Shallow Lake Ecology

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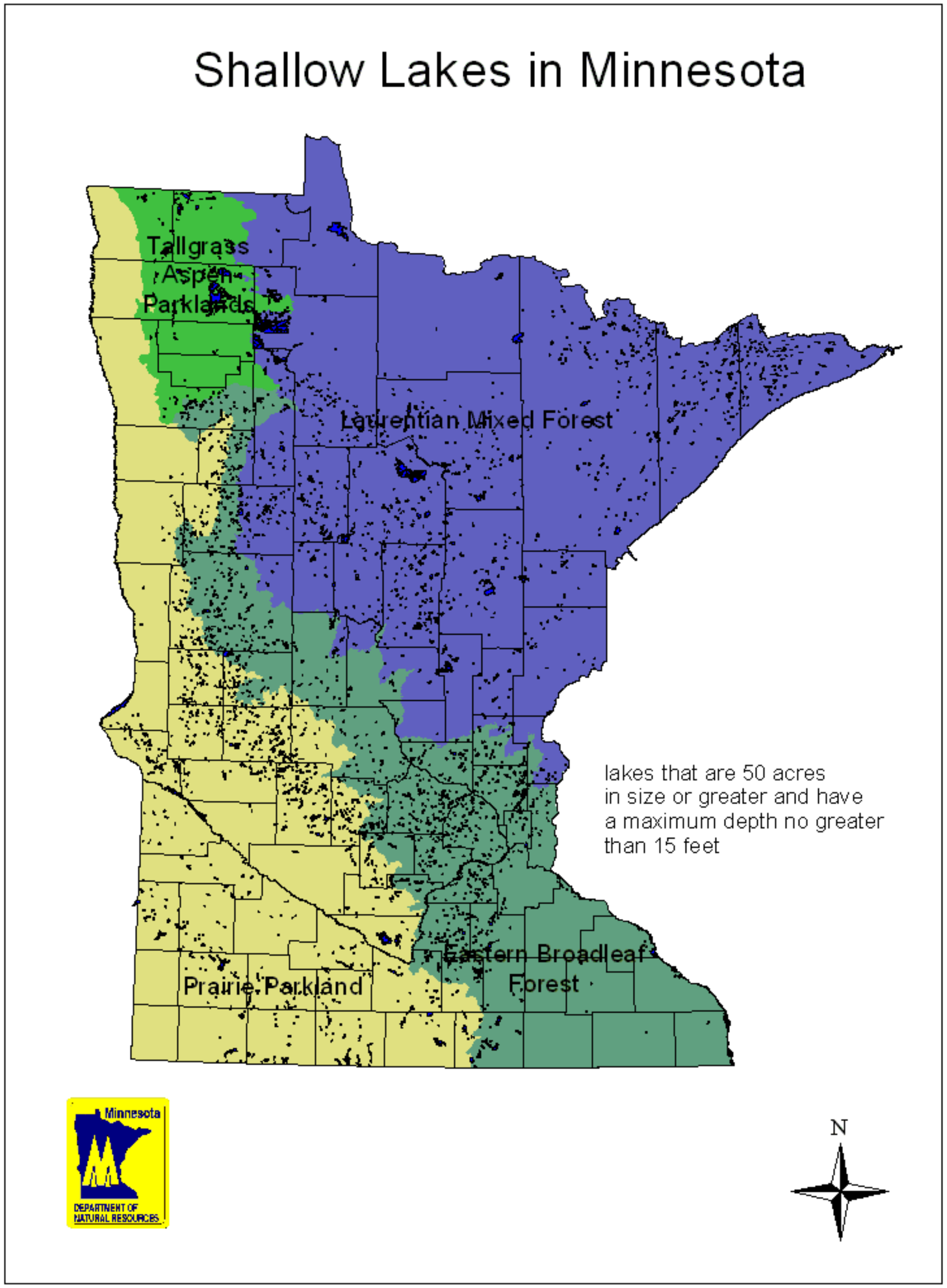
Objectives of this Presentation

- Overview of Shallow Lake Ecology
  - What is a shallow lake?
  - Physical differences from deep lakes
  - The role of nutrients in shallow lakes
  - What about biology?
  - Alternative Stable States
  - Implications for management activities



- Minnesota DNR identified over 4,000 shallow lakes greater than 50 acres with a maximum depth less than 15 feet

John Downing, Iowa State University, unpublished data

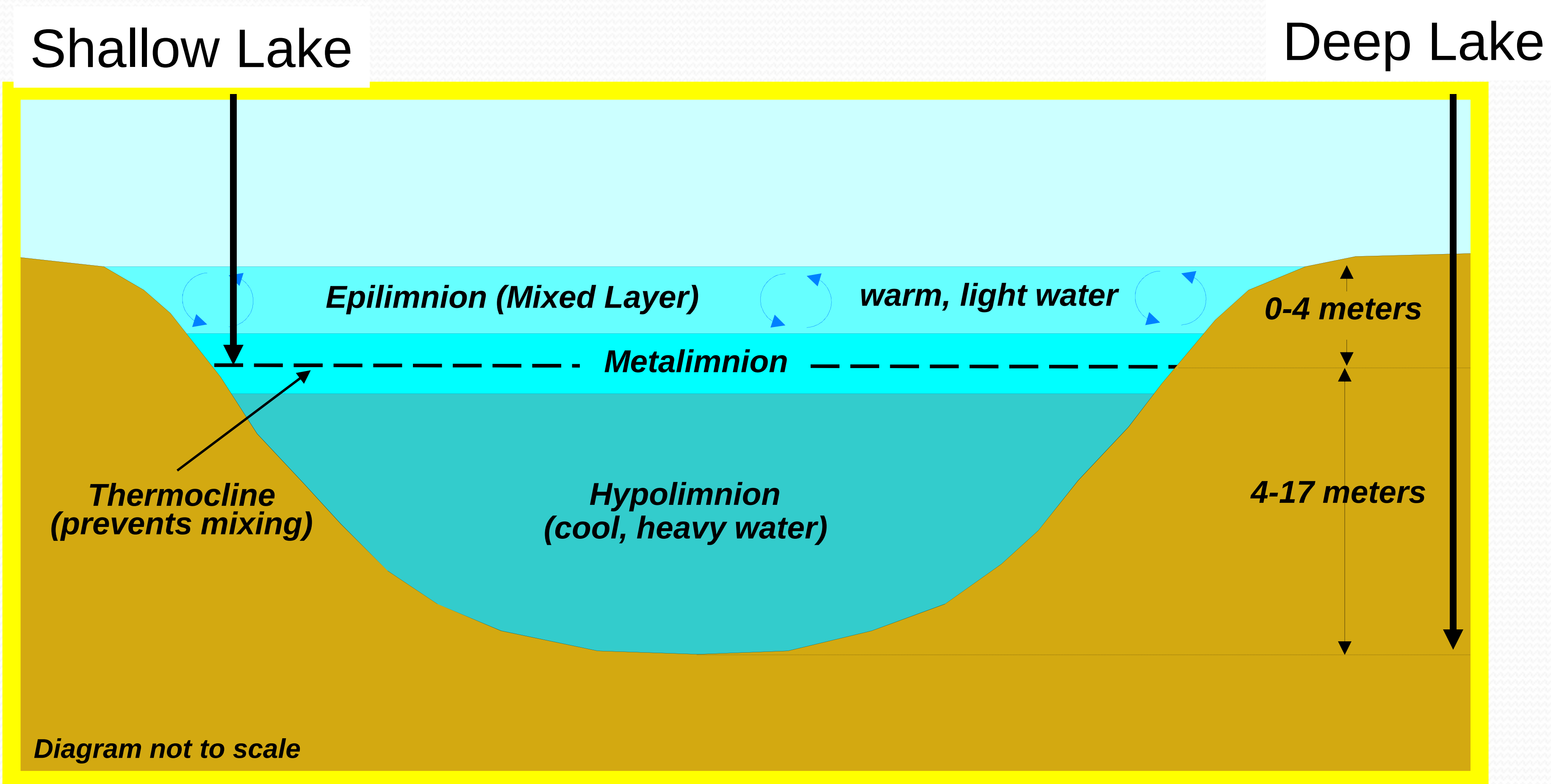
Physical Features

What is a Shallow Lake?

