Paul Cunningham
Bureau of Fisheries Management

WISCONSIN
DEPT. OF NATURAL RESOURCES

Ecology of Shallow Lakes

A Primer

Management Tools for Rehabilitation

Will Rehab Work for my Lake?

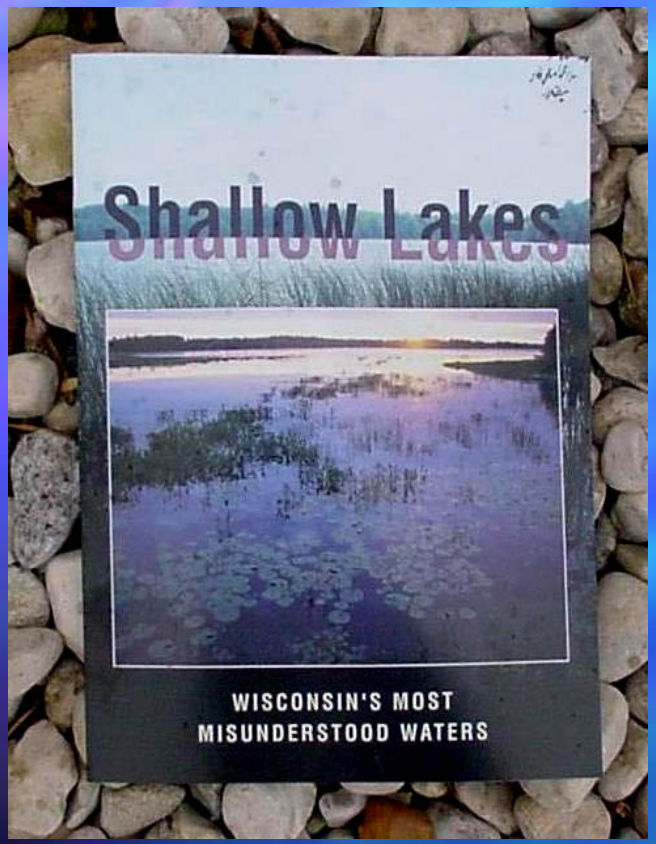
Shallow Lakes

WISCONSIN'S MOST
MISUNDERSTOOD WATERS

SHallow LAKES

HOPE FOR MINNESOTA'S TROUBLED WATERS

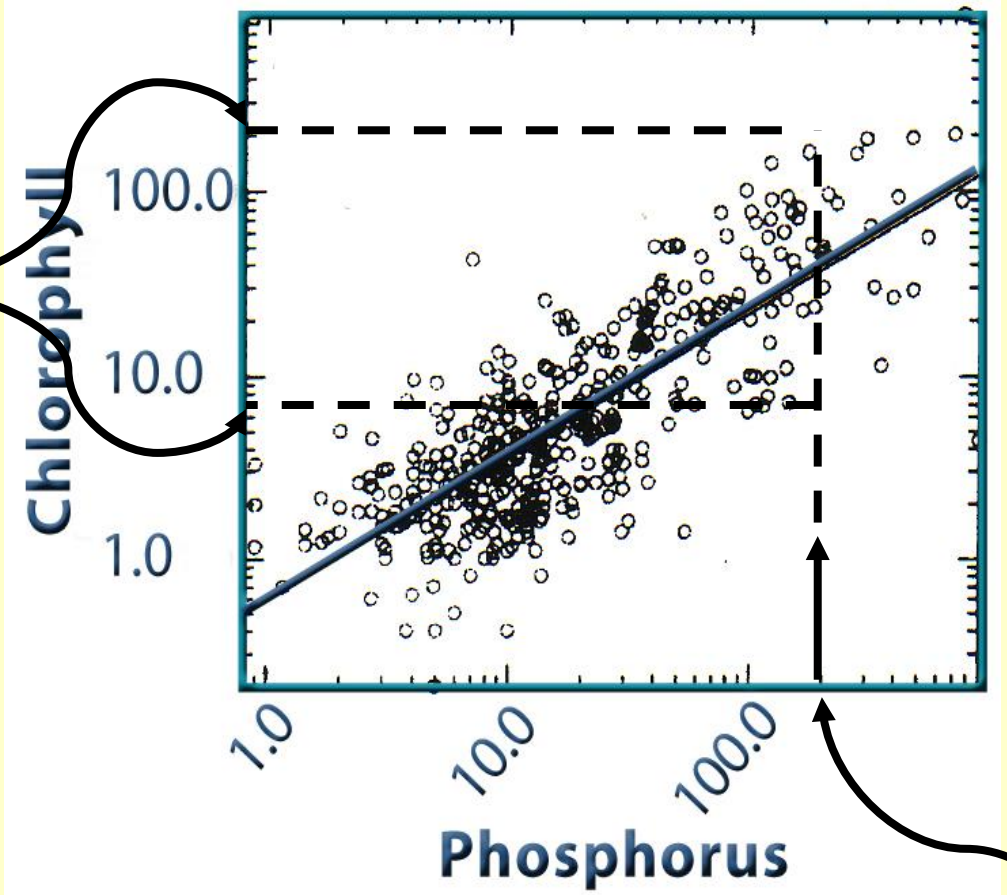
SHALLOW LAKE



- > One third of WI lake acres, > 300k ac
- WI's largest , Winnebago @ 137,708 ac
- Large littoral zone area(>50%criteria)
- Aquatic plants = Heart of ecosystem
- Exist in turbid or clear water state
- Water column stays mixed
- User expectations often unrealistic

Good Resource Management is Driven by Sound Science and Data.

Chlorophyll varies between ~ 10 and 220 ug/l



High inter-lake variability in Chlorophyll at a given concentration of TP

For TP=200 ug/l

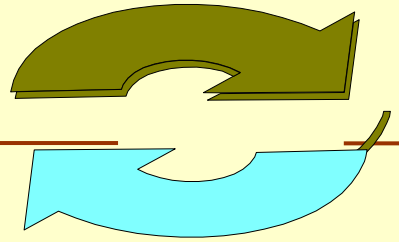

Photo Courtesy of MNDNR

Shallow Lakes of
Northeast South Dakota

Catastrophic Regime Shifts

- **Kelp Forests**
- **Drylands**
- **Coral Reefs**
- **Shallow Lakes**

Stable States in Shallow Lakes

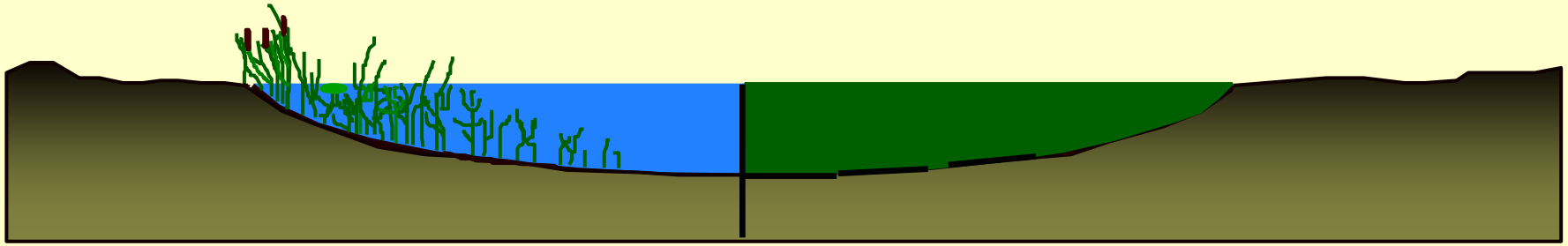


Clear State

- clear water
- low algal biomass
- high macrophyte biomass
- Piscivores dominate

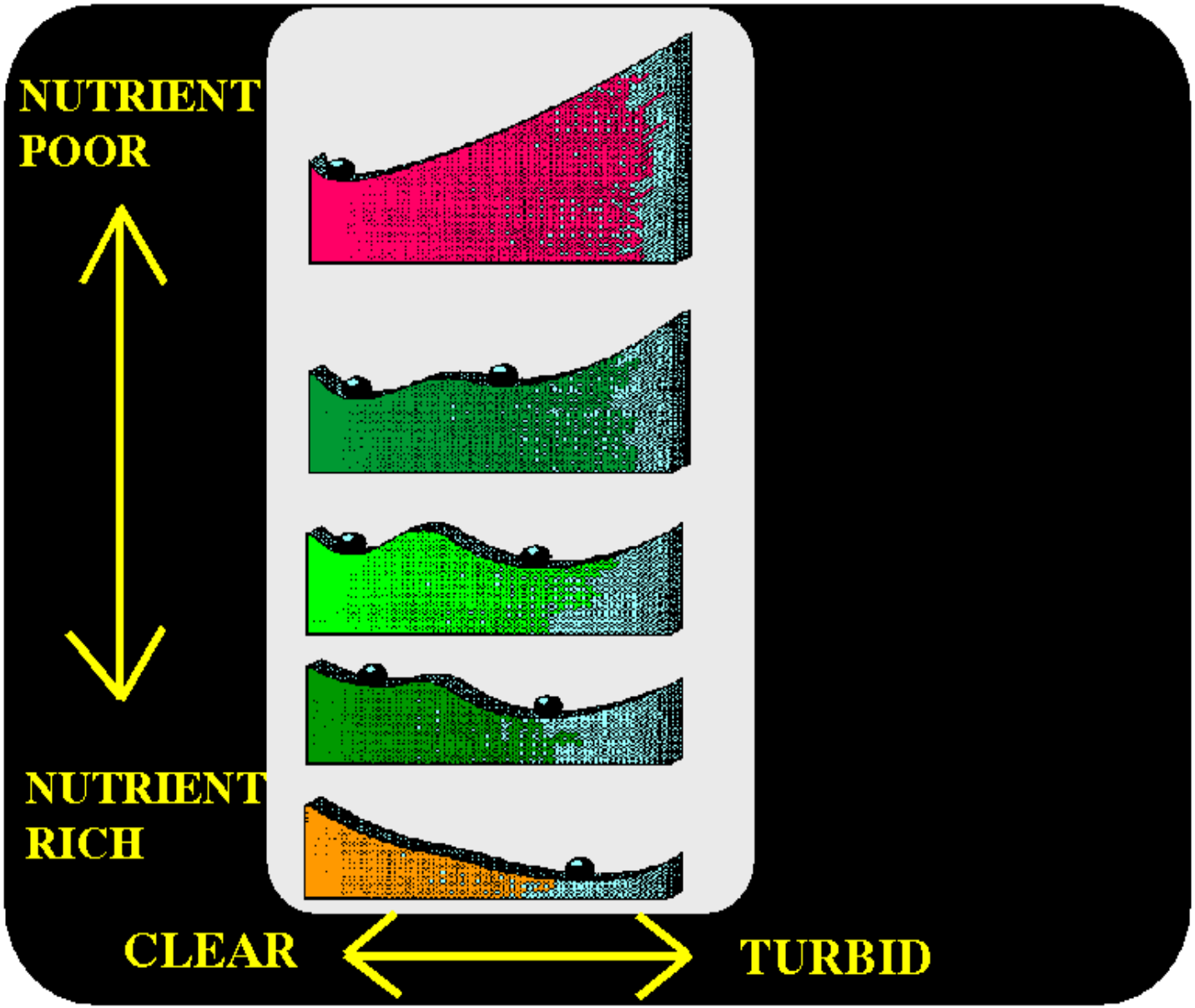
Turbid State

- murky water
- high algal biomass
- sparse macrophytes
- Planktivores/benthivores dominate



Shallow Lake Ecology

(From Scheffer et al. 1993)



Shallow Lake Ecology

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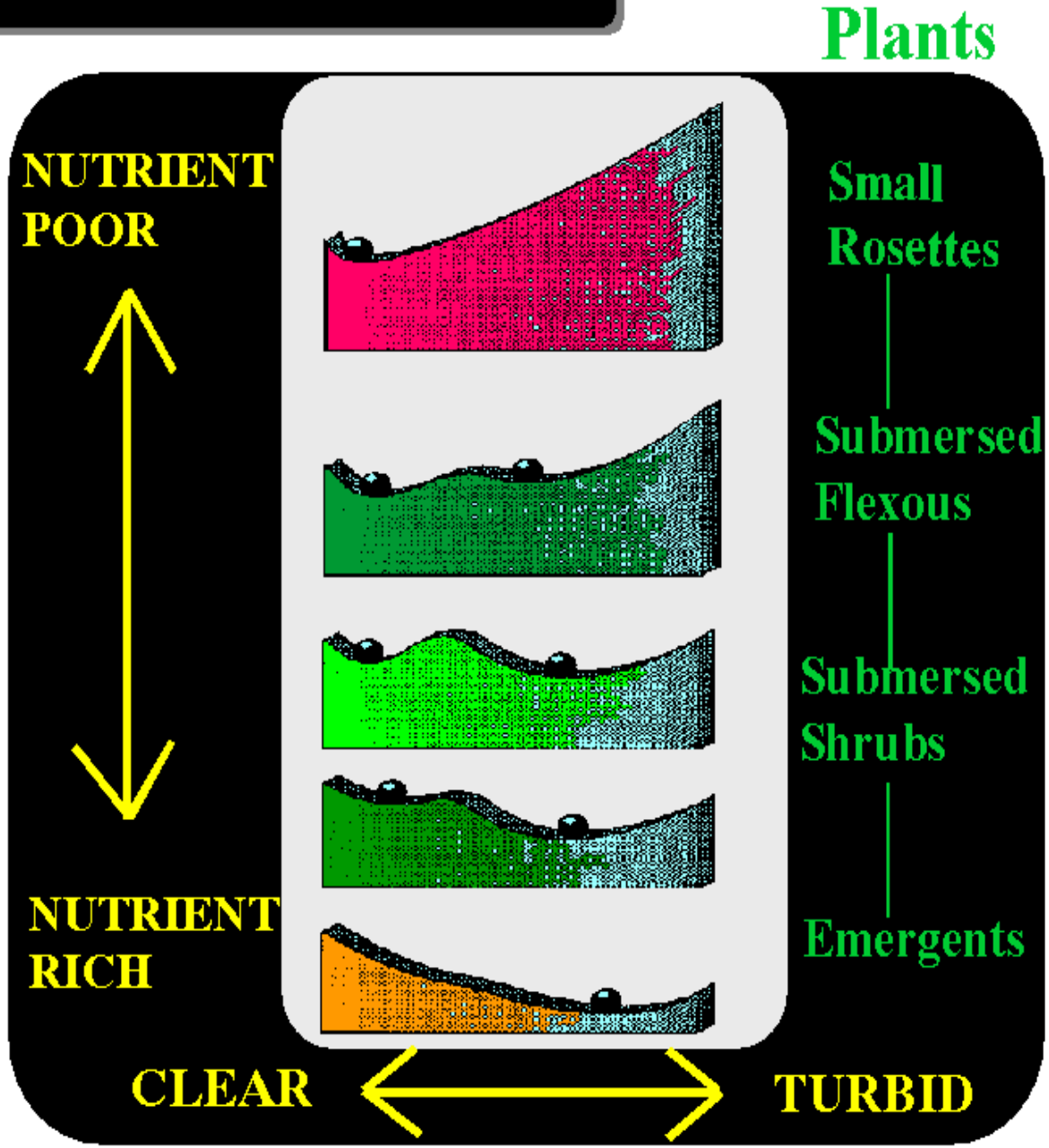

