CHAPTER

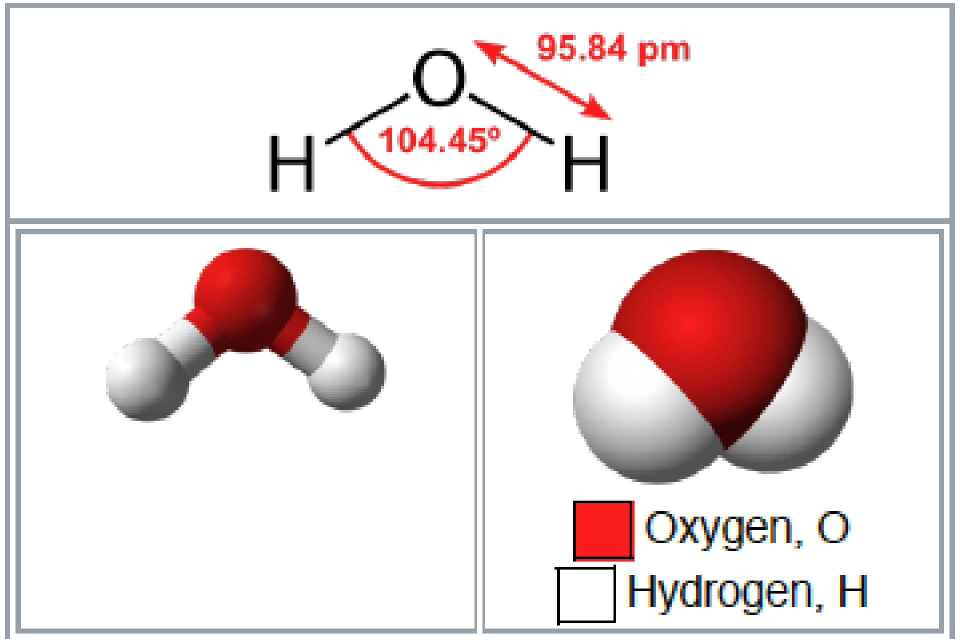
8

Inland Waters

OUTLINE

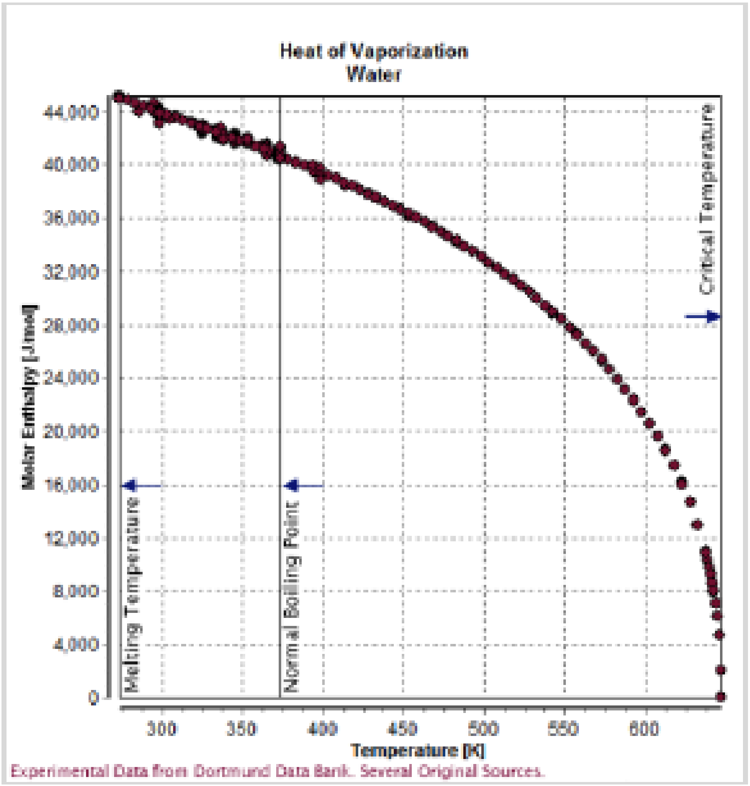
Special Properties of Water

Polar Molecule



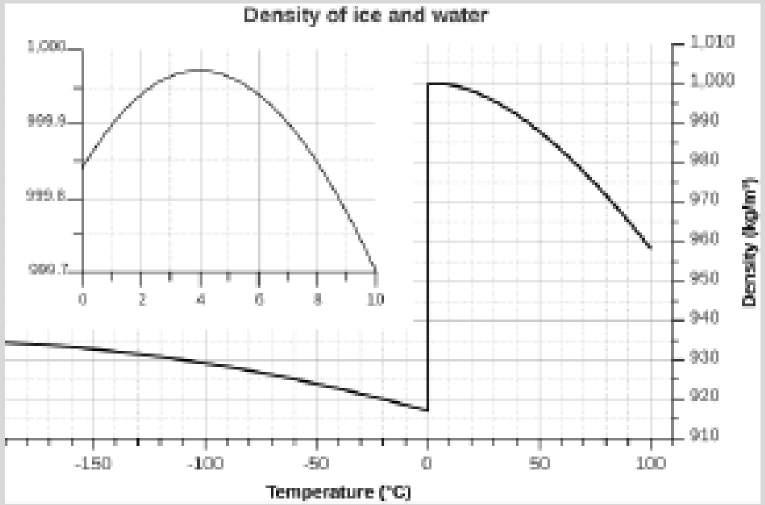
- Excellent Solvent
- Surface Tension
- Capillary Action

