Chemical limnology

Limnology

Lecture 8

Outline

- Carbon cycle
- Nutrients
- Toxic chemicals

pH

Measure of hydrogen ion concentration
Expressed as 10^x moles of hydrogen ions per liter
pH = - log10(H+ ions)

0.0000001 = 1 x 10^{-7} moles H+
-log10(1 x 10^{-7})
pH = 7

pH < 7 acid
pH = 7 neutral (H+ and OH- equal)
pH > 7 basic

Sources and forms of carbon in Lakes

- Sources
  - Atmosphere
  - Rocks (limestone and dolomite) and soils
  - Detritus – dead organic material
- Forms
  - Dissolved Inorganic Carbon (DIC) – CO_2
  - Dissolved Organic Carbon (DOC) – methane, humic acids
  - Particulate Organic Carbon (POC) – living, dead organisms, feces

Carbon cycle

- Fig. 10.1

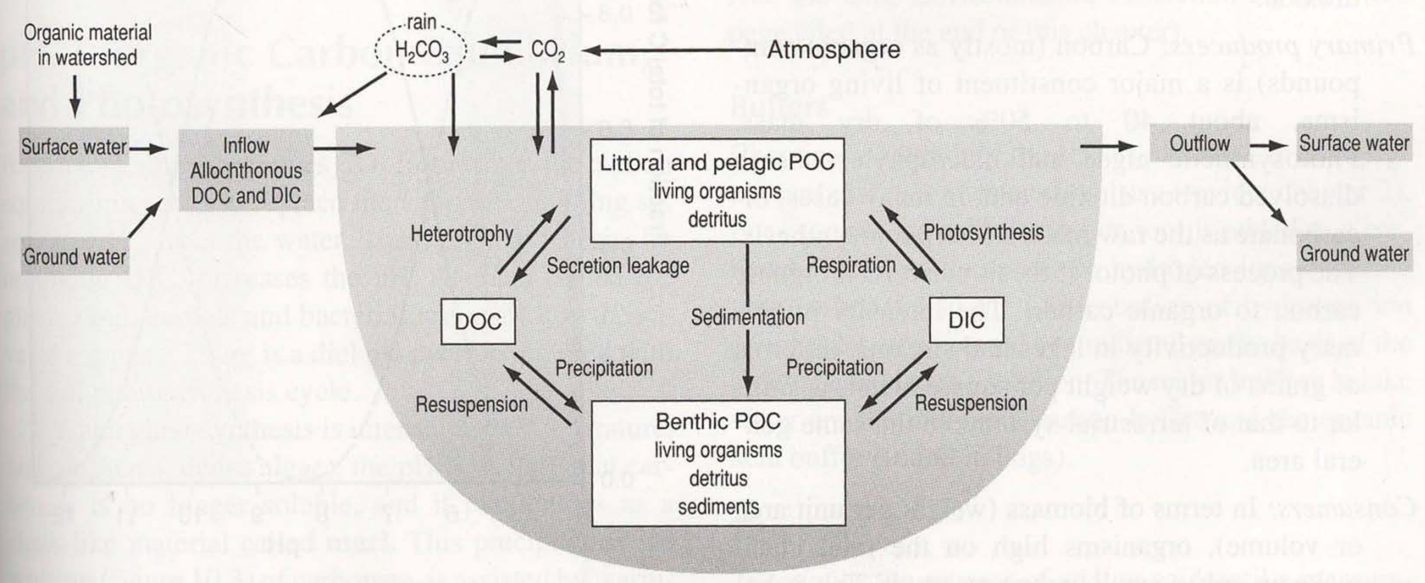


FIGURE 10.1 The carbon cycle for Lawrence Lake, Michigan. POC = particulate organic carbon; DIC = dissolved inorganic carbon; DOC = dissolved organic carbon. The boxes represent various carbon reservoirs in lakes.