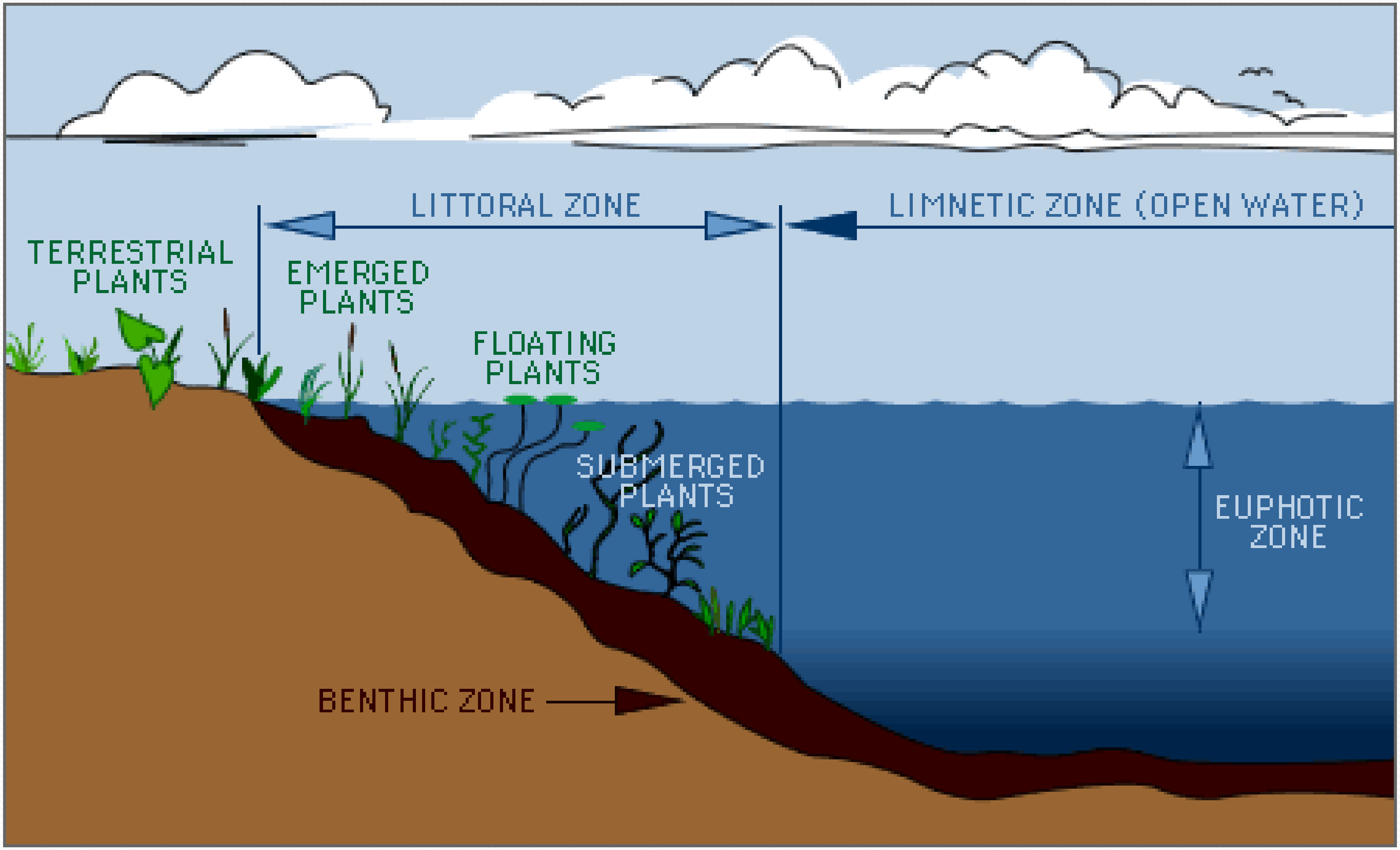
- Generally, any lake that does not stay stratified throughout the summer season is a shallow lake.
- MPCA defines a shallow lake as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants.
- Functionally different
  - Volume limited
  - Vertically concentrated
  - Dynamic systems

Generalized Lake Ecosystem

(Summertime Average Conditions)



Lake Zones



LITTORAL ZONE
LIMNETIC ZONE (OPEN WATER)
TERRESTRIAL PLANTS
EMERGED PLANTS
FLOATING PLANTS
SUBMERGED PLANTS
EUPHOTIC ZONE
BENTHIC ZONE

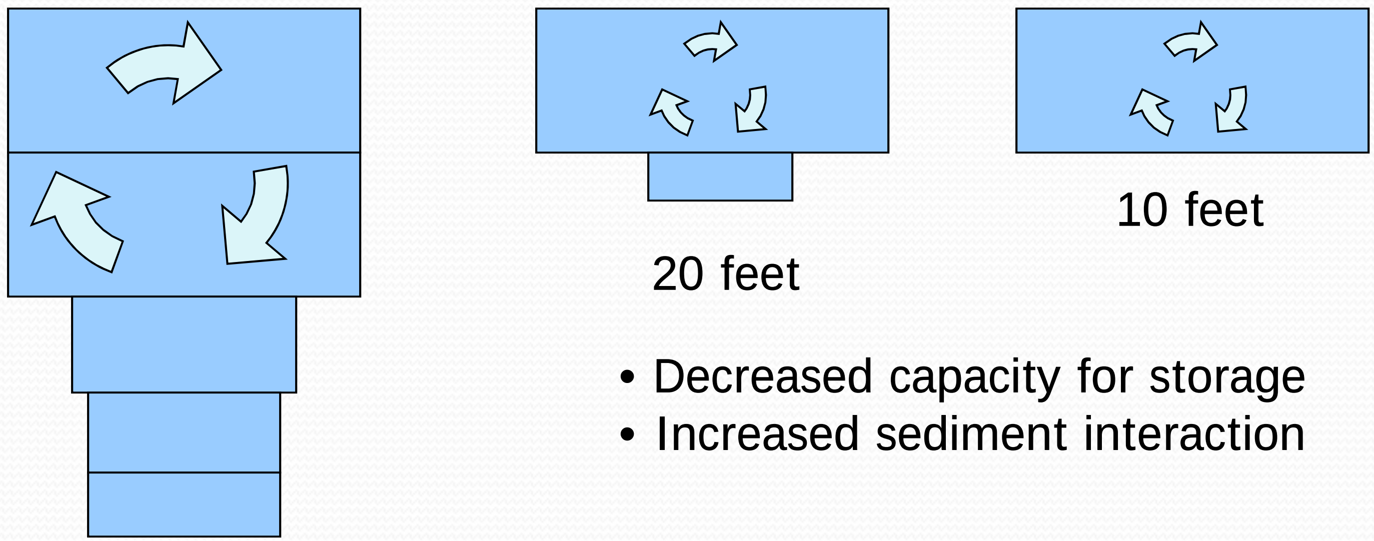
Shallow Lakes are Dynamic

- Because shallow lakes are vertically concentrated, internal loading can have a greater impact on nutrients
- Volume limited, so less volume to assimilate and distribute nutrients
- Dynamic systems
  - Polymictic (mix frequently throughout the year)
  - Complex dissolved oxygen patterns
  - Strong interactions with biological community

Volume, Watershed, and Vertical Concentration

	Lily Lake	Long Lake	McKusick Lake

Littoral



>20 feet

20 feet

10 feet

50 feet

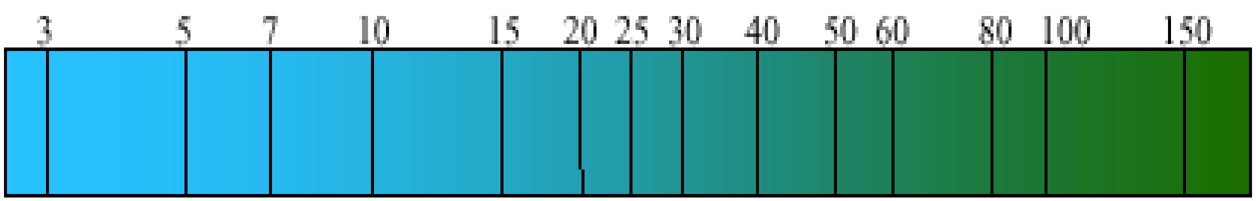
- Decreased capacity for storage
- Increased sediment interaction

	Lily Lake	Long Lake	McKusick Lake
acres/250,000 ft^3	6	21	67
Depth of Lake Volume over Watershed (in)	11	3	1

Nutrient Dynamics

Relationship between TP and Transparency

Oligotrophic **Mesotrophic** **Eutrophic** **Hyper-Eutrophic**



Total Phosphorus (µg/L)

MPCA Standards

	North Central Hardwood Forest		Western Cornbelt Plain and Northern Glaciated Plains		Northern Lakes and Forests
Parameters	**Shallow[1]**	**Deep**	**Shallow[1]**	**Deep**	
Phosphorus Concentration (µg/L)	60	40	90	65	30
Chlorophyll-a Concentration (µg/L)	20	14	30	22	9
Secchi disk transparency (meters)	>1	>1.4	0.7	0.9	2.0

[1] Shallow lakes are defined as lakes with a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

Internal and External Phosphorus Loading

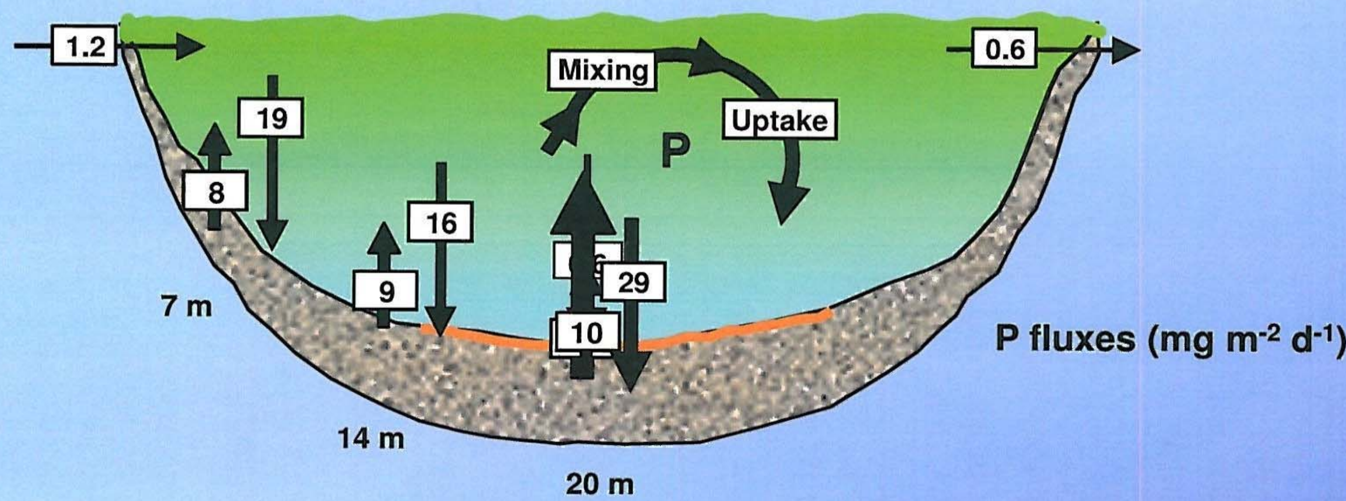
- External Sources
  - Stormwater
    - Fertilizer
    - Organic material (leaves)
    - Agricultural runoff
  - Precipitation
  - Degraded wetlands
  - Construction runoff
  - Geese
  - Wastewater discharges