Shallow Lake Ecology

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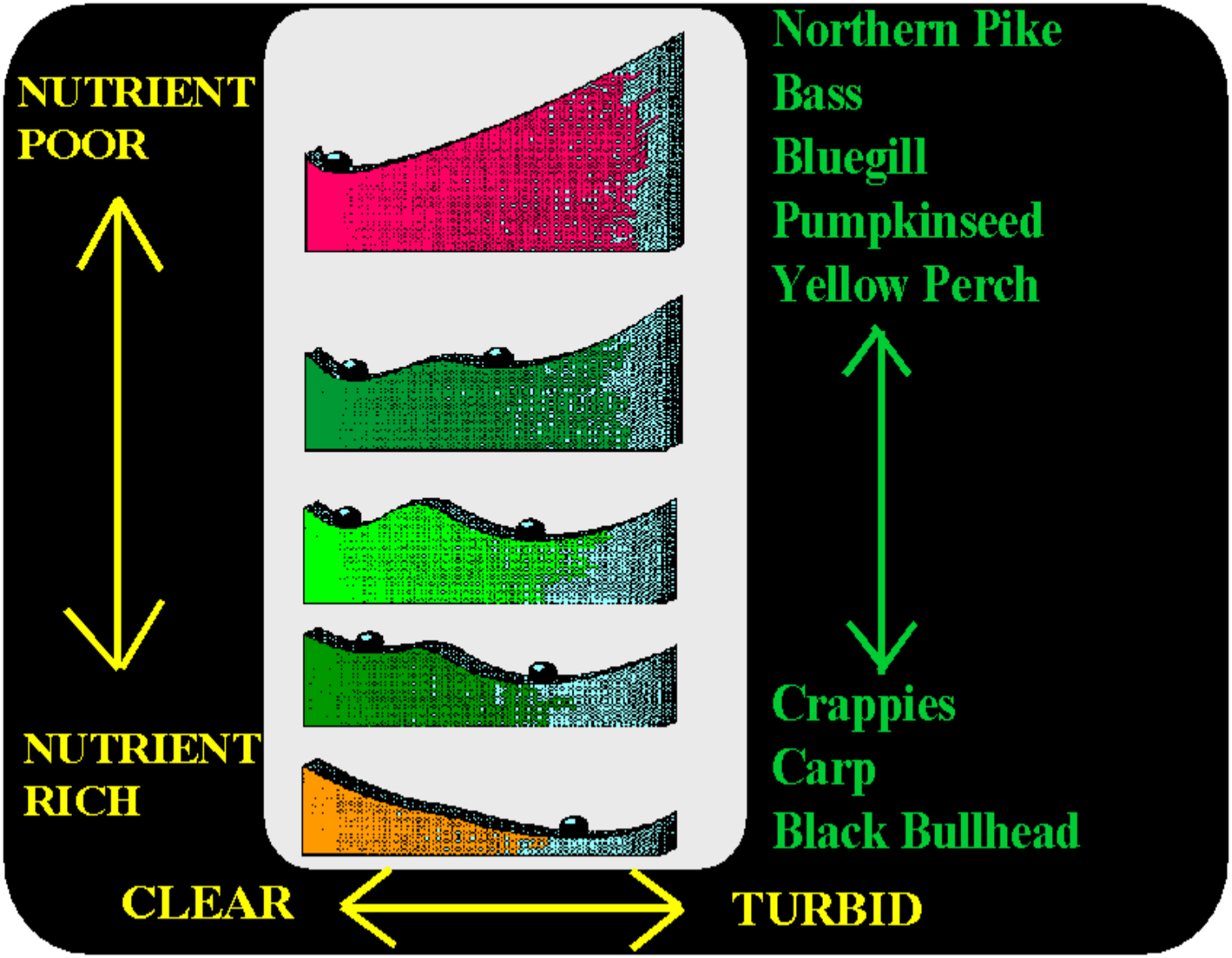
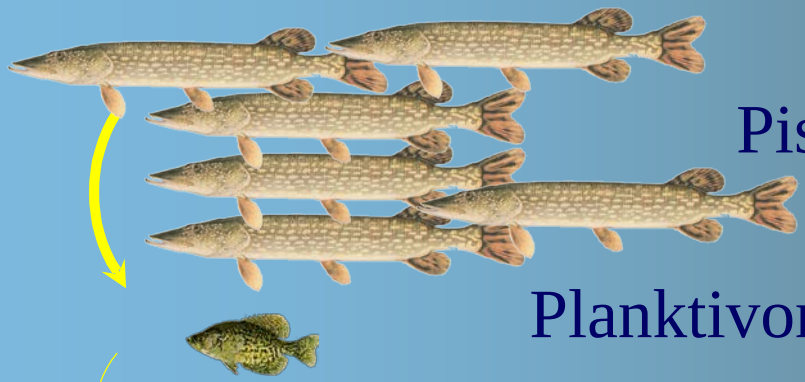


Clear-water State

Turbid-water State



Piscivores

Planktivores/Benthivores

Zooplankton grazing

Algae biomass

Aquatic plant biomass

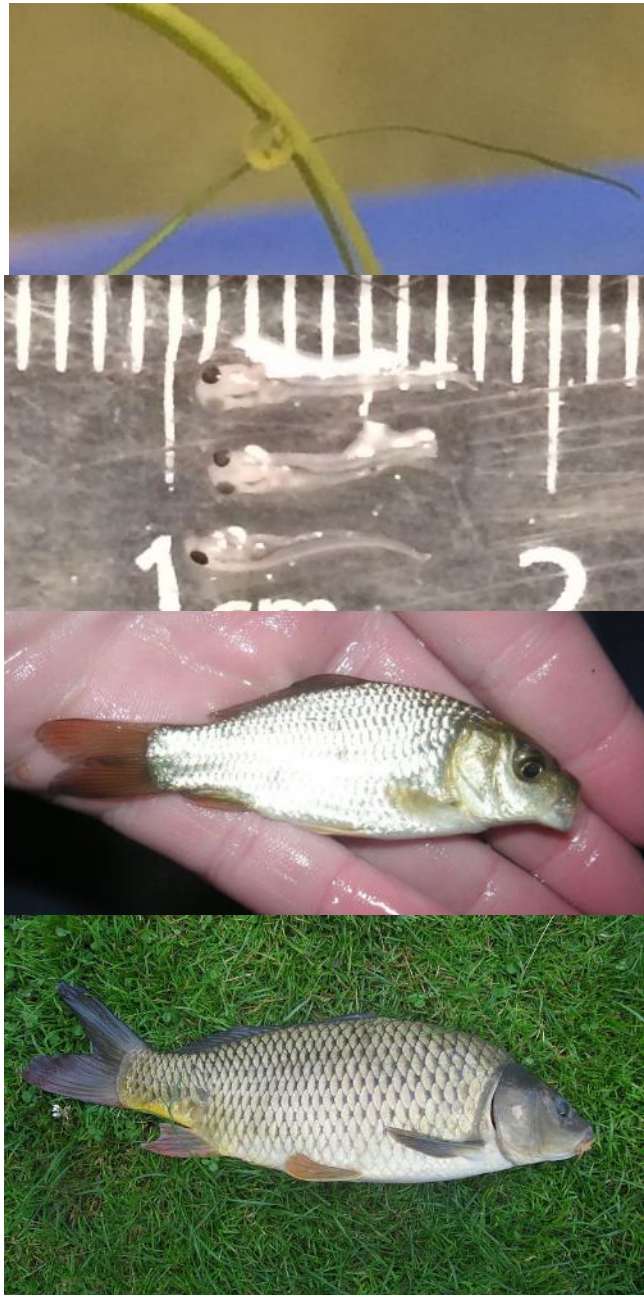
Sediment Resuspension

N. Hansel-Welch & M.B. Butler, 199

Cladocerans, or water fleas "vacuum" the algae from lake water. When they are abundant, the water is more clear.

Common Carp

- Spawning
- Egg
  - 1.5 mm diameter
  - Unguarded
  - Hatch in 3-4 days
- Larvae
  - 5 mm length at first hatching
  - Feed on yolk sac for 2-3 days
  - Weak swimmers
- Bottleneck at early life stages