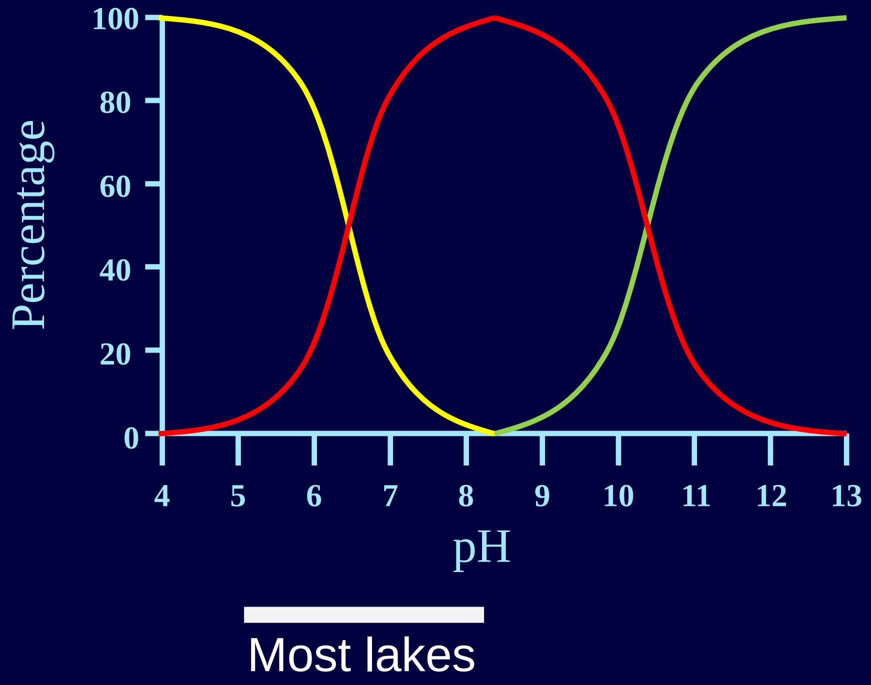
Carbon Dioxide in Lakes

- Critical: Photosynthesis
- Highly soluble – CO_2 200x more soluble than O_2

Carbon Dioxide in Lakes

$CO_2 + H_2O \Leftrightarrow H_2CO_3$

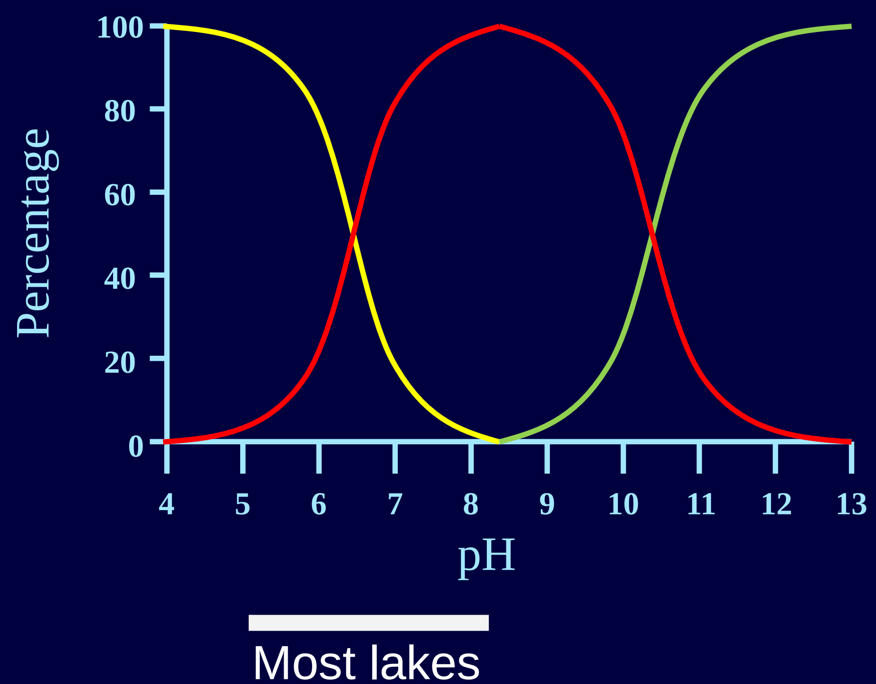
Carbonic acid



Carbon Dioxide in Lakes

$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+$

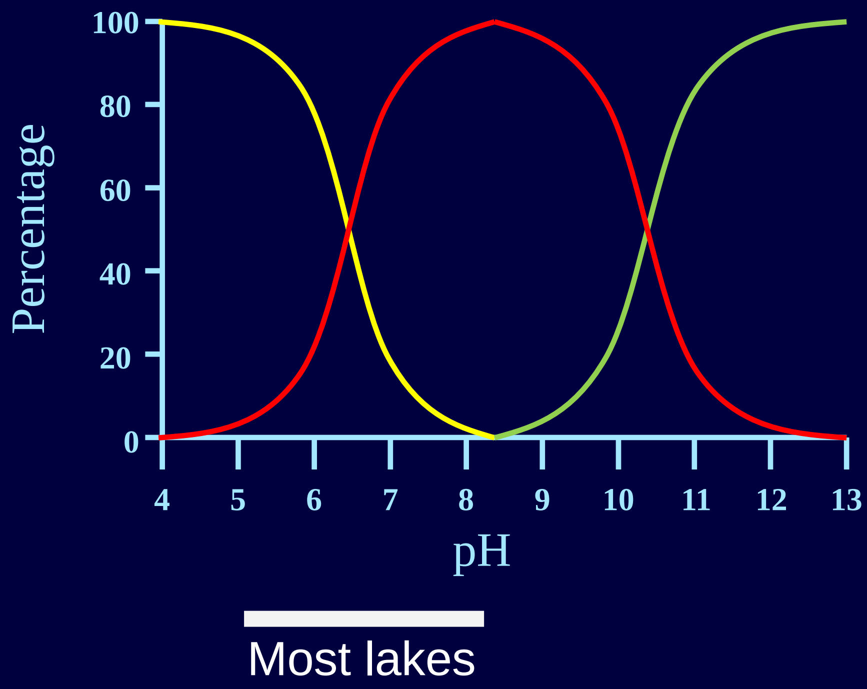
Carbonic acid   Bicarbonate



Carbon Dioxide in Lakes

$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2\ H^+$

Carbonic acid Bicarbonate Carbonate



Carbon Dioxide in Lakes

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2\,H^+$$

Carbonic acid Bicarbonate Carbonate

