

Supplement to Chapter 12

NUTRIENT IMPACT

Vladimir Novotny

Nutrients are primarily nitrogen and phosphorus that stimulate the growth of algae

Algae and plants generally can use nitrogen in a form of ammonium and nitrate. Some algae (obnoxious blue greens) and plants (legumes) can fix atmospheric nitrogen

Algal
Bloom of
Ulva
in the
Lagoon
of
Venice



Historic city

Algal bloom



0 5 10
Scale (km)

NUTRIENT IMPACT

- Photosynthesis is the driving process
 - $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow 6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6$
- Photosynthesis occurs in the water layer where light can penetrate (euphotic zone)
- In the layer with insufficient light, on cloudy days and during night algae respire and impose oxygen demand (the equation is reversed)



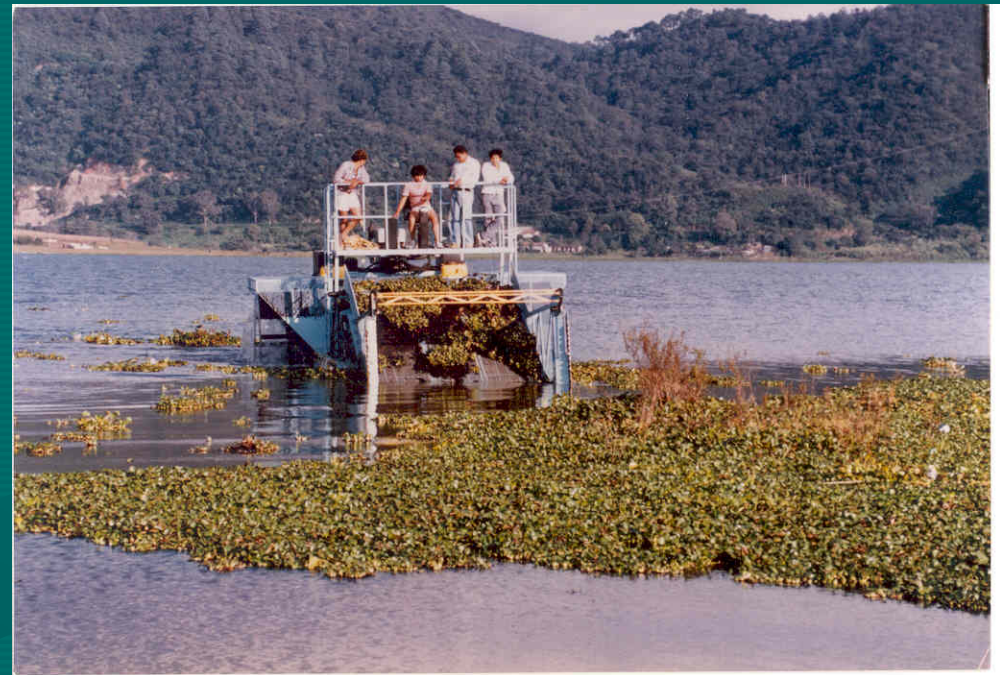
Algae In Venice (Lagoon) and Milwaukee River



Algae in Venice and in Mexico



Ulva



Water Hyacinth at Lake Victoria in Africa



EUTROPHICATION

Macronutrients

CO₂ (alkalinity)

N, P

Micronutrients

Mn, Cu, Zn, etc.

Stimulate production of organic matter



Primary productivity = organic matter produced from CO₂ (alkalinity - HCO₃⁻) and nutrients

