How long the road to recovery?

Factors determining the persistence of P loading in aquatic systems

Global View

- Eutrophication of surface waters
  - Drinking water supplies
  - Biological diversity
  - Habitat

Smith and Schindler 2009

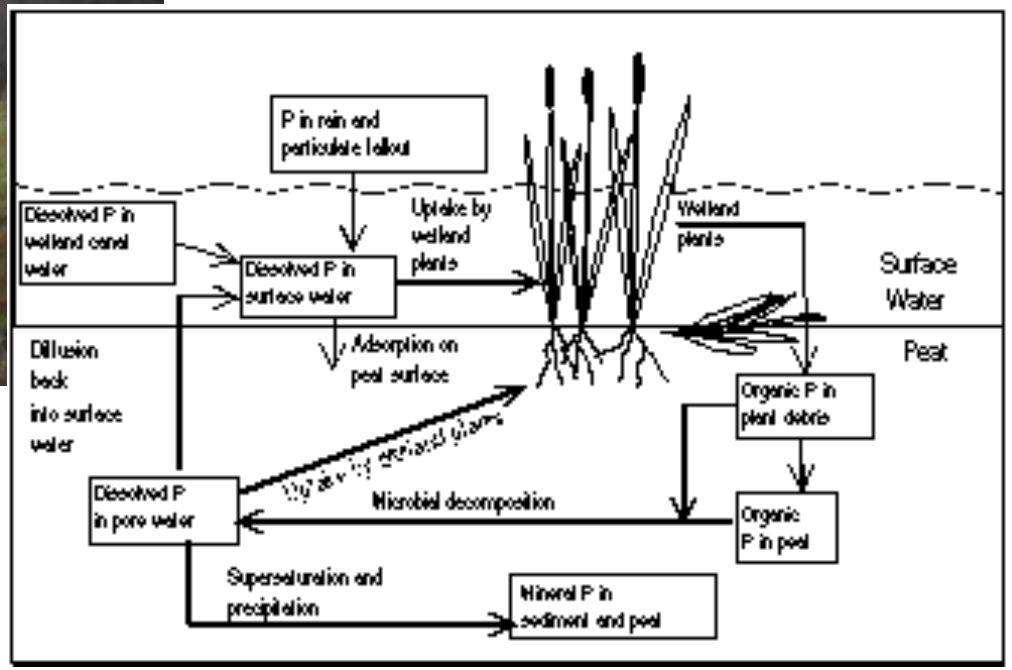
Wetlands at Risk

- In last 100 years, 50% of world's wetlands lost to agriculture, urban development, draining for malaria
- Ramsar Convention (1971 in Iran) (Convention on Wetlands of International Importance)
  - "…the conservation and wise use of all wetlands through local and national actions and international cooperation…"

Wetlands

- Value of wetlands ~ 12.5 trillion Euros Nature (1997)
- Store and purify water
- Recharge natural aquifers
- Retain nutrients in floodplains → control flooding
- Home to significant biodiversity

P Cycle Revisited (Wet Version)



INPUTS of P

- Atmospheric
  - Deforestation
  - Agricultural activity
  - Urban development/ construction
- Surface runoff
  - Erosion
  - Land use change

INPUTS of P

- Agricultural origin
  - Fertilizers
  - Manure
  - Pesticides
  - Insecticides

INPUTS of P

- Urban
  - Garbage/Waste
  - Sewage*
- Industry
  - Effluent from wastewater
  - Mining operations