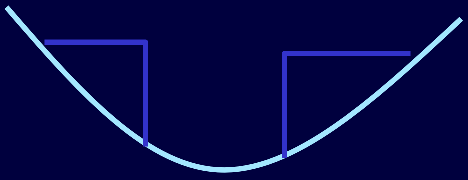
Add CO_2, increase H+, decrease pH

Remove CO_2, decrease H+, increase pH

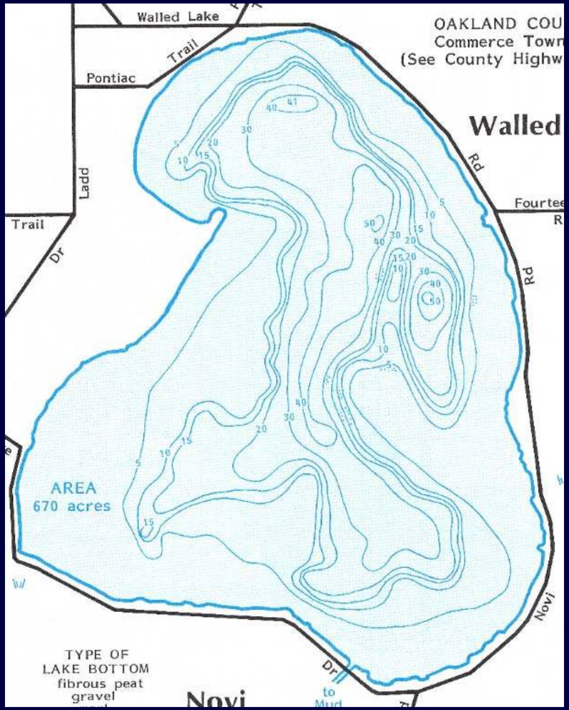
Marl Lake (also known as Bench Lake)

$$Ca(HCO_3) \Leftrightarrow CaCO_3 + H_2CO_3$$

Calcium bicarbonate (highly soluble) | Calcium carbonate (low solubility)



'Marl Lakes' or 'Bench Lakes'



Shallow margin created by Calcium Carbonate deposition over thousands of years

Carbon Dioxide in Lakes

Alkalinity – buffering capacity of water relative to acid input

Alkalinity = HCO_3^{-} +2 CO_3^{2-} + OH^{-} - H^{+}

Limiting nutrients

Nitrogen (amino acids)

Phosphorus (ATP)

