Trophic State and Eutrophication: Ch. 17

Trophic State and Eutrophication

- Definition of Trophic State
- Why Do Eutrophication and Algal Blooms Matter?
- Natural and Cultural Processes of Eutrophication
- Relationships Among Nutrients, Water Clarity, and Phytoplankton
- Mitigating Lake Eutrophication
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Definition of Trophic State

- Based on nutrients or producer biomass
- A way to describe a continuum of possible trophic states
- Useful in comparing systems across large areas (e.g. an 'oligotrophic' lake in Iowa may be 'eutrophic' in Idaho)

Why Do Eutrophication and Algal Blooms Matter?

- Taste and odor problems
- Blooms of toxic algae
- Aesthetics (people less willing to pay to live near, or recreate on, eutrophic lakes)
- Fish kills

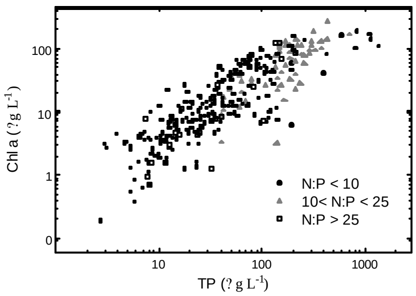
Natural and Cultural Processes of Eutrophication

- Classical view that lakes slowly become more eutrophic as they fill and become shallow, eventually succession leads to a marsh, then a meadow
- Many large lakes may be oligotrophic for much of their history
- Natural eutrophication can occur, but eutrophication caused by humans (cultural eutrophication) is much more rapid and a world-wide problem

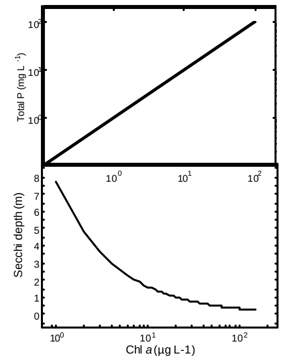
Relationships Among Nutrients, Water Clarity, and Phytoplankton:

- Managing eutrophication in lakes requires understanding of correlations between nutrients and algal biomass
- Management of fish populations can also include consideration of trophic state
- A mechanistic understanding is most useful to managing the problems

Nutrient-Phytoplankton Relationship



Linking Lake Clarity to Nutrients

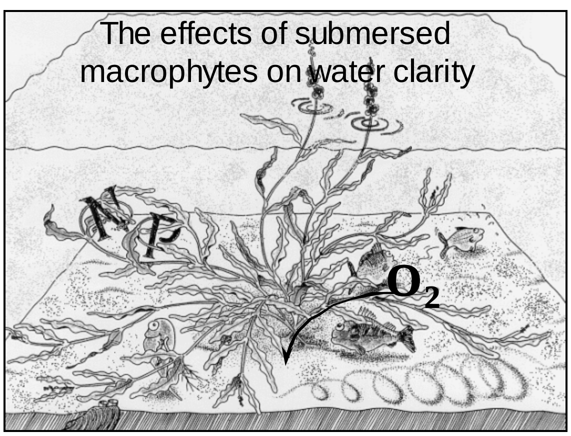


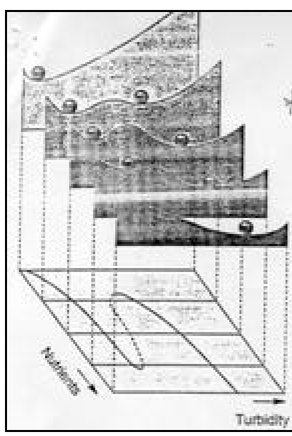
Mitigating Lake Eutrophication

- Control of nutrient sources
  - internal versus external loading
- Treatment in the lake (e.g., mixing)
- Kill all the fish
- Removal of macrophytes

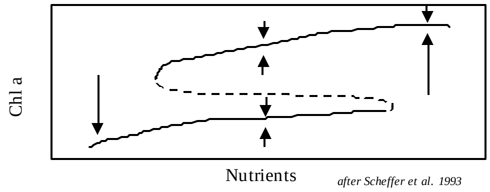
Why should Eutrophication be Controlled before the Hypolimnion goes Anoxic?