- Internal loading
  - Sediment Anoxia
    - Chemical loading
  - Invasive Species
    - Curly leaf pondweed
  - Carp and bullhead

Factors Controlling Internal Load

- Shallow lakes are vertically concentrated
  - Increased sediment interaction with water column
- There primary factors controlling internal load
  - Re-suspension of sediments
    - Wind mixing/lack of vegetation
    - Rough fish
  - Chemical release of phosphorus
    - Redox reactions release stored phosphorus from the sediment
  - Invasive aquatic vegetation
    - Curlyleaf pondweed
      - Mid summer die off may cause phosphorus increase or result in exposed sediments for re-suspension

Lake sediments are a net sink for catchment nutrients



Decomposition processes release these stored nutrients from the sediments – especially during stratification

The efflux of nutrients is a function of DO concentration

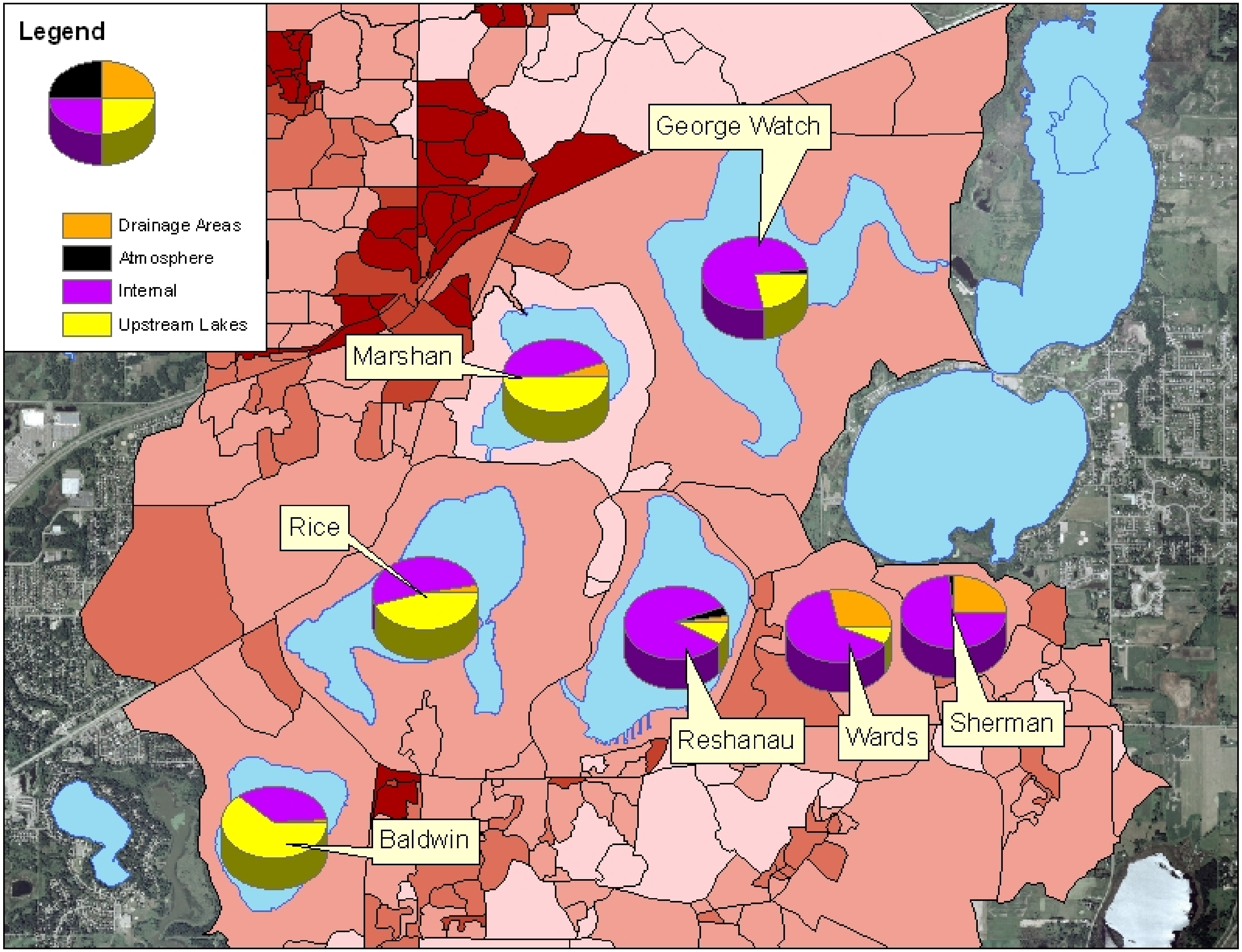
When the lake mixes these nutrients drive primary production

Sedimentation of the algae returns these nutrients to the sediment

Burger et al. 2007. Benthic nutrient fluxes in a eutrophic, polymictic lake. Hydrobiologia 584:13–25.

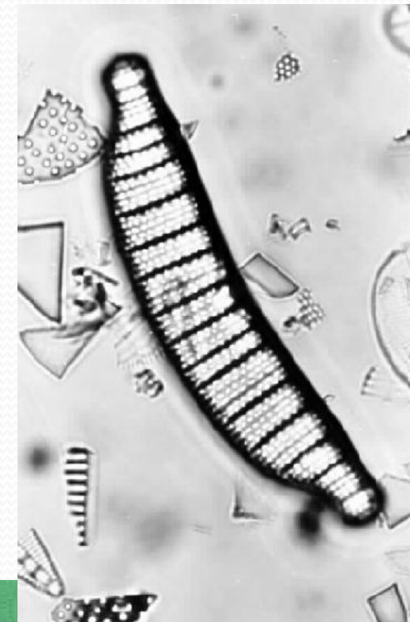
Internal Load Estimate

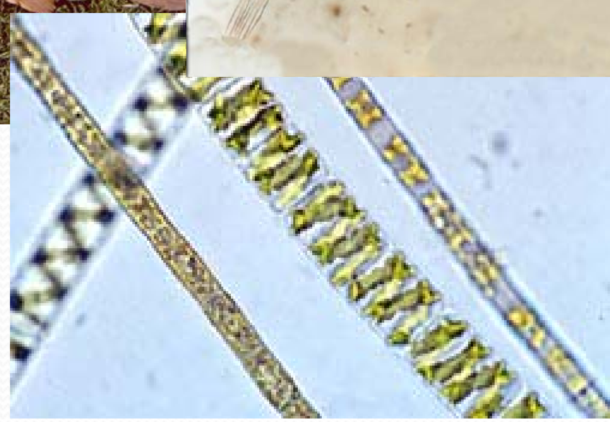
TP BUDGET

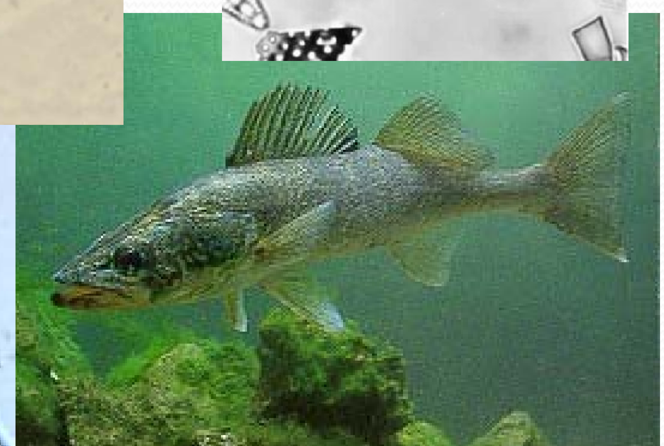

Legend
Drainage Areas
Atmosphere
Internal
Upstream Lakes
George Watch
Marshan
Rice
Reshanau
Wards
Sherman
Baldwin