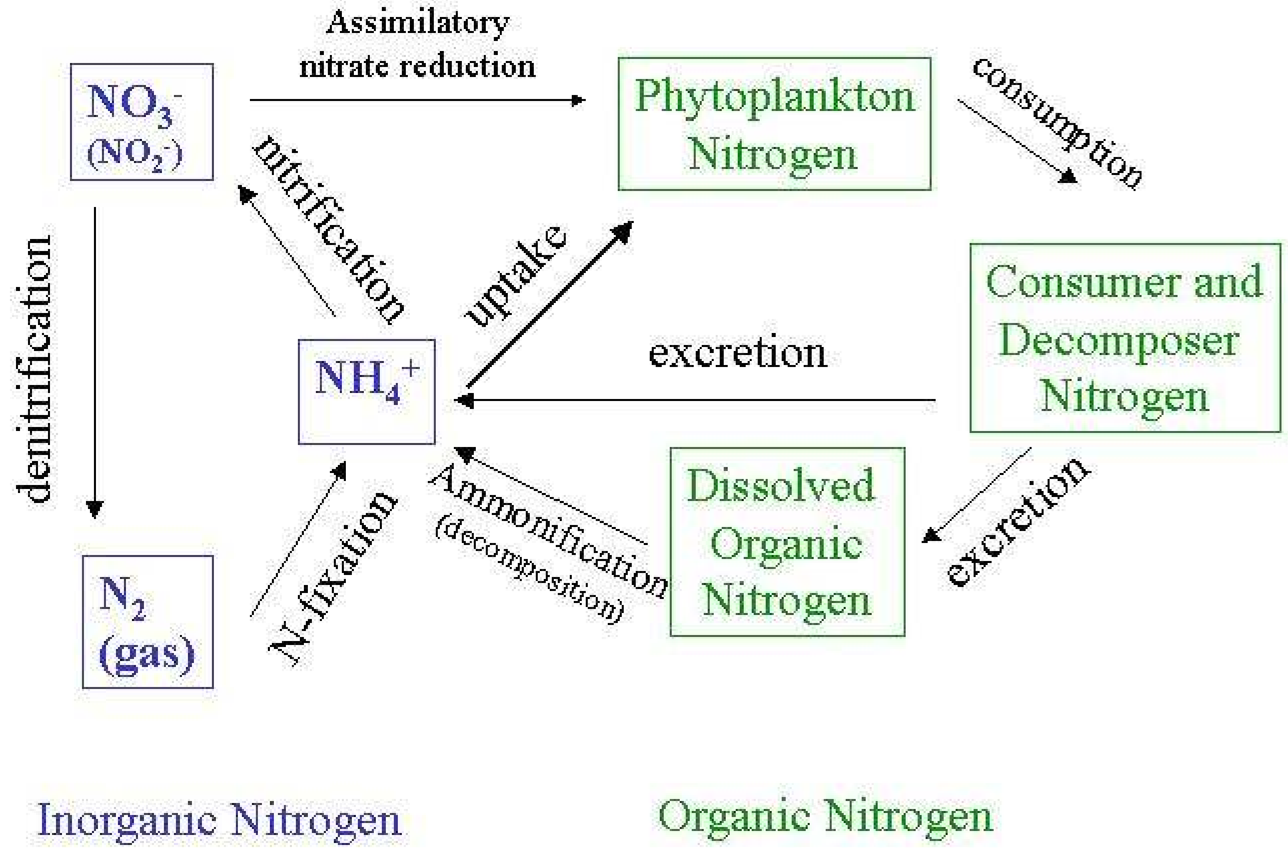
Nitrogen

Forms
- Nitrogen gas (N_2)
  - inert, not bio-available
- Nitrate (NO_3^-)
  - bioavailable
- Nitrite (NO_2^-)
  - toxic
- Ammonia (NH_3 in water NH_4^+)
  - Nitrogen fixation from bacteria
  - Excretion

Sources of N
- Fixation by bacteria (e.g., cyanobacteria)
- Lightning/precipitation
- Weathering of minerals/runoff
- Anthropogenic N

Denitrification

Aquatic Nitrogen Cycle



Phosphorous

Sources of P

- Weathering of minerals (deep ocean, coastal sediments)
- Lake sediment
- Decomposition and excretion (major source)
- Anthropogenic P greater than natural inputs of P

Experimental Lakes Area, Lake 227
Experimental addition of P

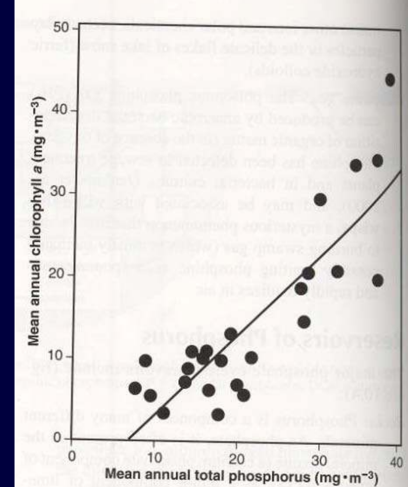


FIGURE 10.5 The relationship between average annual concentrations of total phosphorus and chlorophyll *a* (a measure of algal abundance) in lakes of the Experimental Lakes Area, Ontario, Canada. See figure 8.4 for the relationship between fish production and phosphorus concentration. The wide range of phosphorus concentrations in this figure was made possible by including data from fertilized and unmodified lakes. The correlation explains about 74% of the variation in algal abundance. **Source:** data from Schindler, 1977.