Volga River, Volgograd, Russia

Eutrophication

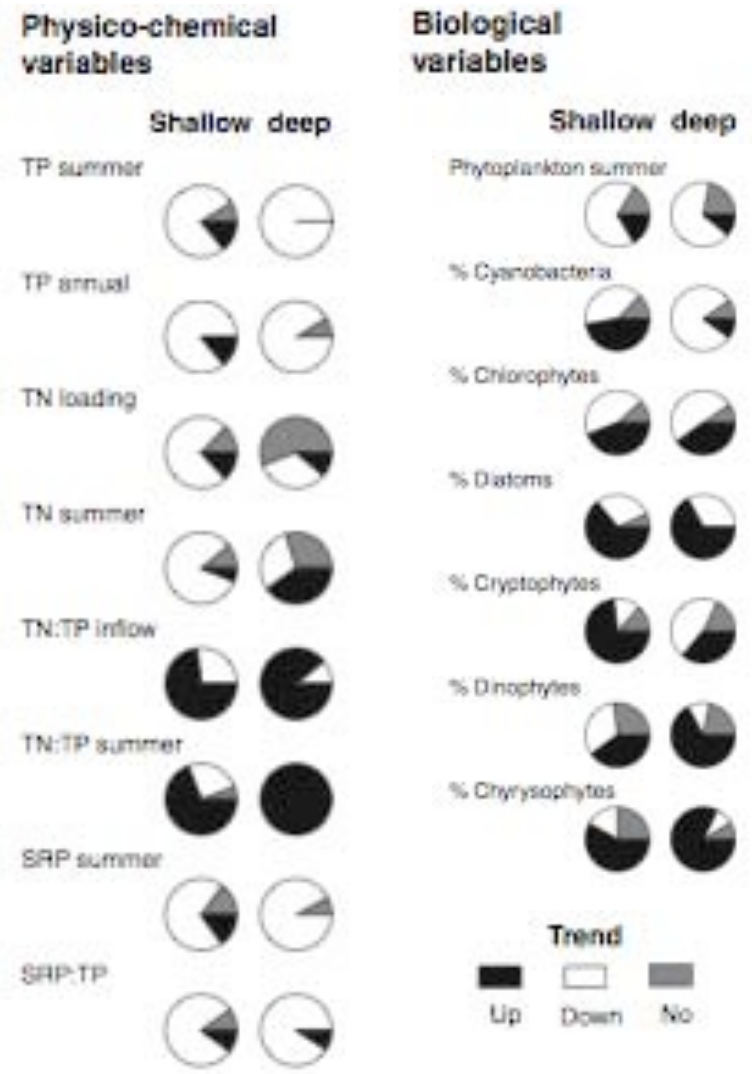
- P sensitivity
  - 10 ug P L^{-1} can support algal growth reducing water clarity
  - > 50 ug P L^{-1} → deoxygenation of waters and fishkills
- Excessive eutrophication preventable at <10 kg P ha^{-1} yr^{-1} (Smil 2002)

Eutrophication

- Bennett et al. 2001 inquire “Are there changes in the global P cycle that could increase impacts on freshwater systems?”
  - Is there increased storage of soil P?
- “What potential changes in the global climate can alter P cycling in freshwater systems?”

The Good News

- Survey 35 Lakes
  - Max P loads 3500-8 ug P/L and MRT from 0.2 – 56 years



Jeppesen et al. 2005

The Good News

- Re-oligotrophication is Possible! (10-15 years)

Response variable	Shallow lakes (mean depth <5 m or polymictic)	Deep lakes (others)
P response time to TP loading reduction	Typically 10–15 years	Typically 10–15 years
N response time to TN loading reduction	Typically <5 years	Typically <5 years
TP summer and annual	Decreased in most lakes	Decreased in all lakes
TN summer	Decreased in most lakes	No clear pattern
TN : TP summer	Increased in most lakes even in some lakes with lower TN : TP in the inlet	Increased in most lakes
SRP summer	Decreased in all lakes when TP decreased	Decreased in all but one lakes when TP decreased
SRP : TP summer	Decreased in all lakes when TP decreased	Decreased in all but one lakes when TP decreased
DIN : SRP summer	Increased in most lakes	Increased in most lakes
Secchi depth summer	Increased in most lakes	Increased in most lakes
Chl a summer	Decreased in most lakes	Decreased in most lakes
Chl a : TP summer	Increased or no changes	Increased or no changes
Phytoplankton biovolume	Decreased in most lakes	Decreased in most lakes
Phytoplankton community changes	Higher importance of diatoms, cryptophytes and chrysophytes	Decline in cyanobacteria and greater importance of dinophytes and chrysophytes