Heat Capacity and Heats of Vaporization

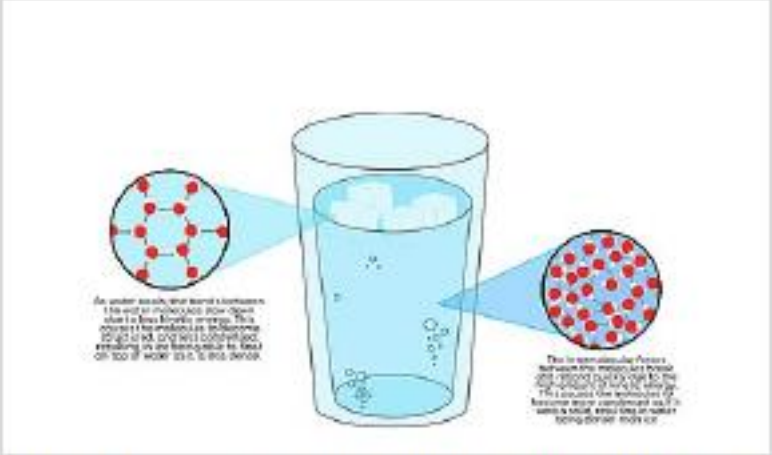


Heat of vaporization of water from melting to critical temperature

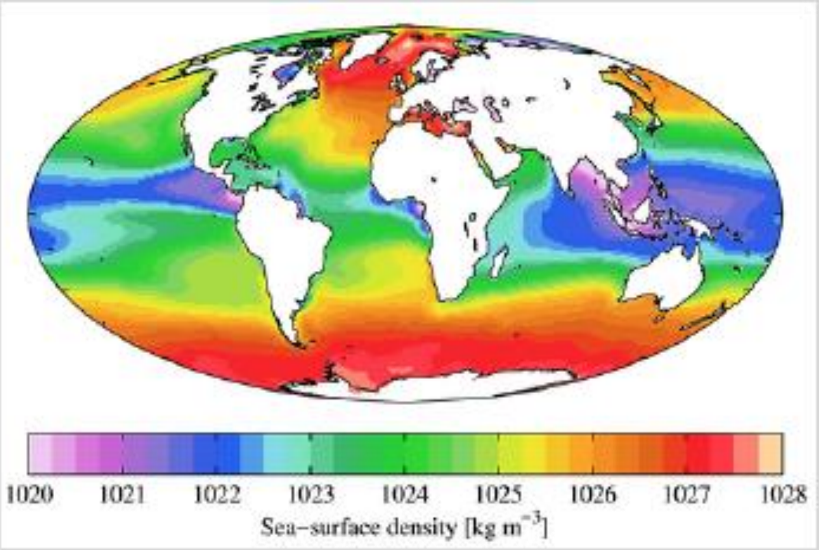
Special Properties of Water



Density of ice and water as a function of temperature



The difference in the molecular structures of water and ice.



WOA surface density

Ion Chemistry

Cations

$(Ca^{2+}, Mg^{2+}, Na^{+}, \text{and } K^{+})$

Anions

$(HCO_3^{-}, CO_3^{-}, SO_4^{2-}, \text{and } Cl^{-})$

Atmospheric Deposition

Marine Salts

$(Na^{+}, Ca^{2+}, Mg^{2+})$

Acid ions

(SO_4^{2-}, NO_3^{-})

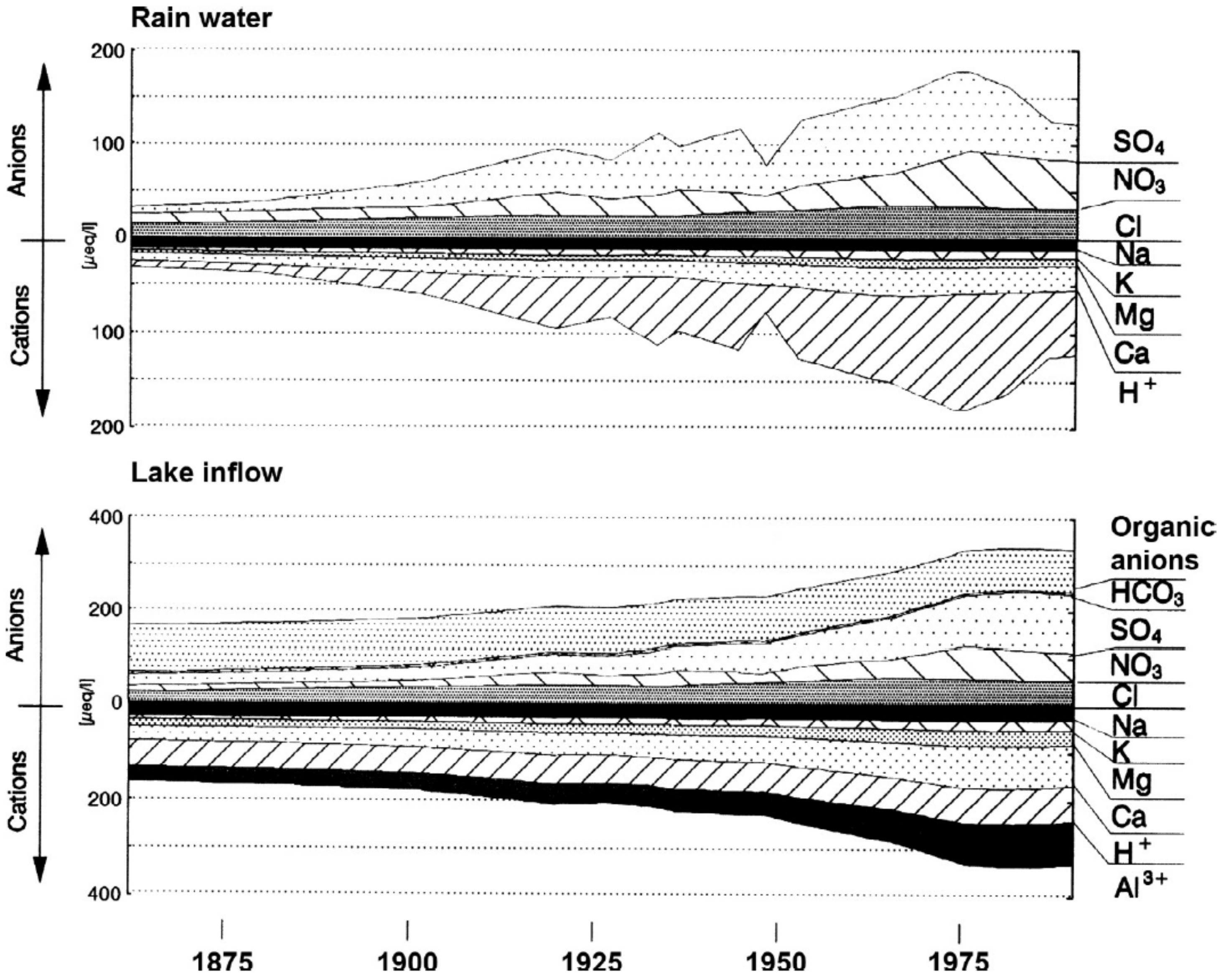


FIGURE 8. 6 A paleolimnological reconstruction of changes in the charge balance of rain and lake inflow over the period of the Industrial Revolution. Note that while rainwater became more acidic over the record (increasing contribution of H^+ and the acid anions SO_4^{2-} and NO_3^- through time) the interflow waters have seen little change in pH (H^+). Instead, large increases in the concentrations of sulfate and nitrate over time have been accompanied by increases in the base cations (K^+, Mg^{2+}, Ca^{2+}) and in soluble Al^{3+}. *Source: Hinderer et al. 1998.*

