Applied Freshwater Ecology / Restoration

(A rare opportunity for ecologist to study whole system manipulations)

Several potential problems in aquatic systems. For example:

1. Sediments

   How do sediments impact aquatic ecosystems?

2. Pathogens

   If fecal coliform bacteria are generally not harmful to humans, why are they used to monitor pathogens? Why are fecal coliforms not a perfect tool for monitoring pathogens?

3. Toxins (often measured in sediment, water, and fish tissue)

4. Taste and order in water treated for drinking (geosmin and MIB)

5. Diminished sport fisheries

6. Invasive species

   Why are invasive species often much more abundant in their new environment than the environment in which they evolved in?

7. Thermal pollution

   In what way, in addition to direct effects of temperature change on organism, does thermal pollution impact aquatic organisms?

Wetlands

Problems typically involve diminished hydrological function that lead to diminished ecosystem function.

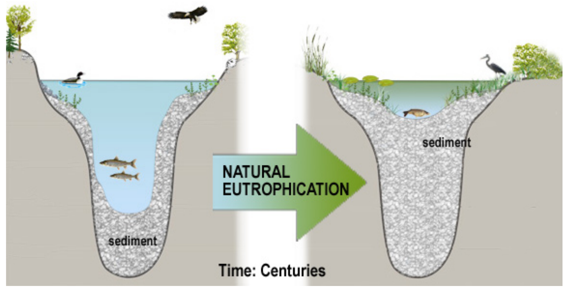
Streams

Problems typically involve diminished hydrological function and ecosystem function. Both are evaluated in stream assessment protocols

Lakes

The two most common problems in lakes deal with eutrophication (though not unrelated to the above problems):

1) DEEP LAKES WITH HIGH PHYTOPLANKTON PRODUCTIVITY

What are the negative effects associated with eutrophication?

	Oligotrophic Chl a 4 ug/l	Mesotrophic Chl a 4-10 ug/l	Eutrophic Chl a >10 ug/l
Conditions	• few nutrients • few phytoplankton, clear • not stratified • oxygen from top to bottom	*Intermediate conditions*	• many nutrients • many phytoplankton, turbid • orders and scum • stratified • no oxygen in deeper waters
Effects for human users	• supports most uses	supports most uses	• diminished sport fishery* • increase cost of treating drinking water • loss of recreation • loss of aesthetics

*note that the fisheries in small ponds behave differently than large lakes and objectives of management may be different.

A. Determining that eutrophication has reached a problematic stage; Methods of estimating trophic state:

1. **Direct measurements of phytoplankton productivity**

2. **Traditional indirect indicators of of productivity**

Trophic State Indices

An average index value of **35** is used as the transition value between oligotrophic and mesotrophic lakes; an average value of **50** is considered the transition between mesotrophic and eutrophic lakes.

-TSI based on chlorophyll

TSI(Chl) = 30.6 + 9.81 ln(Chl)

where: Chl is expressed in ppb (ug/l)

-TSI based on phosphorus concentration

TSI(TP) = 4.15 + 14.421 ln(TP)

where: TP is expressed in ppb (ug/l) of P (not PO_4)

-TSI based on secchi depth

TSI(SD) = 60 - 14.41 ln(SD)

where: SD is expressed in meters

B. Determining the limiting nutrient

The limiting nutrient is the nutrient that is in shortest supply relative to demand

-**N:P ratios -** Nitrogen and phosphorus are taken up by algae in an approximately constant ratio of 16 atoms of nitrogen per 1 atom of phosphorus, or 7.2:1 by weight.

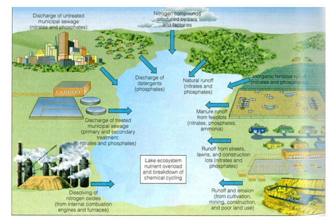
<10:1 nitrogen limited
10:1 to 20:1 co-limited
>20 phosphorus limited

-**Algal growth potential test** autoclaved lake water inoculated with single species of algae and 4 treatments (P, N, PN, and control).

C. Narrowing down the sources of nutrients

-**Point versus non-point sources**: Correlation between nutrient concentration and stream discharge where a positive relationship is associated with non-point sources and a negative relationship is associated with point sources.

