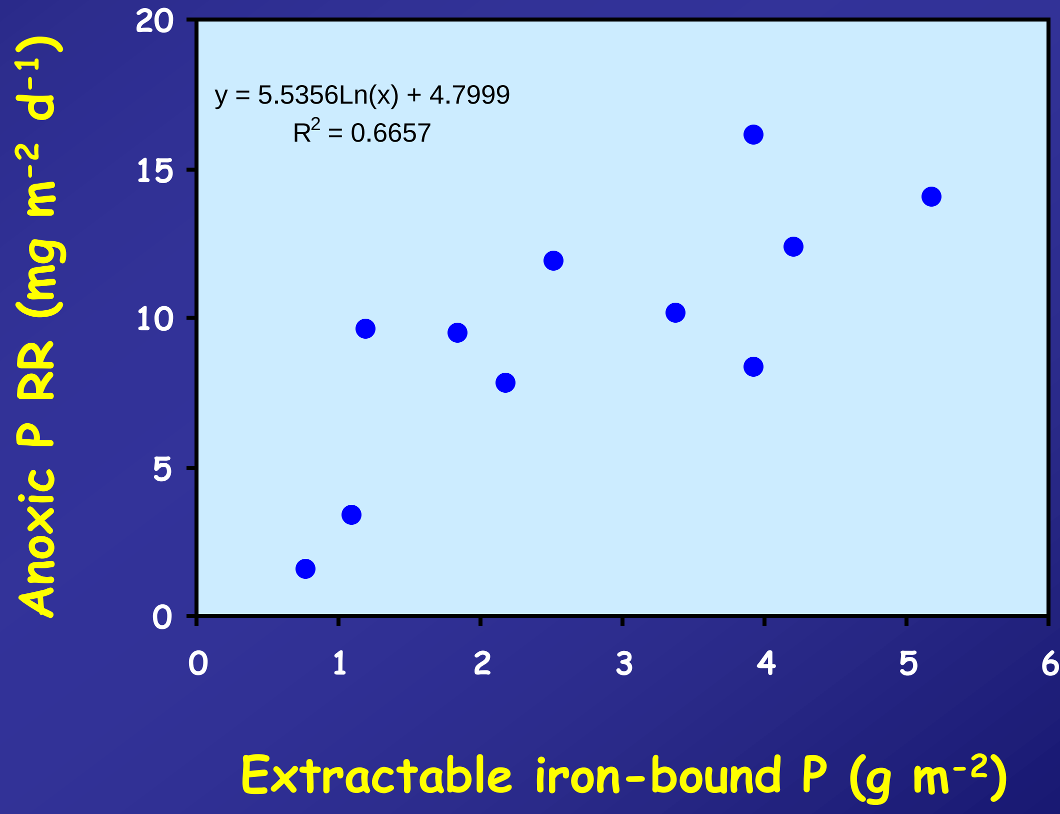
Mean Depth = 1.6 m
Max Depth = 4.0 m

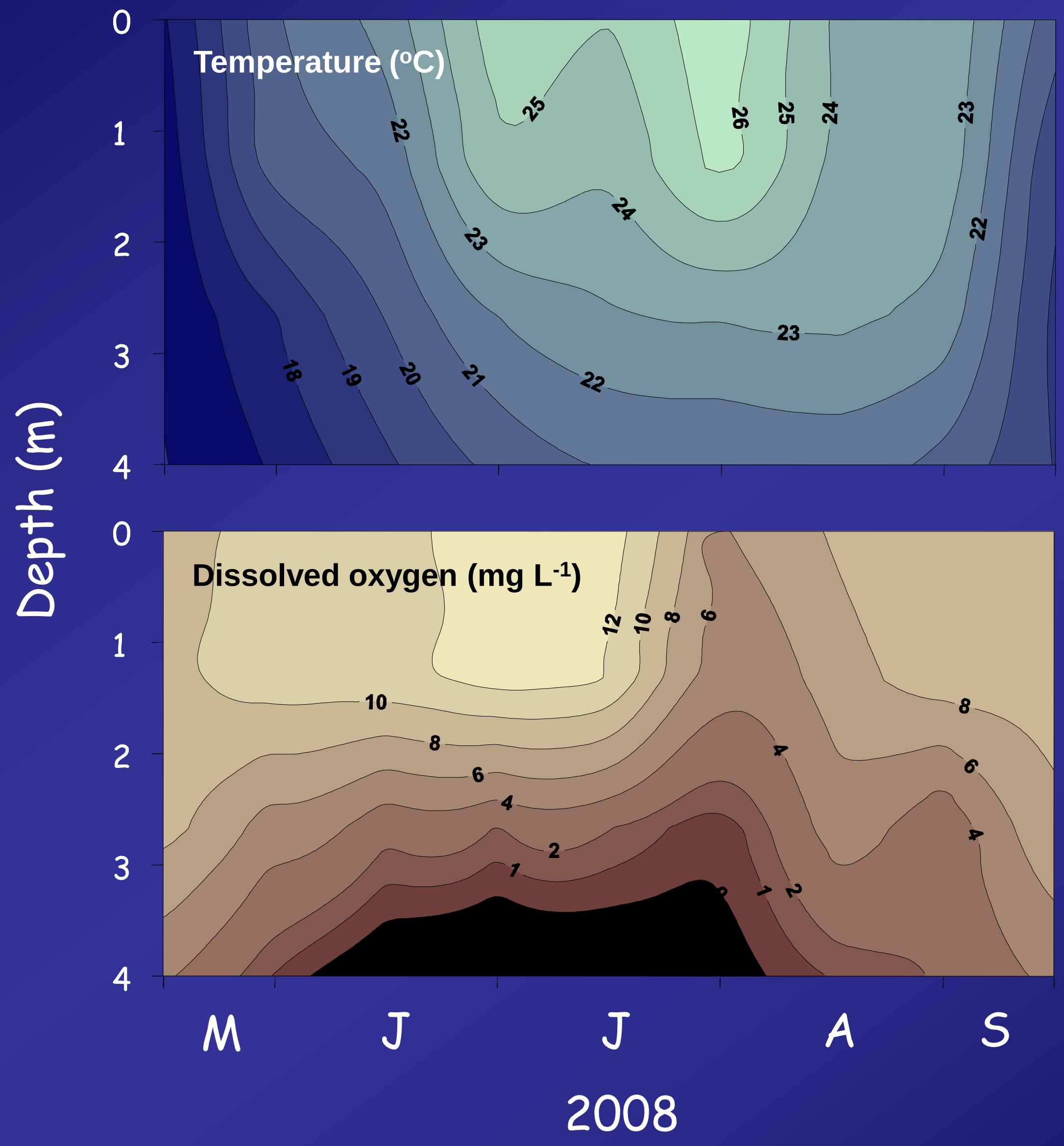
Middelboe and Markager 1997. Depth limits and minimum light requirements of freshwater macrophytes. Freshwater Biology 37:553-568.

Management for Improved Light Penetration

- Management strategy is several-fold
  - Control internal P loading via aluminum sulfate
  - Reduce motor boat activity and resuspension
  - Reduce invasive curly-leaf pondweed and eurasian watermilfoil biomass via early-spring herbicide application

Empirical relationships between iron-bound phosphorus concentration and rates of release under anoxic conditions