Gas Diffusion and Solubility

Dissolved Inorganic Carbon (DIC)

ΣCO_2

$$CO_2 + H_2O <=> H^+ + HCO_3^- <=> 2H^+ + CO_3^{2-}$$

pH < 4.3	CO2	
pH 4.3– 8.3	HCO_3^-	Acid Neutralizing Capacity (ANC) pH 4.3
pH > 8.3	CO_3^-	

TABLE 8.1 Estimates of CO_2 Outgassing from Inland Waters

	Area of inland waters (1000s km^2)	pCO_2 (ppm)	Gas exchange velocity (k_{600}, cm hr^{-1})	Areal outgassing (g C m^{-2}yr^{-1})	Zonal outgassing (Pg C yr^{-1})
Zone-class	**min-max**	**median**	**median**	**median**	**median**
Tropical (0°–25°)					
Lakes and reservoirs	1840–1840	1900	4.0	240	0.45
Rivers (>60–100 m wide)	146–146	3600	12.3	1600	0.23
Streams (>60–100 m wide)	60–60	4300	17.2	2720	0.16
Wetlands	3080–6170	2900	2.4	240	1.12
Temperate (25°–50°)					
Lakes and reservoirs	880–1050	900	4.0	80	0.08
Rivers (>60–100 m wide)	70–84	3200	6.0	720	0.05
Streams (<60–100 m wide)	29–34	3500	20.2	2630	0.08
Wetlands	880–3530	2500	2.4	210	0.47
Boreal and Arctic (50°–90°)					
Lakes and reservoirs	80–1650	1100	4.0	130	0.11
Rivers (>60–100 m wide)	7–131	1300	6.0	260	0.02
Streams (<60–100 m wide)	3–54	1300	13.1	560	0.02
Wetlands	280–5520	2000	2.4	170	0.49
Global		*Global land area*			
Lakes and reservoirs	2800–4540	2.1–3.4%			0.64
Rivers (>60–100 m wide)	220–360	0.2–0.3%			0.30
Streams (<60–100 m wide)	90–150	0.1–0.1%			0.26
Wetlands	4240–15 220	3.2–11.4%			2.08
All inland waters	**7350–20 260**	**5.5–15.2%**			**3.28**

Source: Aufdenkampe et al. 2011. Used with permission of the Ecological Society of America.

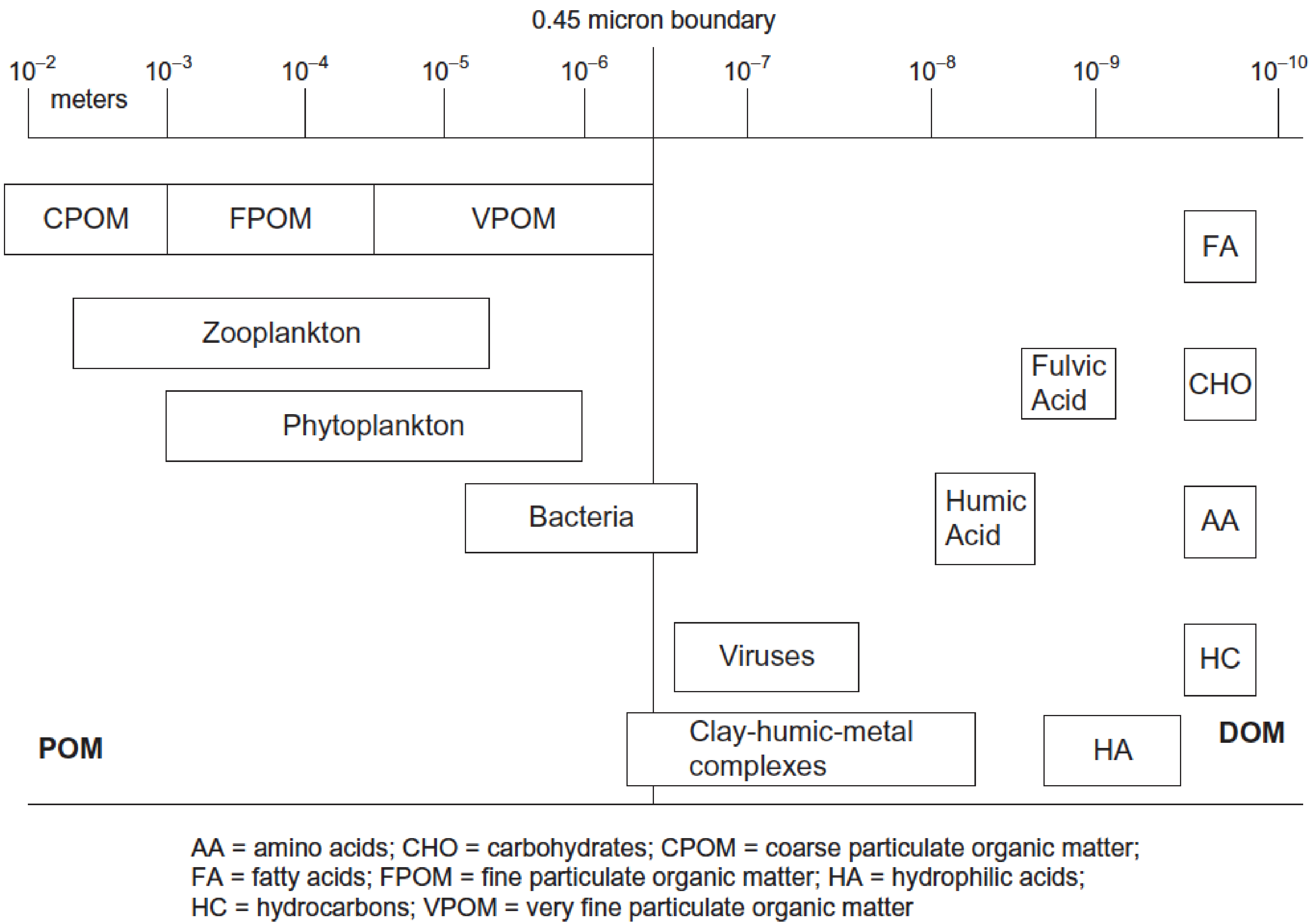
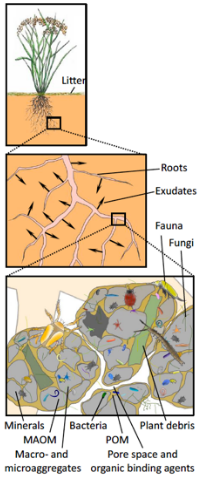
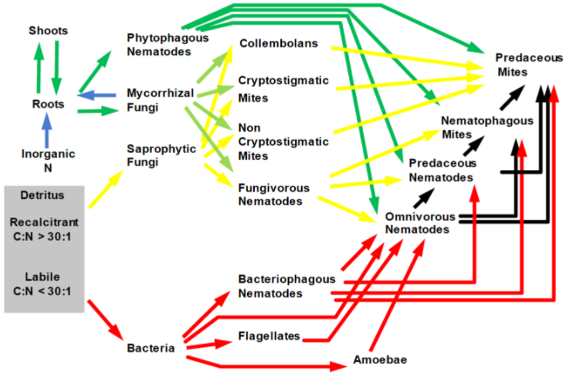