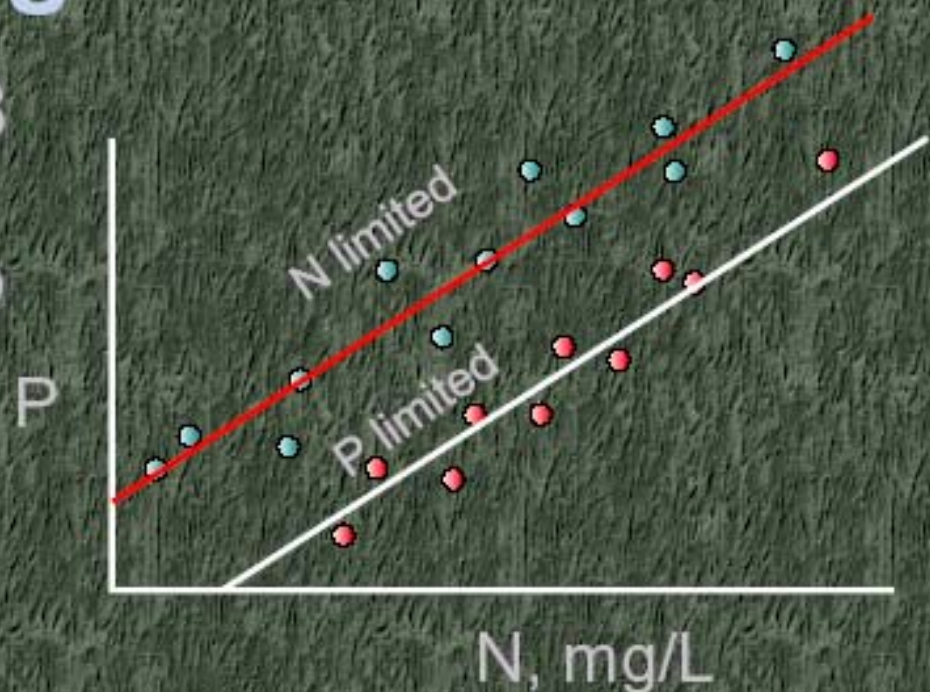


Limiting Nutrient

N/P ratio for algae ≈ 8

* if N/P of water > 8 to 15, phosphorus is limiting

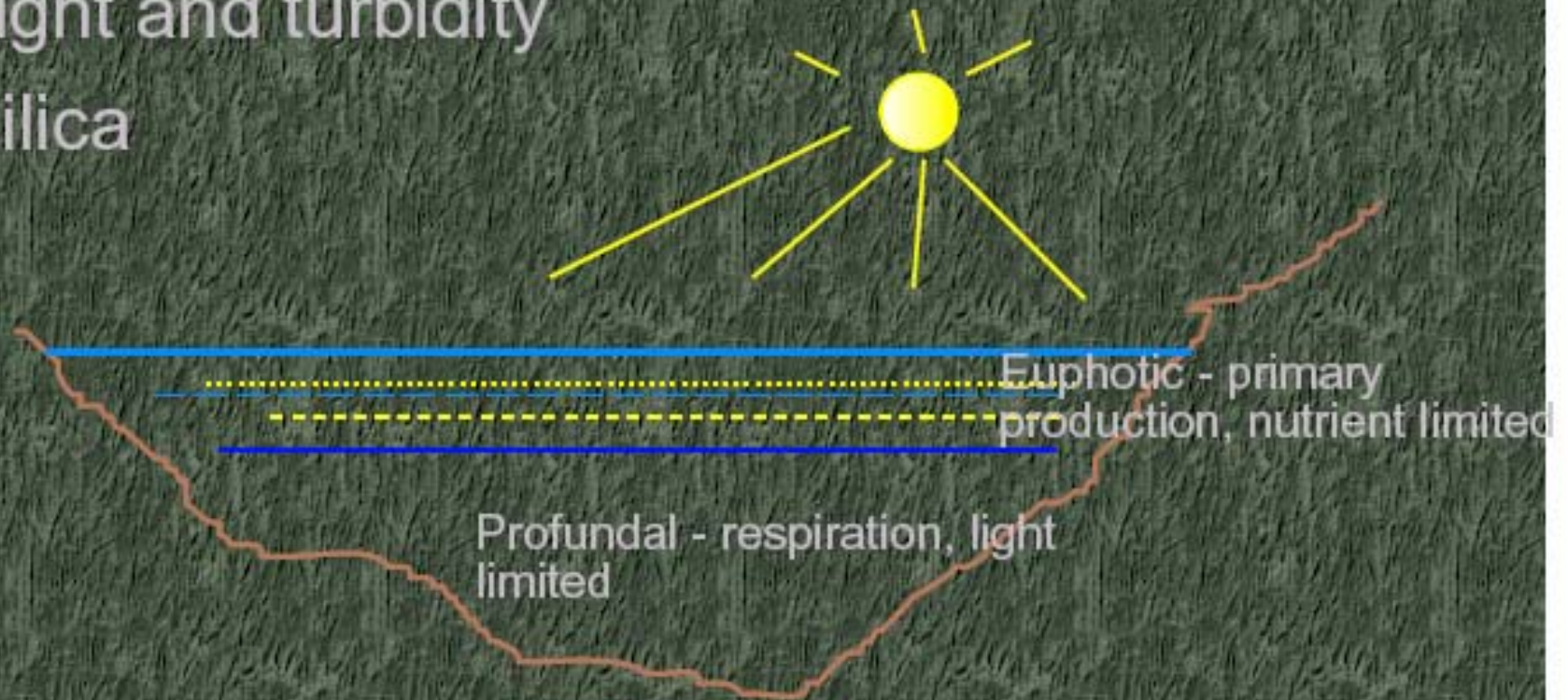
* if N/P < 5 to 8, N is limiting

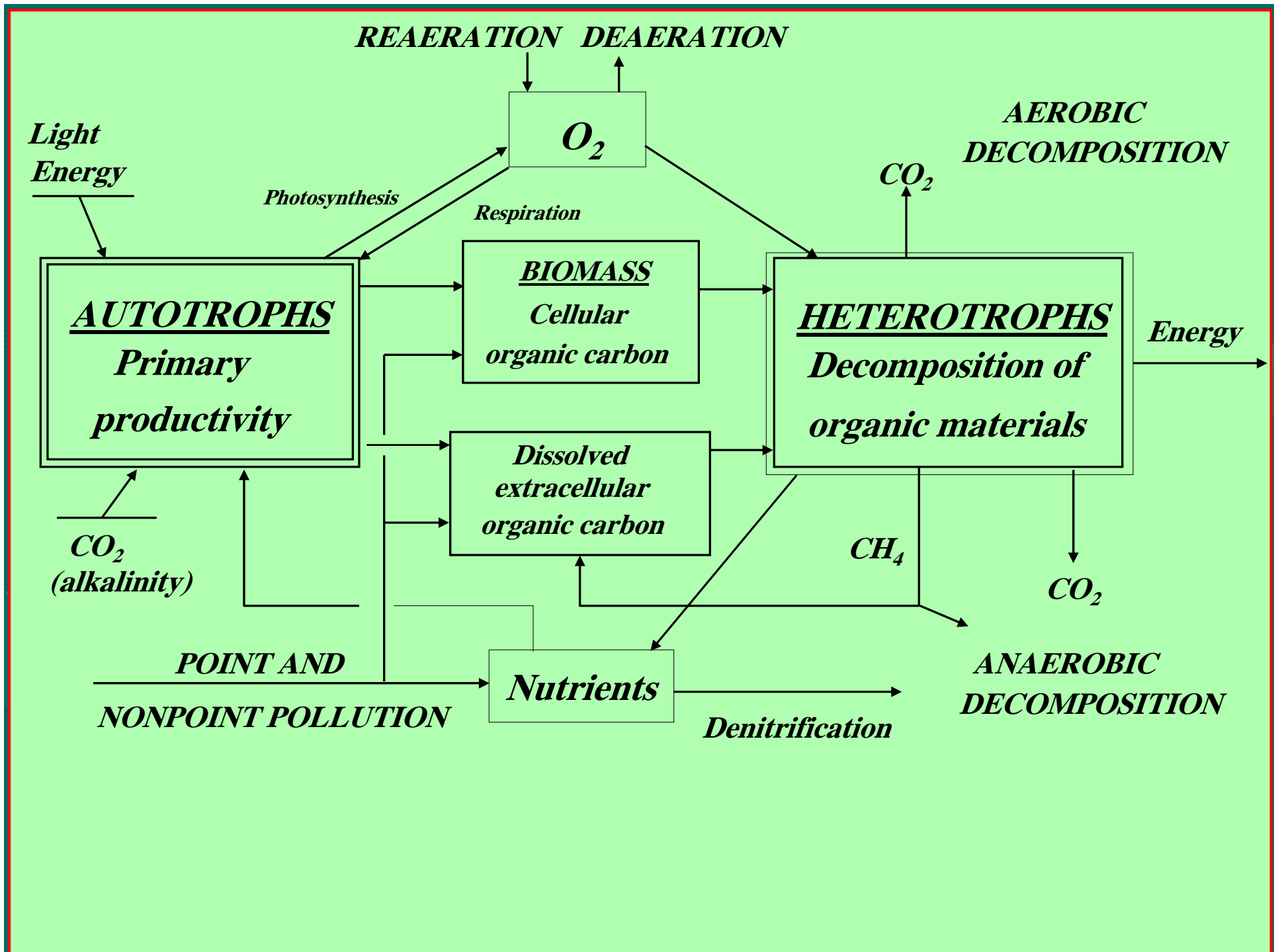