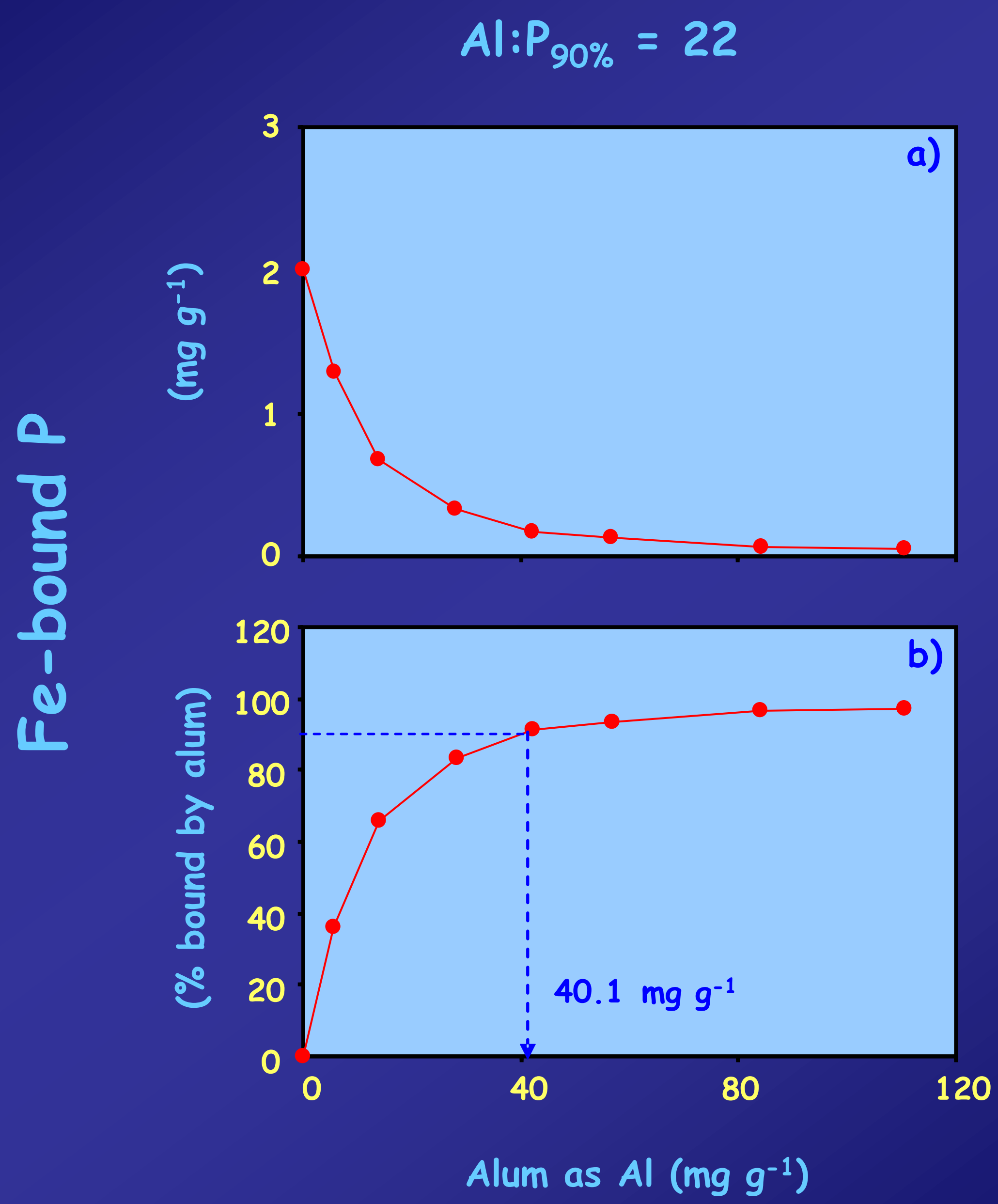




Temperature (°C)
Dissolved oxygen (mg L-1)
Depth (m)
0
1
2
3
4
18
19
20
21
22
23
24
25
26
12
10
8
6
4
2
1
M
J
J
A
S
2008

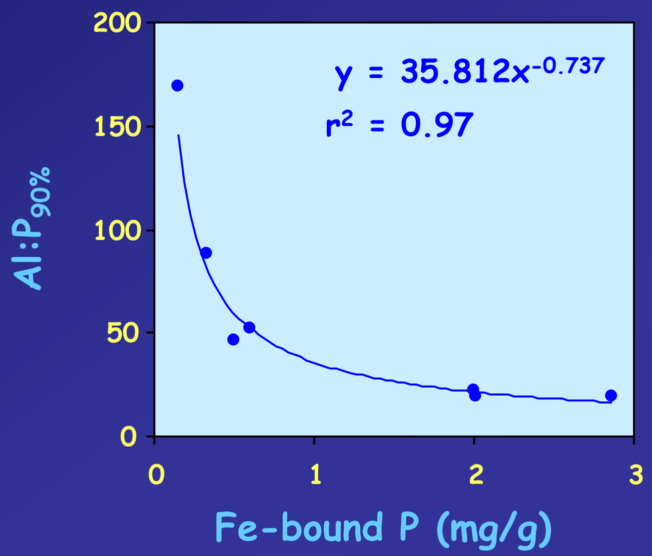
Alum Dosage Considerations

- Maximum allowable based on pH and alkalinity (Kennedy and Cooke 1982)
- Rate of internal P loading and Al:P binding ratio assumption of 1:1
- Extractable P in the sediment (Rydin and Welch 1999)
  - Found much higher Al:P binding ratios were required
  - 10:1 to > 100:1