FIGURE 8.7 Size range of particulate and dissolved organic matter and carbon compounds in natural waters. The distinction between dissolved and particulate organic carbon is operationally defined, with investigators typically considering organic molecules that pass through a 0.45-mm filter dissolved. *Source: Reproduced from Hope et al. 1994.*

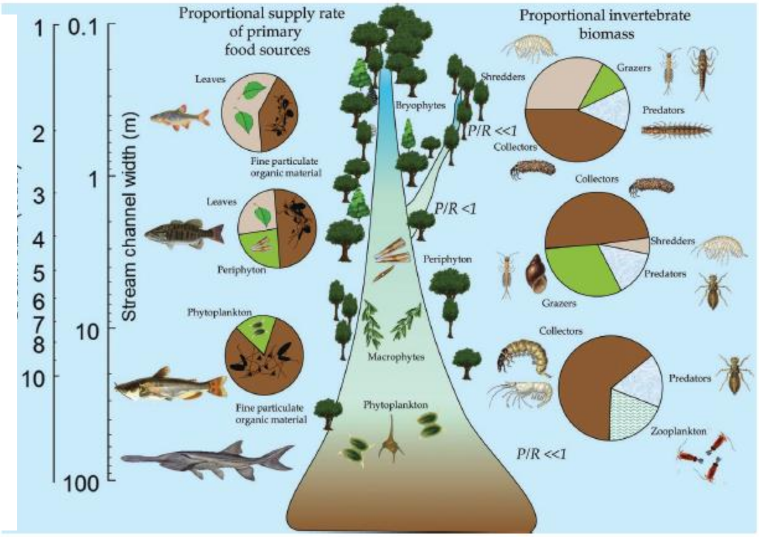
Food Webs



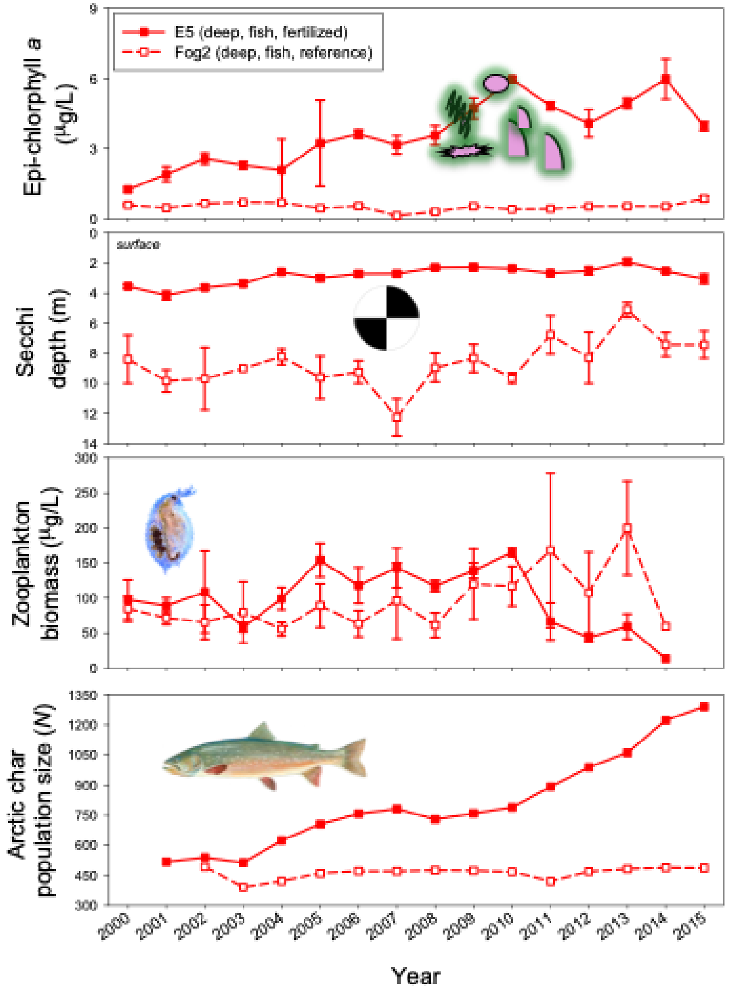
Litter
Roots
Exudates
Fauna
Fungi
Minerals
Bacteria
Plant debris
MAOM
POM
Macro- and microaggregates
Pore space and organic binding agents



Shoots
Roots
Inorganic N
Detritus
Recalcitrant C:N > 30:1
Labile C:N < 30:1
Phytophagous Nematodes
Mycorrhizal Fungi
Saprophytic Fungi
Bacteria
Collembolans
Cryptostigmatic Mites
Non Cryptostigmatic Mites
Fungivorous Nematodes
Bacteriophagous Nematodes
Flagellates
Amoebae
Predaceous Mites
Nematophagous Mites
Predaceous Nematodes
Omnivorous Nematodes