Bioturbation

Biomanipulation

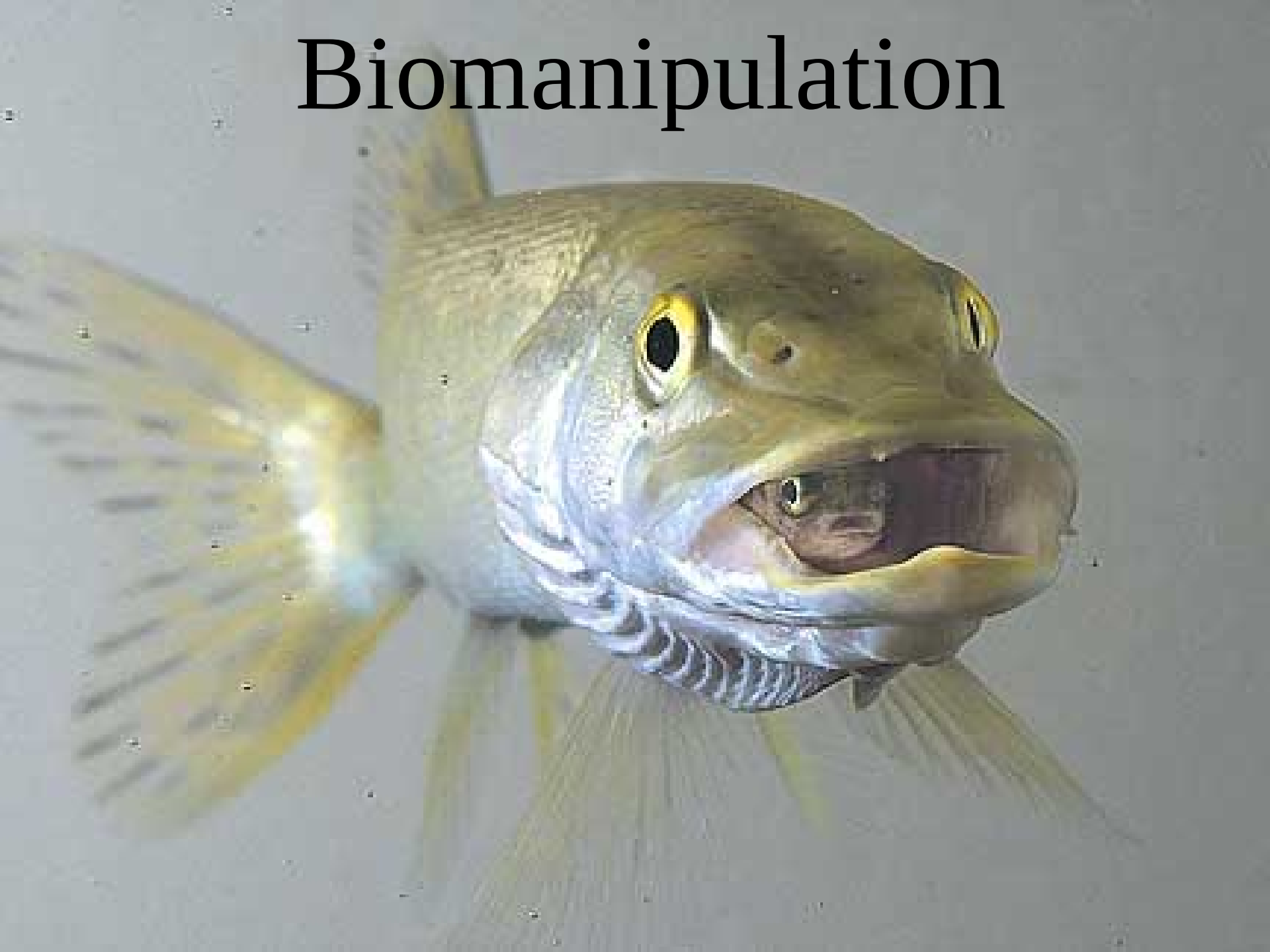
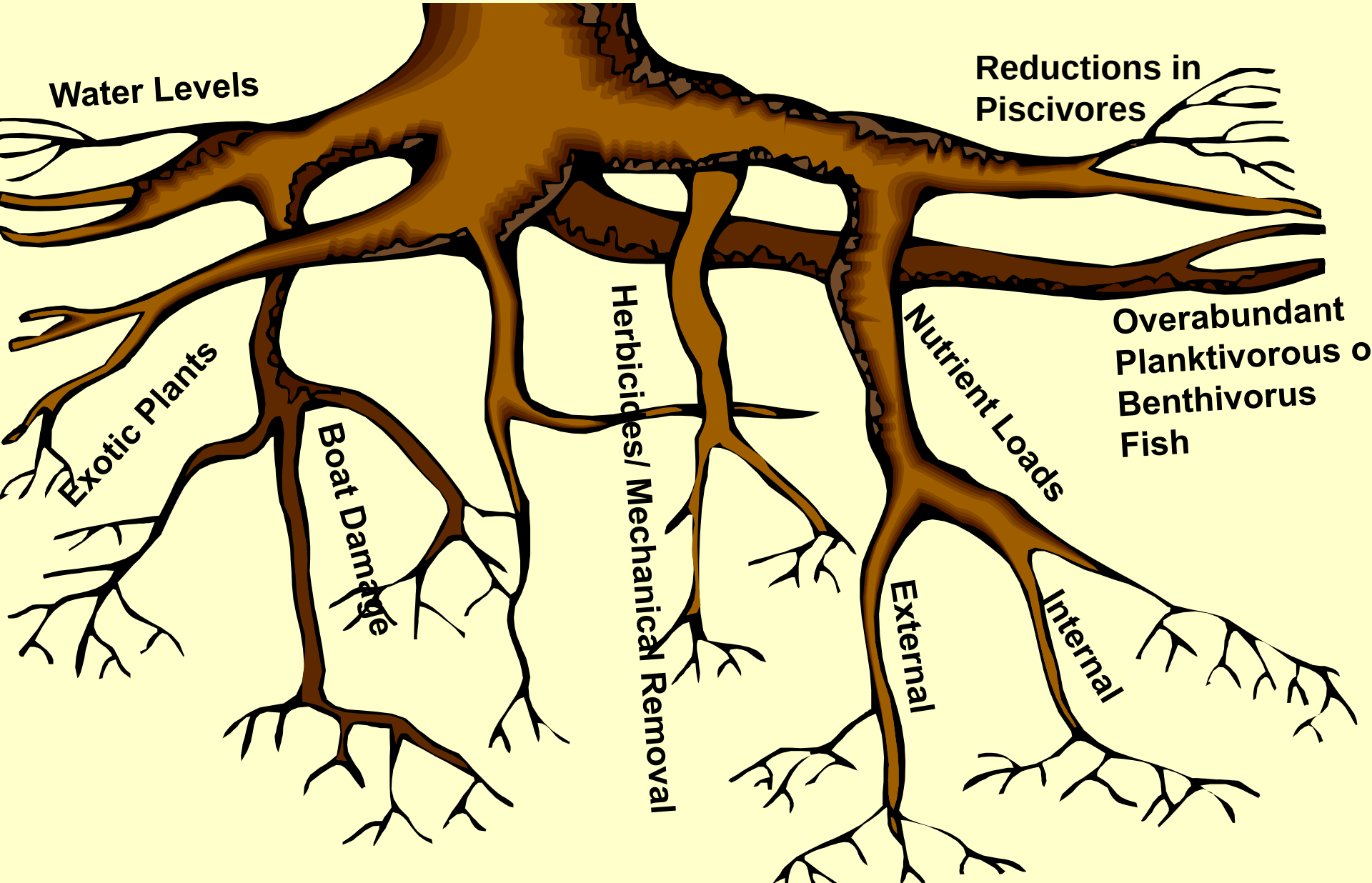
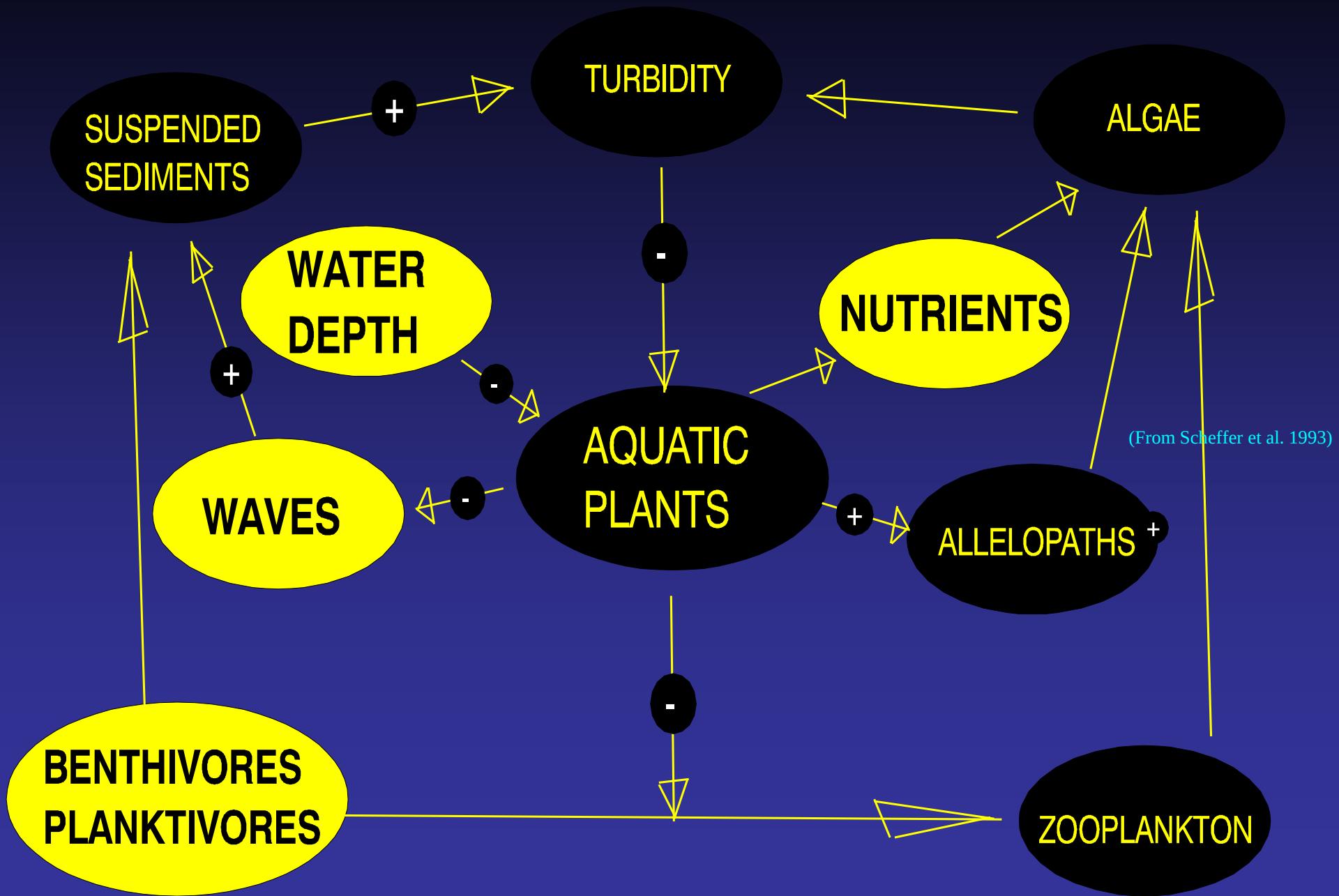


Photo: Mike DeVries, The Capital Times, 5 July 2007

What is the Root Cause of this Regime Shift?

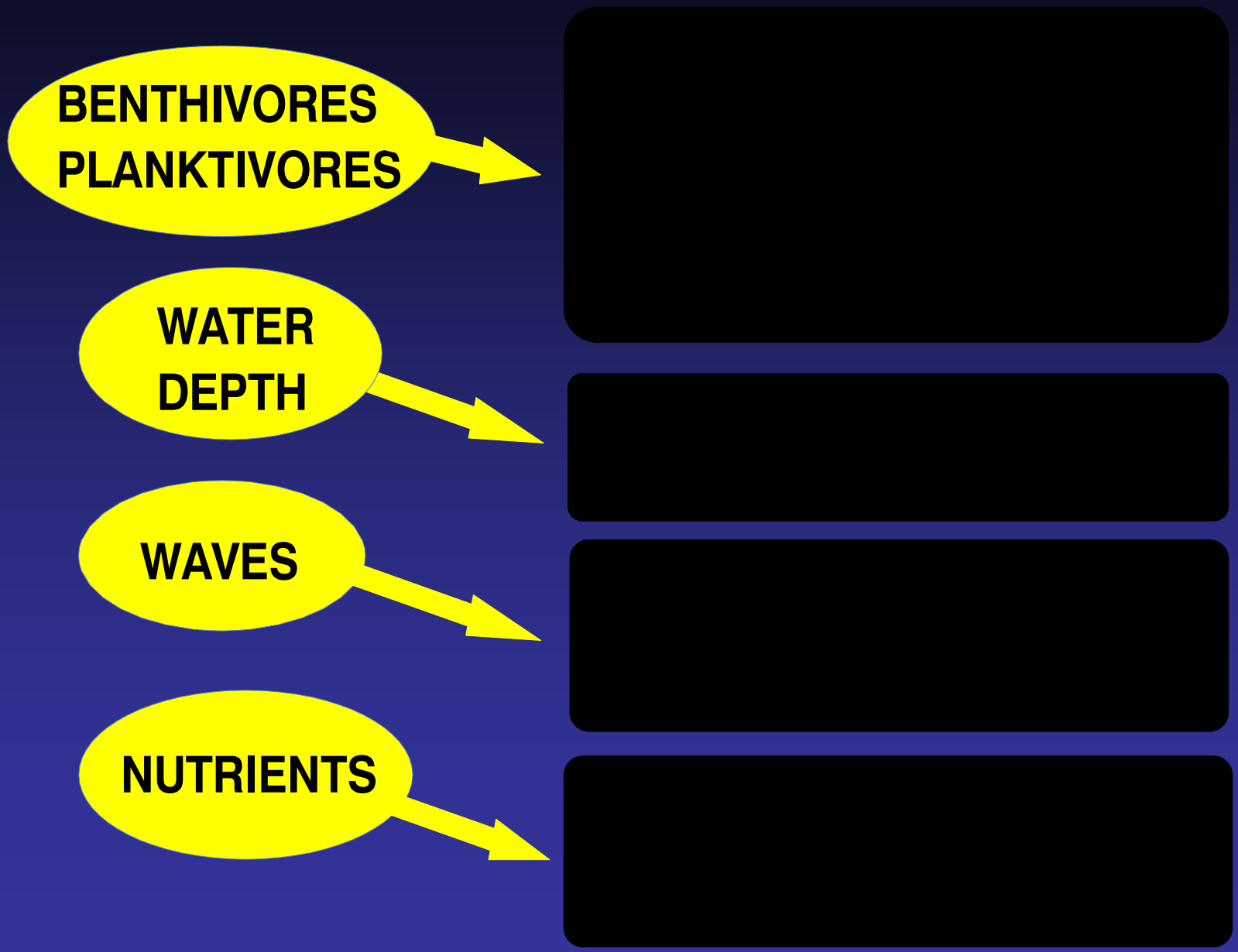


Shallow Lake Management Tools



(From Scheffer et al. 1993)