-hand sampling at multiple times
-automated storm event monitoring



- **External and internal loading**

-**direct measurement of sediment phosphorus exchange using sediment chambers**
What is the advantage and disadvantage of this method?

-**indirect measurement by calculating nutrient budget**

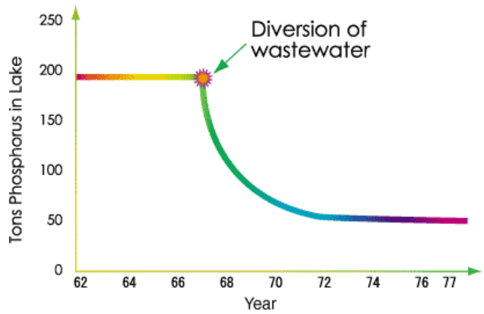
How much of a nutrient is moving out (or into) the bottom sediments in a lake can be determined from measuring the change in phosphorous in the lake's water column while accounting for the amount of nutrient coming into the lake from its tributaries and is leaving the lake.

Analogy: If the change in your bank account (lake water) cannot be accounted for by deposits (load entering through inflows) relative to withdrawals (load leaving the outflow), then somebody (the sediment) in the bank must be stealing or adding money from your account

D. Choosing a restoration strategy for a lake with excessive phytoplankton productivity based on the above information.

- **Divert or treat nutrient-laden wastewater or storm water**

Lake Washington (Seattle) - wastewater diversion



Sewage from Seattle during first half of 1900's resulted in algal blooms by the mid 1950's (*Oscillatoria rubescens*). Sewage effluent diverted to Pugeut Sound (Pacific Ocean) eliminated 99% of nutrient inflow to the lake resulting in decline of phosphorus levels in the lake (from 70 to 16 ug/L), and increased water clarity , and declines in algal biomass (from 35 to 4 ug/L).

Lake Shagawa (MN) Wastewater treatment

Reduction in wastewater phosphorus did not result in major changes in chlorophyll levels. *Why?*

What are the disadvantages of this strategy?

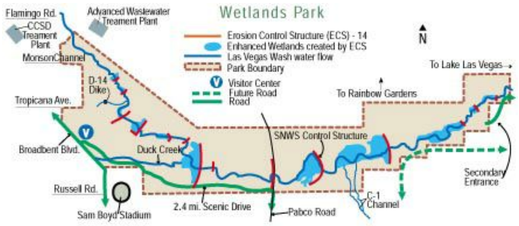
- **Flush lake with nutrient-poor water**

Moses and Green Lakes in Washington State. The dilution water was low in nitrogen and phosphorus content relative to the lake. Flushing rates were 10X normal in Moses Lake and 3X in Green Lake. Improvement in quality (nutrients, phytoplankton, and transparency) was on the order of 50% in Moses Lake and even greater in Green Lake (Welch 1981).

Besides reducing phosphorus concentration, what other factor might result in phytoplankton decline?

What are the limitations/disadvantages?

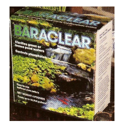
- **Lake protection from runoff**
  - In stream treatments
  - Detention and retention basins
  - Wetlands



What are the limitations/disadvantages?

- **Phosphorus inactivation**

aluminum sulfate salts (alum) -- -- > insoluble floc of aluminum hydroxide that bounds tightly to P regardless of oxygen concentration

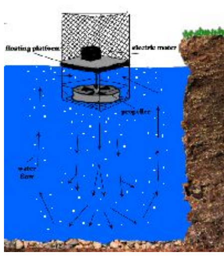


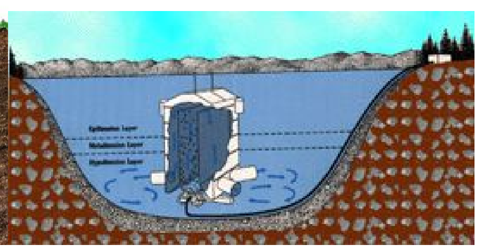
Lafayette Reservoir, California

Sodium aluminate for soft water lakes. Lime ($CaCO_3$) may also improve effectiveness in some situations as alum does not work well if pH<6.2 (or use other P binders).

What are the limitations/disadvantages?