Jeppesen et al. 2005

Factors Affecting Recovery

- Physical dynamics
  - Phosphorus loads
  - Retention time

  - Tyne estuary:
    - Load = 1900 kg P/ha; MRT = 14 days
  - Potomac estuary:
    - Load = 43 kg P/ha; MRT = 85 days

  (Smil 2000; Metropolitan Washington Council of Governments, 2008)

Factors Affecting Recovery

- Internal loading
  - Iron
    - Fe:P > 2
  - "Scavenging" by Fe influenced
    - sulfides (FeS)
    - Fe-carbonate minerals

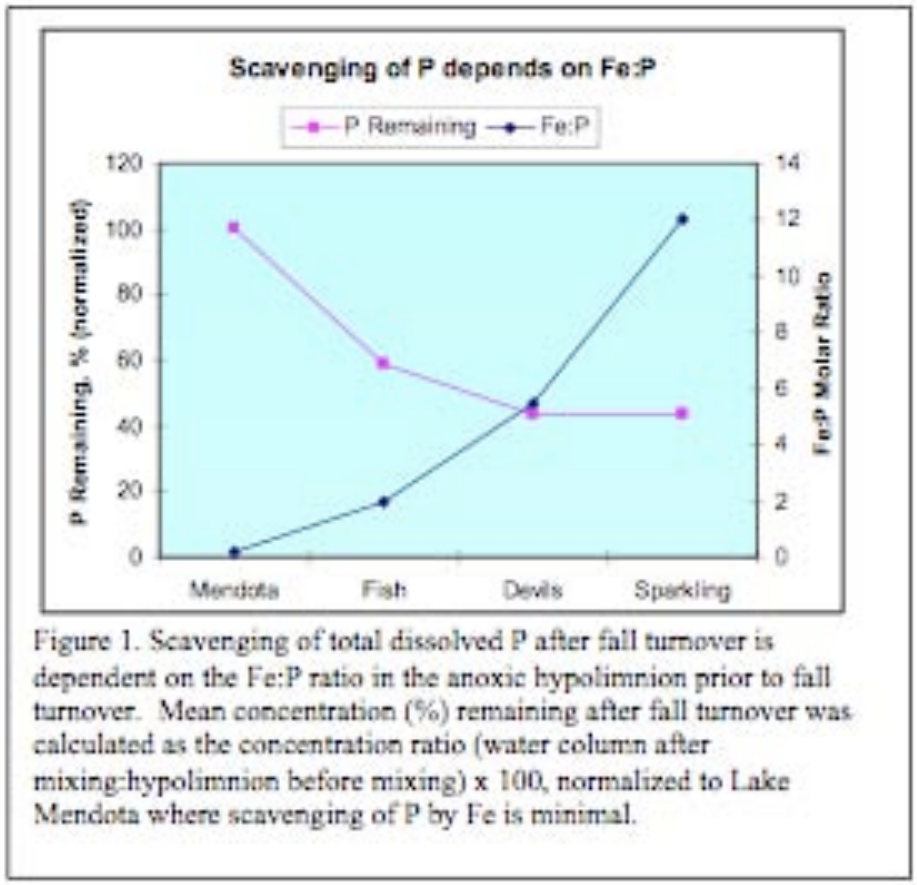


Figure 1. Scavenging of total dissolved P after fall turnover is dependent on the Fe:P ratio in the anoxic hypolimnion prior to fall turnover. Mean concentration (%) remaining after fall turnover was calculated as the concentration ratio (water column after mixing:hypolimnion before mixing) x 100, normalized to Lake Mendota where scavenging of P by Fe is minimal.

Hoffman et al. 2008

The Bad News

- Recovery isn't "complete"
- Water quality is key however, alternative ecosystems result

What are the effects of changed ecosystem function?