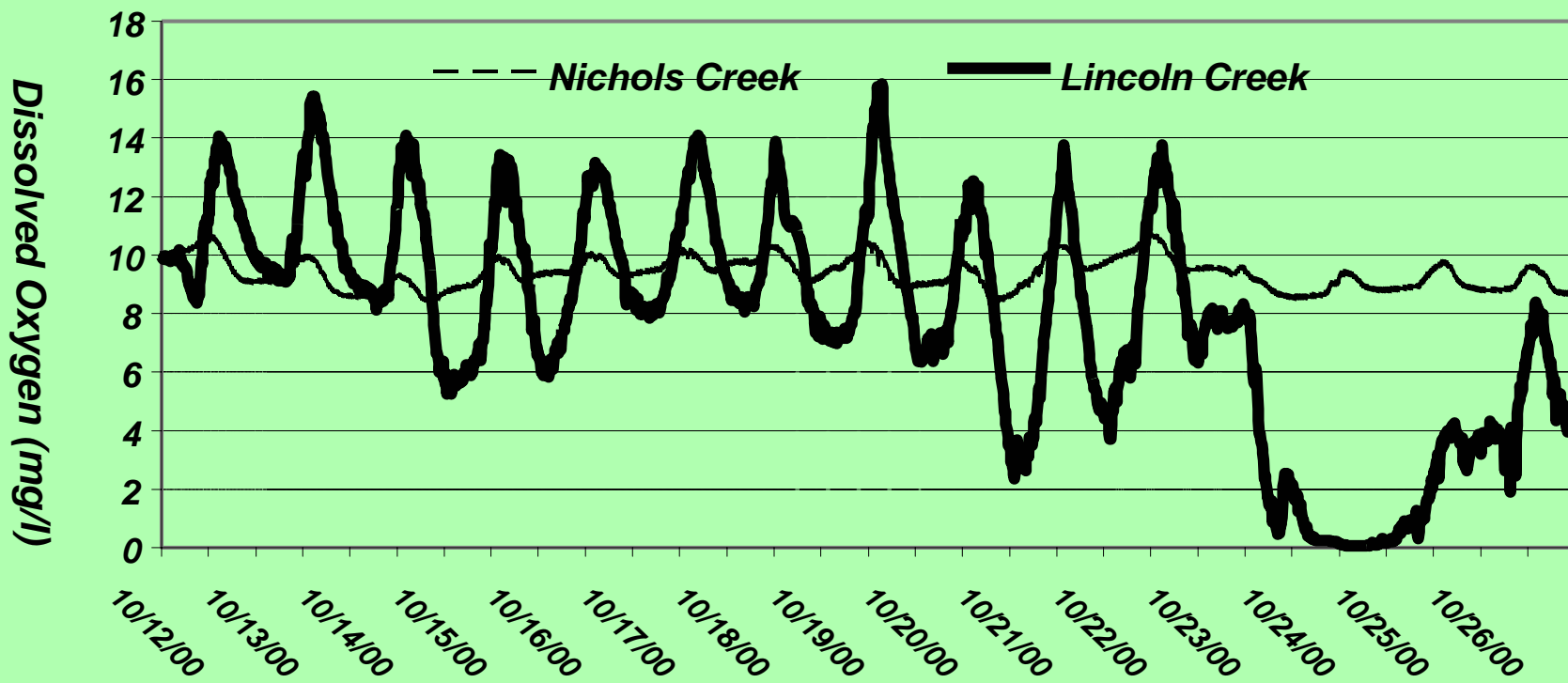
Typically, for inland lakes P is limiting
For marine waters N is limiting
Rivers both can be limiting

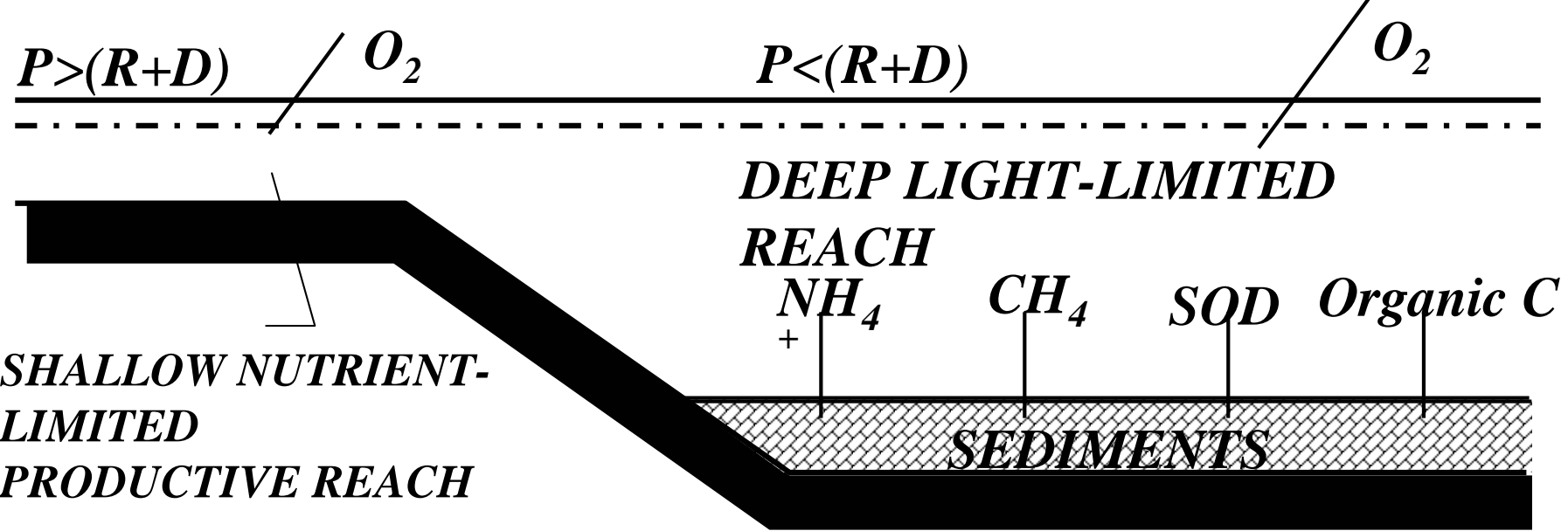
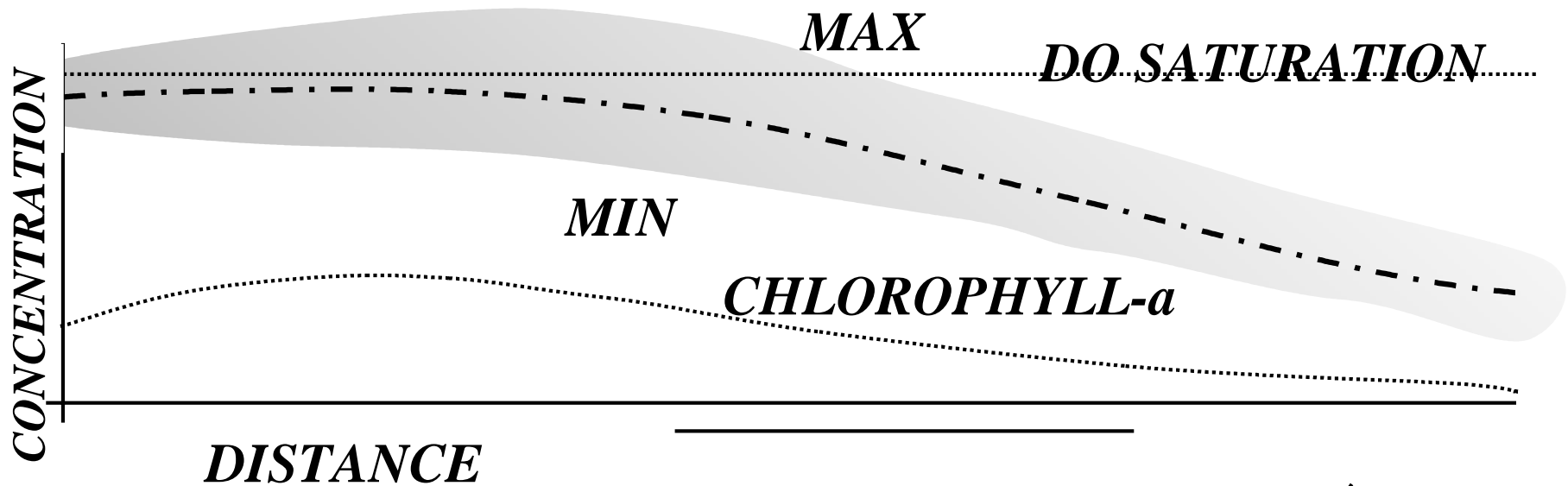
Other limitations