- ***Artificial Circulation/Hypolimnetic aeration***



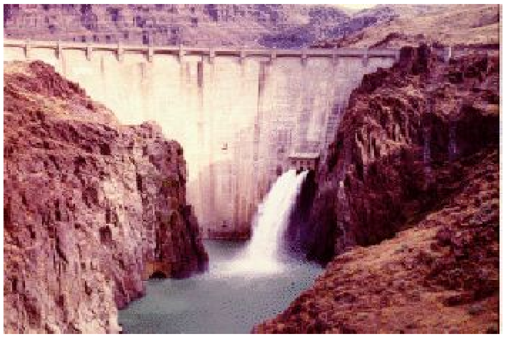


Why might this work?

To calculate the energy needed to breakdown stratification, RTRM should be calculated.

What are the limitations/disadvantages?

- **Hypolimnetic withdrawl**



Why might this work?

What are the limitations/disadvantages?

- **Top-down restoration**
  - Eliminate littoral browsers consuming macrophytes. *Why might this work?*

  - Trophic cascade e.g. Lake Vikvatan
    - increased herbivory by zooplankton
    - feces of large zooplankton have higher sedimentation rates
    - more macrophytes due to increased transparency

    Methods include:
    - stocking of piscivores
    - rough fish removal

    Click here for detailed discussion

  What are the limitations/disadvantages?

- **Copper Sulfate poisoning**

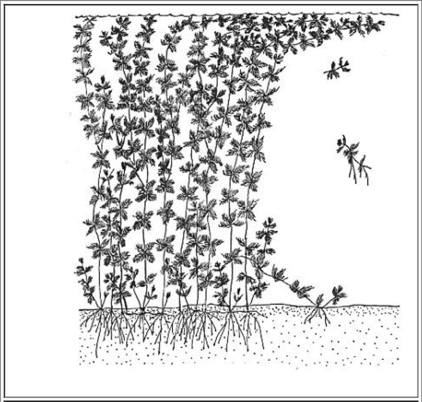
What are the limitations/disadvantages?

http://ace.ace.orst.edu/info/extoxnet/pips/coppersu.htm

Other chemical and biocides used to reduce phytoplankton directly, though how they work and how effective they are may not be clearly understood:

- barley straw
- ultrasonic devices
- selectively adapted strains of bacteria that may outcompete algae (though used in conjuction with enzymes that possibly act on algae directly).

2) SHALLOW WEED CHOKED LAKES (Macrophyte dominated lakes)



One example of potentially problematic aquatic macrophytes: Eurasian watermilfoil (*Myriophyllum spicatum*). Several others are problematic in the Southeast as well.

Nutrient reduction does not necessarily lead to macrophyte reduction and sometimes increases macrophytes. *Why?*

What is the main factor driving increased dominance of macrophytes in a lake?

Restoration strategies for macrophyte dominated lakes:

- **Harvesting**

http://www.ecy.wa.gov/programs/wq/plants/management/

What are the limitations/disadvantages?

- **Herbicides**

[Numerous types]

What are the limitations/disadvantages?

- **Biological Controls**

Addition of tripliod grass carp.

What are the limitations/disadvantages?

- **Lake Level Drawdown**

Expose rooted plants to heat or freezing. [Results variable]

What are the limitations/disadvantages?

- **Shading and Sediment Covers**

[Various materials]

What are the limitations/disadvantages?

Controlling macrophytes have often increased phytoplankton. *Why?*

SOLUTIONS THAT MAY ADDRESS BOTH PHYTOPLANKTON AND MACROPHYTE PROBLEMS

- **Sediment Removal**
  - deepens lake for macrophyte control
  - removes internal P loads
  - potentially removes toxic substances

What are the disadvantages?

- **Watershed protection**
  - stream buffers
  - Best Mananagement Practices (BMP's)
  - enforcment of silt fences, septic tank construction and maintence, sewer line maintence

What are the disadvantages?

Conclusions:

Effectiveness depends on funds available, risks willing to be taken, goals, and the lake system.
(from Soil & Water Conservation Society of Metro Halifax at http://www.chebucto.ns.ca/Science/SWCS/lakerest.html)

Overall problems complex. Every lake is different and must understand the basic limnology to evalute the effectiveness of a possible treatment.

Lake Allatoona

Lake Acworth