Nutrients

Phosphorus (ATP)

Nitrogen (amino acids)

Redfield ratio: normal ratio in water

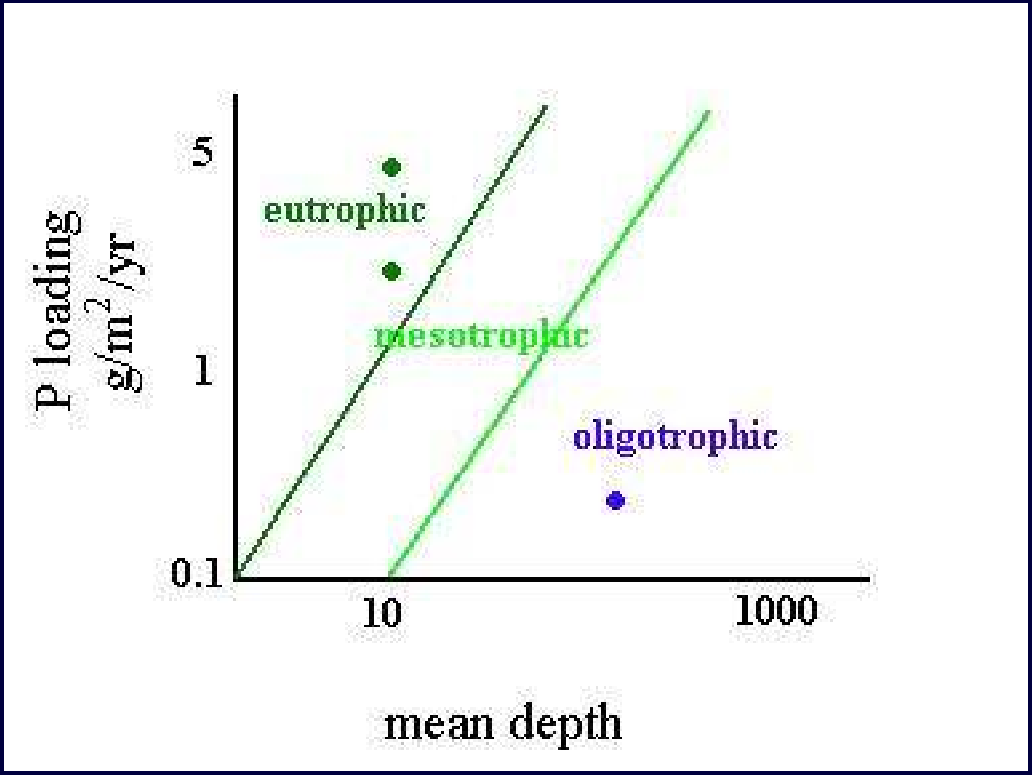
oceans → 106 C : 16 N : 1 P

lakes → 400 C : 30 N : 1 P

Phosphorous often limiting (i.e., available in less quantities than required by organisms)

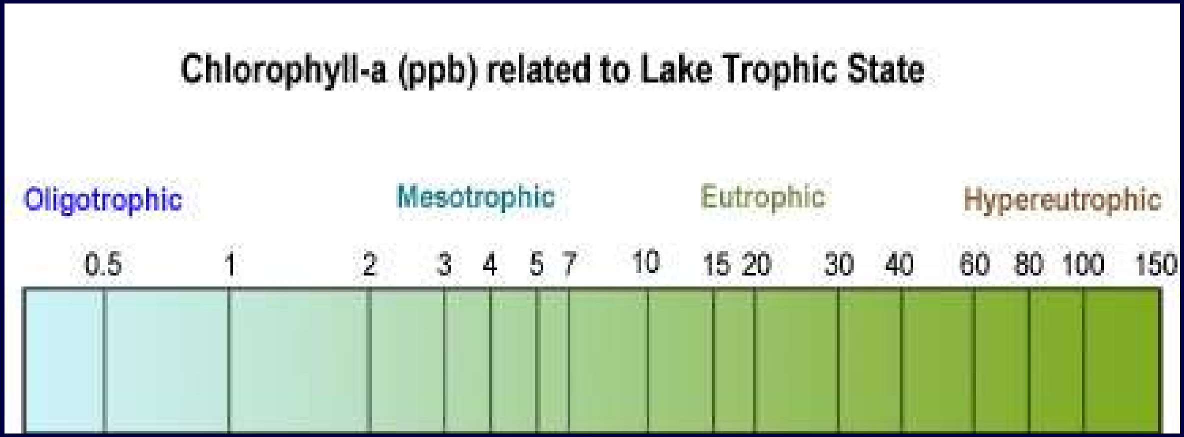
? What does this mean practically?