- Alkalinity (Inorganic carbon) Alk , 25 mg/l
- Light and turbidity
- Silica

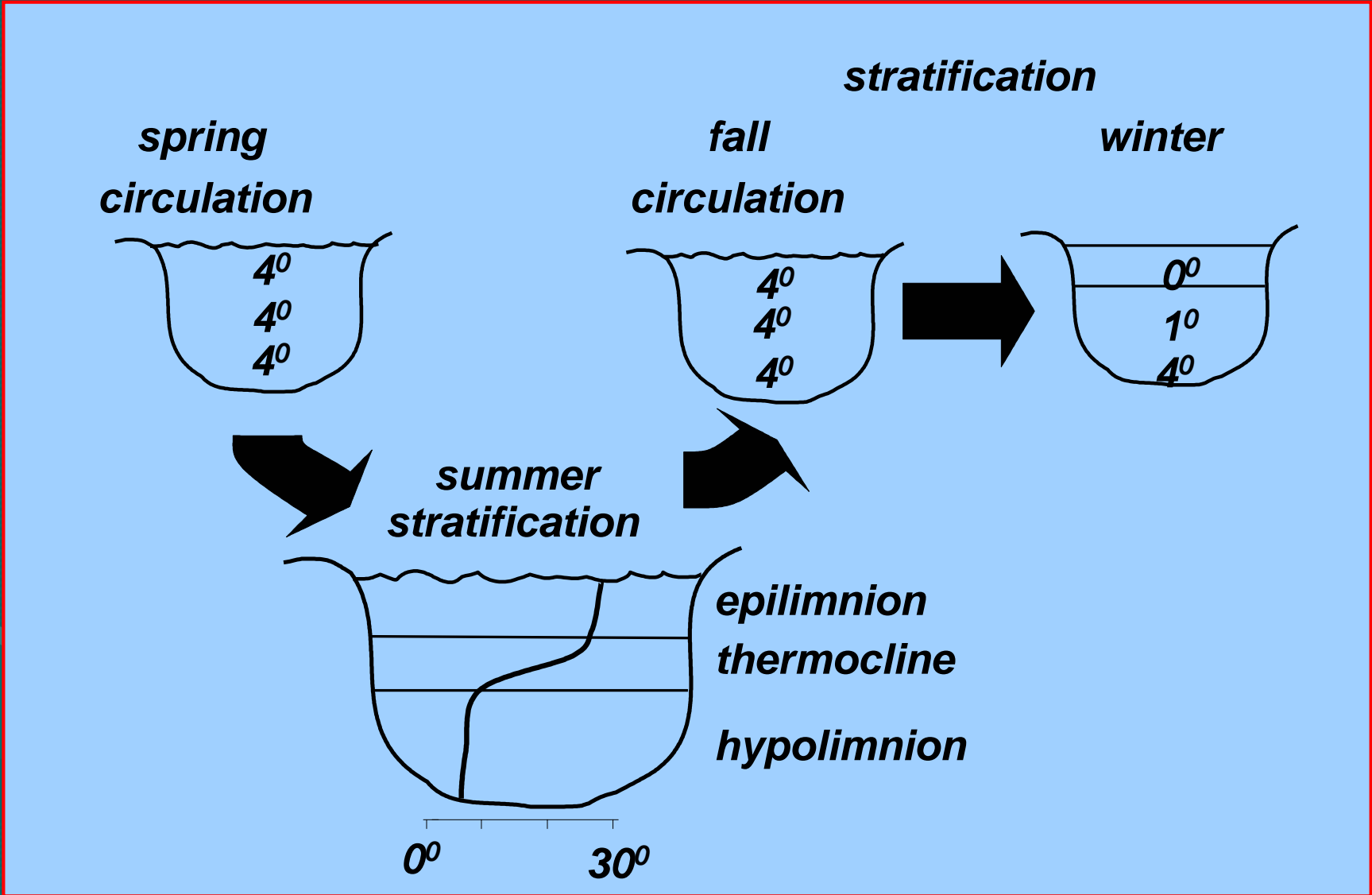




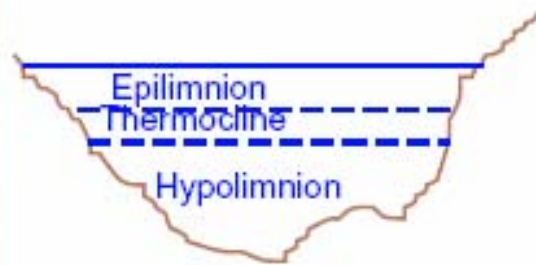




P - photosynthesis
(R+D) - respiration, death and grazing



Pollutant concentrations during stratification



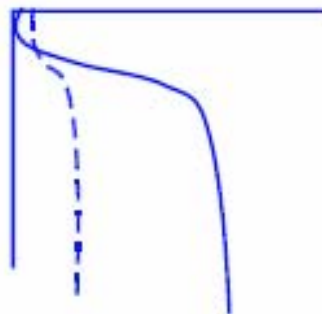
Temperature



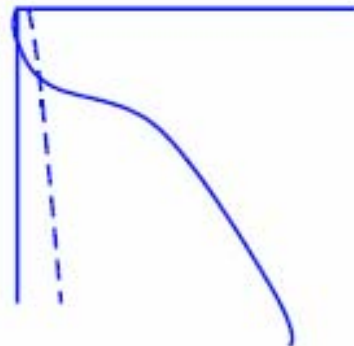
Dissolved Oxygen



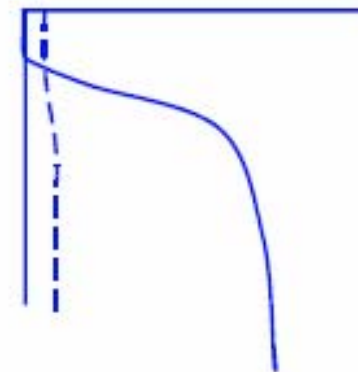
Iron (Fe), Manganese (Mn)



Phosphorus



Ammonium



Reason - anoxic hypolimnium

Trophic status of lakes.