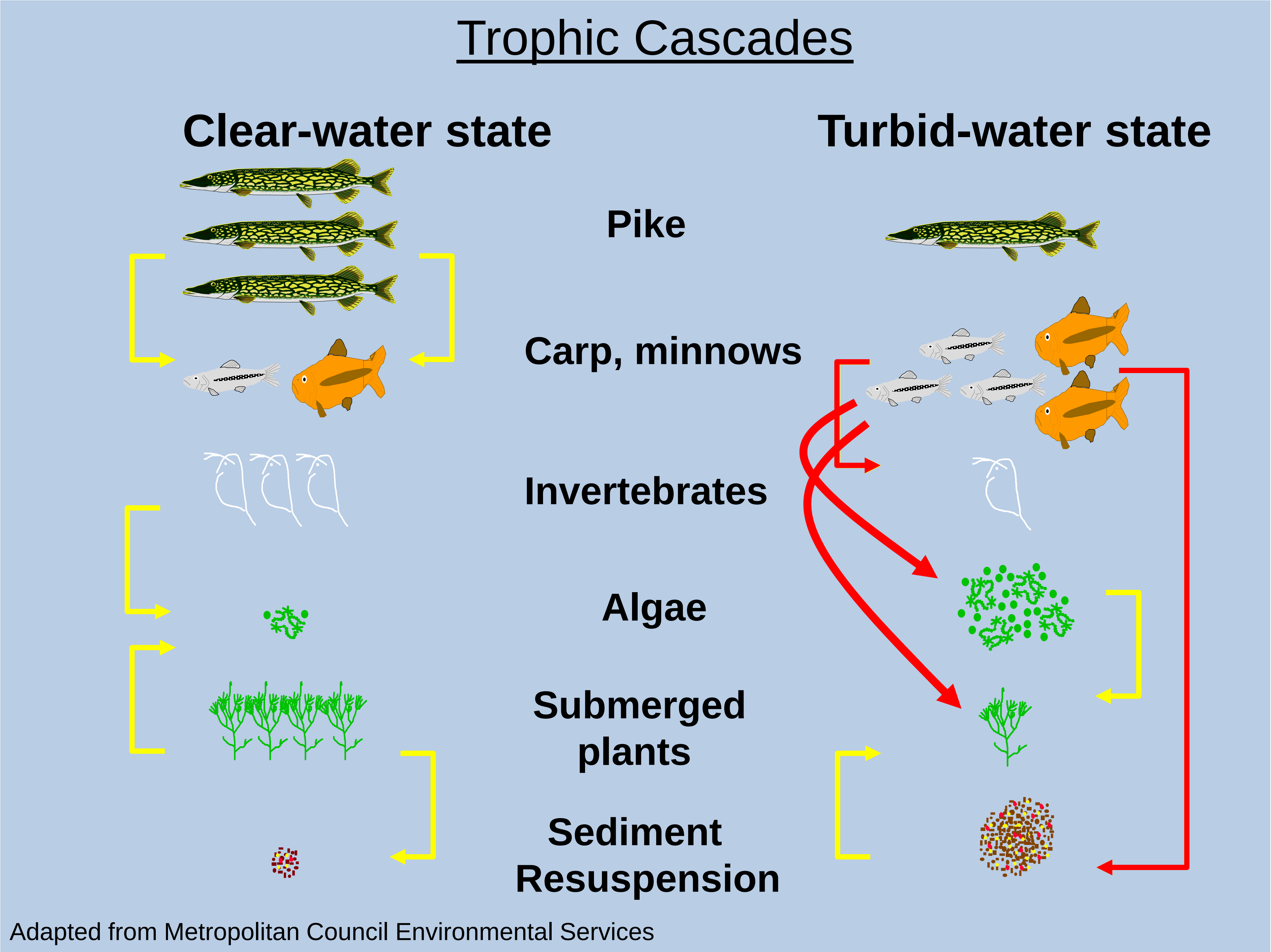
Fisheries

Aquatic Communities – Plankton & Fisheries








Trophic Cascades
Clear-water state
Turbid-water state
Pike
Carp, minnows
Invertebrates
Algae
Submerged plants
Sediment Resuspension
Adapted from Metropolitan Council Environmental Services

Biomanipulation of Fish Community

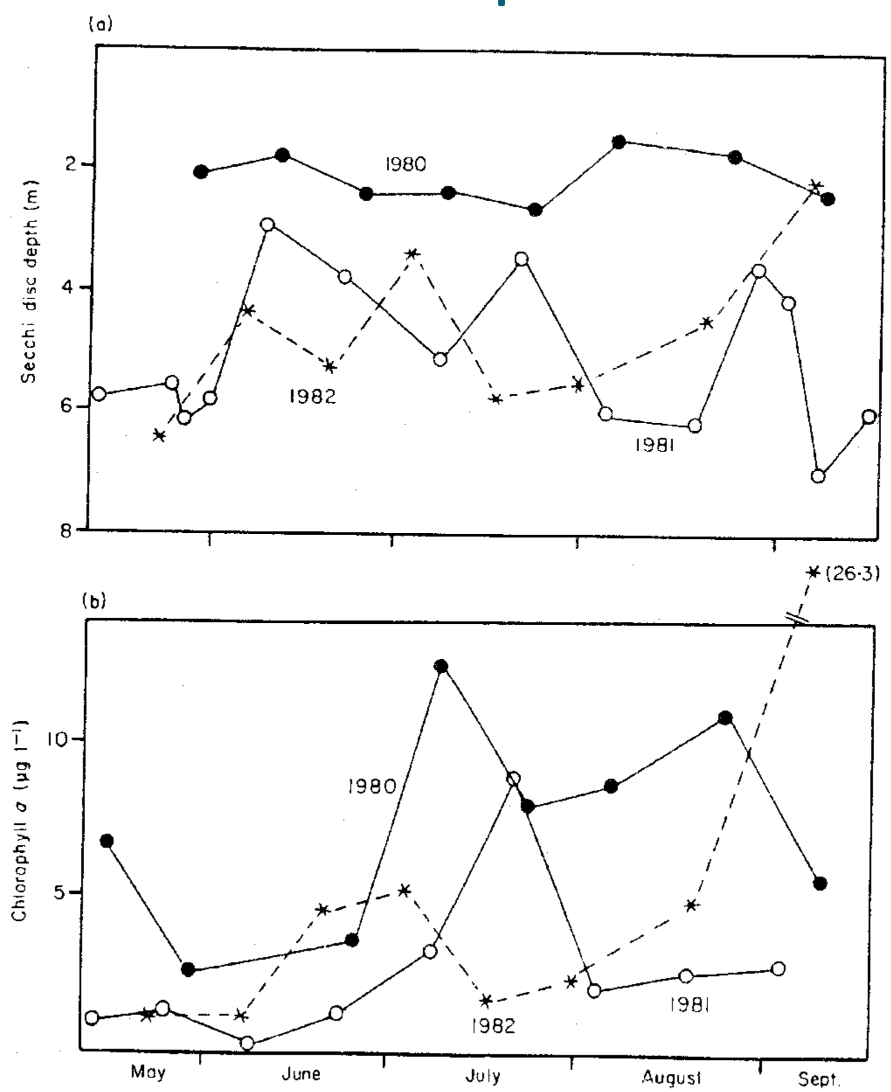


Figure 9-3.—Secchi depth transparency and epilimnetic chlorophyll *a* concentrations in Round Lake, Minnesota, in 1980 before biomanipulation; and in 1981 and 1982 after treatment (source: Shapiro and Wright, 1984).

- Rotenone was used to eliminate planktivorous fish in 1980
- Restocked with Bass and walleye to control planktivores
- Increase in water clarity for 2 years after manipulation

Shapiro and Wright 1984

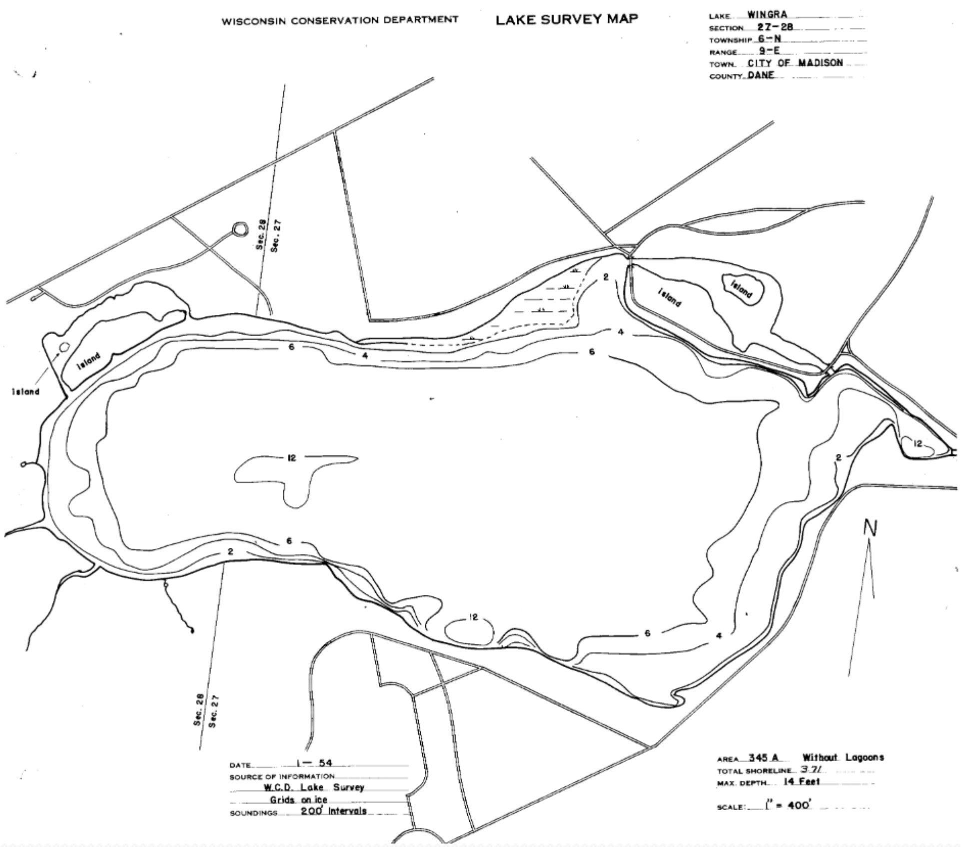
McKusick Lake Winter Kill

Stillwater, MN

Lake Wingra Case Study, WI

Name	Lake Wingra
Waterbody ID (WBIC)	805000
Area	336 ACRES
Maximum Depth	14 feet
Bottom	5% sand, 10% gravel, 0% rock, 85% muck
Waterbody Type	lake
Hydrologic Lake Type	DRAINAGE
County	Dane