Phosphorus and productivity



K. Shulz

Lake trophic status



Oligotrophic – low nutrients, high oxygen, low productivity, clear

Eutrophic – high nutrients, anoxic hypolimnion in summer, high productivity, opaque

→ wet meadow (natural)

cultural eutrophication if human

Dystrophic – stained with DOC, low nutrients, low productivity (often small, mtn. lakes in forests)

Oligotrophic – Lake Tahoe

Eutrophic – Lake Mendota

dystrophic – Adirondacks lakes

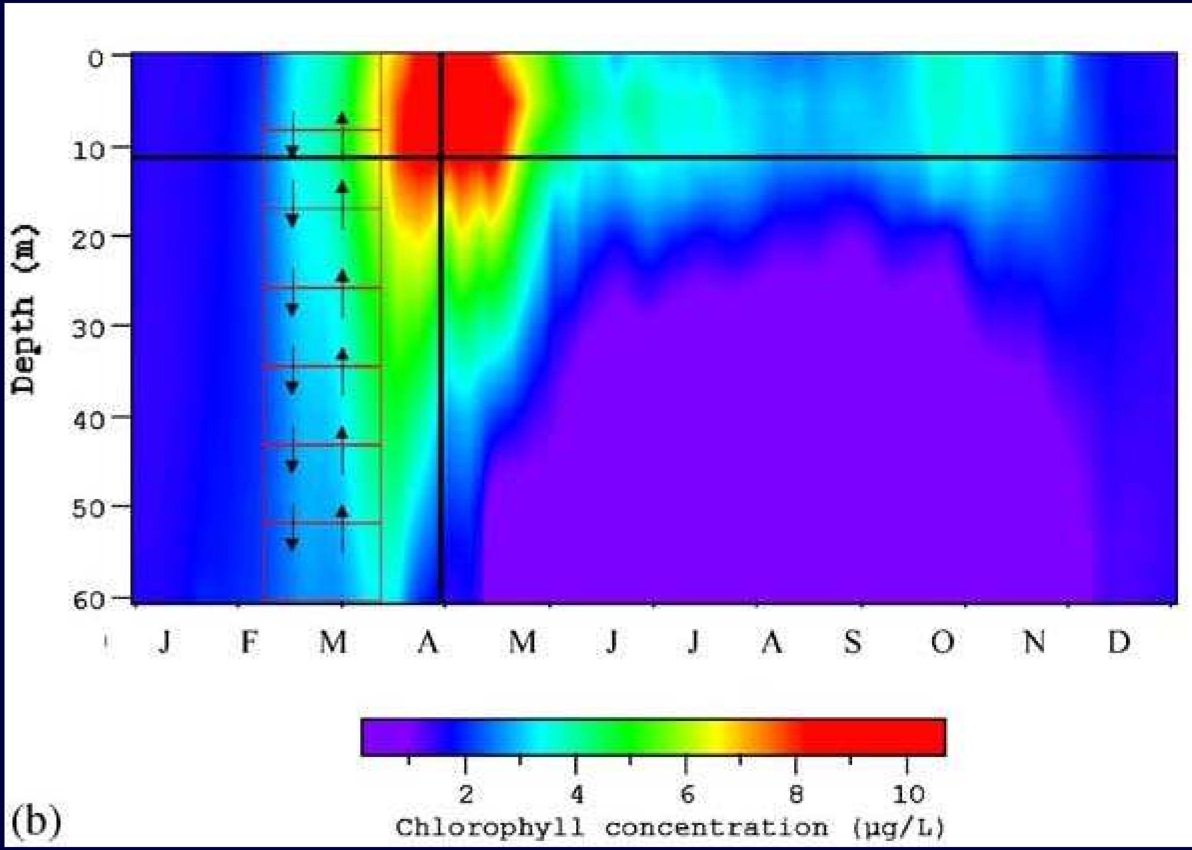
Lake trophic status

PHOSPHORUS AND CHLOROPHYLL CONCENTRATIONS AND SECCHI DISK DEPTHS CHARACTERISTIC OF THE TROPHIC CLASSIFICATION OF LAKES			
	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (mg/m3) Average	8	26.7	84.4
Chlorophyll *a* (mg/m3) Average	1.7	4.7	14.3
Secchi Disk Depth (m) Average	9.9	4.2	2.45
Data from Wetzel, 2001 Table 13-18			

Often spring and late fall algal blooms in temperate lakes

Why?