Water quality	Oligotrophic	Mesotrophic	Eutrophic	Source
Total P ($\mu\text{g/L}$)	<10	10 - 20	>20	U.S. EPA (1974)
Chlorophyll <i>a</i> ($\mu\text{g/L}$)	<4	4 - 10	>10	U.S. EPA (1974)
Secchi disc depth (m)	>4	2 - 4	<2	U.S. EPA (1974)
Hypolimnetic oxygen (%saturation)	>80	10 - 80	<10	U.S. EPA (1974)
Phytoplankton Production (g of org C/m ² -day)	7 - 25	75 - 250	350 - 700	Mason (1991)

SCREENING MODELS

Trophic index by Carlson

$$\text{TSI}(\text{SD}) = 60 - 14.43 \ln(\text{SD})$$

$$\text{TSI}(\text{Chl}) = 30.56 - 9.81 \ln(\text{Chl})$$

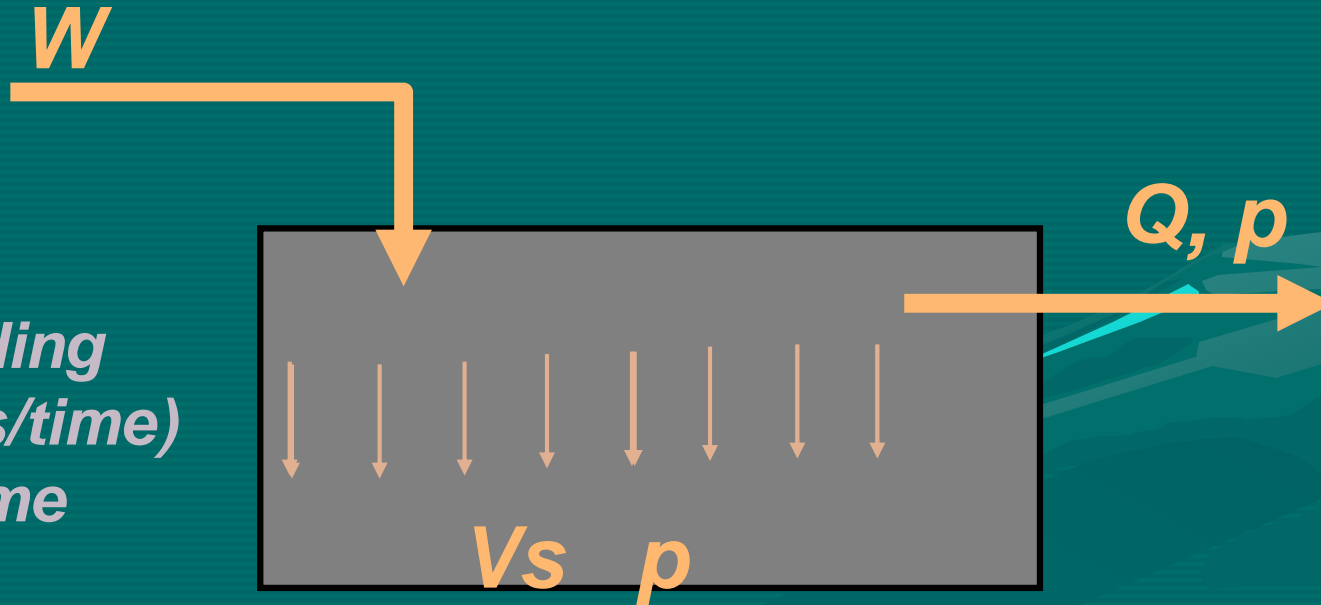
$$\text{TSI}(\text{TP}) = 4.14 + 14.43 \ln(\text{TP})$$

where SD = Secchi disc depth in meters

Chl = Chlorophyll concentration in $\mu\text{g/L}$

TP = Total phosphorus concentration in $\mu\text{g/L}$

VOLLENWEIDER'S COMPLETELY MIXED LAKE SCHEMATIC



W = loading
(Mass/time)

V = volume

Q = flow

p = concentration

n

V_s = settling
velocity

A_s = surface
area

$$V \frac{dp}{dt} = W - V_s A_s p - Qp$$

SIMPLE STEADY STATE SOLUTION

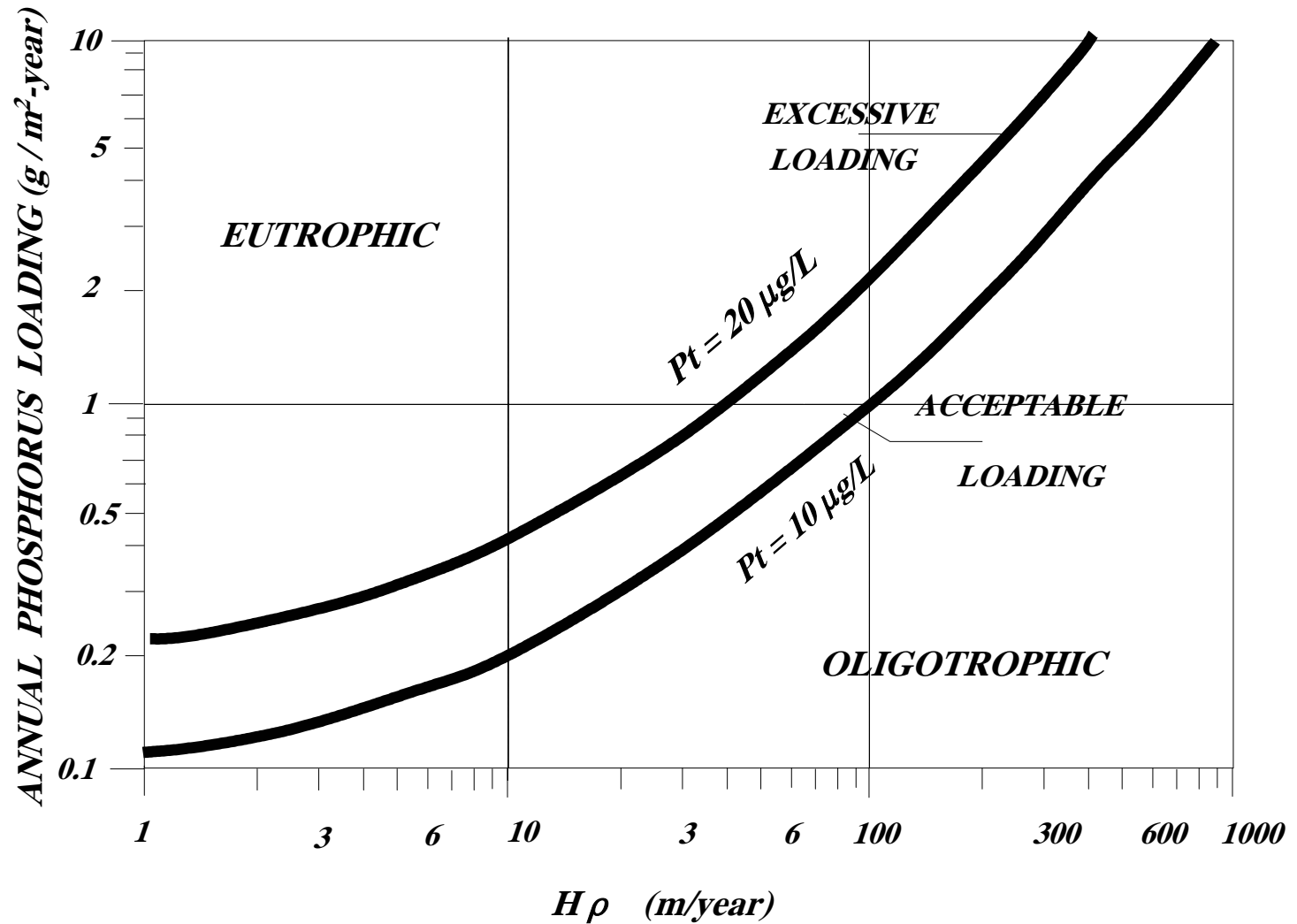
$$p = \frac{W'}{H\rho(1 + \sqrt{1/\rho})}$$