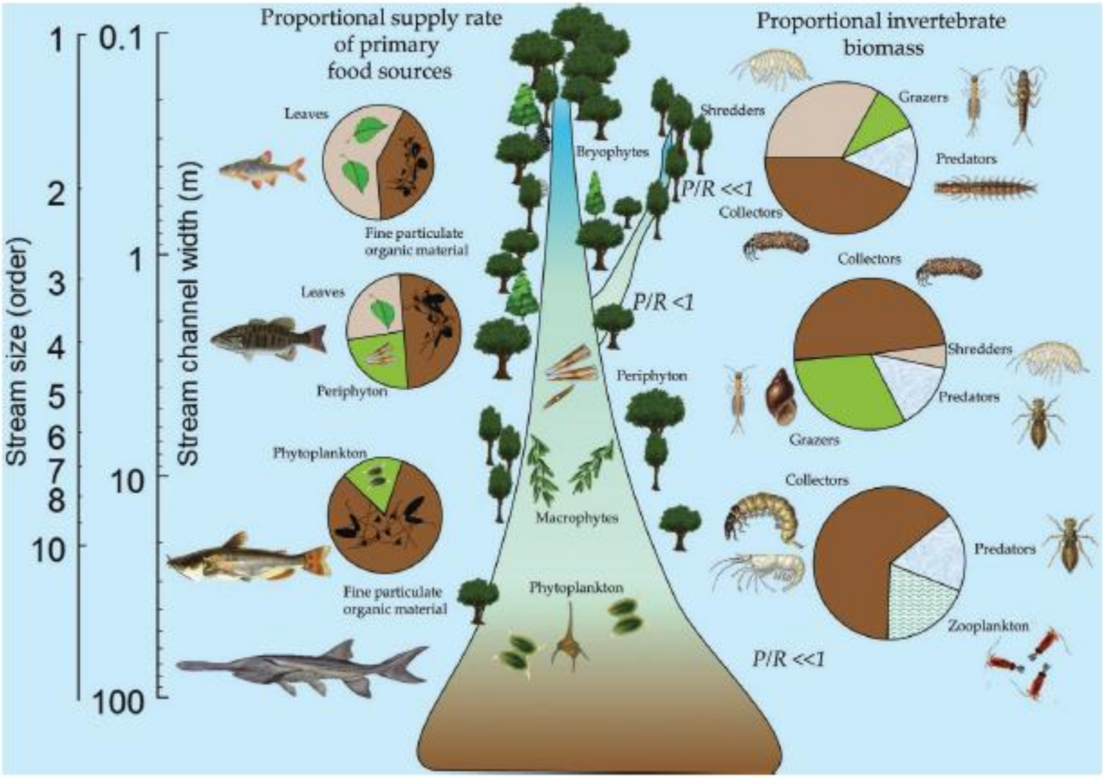


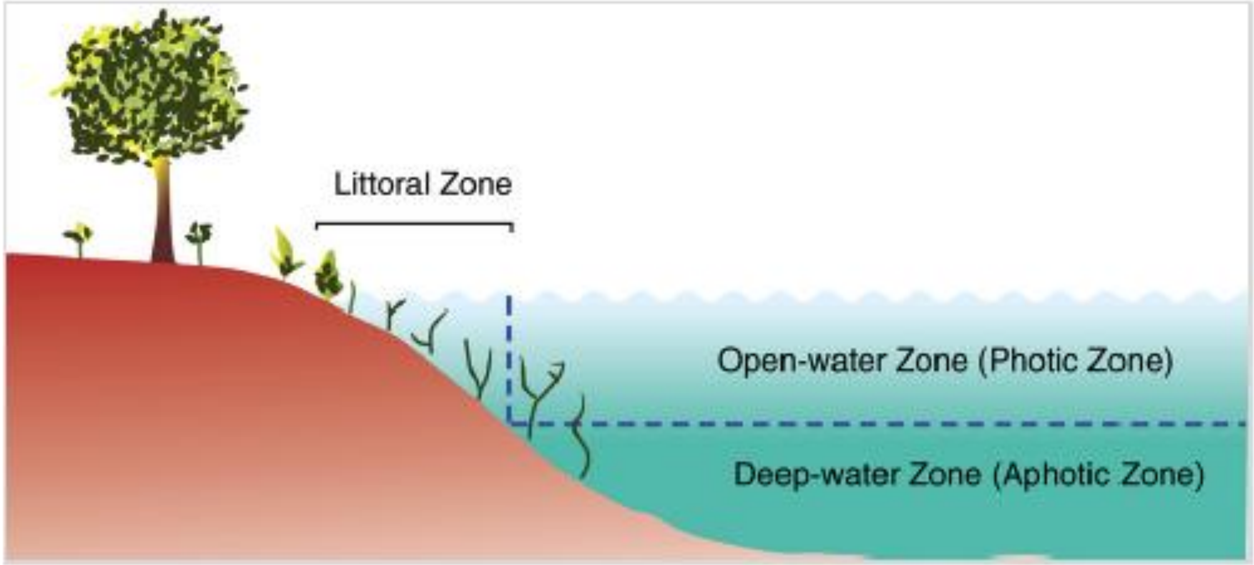
Proportional supply rate of primary food sources
Proportional invertebrate biomass
Stream channel width (m)
0.1
1
10
100
1
2
3
4
5
6
7
8
10
Leaves
Fine particulate organic material
Phytoplankton
Bryophytes
Periphyton
Macrophytes
P/R <<1
P/R <1
Shredders
Collectors
Grazers
Predators
Zooplankton



E5 (deep, fish, fertilized)
Fog2 (deep, fish, reference)
Epi-chlorphyll a (µg/L)
surface
Secchi depth (m)
Zooplankton biomass (µg/L)
Arctic char population size (N)
Year
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