Management Tools

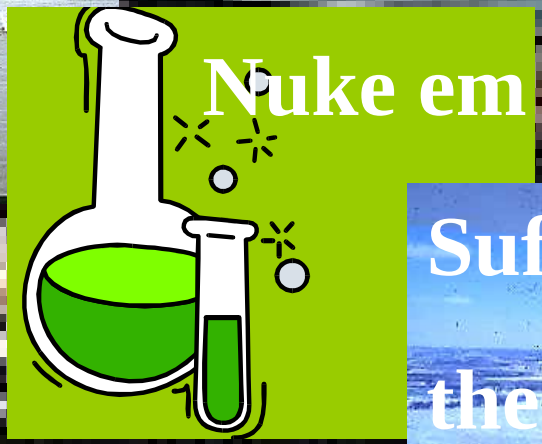


Management Tools

BENTHIVORES
PLANKTIVORES

SPOT TREATMENTS
CHEMICAL RECLAMATION
COMMERCIAL HARVEST
STOCK PISCIVORES
PROTECT PISCIVORES
FISH BARRIERS
AERATION

Hammering Carp



“Advances” in Fisheries Management

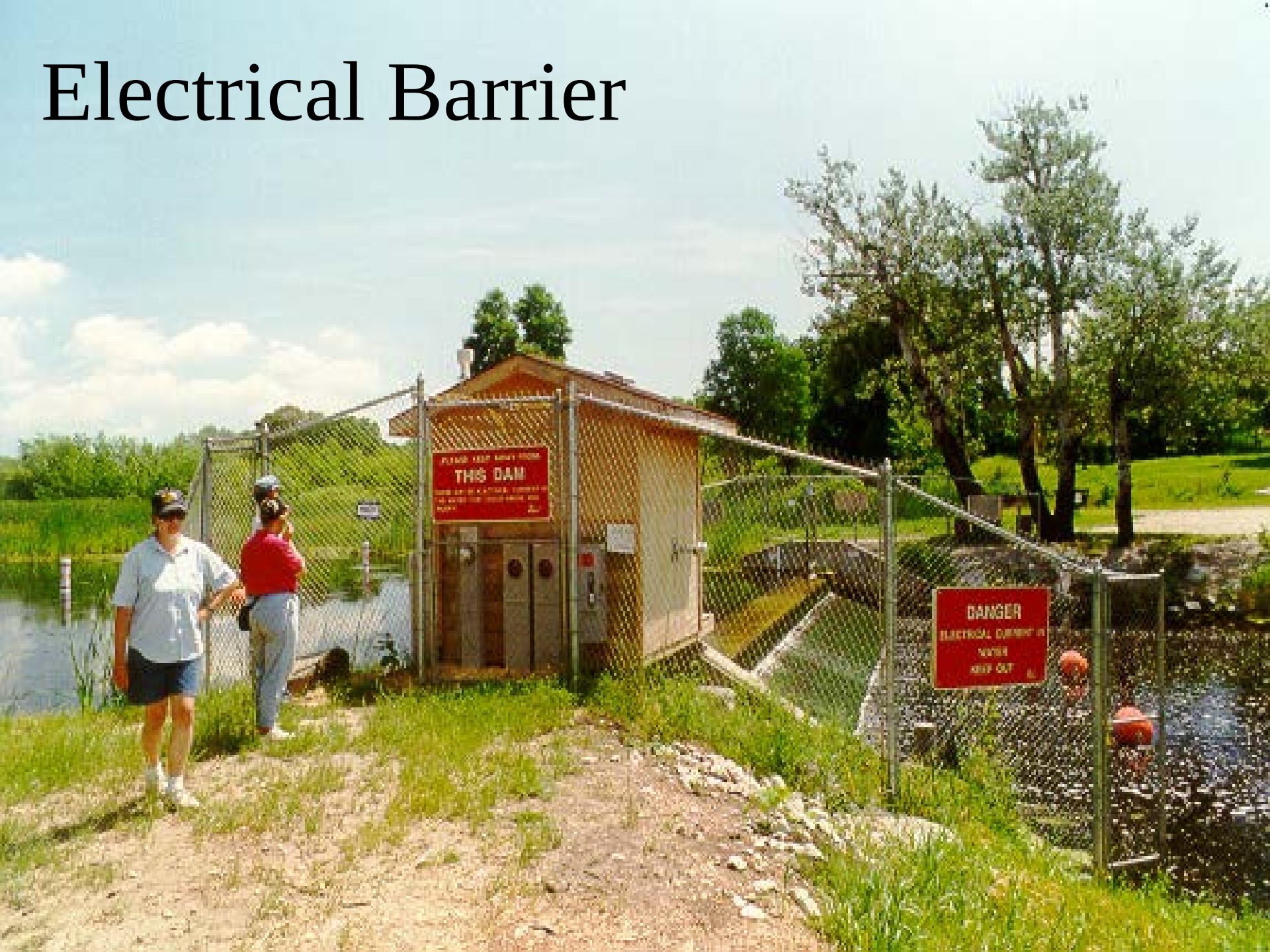
Mechanical Removal

Rotenone

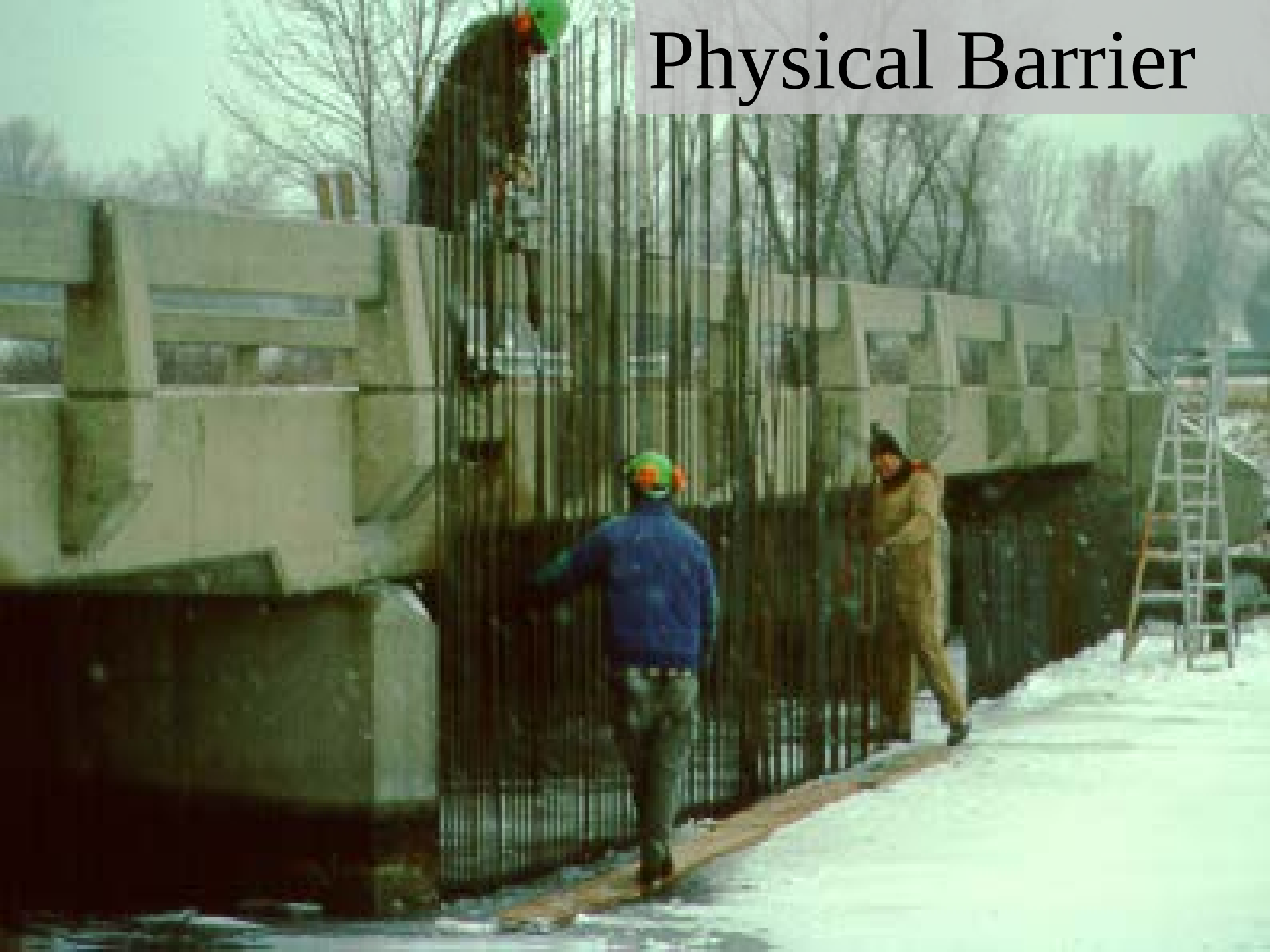

Fry Stocking

Aeration to Prevent Winterkill

Electrical Barrier



Physical Barrier



Management Tools

BENTHIVORES
PLANKTIVORES

PROTECT PISCIVORES
STOCK PISCIVORES
COMMERCIAL HARVEST
CHEMICAL RECLAMATION
SPOT TREATMENTS

WATER DEPTH

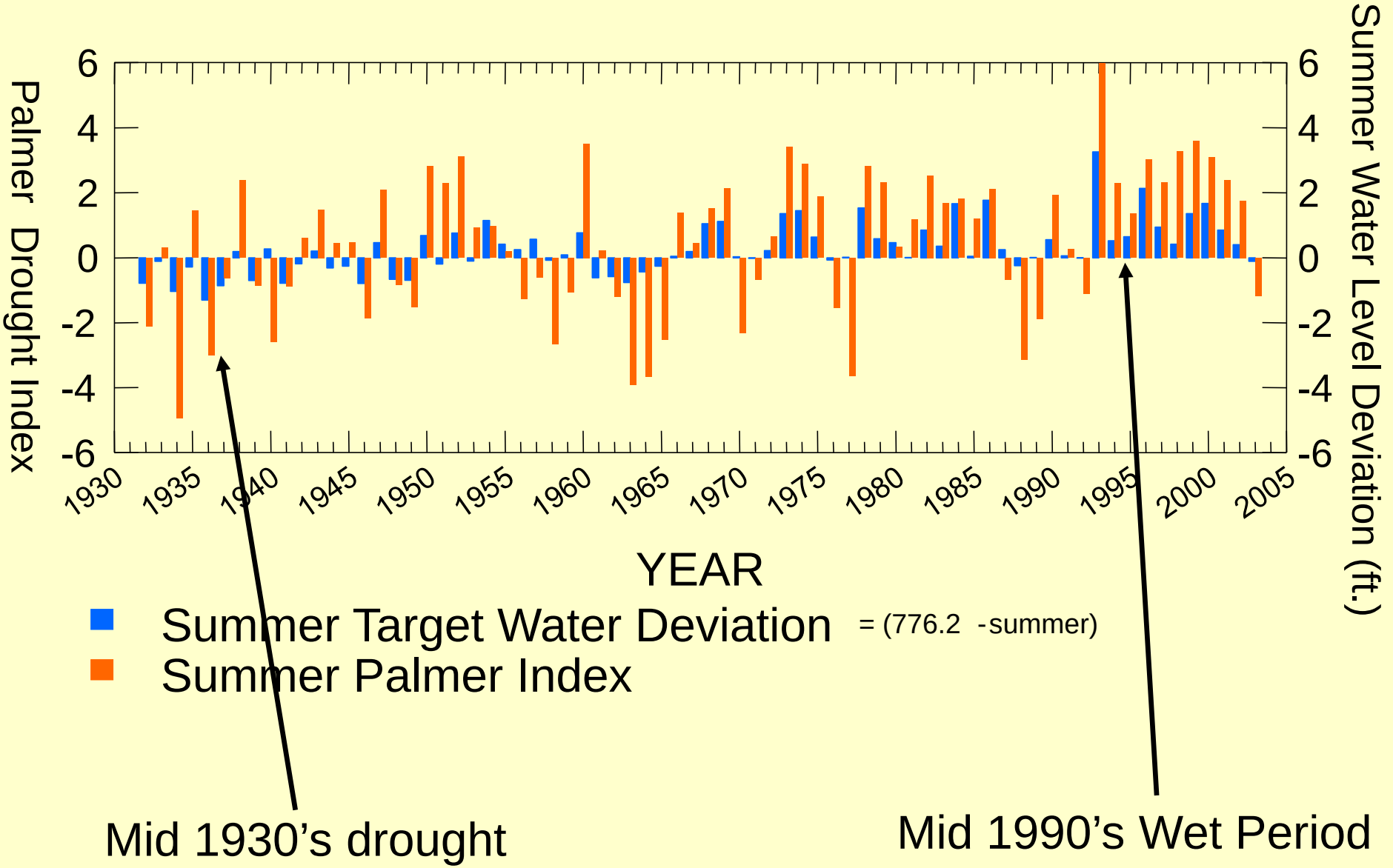
LONG-TERM LEVELS
DRAWDOWN

WAVES

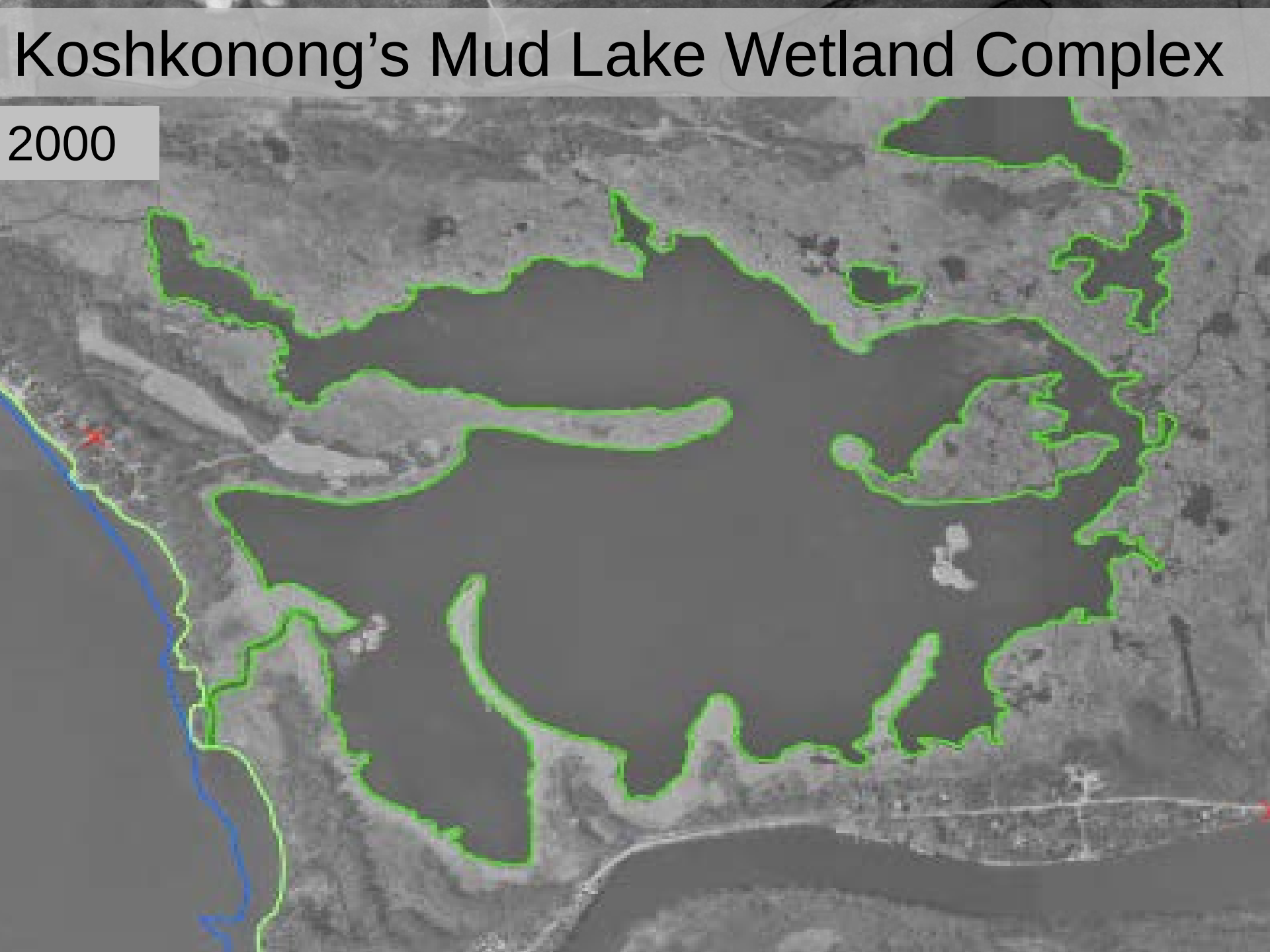
NUTRIENTS

Low Water Levels Rejuvenate Wetlands

Time Series – Relationship between Lake Koshkonong Water Levels and Hydrologic Conditions