Altered States

- High P and changes in species composition

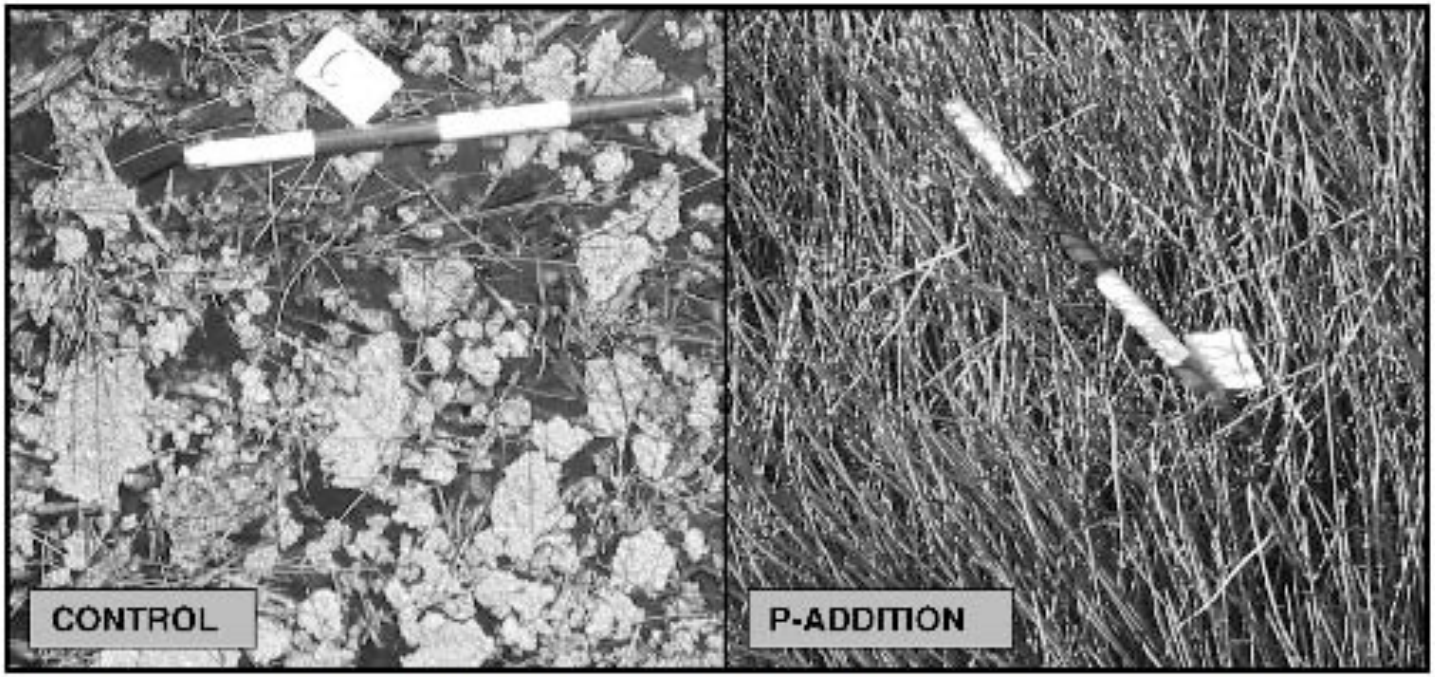


Figure 1. Aerial view of a control and P-addition plot, Buena Vista marsh, March 2003. Bar segment = 20 cm.

Rejmankova et al. 2008

Altered States

- Disease risk?
  - Positive correlation with P loading of wetlands and increased malaria incidence (Pope et al. 2003)
- Need to identify thresholds and feedbacks in interactions between nutrient loading and host-pathogen dynamics

P →  →

Where are Higher Risks?

- Must consider factors affecting recovery
  - Native P status
  - Human impact: Rate of loading
  - Geometry of water body: mean residence time
  - Mineralogy of lake/ wetland sediment
    - Fe concentration
    - Salinity (esp. sulfate salinity)
  - Biology trophic cascade; vegetation

Regionally Specific Concerns:

Tropical versus temperate lakes

- Higher temperatures, higher rates of metabolism → anoxic hypolimnion regardless of trophic activity (Marshall and Falconer 1972)
- Temperature and light virtually never limiting; addition of relatively small amounts of nutrients may greatly increase productivity
- Relative importance of N and P in eutrophication

Regionally Specific Questions:

Tropics

- Might tropical water bodies, surrounded by tropical soils with high fixing capacity be at lesser risk of eutrophication if storage is high?
- Greater eutrophication risk because of Fe-P associations and seasonal flooding? Erosion? Rapid land use change and human population growth?
- Is there greater human impact due to eutrophication because of disproportionate disease risk? Low availability of drinking water?