- Average TP 56 µg/L
- Average chlorophyll-a 52 µg/L



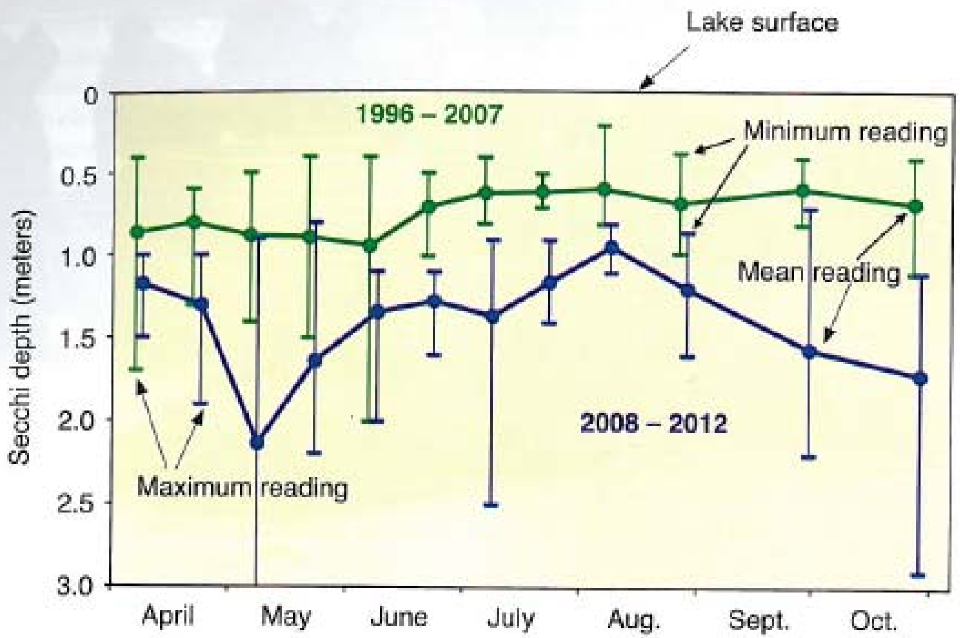
Fisheries Management
and Ecology

Fisheries Management and Ecology, 2011

Using the Judas technique to locate and remove wintertime aggregations of invasive common carp

P. G. BAJER, C. J. CHIZINSKI[1] & P. W. SORENSEN

Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul, MN, USA

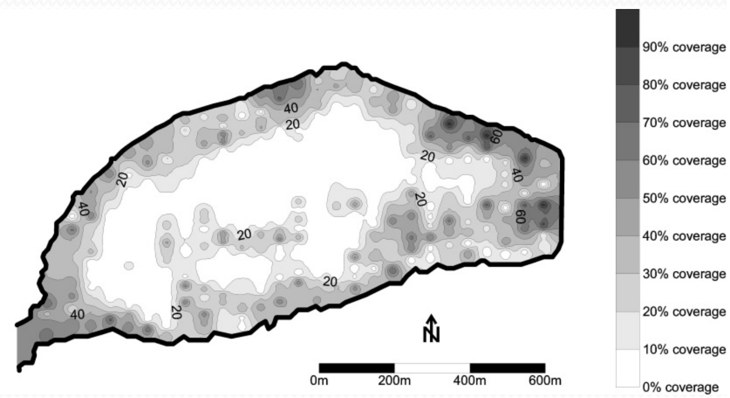


Lake Wingra, WI

- Significant clarity increase after carp removal
- Submerged Aquatic Vegetation response
- Led to SAV management

Clear Lake, Iowa

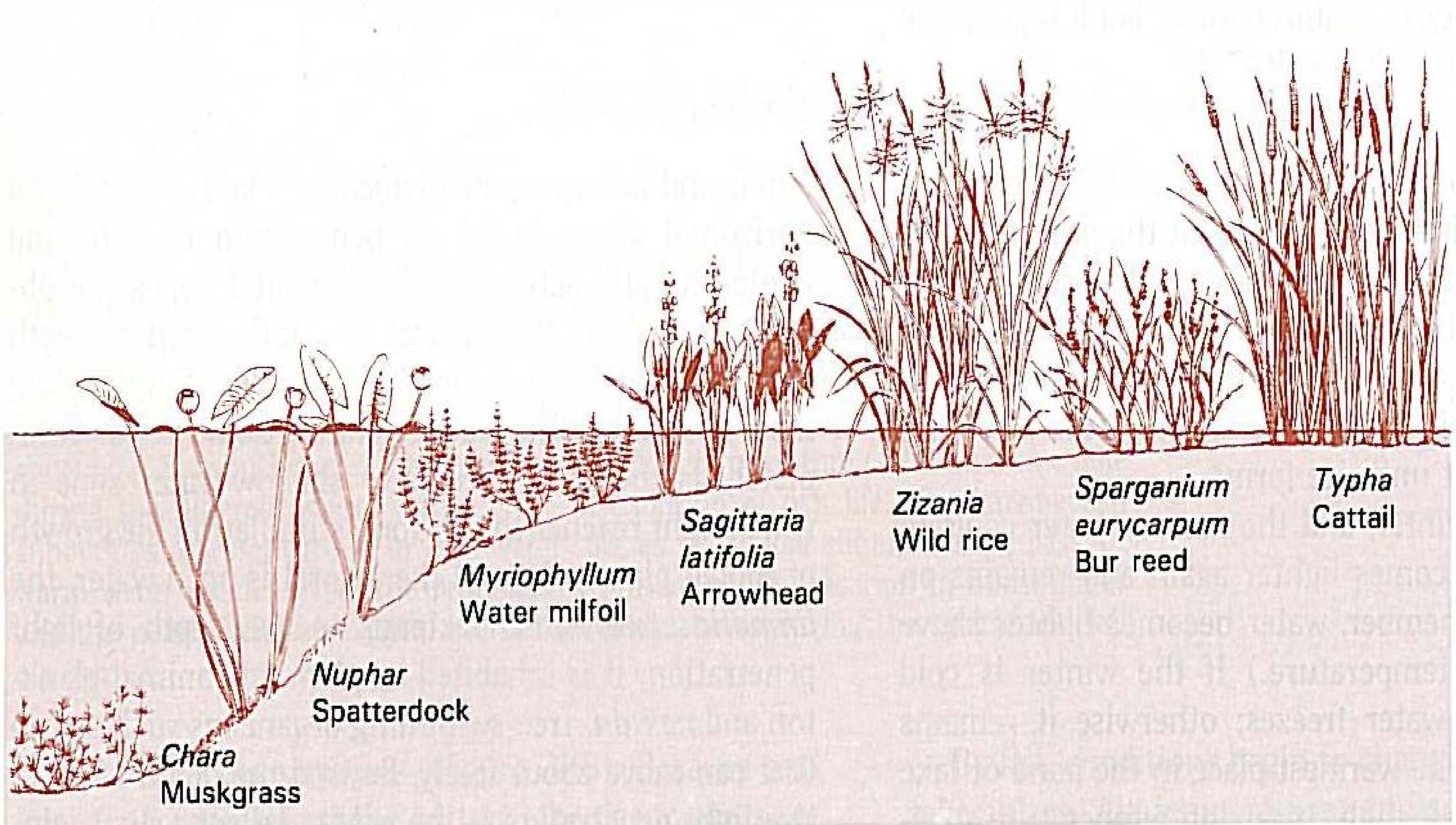
Macrophyte-free before manipulation; macrophyte abundance after→



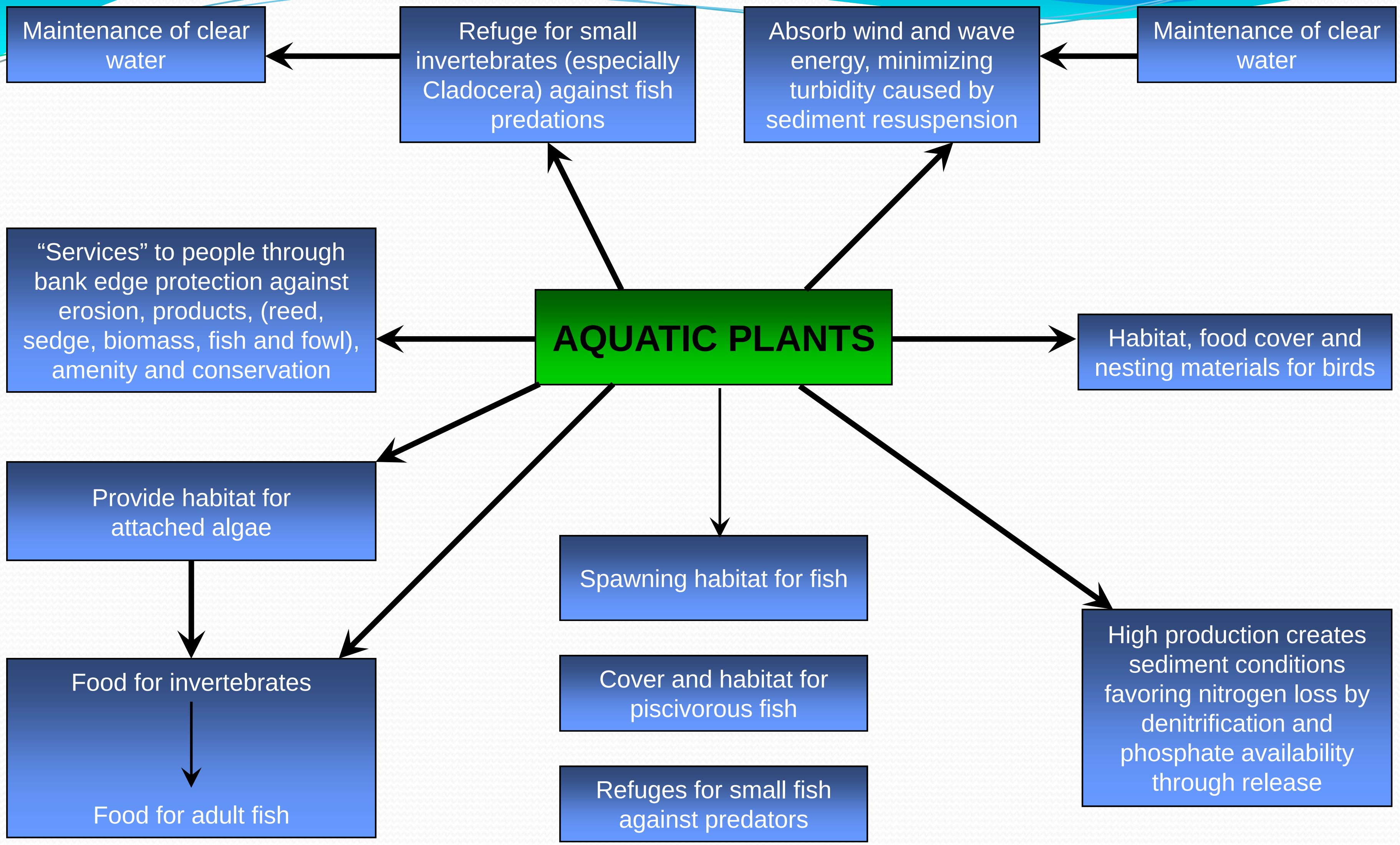
(BACI analysis; Schrage & Downing 2004)