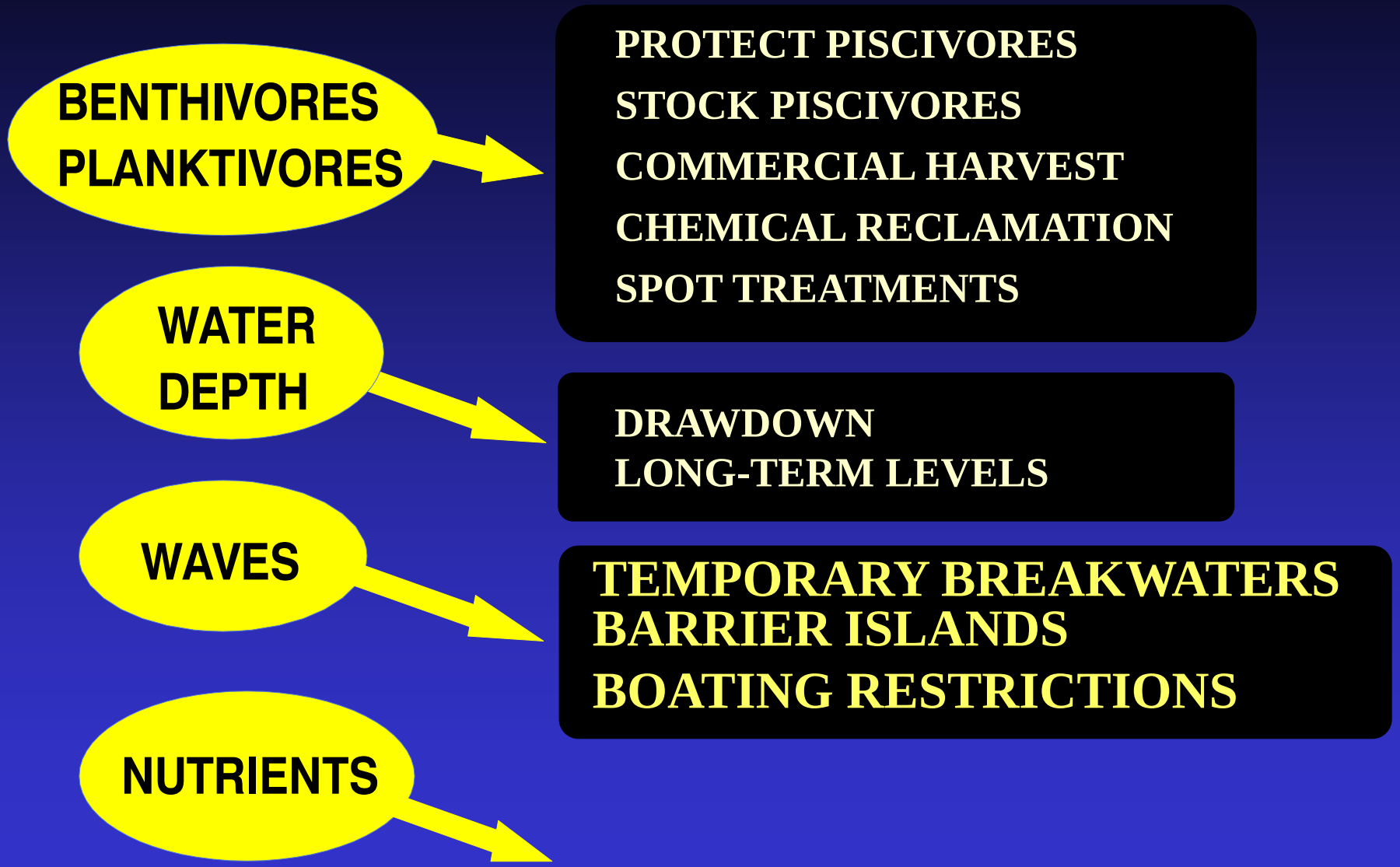


Koshkonong’s Mud Lake Wetland Complex



HIGH WATER LEVELS DESTROY HABITAT

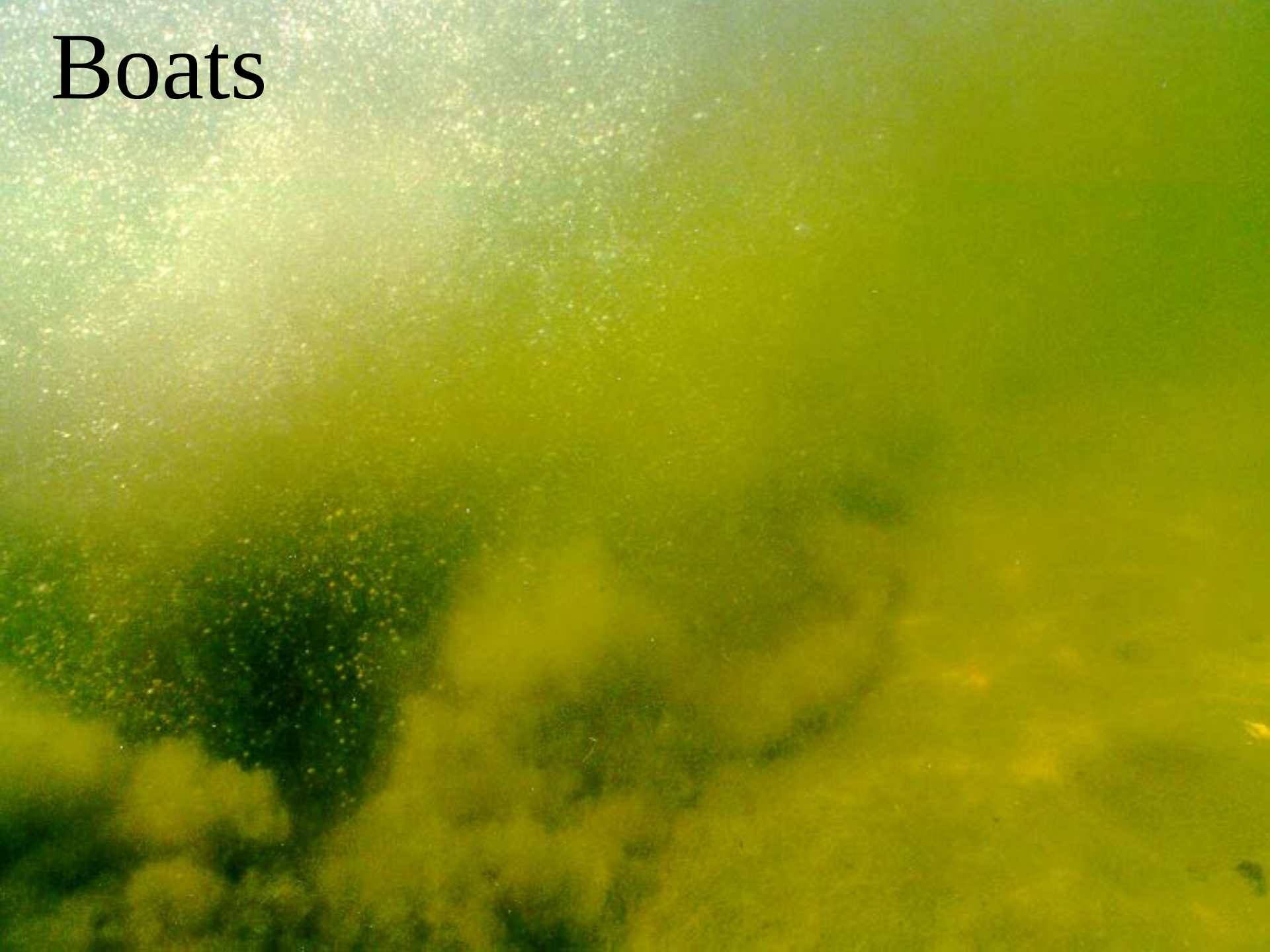
Management Tools



Permanent Breakwater

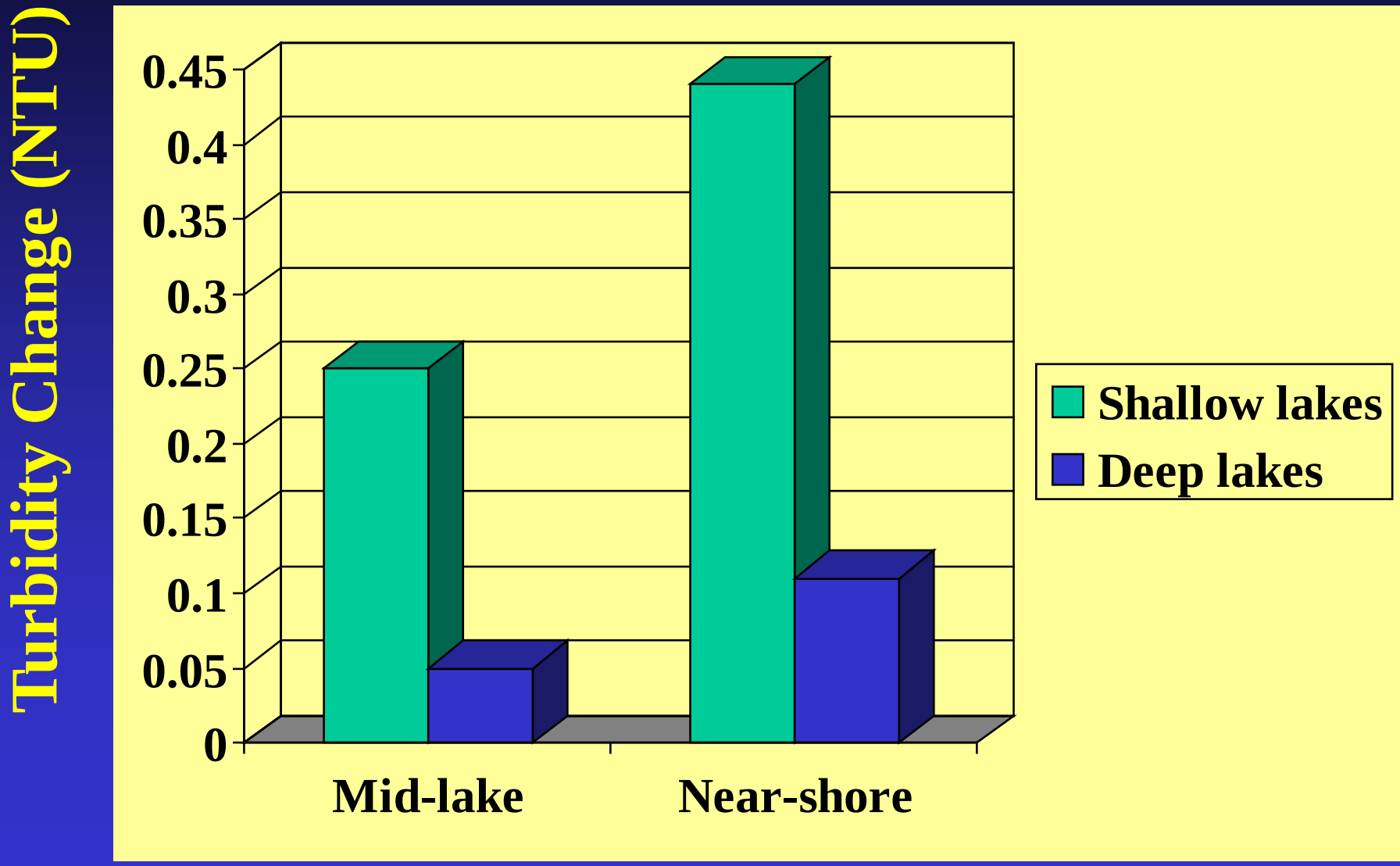
Boats

Boats

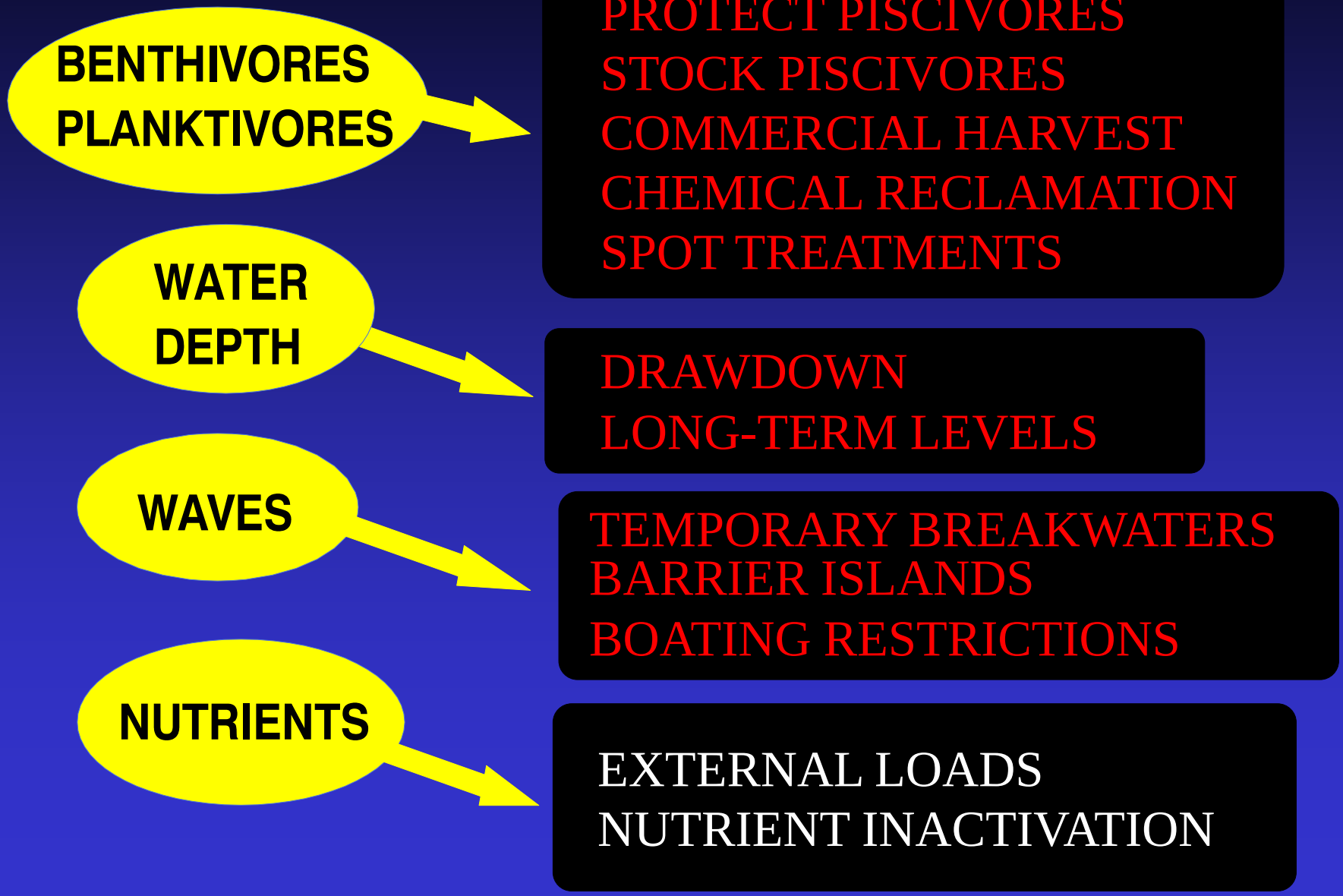


Boating