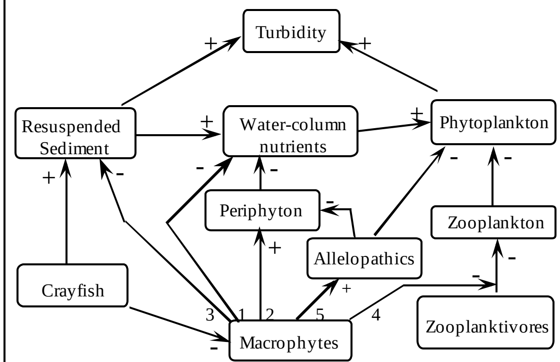
- $FePO_4$ dissociates in anoxic conditions
- If hypolimnion goes anoxic then PO_4^{3-} continuously is recycled from sediments into the water column, and mixed into the epilimnion
- Can take many years to recover from eutrophication even if point sources and non-point sources are controlled





Alternate Stable States of Shallow Lakes





What condition would fishermen enjoy? most people?

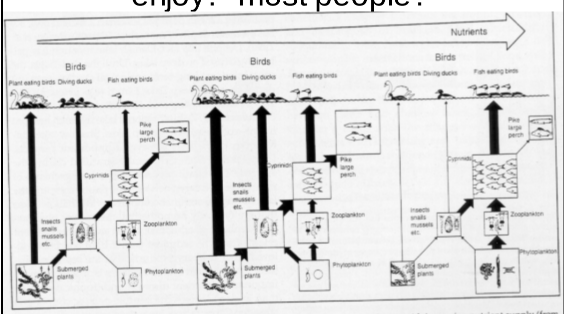


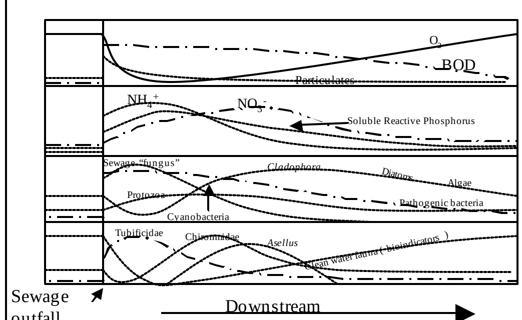
Fig. 1. Scheme illustrating how biological structure and the impact of various processes change with increasing nutrient supply (from left to right). Today, the majority of Danish lakes are found to the right of the scale, whereas they last century typically were found to the left. Partly from Andersson et al. (1990).

Factors that affect phytoplankton biomass

- nutrients set potential biomass
- biotic interactions affect realized biomass
  - predation by zooplankton
    - and by extension, planktivores and piscivores
  - competition with periphyton
  - macrophytes
    - multiple mechanisms
      - competition (interference and exploitative)
      - refugia for zooplankton
      - reduced wave and current energy
    - and by extension, herbivores of macrophytes

Managing Eutrophication in Streams and Wetlands

- Methods not as clearly defined for streams and wetlands, methods for streams more developed than for wetlands
- In general, principles are the same, control of nutrient sources is better than treating the symptoms



Eutrophication and Wetlands

- Wetlands serve as nutrient sinks
- Better at N than P removal because there is no equivalent process to denitrification in the P cycle
- May work to remove plant biomass and allow re-growth (bulk removal of P)
- Many natural wetlands are oligotrophic, and nutrient pollution destroys natural system

Case Studies of Eutrophication

- Lake Washington
- Lake Trummen
- Lake Tahoe
- Lake Okeechobee

Lake Washington

- Noticed shift to eutrophic algal species
- Sewage diverted from Lake Washington in 1960's
- Cyanobacteria dropped out
- Were able to control trophic state before hypolimnion went anoxic

Lake Trummen

- In Sweden, 1 m deep, poor water quality, frequent fish kills
- Controlled point and non point sources to lake in 1960's
- Problems continued, was calculated it would take nutrients in sediments 100's of years to wash back out
- Top half meter of sediments dredged and sold as topsoil.
- Improved water quality to allow fish survival and human recreation

Lake Tahoe

- Ultra-oligotrophic lake on Nevada, California border
- Water retention time 700 years
- Septic systems were polluting lake, N limitation (detergent inputs)
- After sewage pumped out of basin, P limitation (watershed disturbance increased N inputs)
- Secchi depths are now around 20 m rather than 40 m historically
- Future of lake uncertain

Everglades/ Okeechobee

- Everglades once had a sheet of water that flowed across the lower 1/4th of Florida
- Was drained for agriculture and development
- Canals and locks decreasing natural flushing
- Ag fertilizer runoff caused algal blooms in Okeechobee and loss of native plant and algal communities in Everglades
- Billions of dollars being spent on restoring more natural flows
- Experimenting with using wetland areas to scrub P from incoming waters
- Agricultural lobby very powerful, and huge tax base in Southern Florida, so this is a charged issue
- Not clear if the problems will be solved