Submerged Aquatic Vegetation

Typical Littoral Zone Vegetation



Graphic from: Smith, R.L. *Elements of Ecology*. 1992 Third Addition.



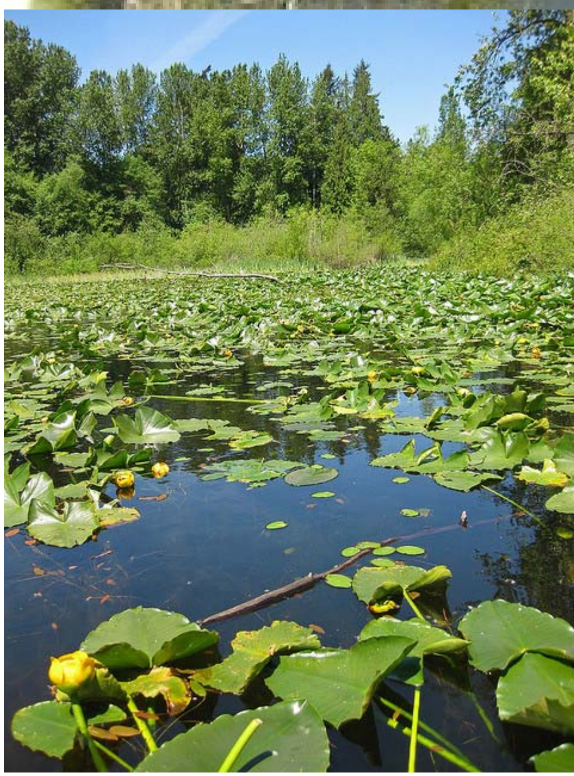
Moss et al. 1996

Importance of Refugia – Aquatic Vegetation

- Zooplankton need refugia to avoid predation
  - Zooplankton in deep lakes migrate between surface and bottom waters
  - Vegetation in shallow lakes provide refugia

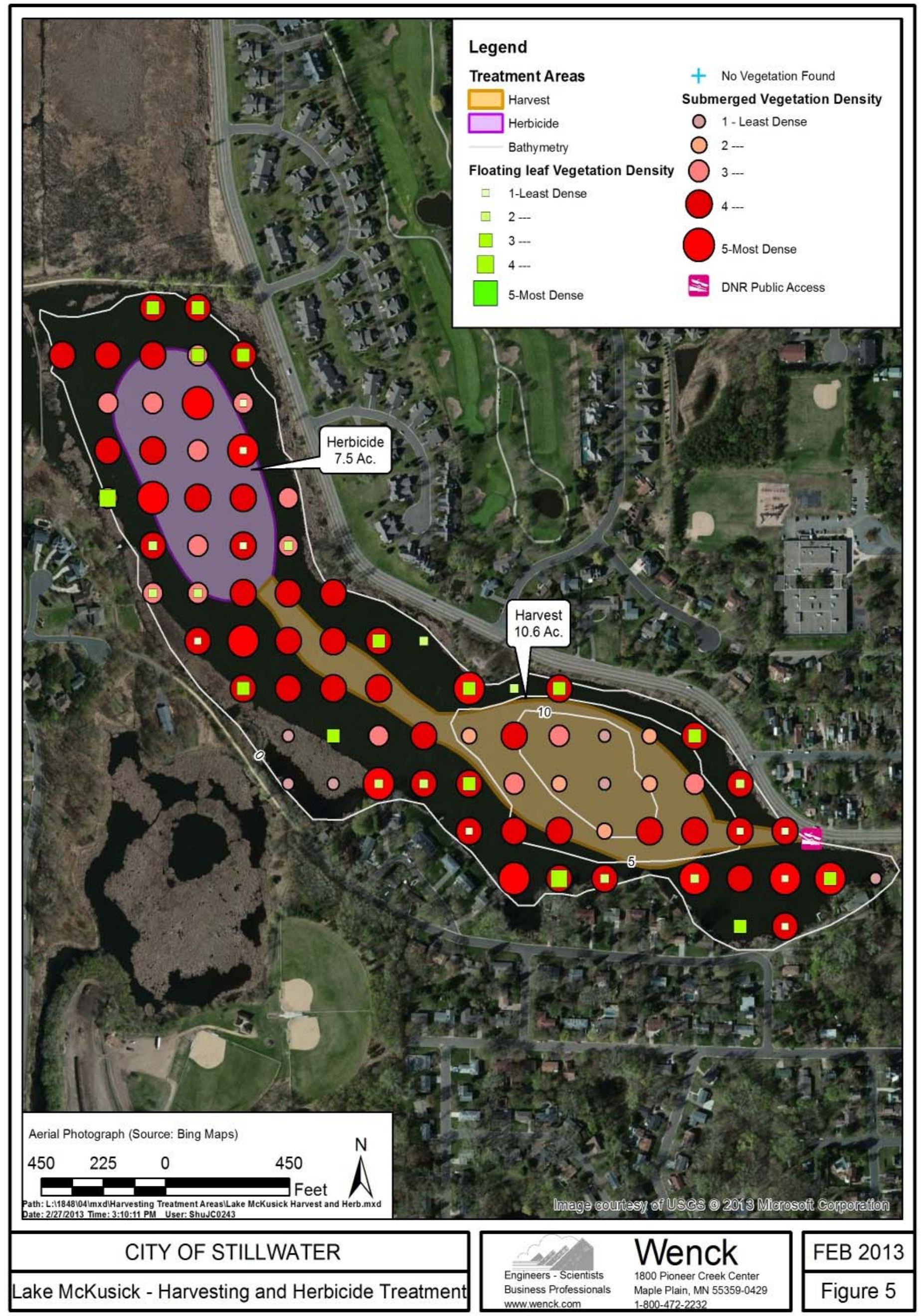

UGA5269050


Coontail
Ceratophyllum demersum
Photo by V. Ramey
Copyright 2002 Univ. Florida



Targeted Alternative #4 – Contractor Harvesting & Herbicide Treatment

- Contractor hired to conduct harvesting and herbicide applications
- Creates two open water areas for recreational use ~18 acres
- Harvesting (3 x per year)
- Herbicide (2 x per year)
- Creates flexibility to treat invasives