W' = Loading of pollutant per unit area,
W/A_s

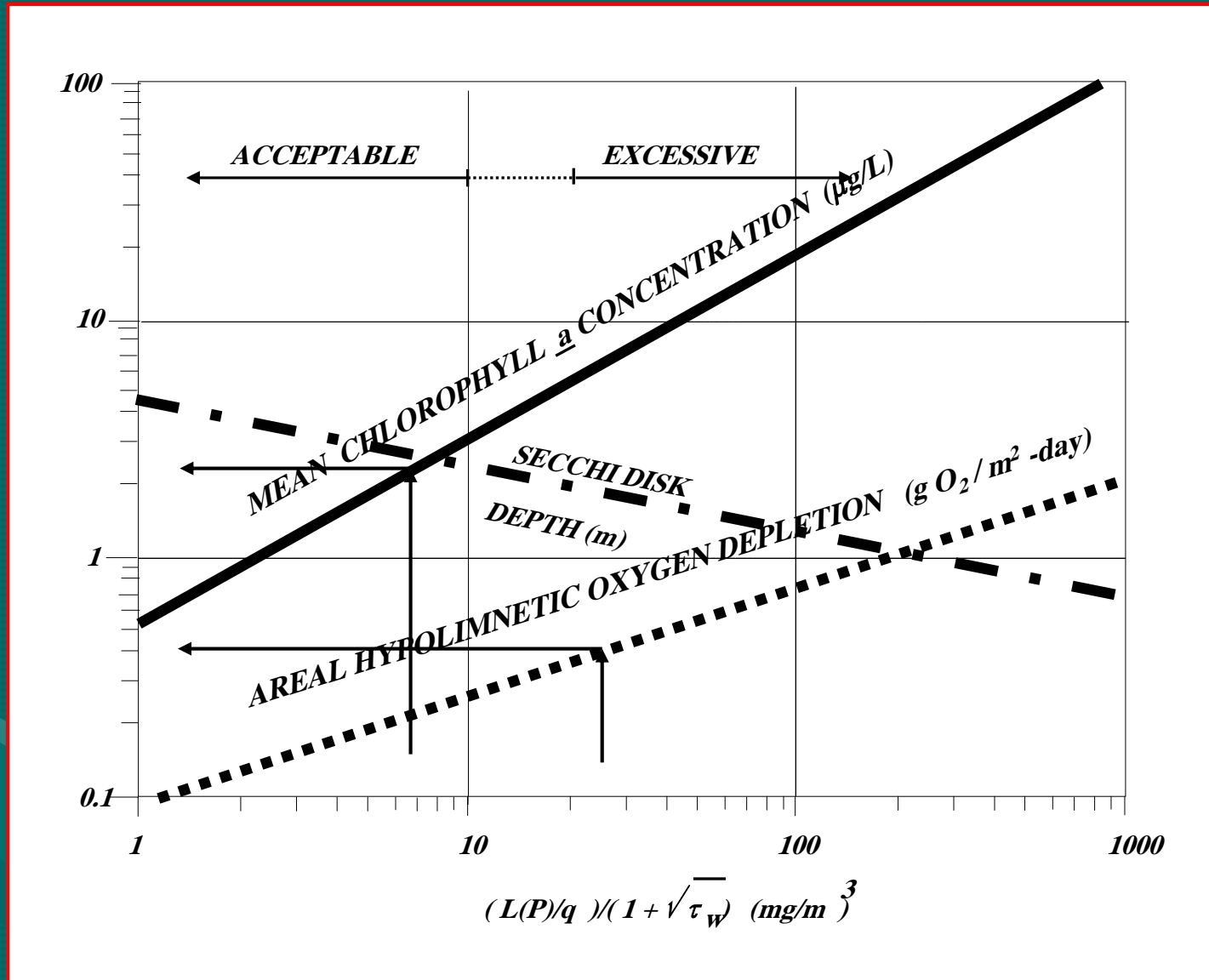
ρ = *Q/V* = flushing rate of the
impoundment

H = average depth

Vollenweider nutrient loading chart



Fred Lee's eutrophication symptoms relationships



Cyanobacteria (Blue Green Algae)

- Cyanobacteria have been around for more than 3 billion years
- These microorganisms are responsible for atmospheric dissolved oxygen
- Some species can assimilate atmospheric nitrogen
- They are ubiquitous to nature
- They prefer warmer water bodies
- They produce toxins and impair taste and odor