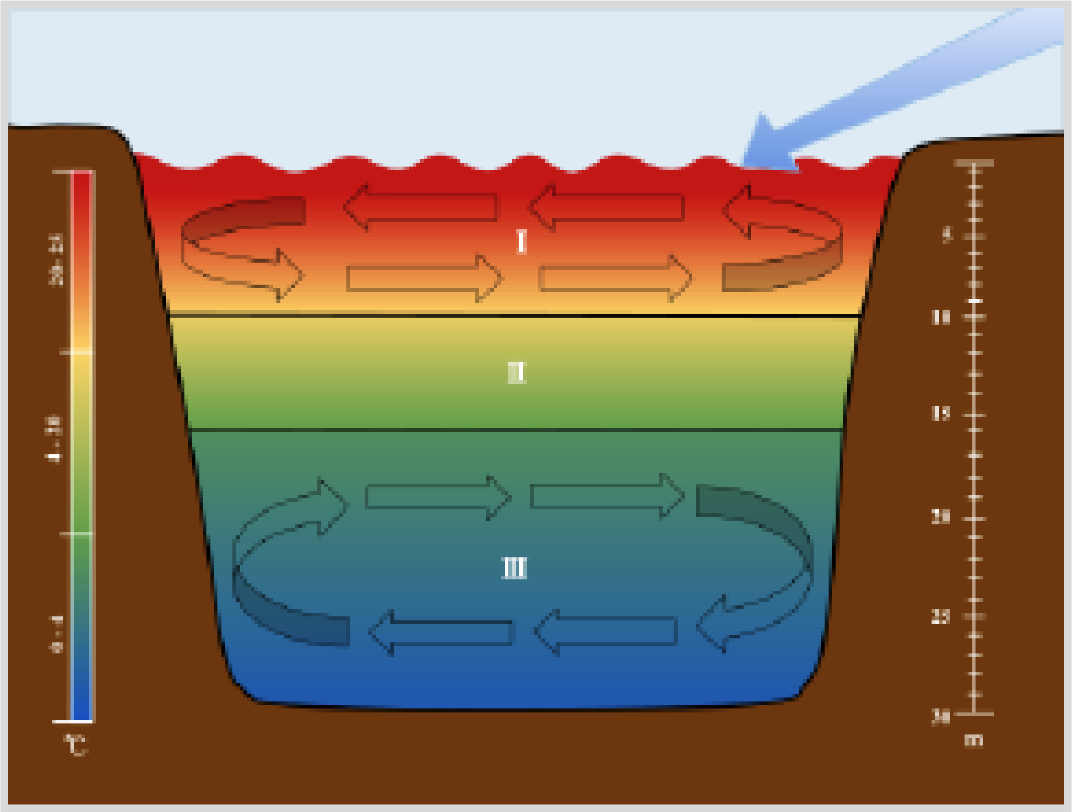
Lakes





The three primary zones of a lake are the littoral zone, the open-water (also called the photic or limnetic) zone, and the deep-water (also called the aphotic or profundal) zone.