Weekday to Weekend Turbidity Change



Management Tools

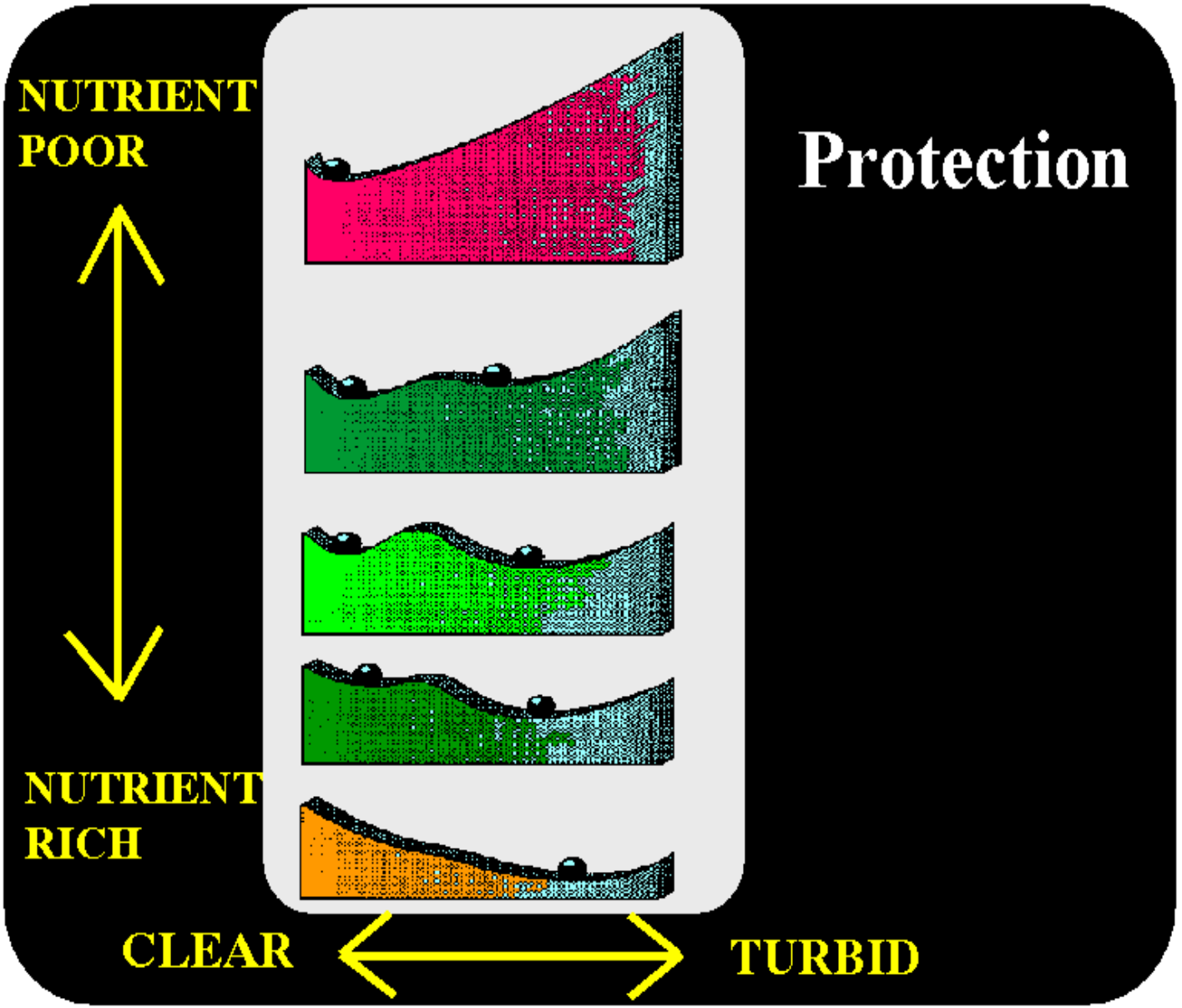


External Nutrient Loads

BMPs
Buffers
Settling basins
Flow diversion

Shallow Lake Ecology

(From Scheffer et al. 1993)



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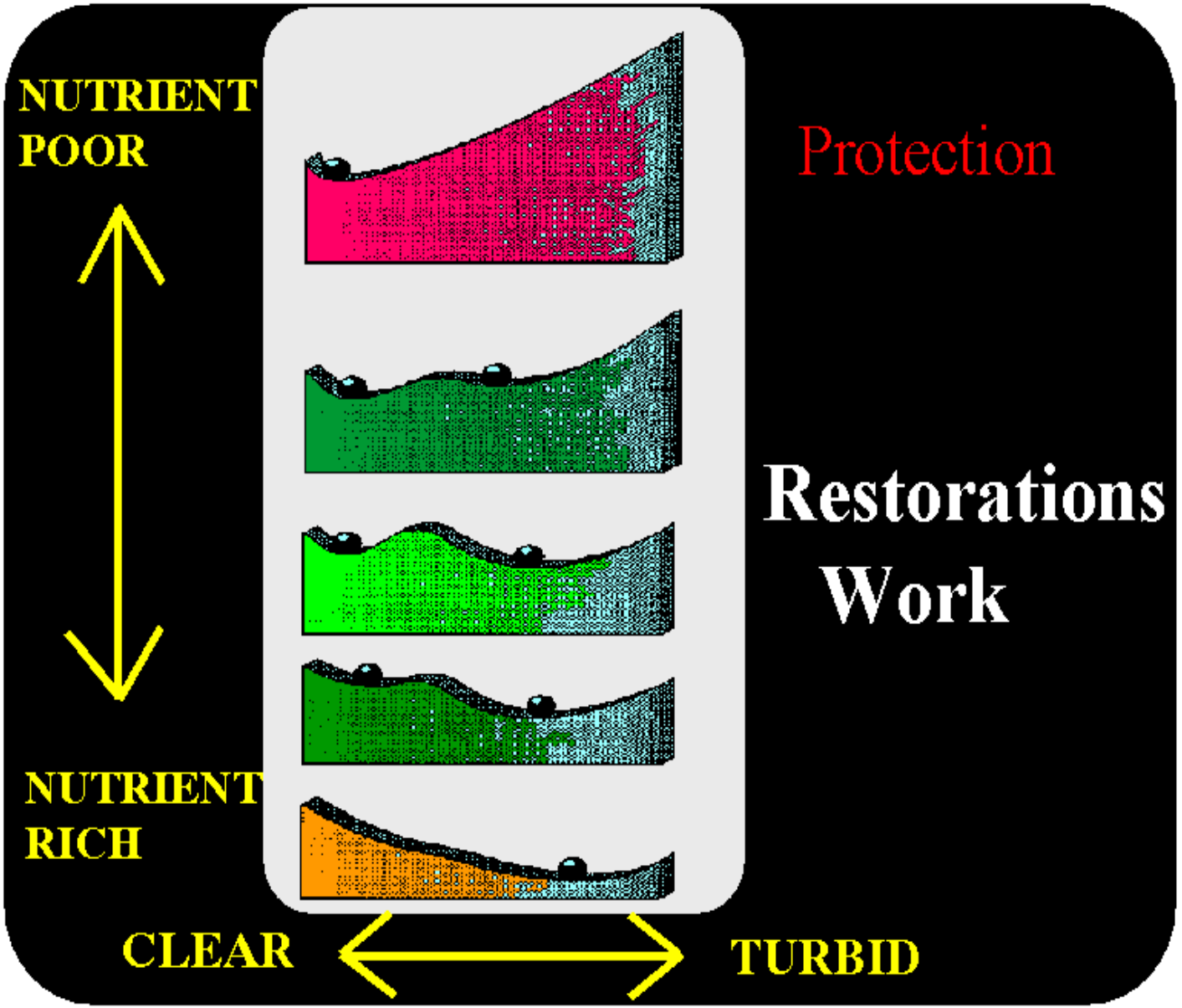