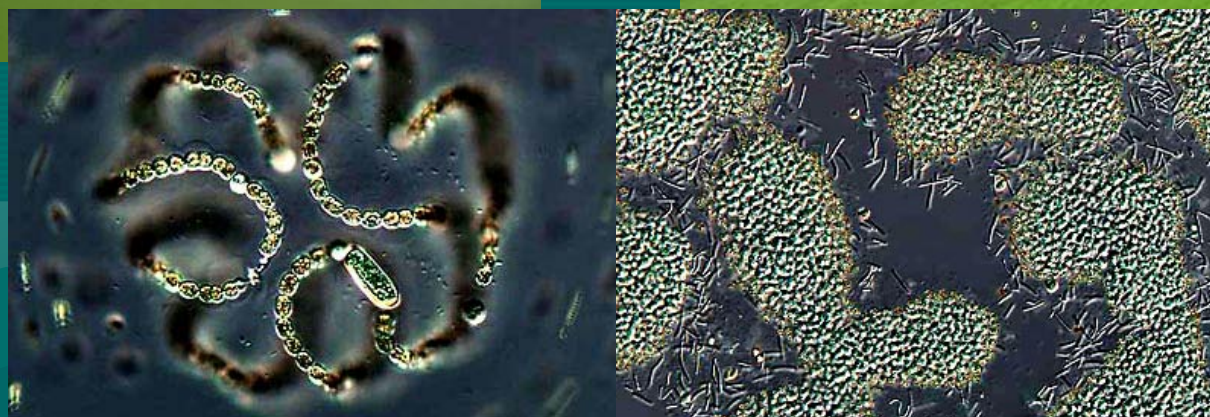
Blue – Greens in Czech Republic



Orlík

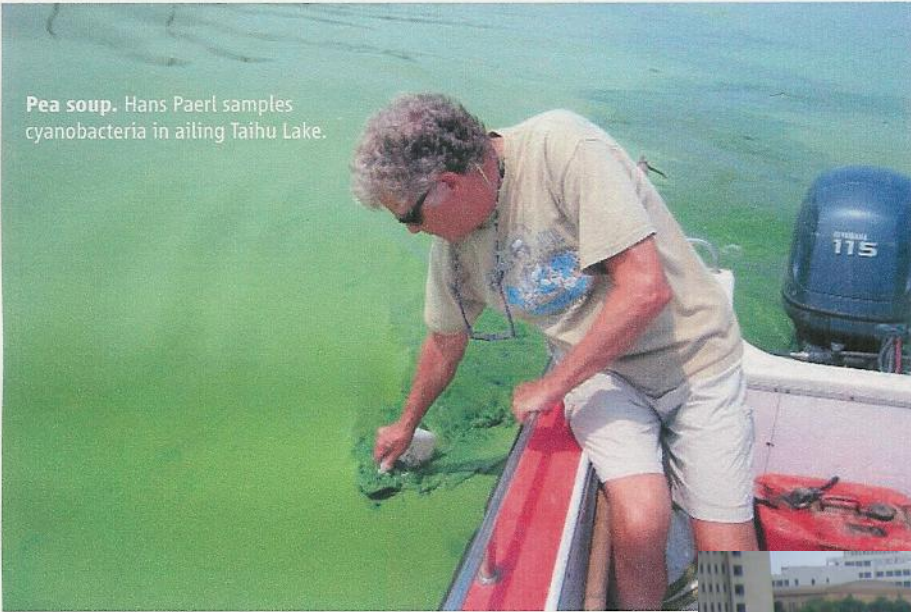


Sedlice



75% of reservoirs have been infected

Pea soup. Hans Paerl samples cyanobacteria in ailing Taihu Lake.