Stratification

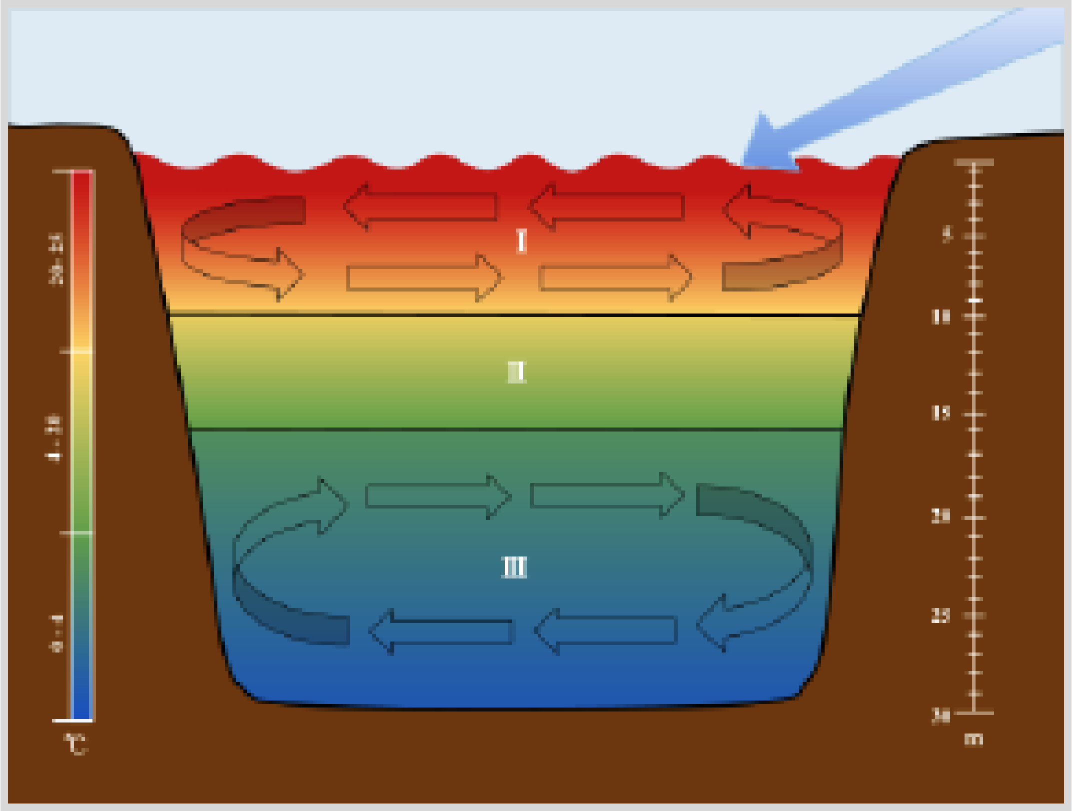


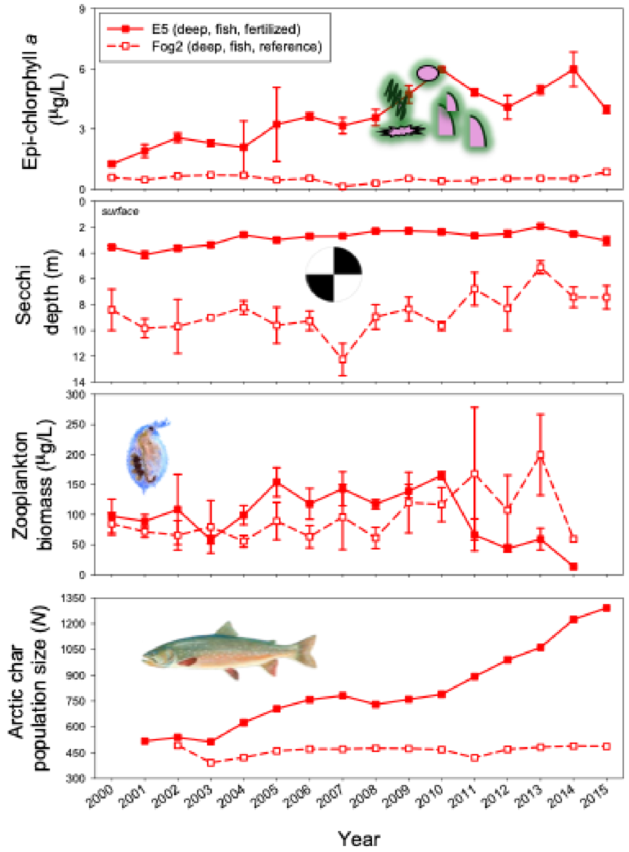
I. Epilimnion

II. Metalimnion (*aka* Thermocline)

III. Hypolimnion

Stratification





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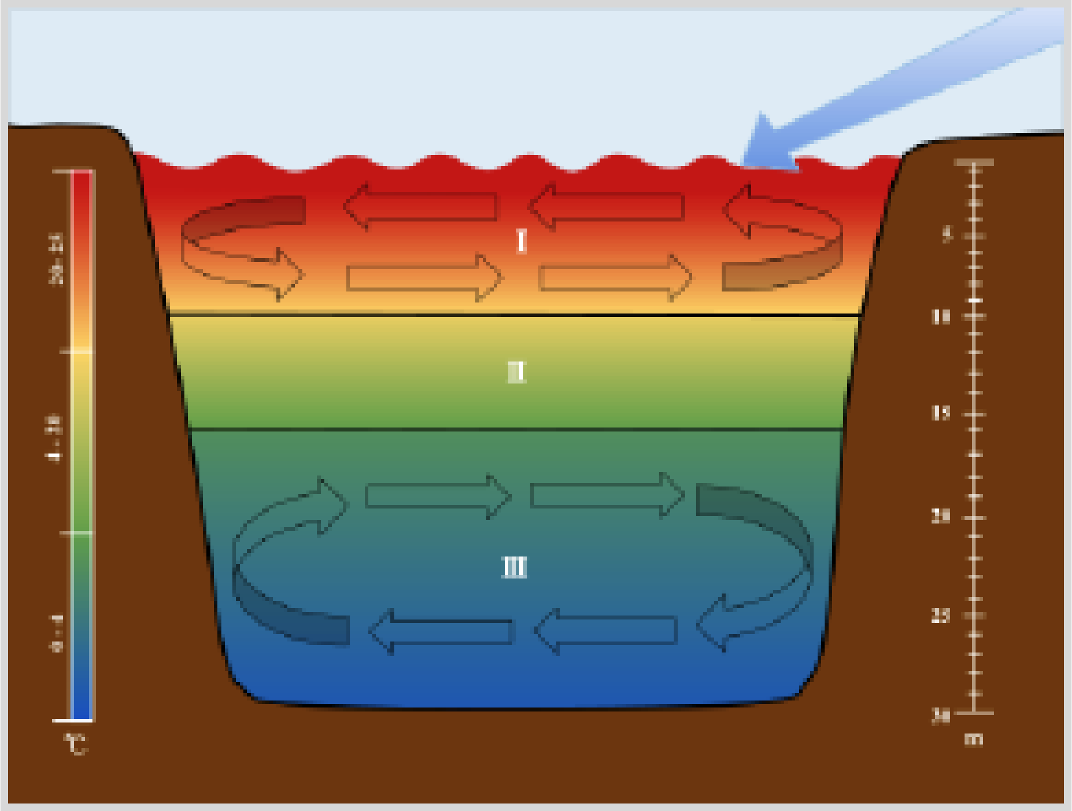

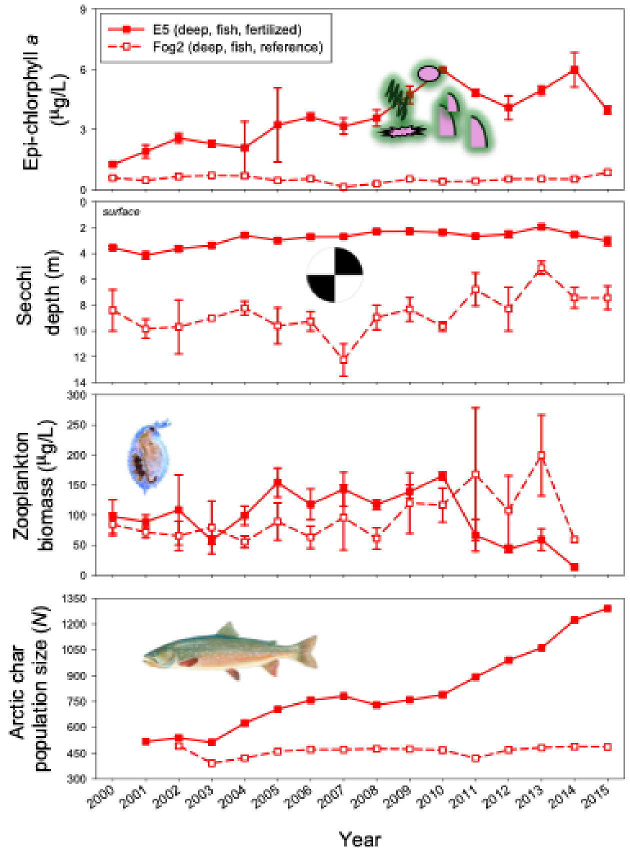

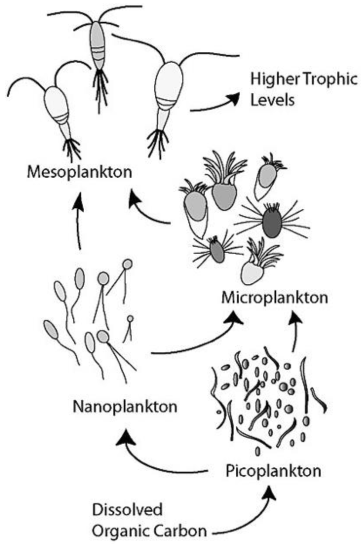

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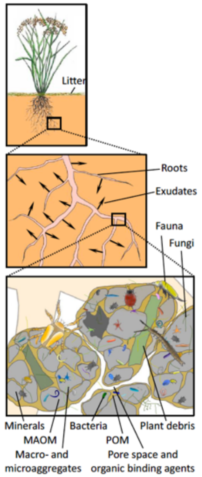