Curlyleaf Pondweed

Eurasian Watermilfoil

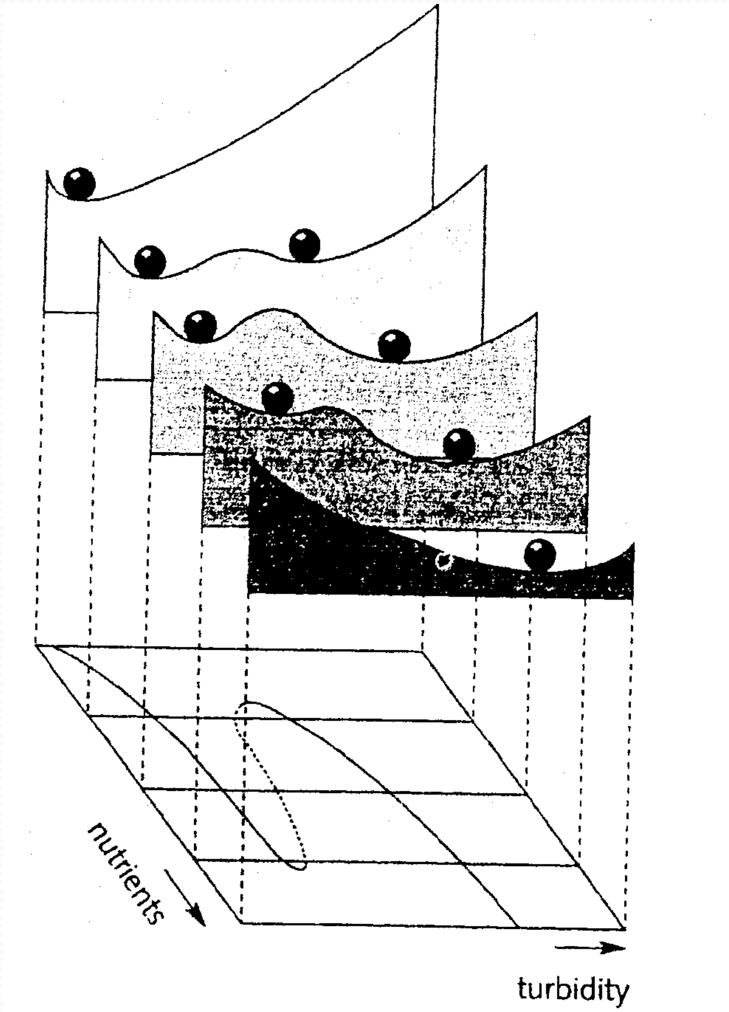
Invasive Species

Shallow Lake Ecology

Turbid and Clearwater States

Competing Equilibria in Shallow Lakes

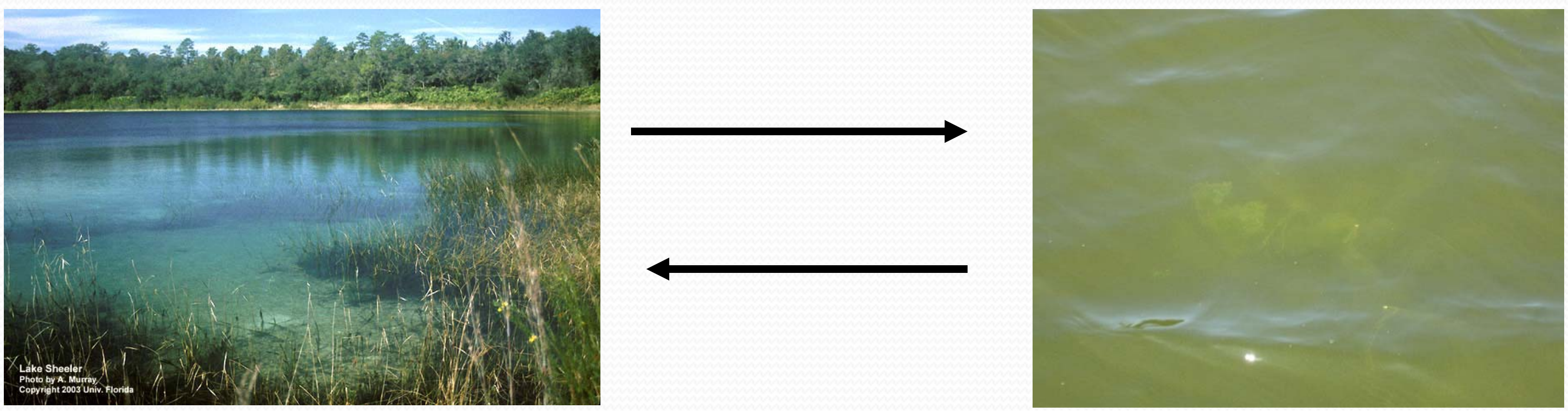
- Turbid State
  - High algal productivity
  - Low aquatic plant productivity
  - Low grazer (zooplankton) productivity
- Clearwater State
  - Large aquatic plant community
  - Low algal productivity
  - Large grazer population



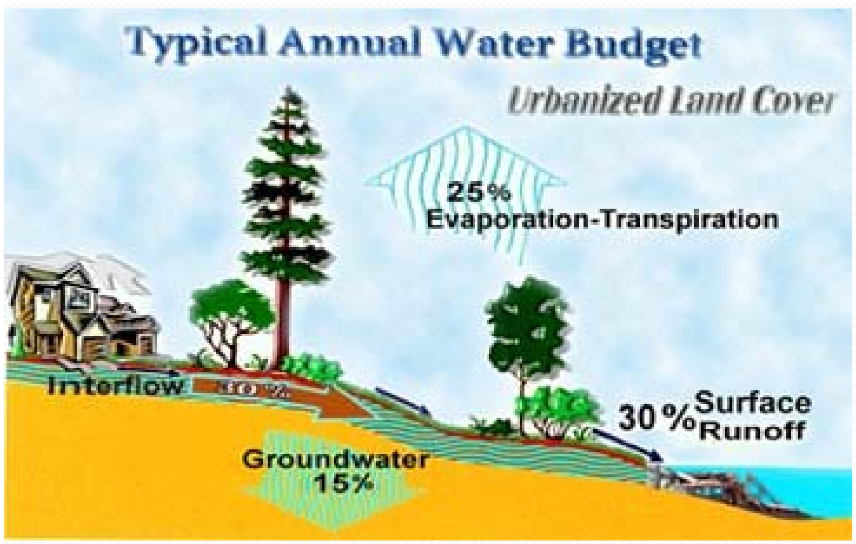
Scheffer 2004

Shallow Lake Switches

- Drivers that cause a lake to shift from either the turbid or clear water state to the opposite state
  - Clear scientific understanding of forward switches
  - Unclear understanding of reverse switches

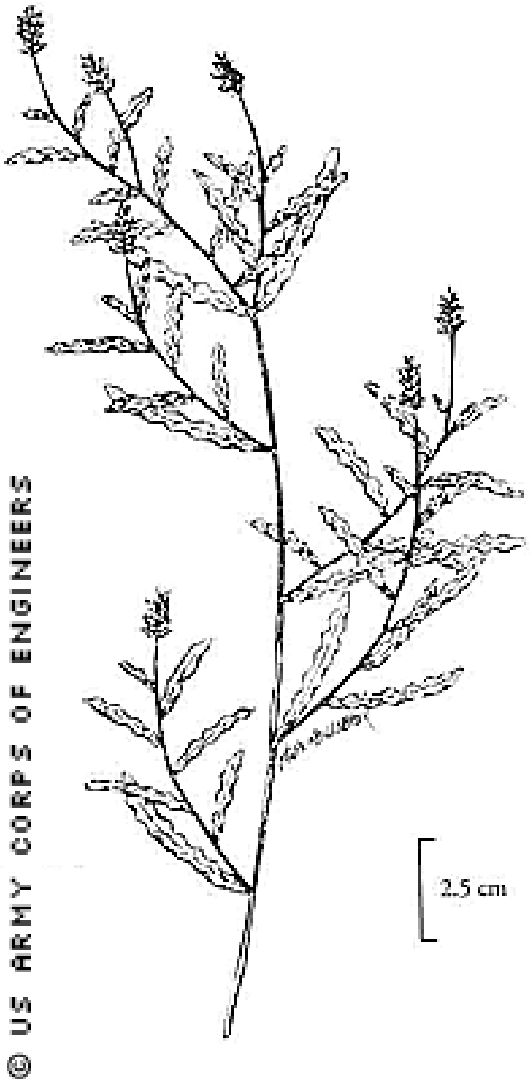


Flipping (Switching) Lakes



- Clear to turbid, back and forth, turbid to clear
- Catchment land use
    - Western Minnesota, shallow lake loss associated with land drainage
    - NZ study found increasing flipped lakes with increasing pasture area in watershed
    - Increased nutrient loads
- Changes in lake hydrology
    - Stabilized water levels for flood control or recreation
    - Increase in bounce
        - Drowns some species

Curly-leaf Pondweed



Flipping (Switching) Lakes

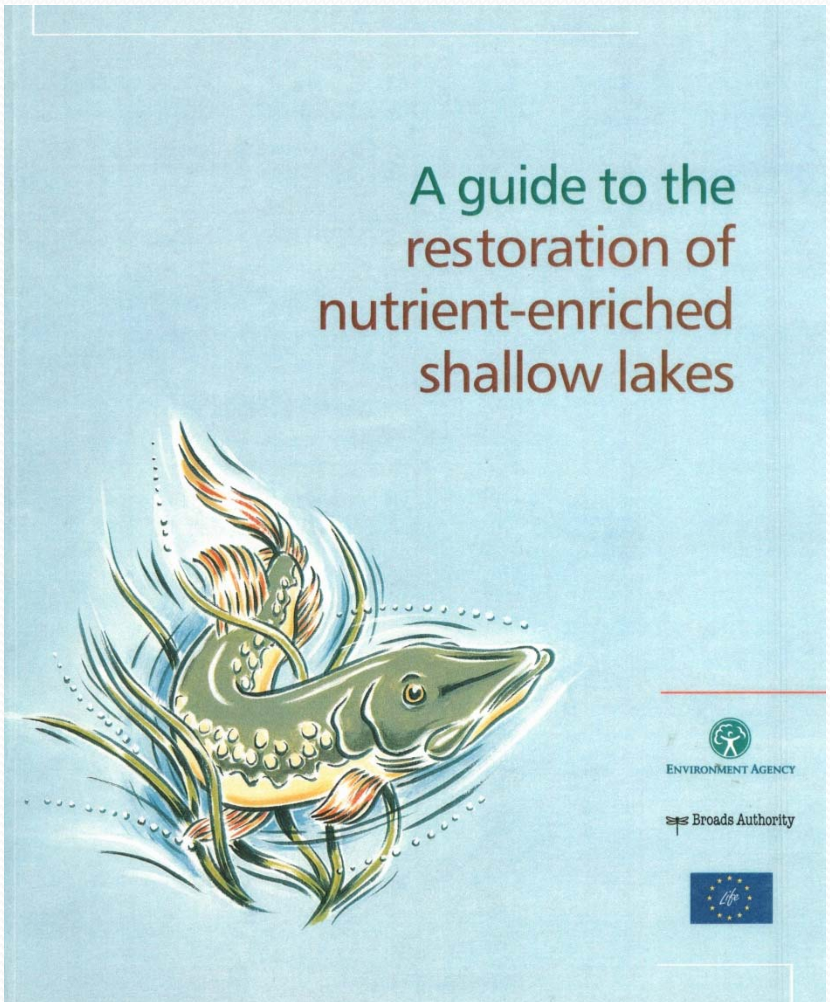
- Invasive Aquatic Vegetation
  - Curlyleaf pondweed is often associated with flipped lakes in Minnesota
    - Unique life cycle
  - 53% of New Zealand lakes had the invasive *Egeria densa* compared to 13% of non-flipping lakes
  - Curlyleaf pondweed
    - Interestingly, flipping lakes was not correlated to curly leaf pondweed presence