Mixing effects



Lake Washington, Arhonditsis et al. 2004

Ecological stoichiometry

How ratio of different chemical elements affects ecology and vice versa

Certain species favored under certain conditions

When N/P is low, favors cyanobacteria

Carbon-rich phytoplankton junk food of the lake

(high calorie, no P/N)

couch potato zooplankton can't keep up with phytoplankton

Shift from *Daphnia* to *Bosmina* with low P

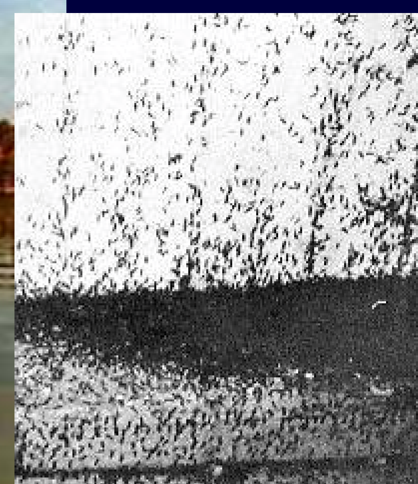
Toxic chemicals

Biomagnification

lipophilic chemicals concentrated up food chain

PCB, DDD/T, Mercury

Clear Lake example



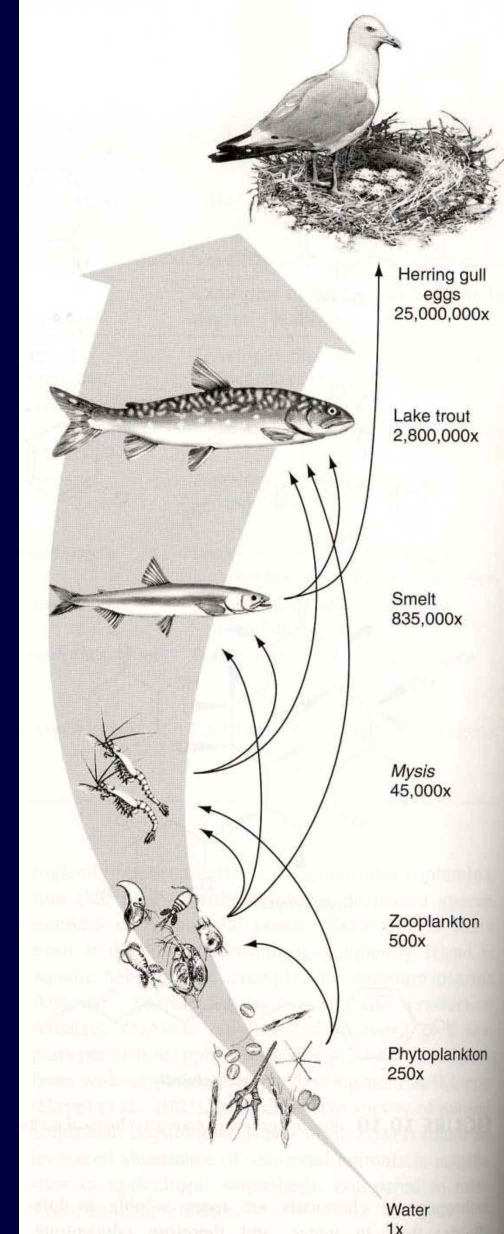
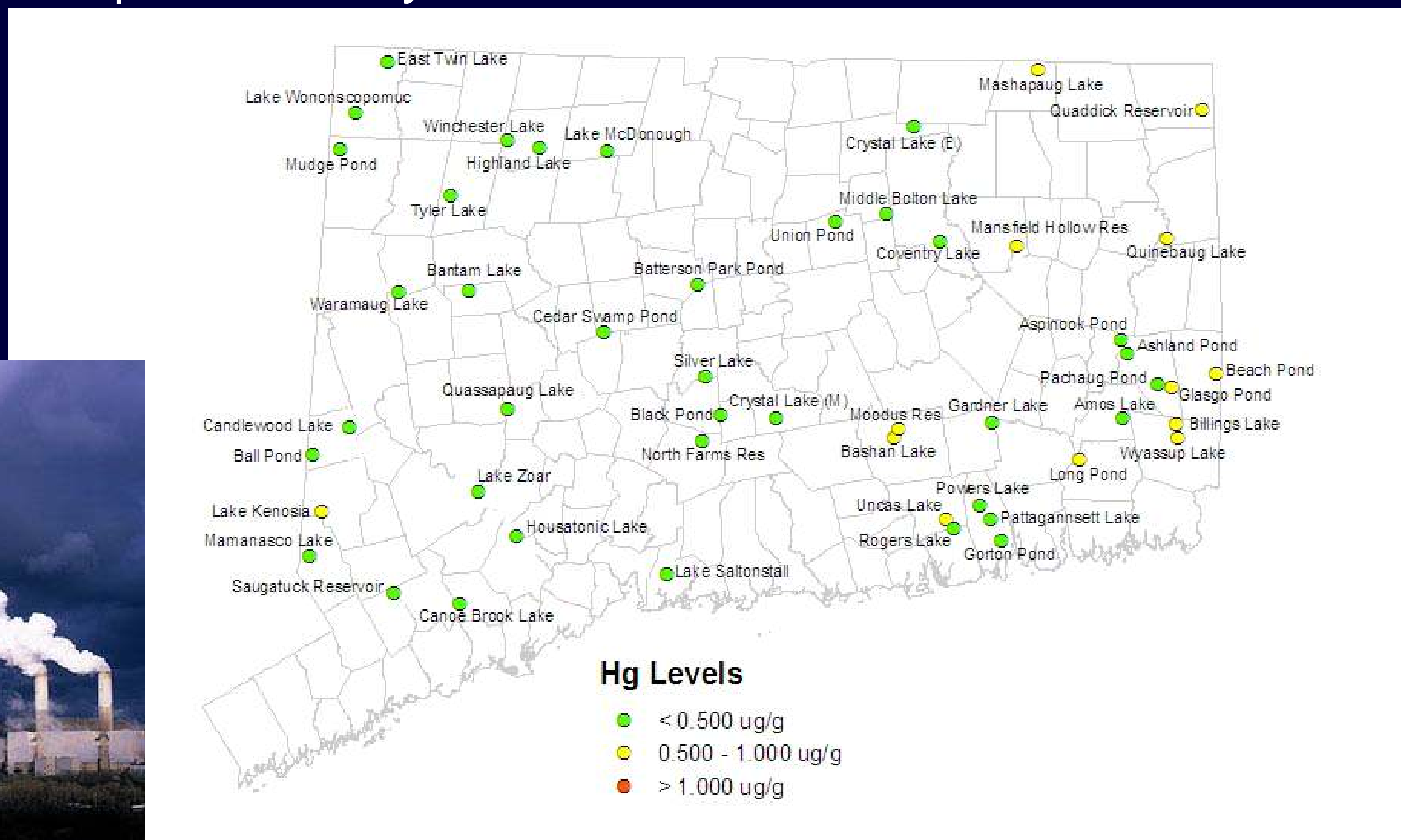