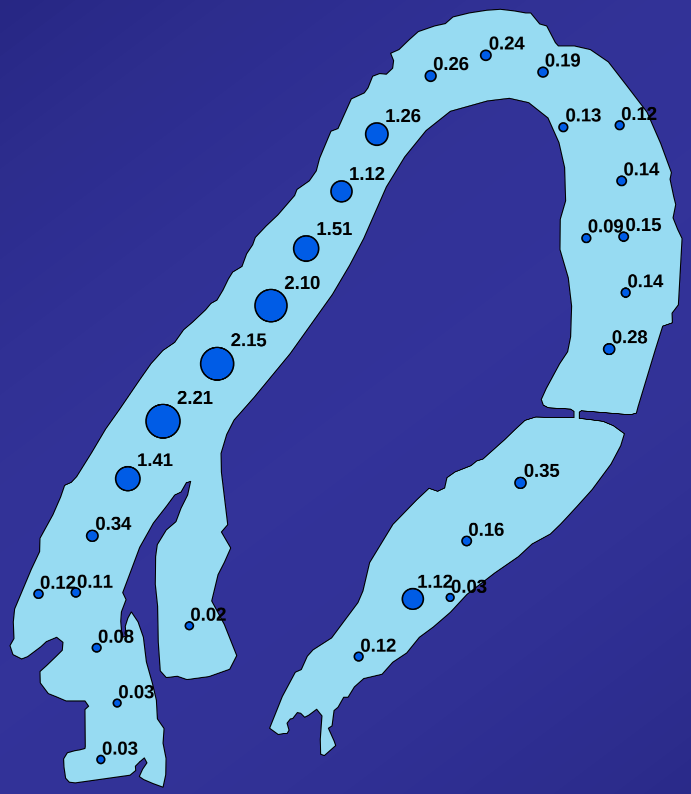
Al:P90% = 22
Fe-bound P
(mg g-1)
3
2
1
0
a)
(% bound by alum)
120
100
80
60
40
20
0
b)
40.1 mg g-1
0
40
80
120
Alum as Al (mg g-1)

Variations in Al:$P_{90\%}$ as a function of Fe-bound P

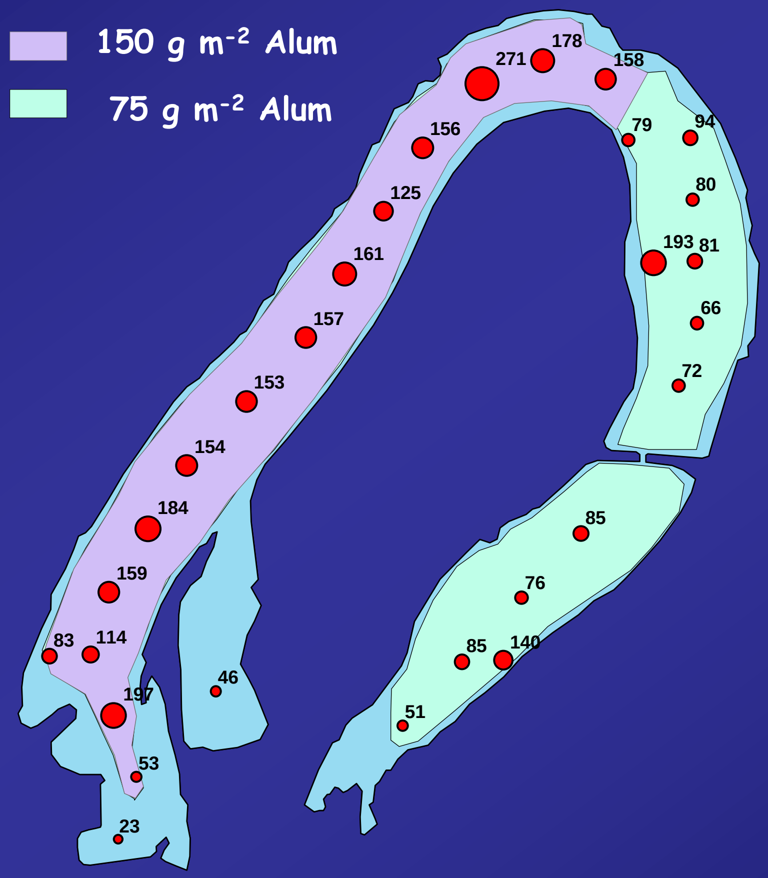


- **Al:$P_{90\%}$ stoichiometry varies**
- **Valuable insight for improving dosage determination**

Iron-bound P (mg g^{-1})



Alum – Aluminate Dosage Zones



Will Submersed Vegetation Rebound?

- Problem identification and management strategies were targeted to improve the potential for native re-establishment
  - Early spring herbicide treatment to selectively control canopy-forming exotics
  - Alum treatment to reduce algal biomass and improve light penetration

- However, successful revegetation depends on:
  - Native inocula and the native seed bank
  - Unforseen problems such as benthic fish

- Long-term studies suggest that revegetation may be a slow process (i.e., hysteresis pattern)

- Vegetation restocking is an option

Acknowledgments

City of Eau Claire, Wisconsin

Wisconsin Department of Natural Resources

U.S. Army Corps of Engineers
ERDC Aquatic Plant Control Research Program