PEA SOUP IN CHINA

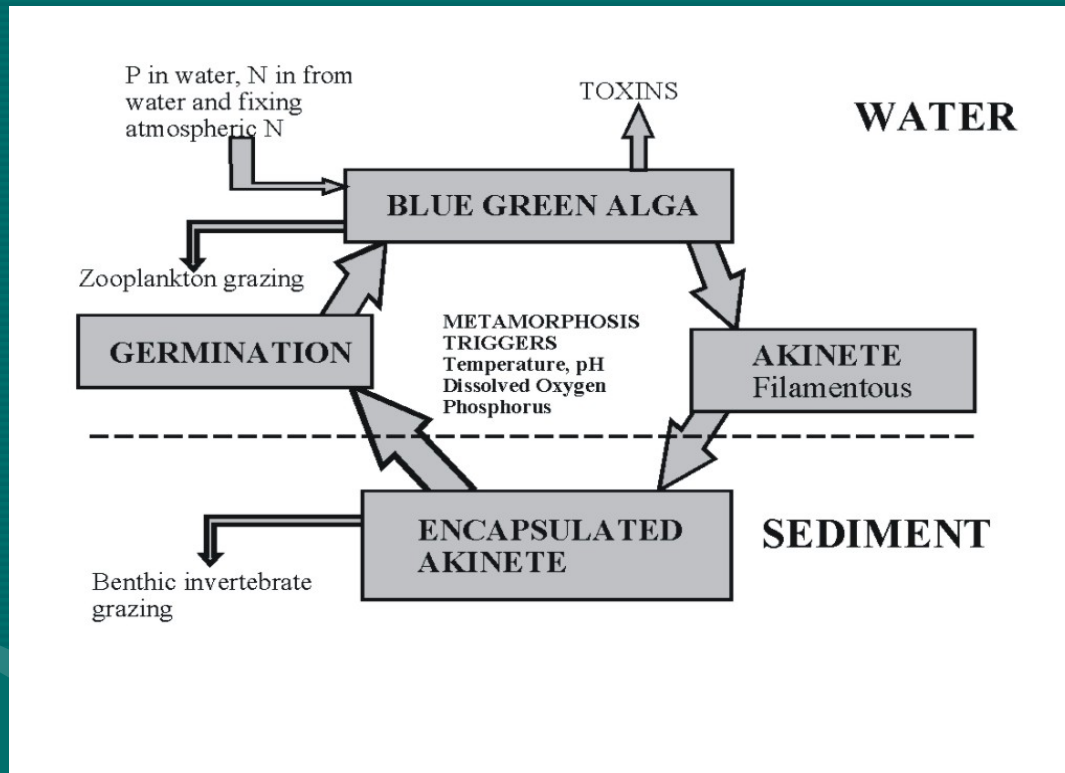
ECOLOGY

Doing Battle With the Green Monster of Taihu Lake

In attempting to subdue a vicious algal bloom, scientists aim to



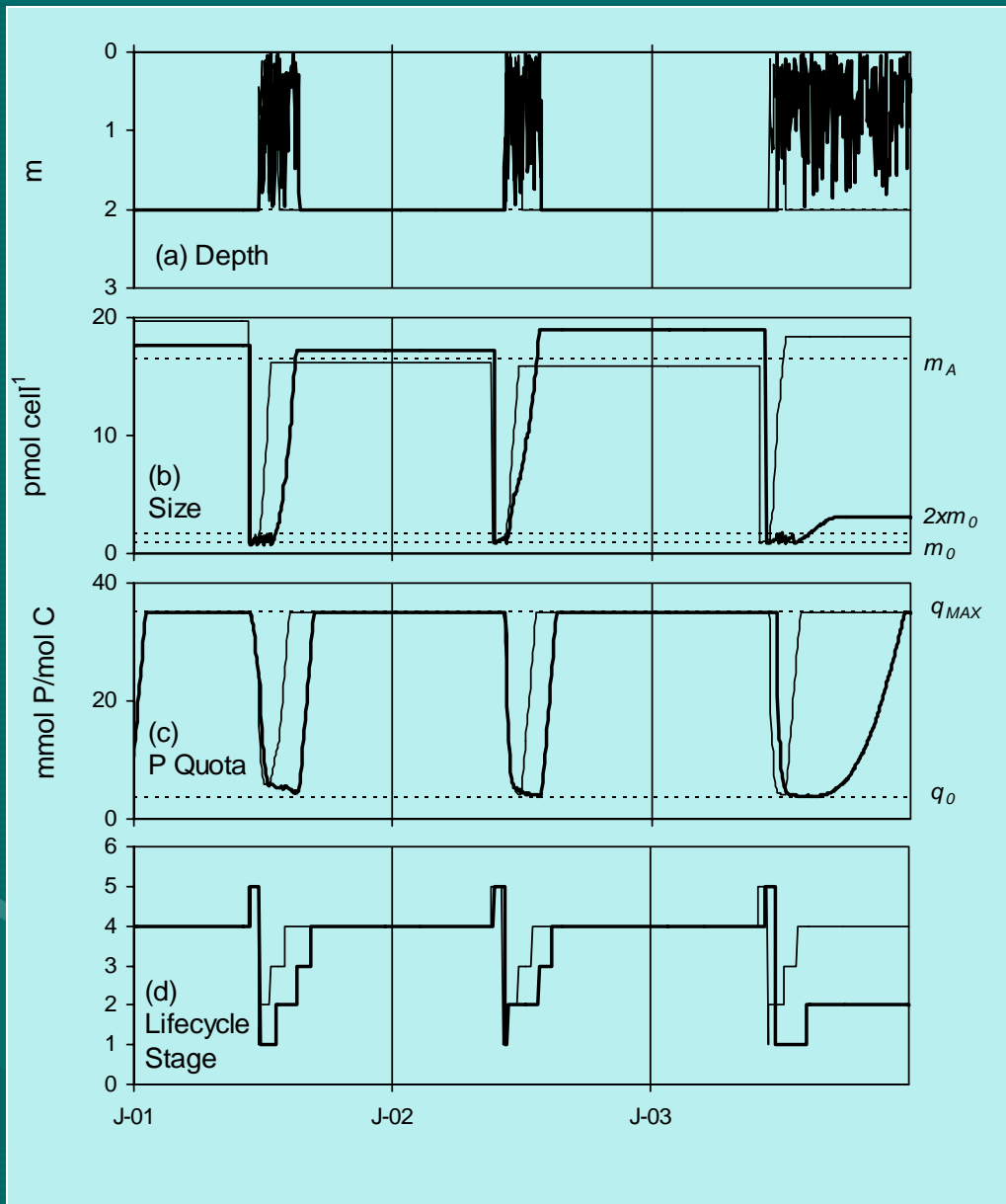
Bluegreens have four lives



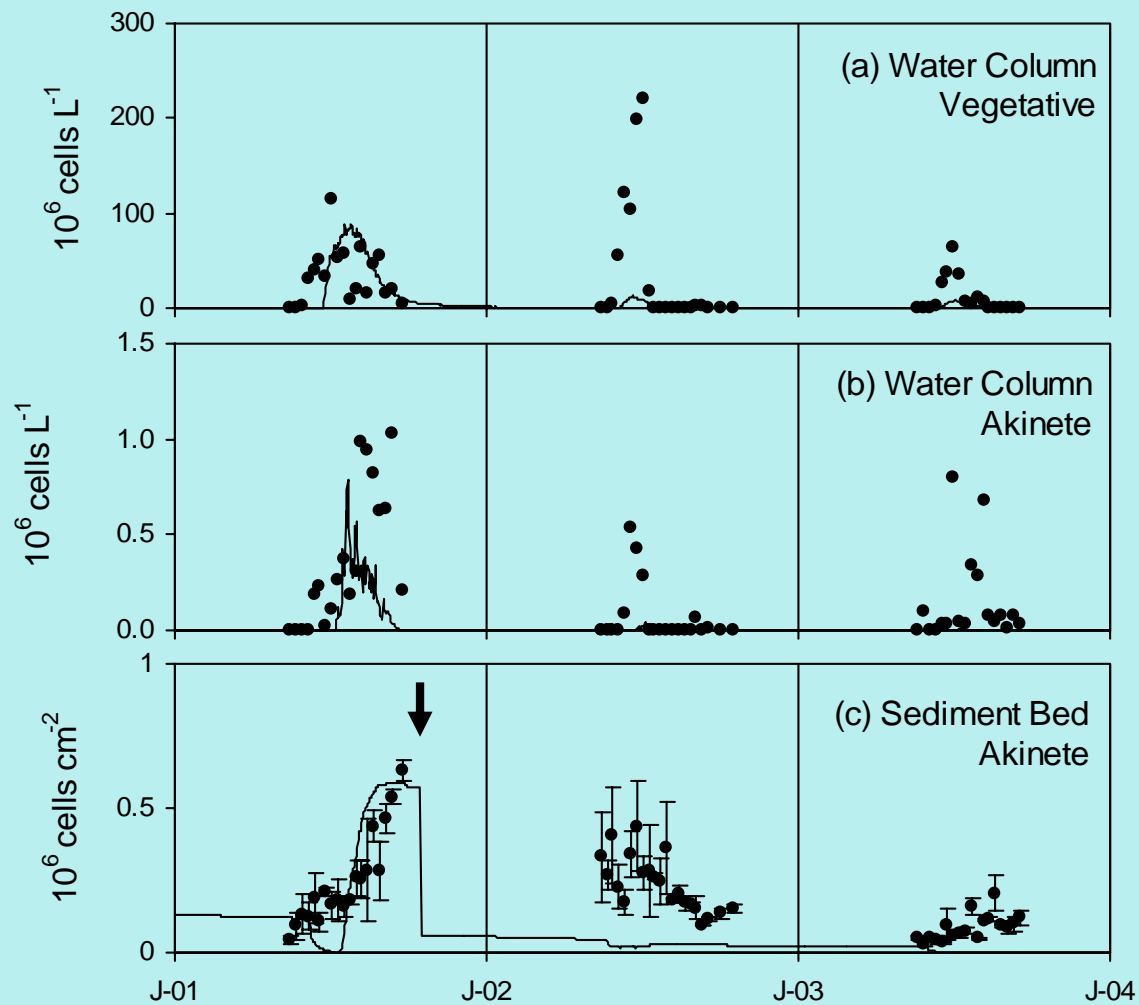
Vollenweider model does not work

Agent Based Modeling

- Ferdi Hellweger is expert
 - See Hellweger, Kravchuk, Novotny and Gladyshev (2008) Agent based modeling of the complex lifecycle of Cyanobacterium (*Anabena*) in a shallow lake, *Limnologia and Oceanographia* to be published soon
- Agent base models follow a history of of thousands of “superagents” and behavior, life cycle and resting stages in water and sediment



History of two randomly-selected individual *Anabaena* cell lineages. (a) Depth (z), (b) size (m), (c) P quota (qP), and (d) lifecycle stage. Only one of two daughter cells is followed after division. Outflow and lysis loss is not permitted for the tracked cells.



Model simulation to investigate the effect of reducing the sediment akinete density. The sediment akinete density was reduced by 90% towards the end of year 1 (see arrow in panel c).

Wetlands are natural sinks of nutrients