Regional Effects of Climate Change

- Shift of relative contribution of sources which can change P loads and retention time
- Changes in hydroperiod and fluctuation of aerobic and anaerobic conditions

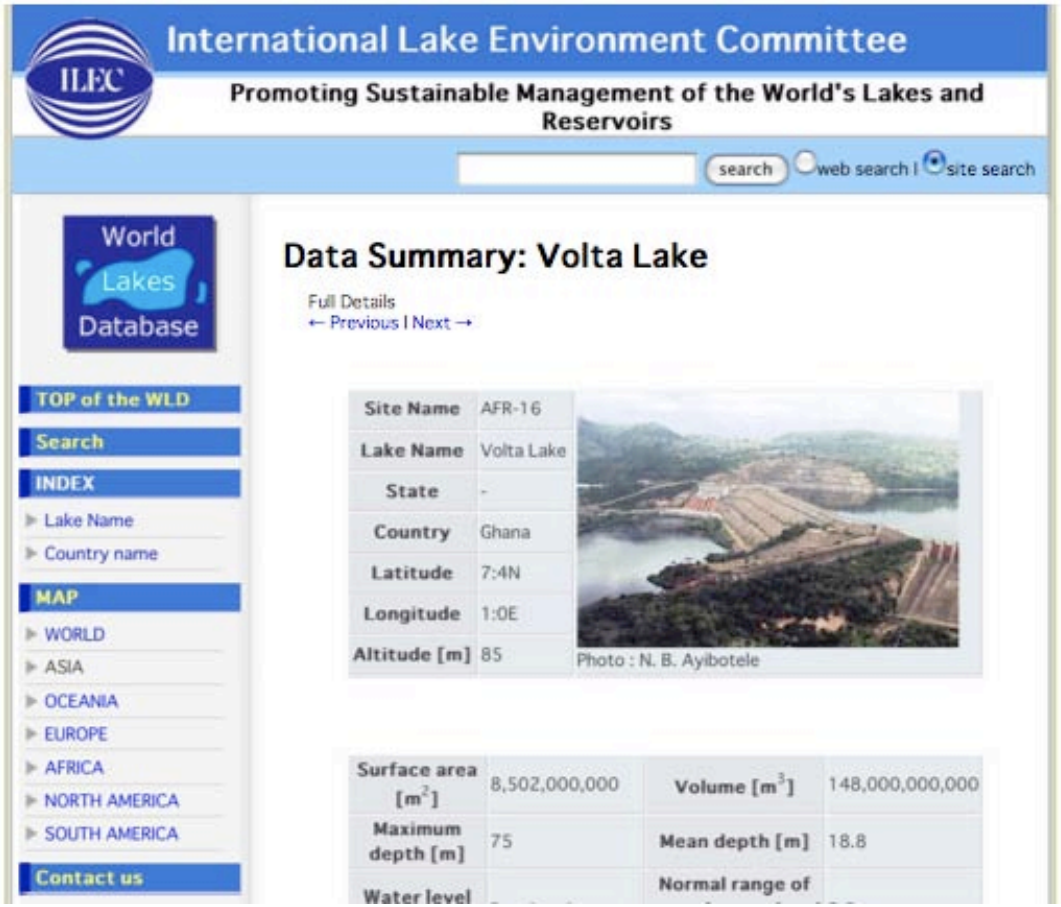
Regional Patterns of Land Use Change

- Deforestation:
  - Interception and retention of water affects P movement into water bodies (flow rates)
  - Increased loads due to erosion, dust production
  - Pasture conversion/ livestock production increases waste flows

The Flip Side

- Terrestrial systems (P deficits for production)
- Aquatic systems (P surpluses for production)

Potential for Risk Assessment



- Information required
  - Map of water bodies
  - Surrounding land uses
  - Estimates of nutrient loads
  - Geometry and geochemistry

Discussion

Laguna Hedionda, Bolivia