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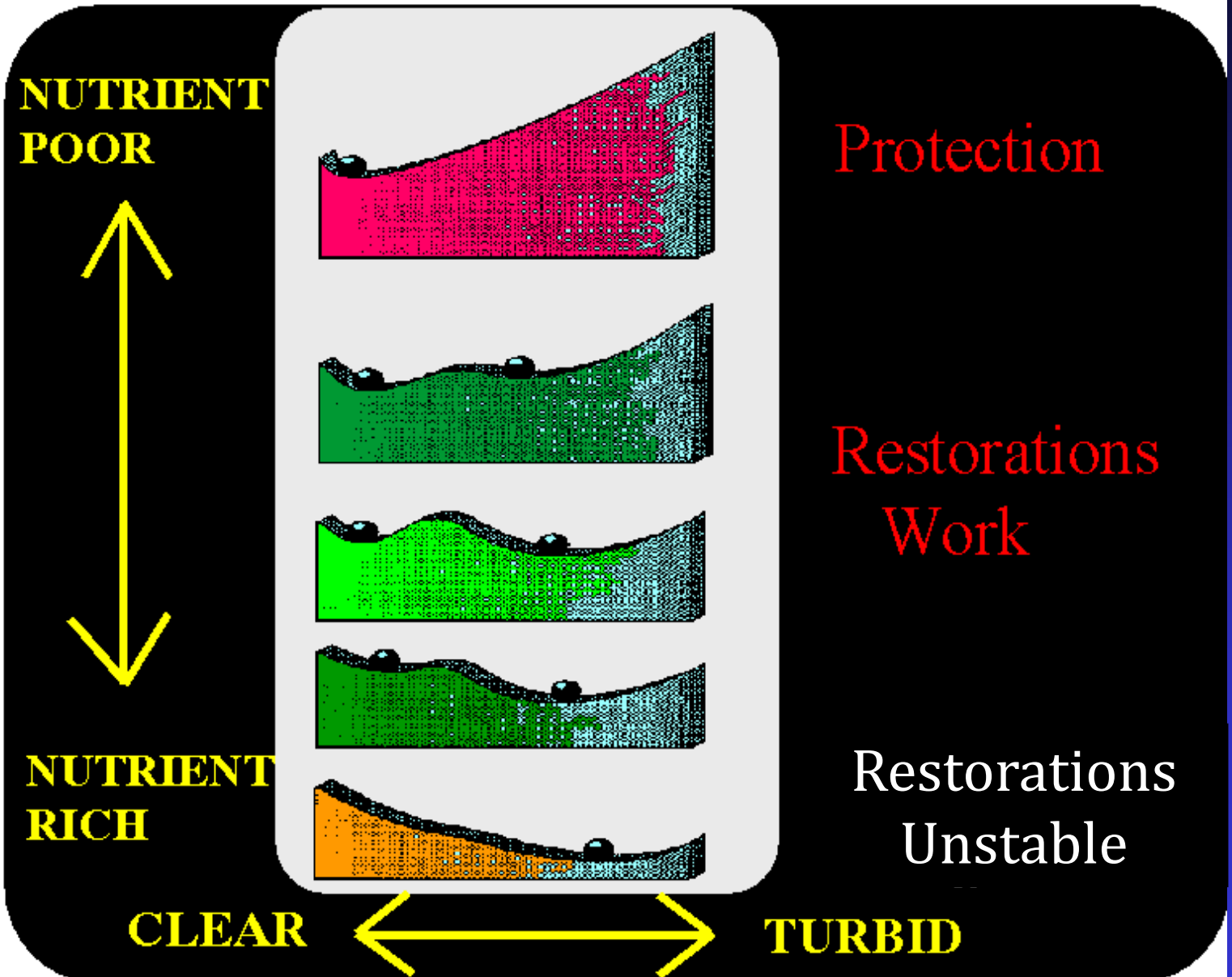
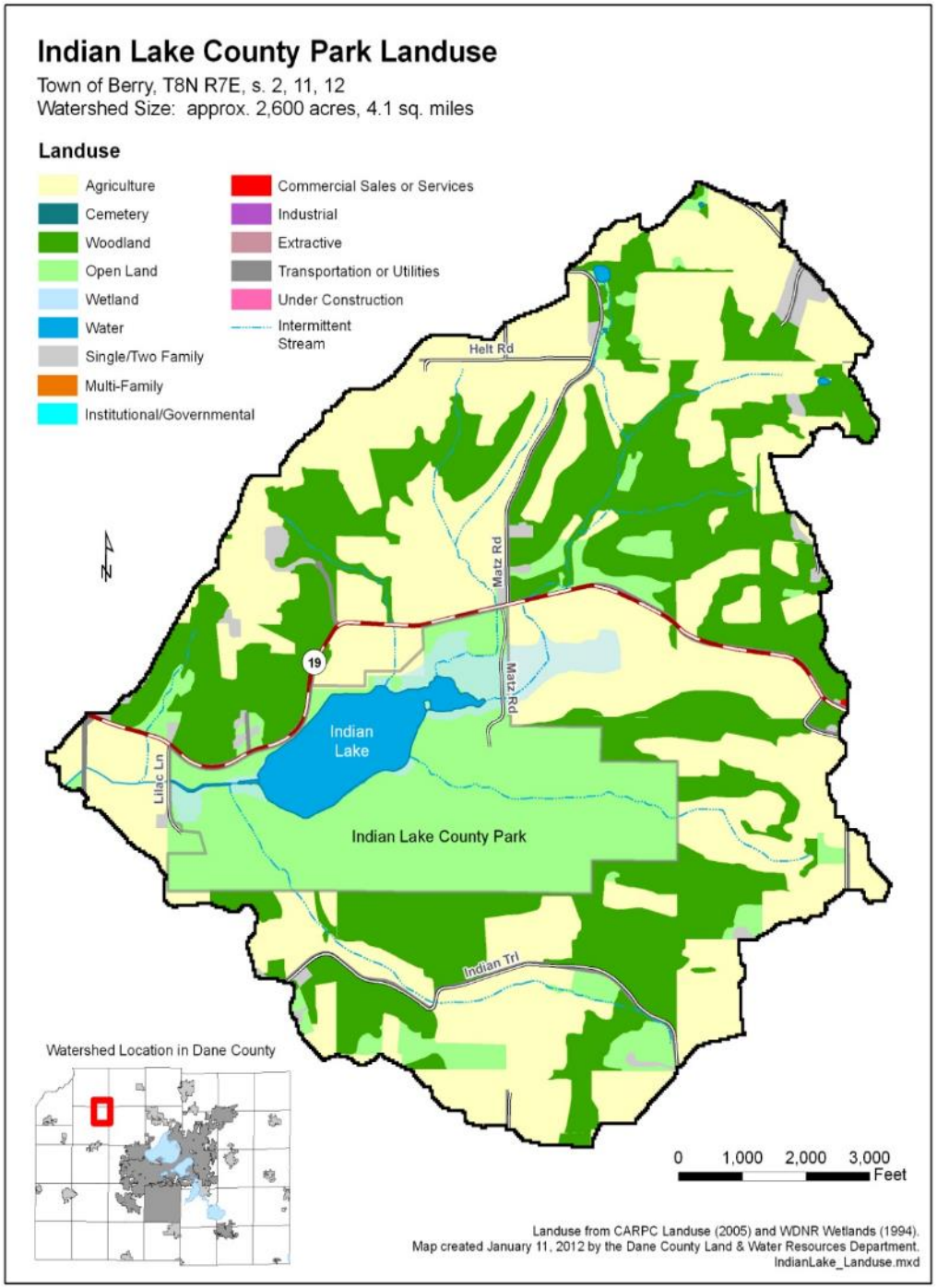


Shallow Lake Ecology

(From Scheffer et al. 1993)

Indian Lake Rehabilitation – Carp, Woeful Weather and a Hail Mary

Pete Jopke - Water Resources Planner, Dane County LWRD
Paul Cunningham, Dave Rowe, Kurt Welke (retired) WDNR Fisheries



- 66 acres drainage lake
- (40:1) Watershed: Lake area
- Dane County Parks - Riparian Owner
- Bass/Bluegill Fishery
- Popular Recreation Park- Best County Park – *Wisconsin Trails, 1994*
- 40 acre Dog Exercise Area
- History of Water Quality Problems

Indian Lake

- 2008-2009-Aeration turned on late resulting in winterkill.
- Flipped from rooted aquatic plants to algae dominated system.


9/2005
2005
Indian Lake
Google ea
Imagery Date: 5/31/2005 43°11'24.22" N 89°37'38.80" W elev 918 ft eye alt 5


9/2006
2006
Indian Lake
Image USDA Farm Service Agency
Imagery Date: 6/3/2006 43°11'24.22" N 89°37'38.80" W elev 918 ft


9/2008
2008
Indian Lake
Image USDA Farm Service Agency
Google ea
Imagery Date: 6/22/2008 43°11'24.22" N 89°37'38.80" W elev 918 ft eye alt 5


9/2010
2014
2010
Indian Lake
Google e
Imagery Date: 9/26/2010 43°11'24.22" N 89°37'38.80" W elev 918 ft eye alt


8/2012
2012
Indian Lake
Image USDA Farm Service Agency
Image © 2015 DigitalGlobe
Google ea
Imagery Date: 8/24/2012 43°11'24.22" N 89°37'38.80" W elev 918 ft eye alt 553

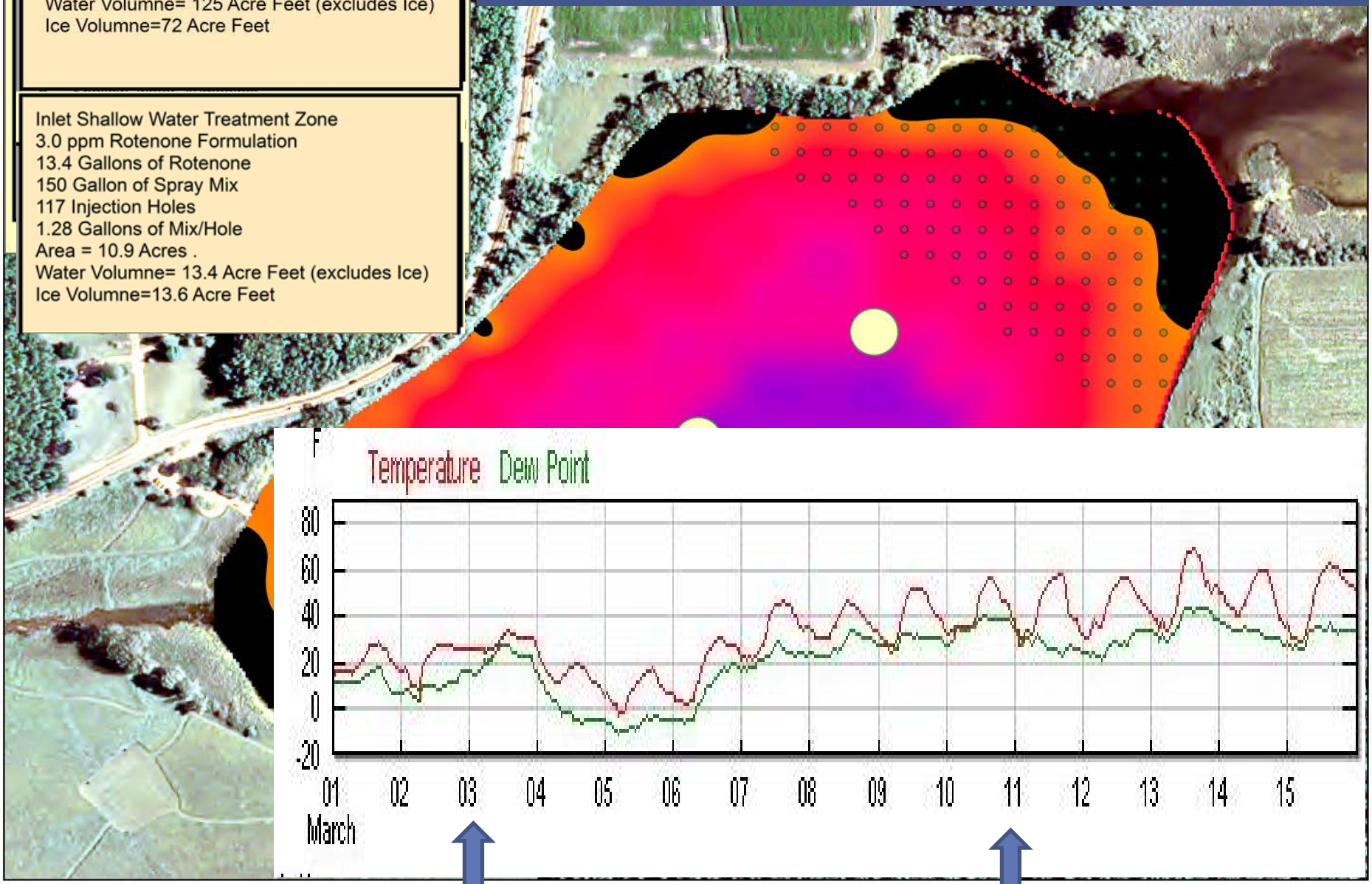

6/2014
2014
Indian Lake
Google
Imagery Date: 6/12/2014 43°11'24.22" N 89°37'38.80" W elev 918 ft eye a

Indian Lake Team - Final Preparations

Rotenone In-lake Treatment Zone

Deep Water Treatment Area
1.45 ppm Rotenone Formulation
60 Gallons of Rotenone
3 Injection Holes
Area = 50.7 acres
Water Volumne= 125 Acre Feet (excludes Ice)
Ice Volumne=72 Acre Feet

Inlet Shallow Water Treatment Zone
3.0 ppm Rotenone Formulation
13.4 Gallons of Rotenone
150 Gallon of Spray Mix
117 Injection Holes
1.28 Gallons of Mix/Hole
Area = 10.9 Acres .
Water Volumne= 13.4 Acre Feet (excludes Ice)
Ice Volumne=13.6 Acre Feet



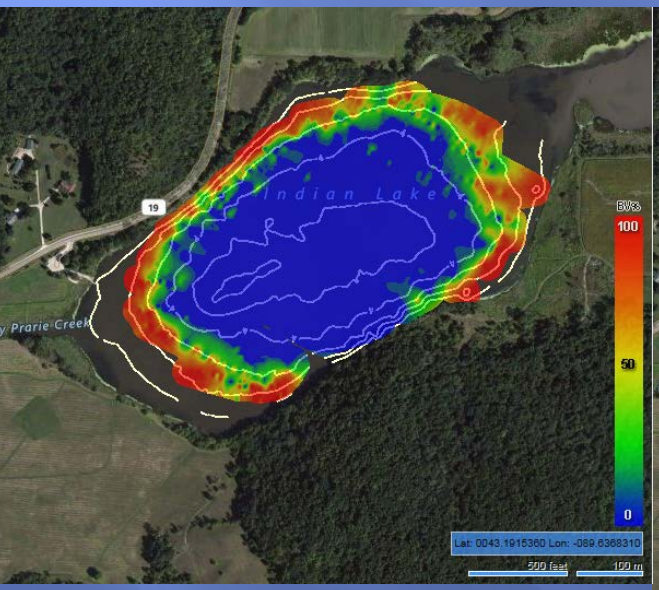
Holy Carp on a Cracker!