Flipping (Switching) Lakes

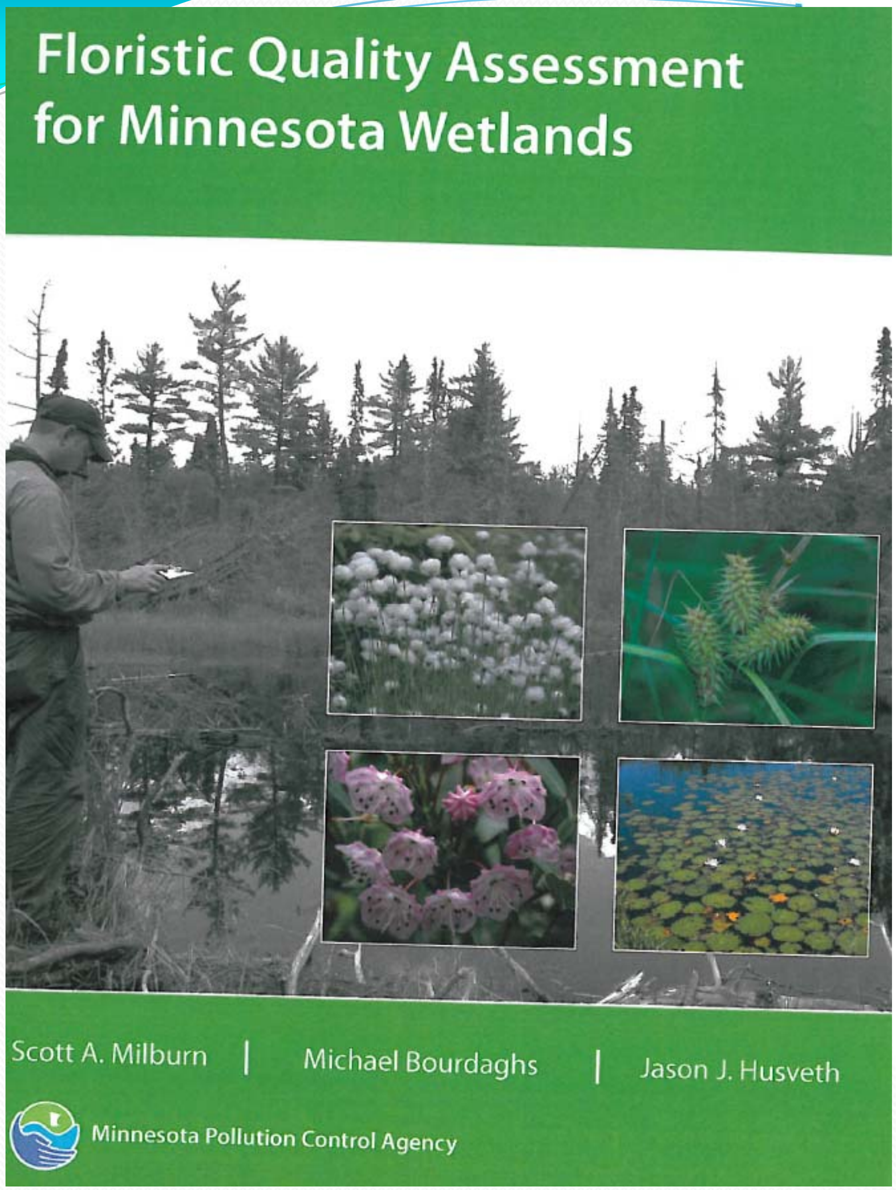
- Rough fish
  - Carp
  - New Zealand found significant correlations with catfish, goldfish, Rudd, Tench, Koi
  - Increased potential for flipping when rough fish species co-occur (Rowe 2007)
- Loss of top predators
  - Dominance by plantktivores
  - Stunted panfish
  - Minnows

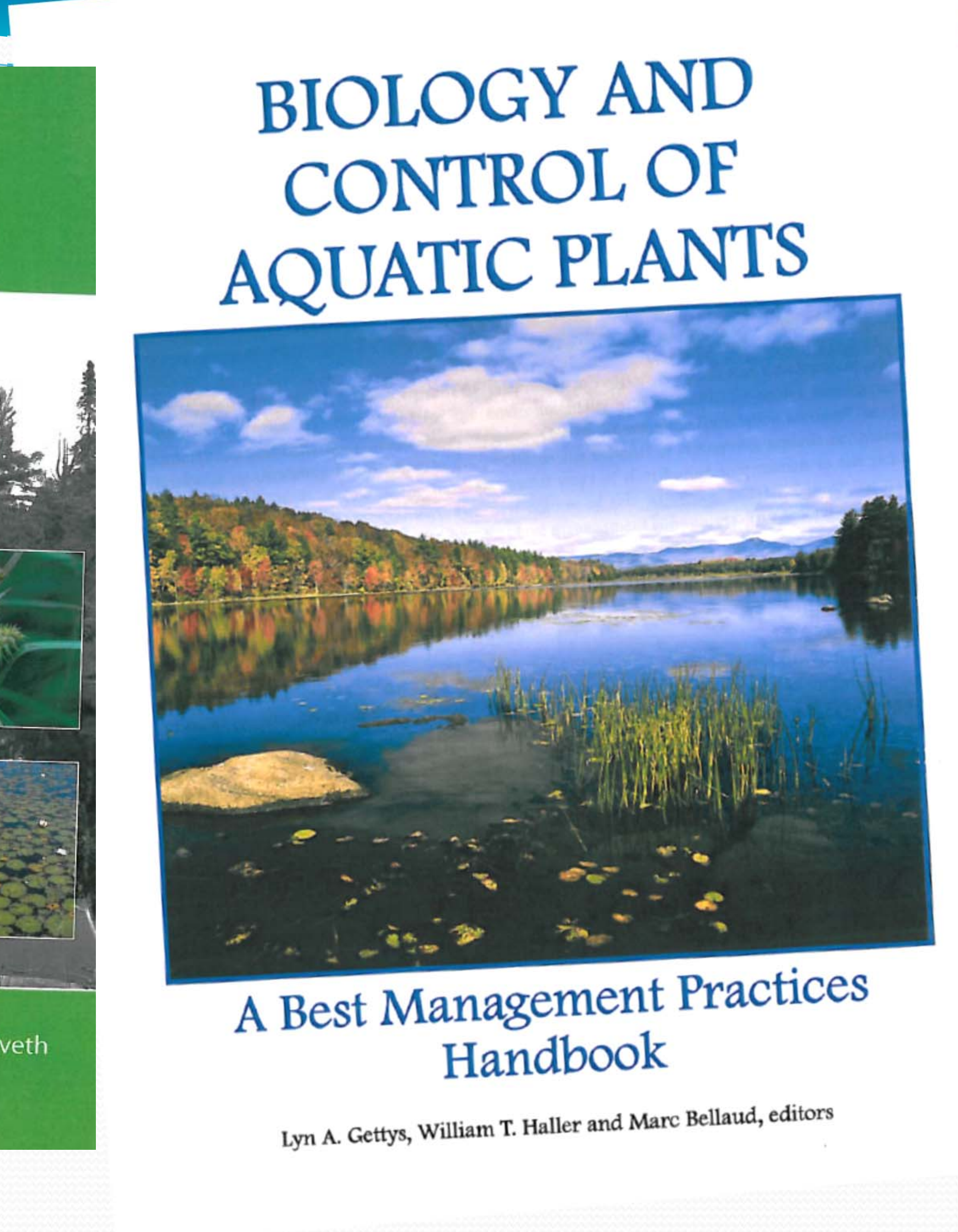
Management Approach

Strategy for Restoring Shallow Eutrophic Lakes



- Forward switch detection and removal
- External and internal nutrient control (TMDL)
- Biomanipulation (reverse switch)
- Plant establishment
- Stabilizing and managing restored system


Floristic Quality Assessment for Minnesota Wetlands
Scott A. Milburn | Michael Bourdaghs | Jason J. Husveth
Minnesota Pollution Control Agency


BIOLOGY AND CONTROL OF AQUATIC PLANTS
A Best Management Practices Handbook
Lyn A. Gettys, William T. Haller and Marc Bellaud, editors

Key Planning Aspects

- Good scientific understanding of watershed and lake
- Set clear, achievable objectives that are appropriate to site
- Plan good science around the restoration to determine effects of the action
- Consider experimental lake for testing new actions

Lake Maria, Murray County, MN

What do we know about shallow lakes?

- Exist in alternative stable states, either a clear water vegetation dominated state or a turbid water, phytoplankton dominated state
- The shallow features of these lakes increases the importance of sediment and biological interactions
- Biological interactions in shallow lake are complex

What do we know about shallow lake stressors?

- Degraded by multiple stressors
  - Nutrient enrichment (N and P), sediment, exotic plants, exotic fish
- Rough fish
  - Disturb sediments and uproot plants
- Planktivores
  - Eat zooplankton that graze algae
    - Increases algae blooms and decreases water clarity
- Submergent aquatic vegetation is critical to maintaining a healthy shallow lake
  - Maintaining stable sediments

Questions?