FIGURE 10.12 An example of bioaccumulation. The concentration factors are for PCBs relative to the concentration in the water, which was estimated to have been about 5×10^{-9} g l^{-1} or 5 parts per trillion (Norstrom et al., 1978). The factor of 25 million biomagnification refers to herring gull eggs, which contained about 125 mg PCB kg^{-1} wet weight. See figure 10.11 for the chemical structure of a typical polychlorinated biphenyl.

Toxic chemicals

Mercury in CT
most fish with Hg
statewide consumption advisory



Vokoun & Perkins 2008

Deformities

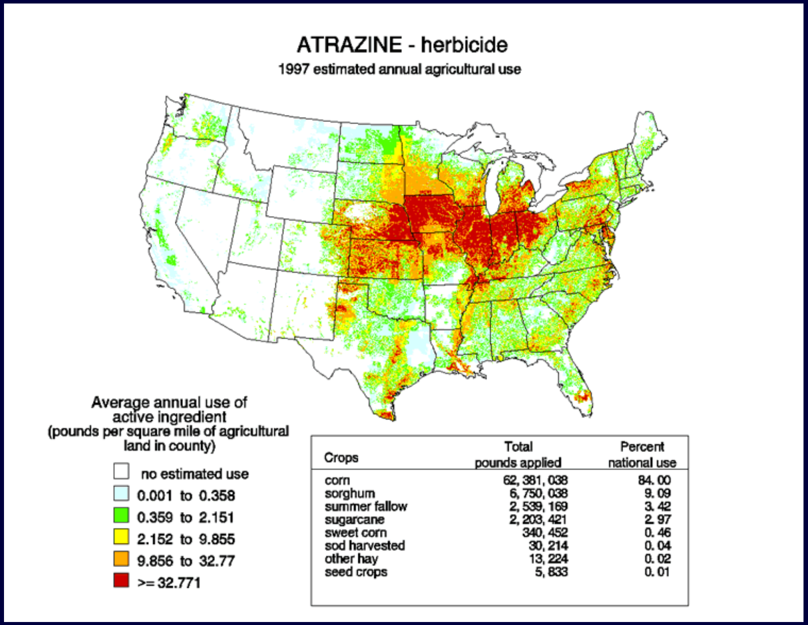
Amphibian deformities reported in many ponds in 90s

- Parasitic infections in limb nodes
- Nutrients increase snails → increases infection by trematode
- Case closed? But high deformities in VT and no trematodes

Deformities

Amphibian males grow female ova producing cells

- Atrazine (common herbicide)
- Case closed? EPA panel reviews experiments and finds faults
  - Results not repeated . . .



Sex and suburban frogs