- Aug 2015 -UWSP Students seine 46 YOY carp
- September 2015 - DNR gillnet and electrofish a few adult carp
- September 2015 – DNR population estimate on YOY Carp
  - Mark Recapture = 5,738
  - CPUE Method (“Sorenson”) = 12,591

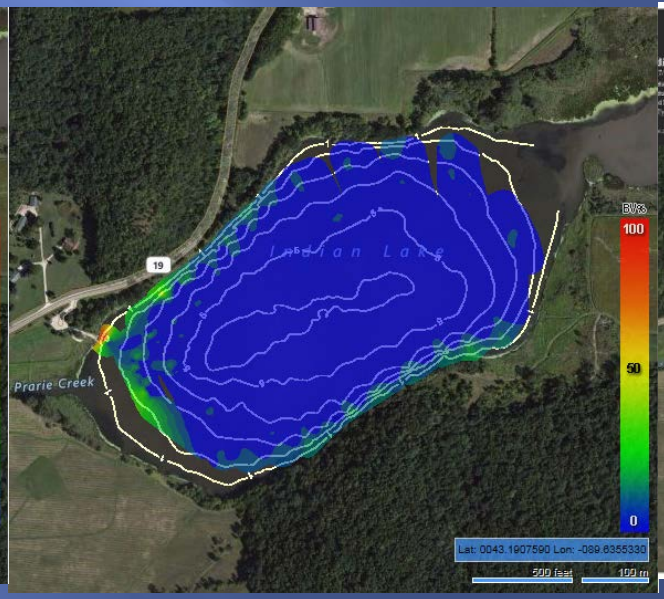
July 4, 2017 Fish Kill-Dissolved Oxygen Crash

Indian Lake Aquatic Plant Survey Results using Sonar

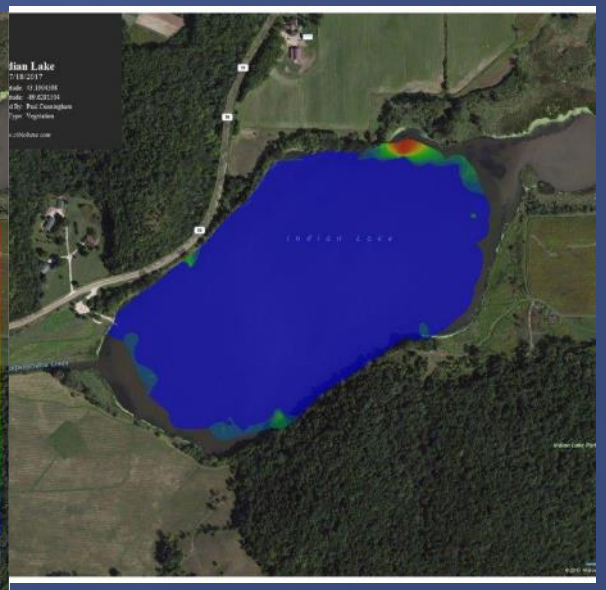
2015



2016



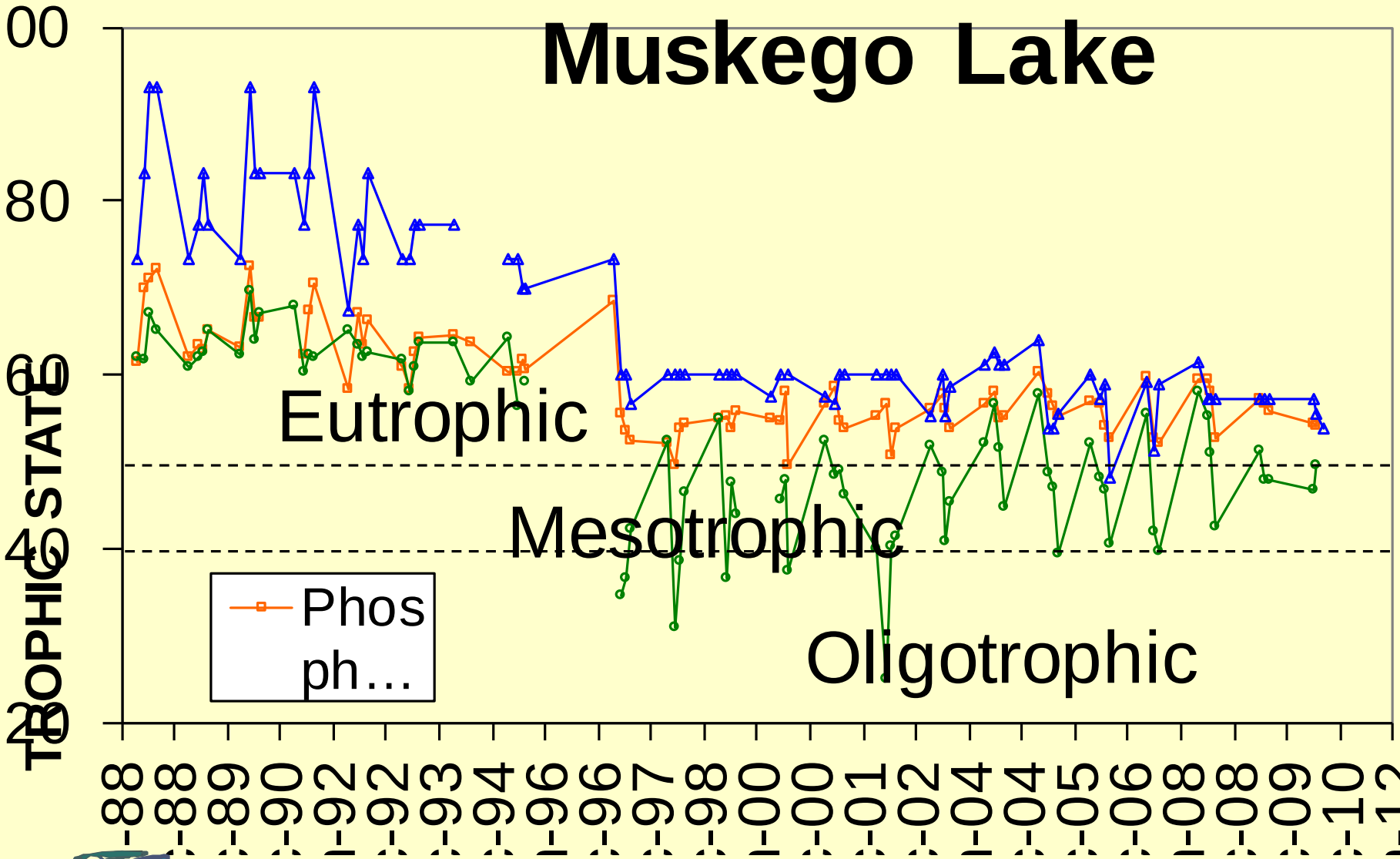
2017



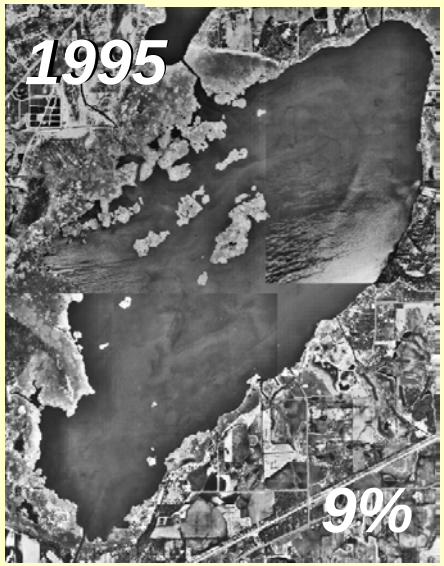
Big Muskego Lake Rehabilitation

- *19 Month Drawdown*
- *Eradication of Carp-Dominated Fish Population via Rotenone (Fall, 1996)*
- *Intensive Fish Restocking*
- *Alum Treatment of Bass Bay*
- *Electrical/Mechanical Fish Barrier*
- *Restrictive Fishing Regulations*
- *Nesting Island Construction*
- *Controlled Burning and Reseeding*
- *Vegetation Management*

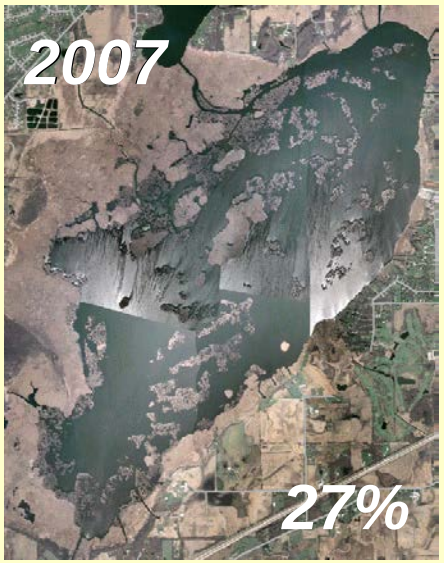
Trophic State Index – Big Muskego Lake

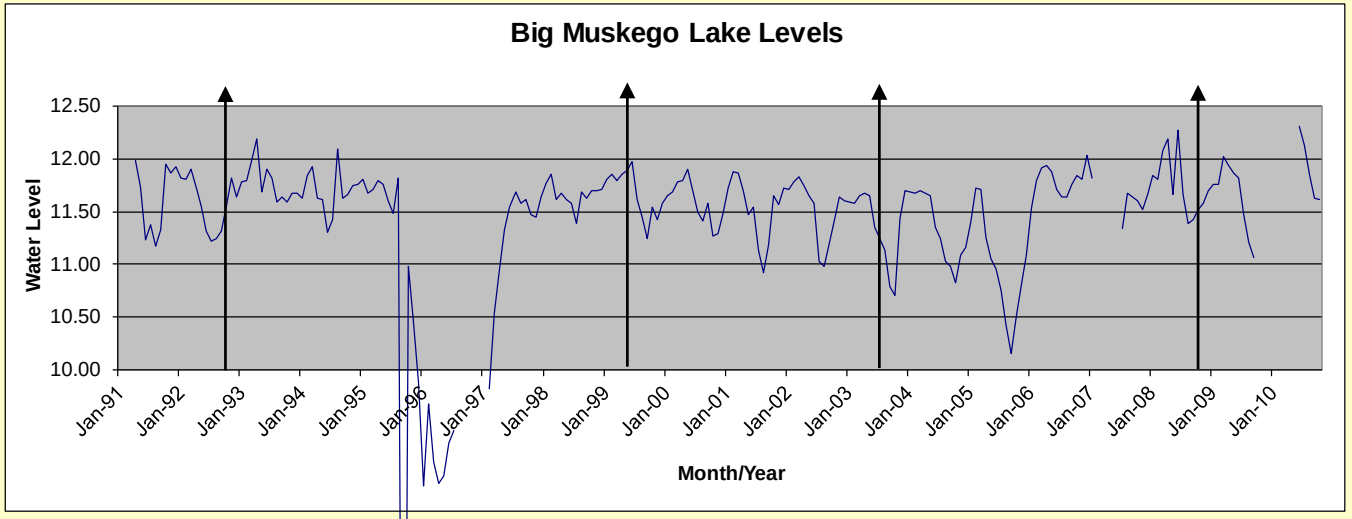


Emergent Plants – Big Muskego Lake

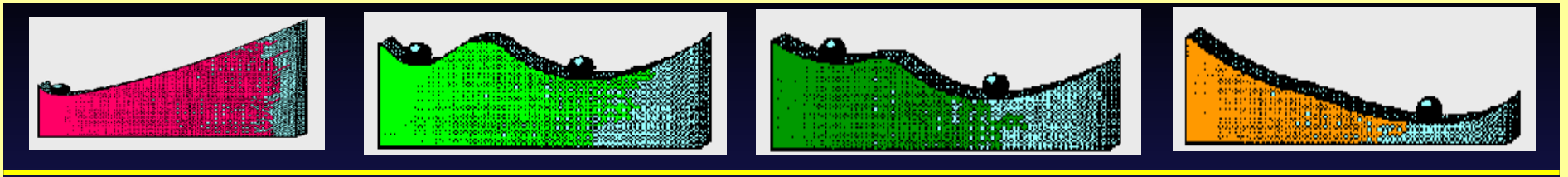


2003

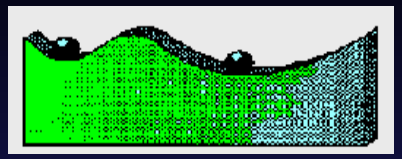
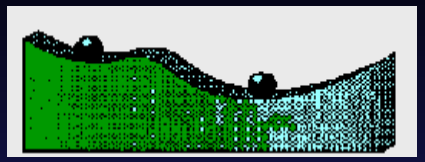
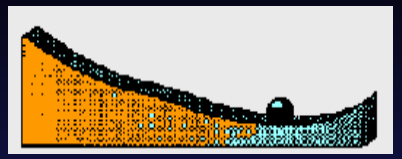




Is Shallow Lake Restoration Feasible



Is Shallow Lake Restoration Feasible?

Attribute			
Ext. Nutrient Load	< 1 g/m^2/yr	1-2 g/m^2/yr	>2 g/m^2/yr
Inlake TP	< 100 ug/l	100-250 ug/l	>250 ug/l
Sediment Resuspension	< 500 acres	500-5,000 acres	> 5,000 acres
Hydrologic Connectivity	Muti-basinal isolated waterbodies	⟷	Direct Connection Floodplain/Riverine
Macrophyte Potential	>50% surface area	⟷	<20% surface area
Fish Biomass	High (>400 lbs/acre)	⟷	Low (<100 lbs/acre)
Fish Community	High Abundance Benthivores/Planktivores	⟷	Low Abundance Benthivores/Planktivores

Ecology and Management of Shallow Lakes Conference

February 7-8, 2017; Horicon Marsh Visitor and Education Center

Media Recordings

- Day one: http://dnrmedia.wi.gov/main/Play/08e48d4fc6674261bdd2608e1514d7551d
- Day two a.m.: http://dnrmedia.wi.gov/main/Play/67cbf09c7f8f4c758b6fb42801a608411d
- Day two p.m.: http://dnrmedia.wi.gov/main/Play/f90402bbf7a04d9da25eaf7d46e6c76f1d