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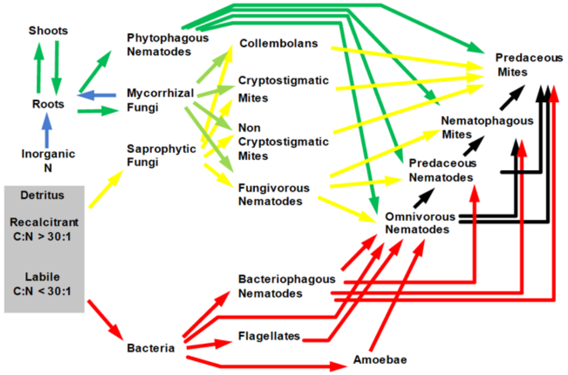

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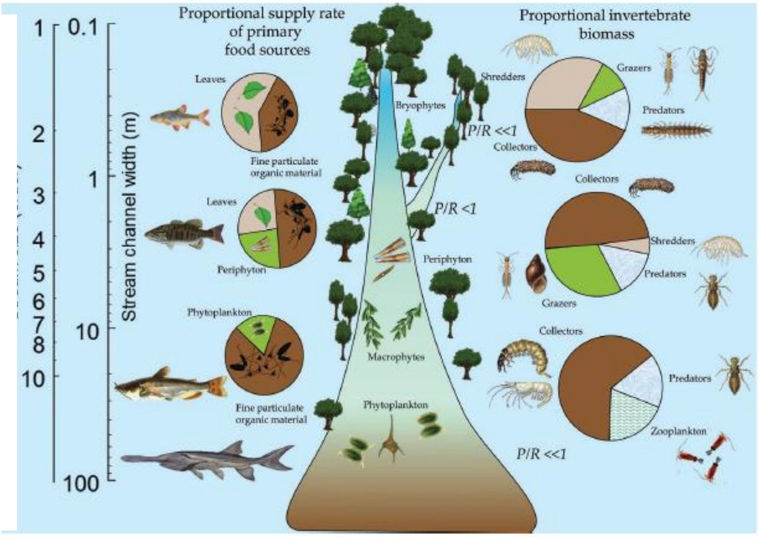
Omnivorous Nematodes



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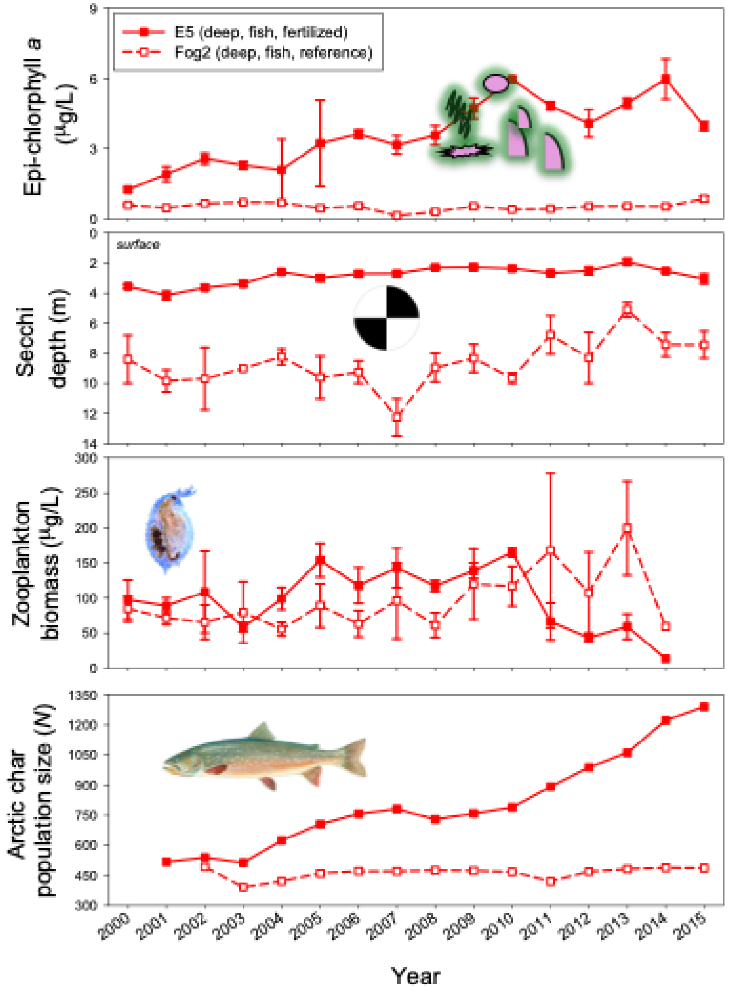

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Arctic char population size (N)
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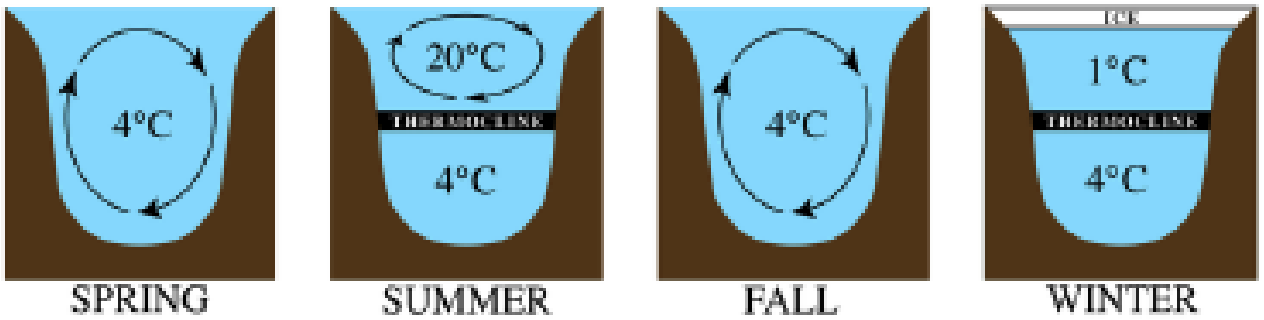
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015

Lake Turnover



- Dimictic Lakes
- Polymictic Lakes
- Meromictic Lakes

O_2

Dissolved Nutrients

Anthropogenic Influences

- Nutrient loads
- Pollution (particulates, Salts, Etc…)
- Temperature (Climate Change)

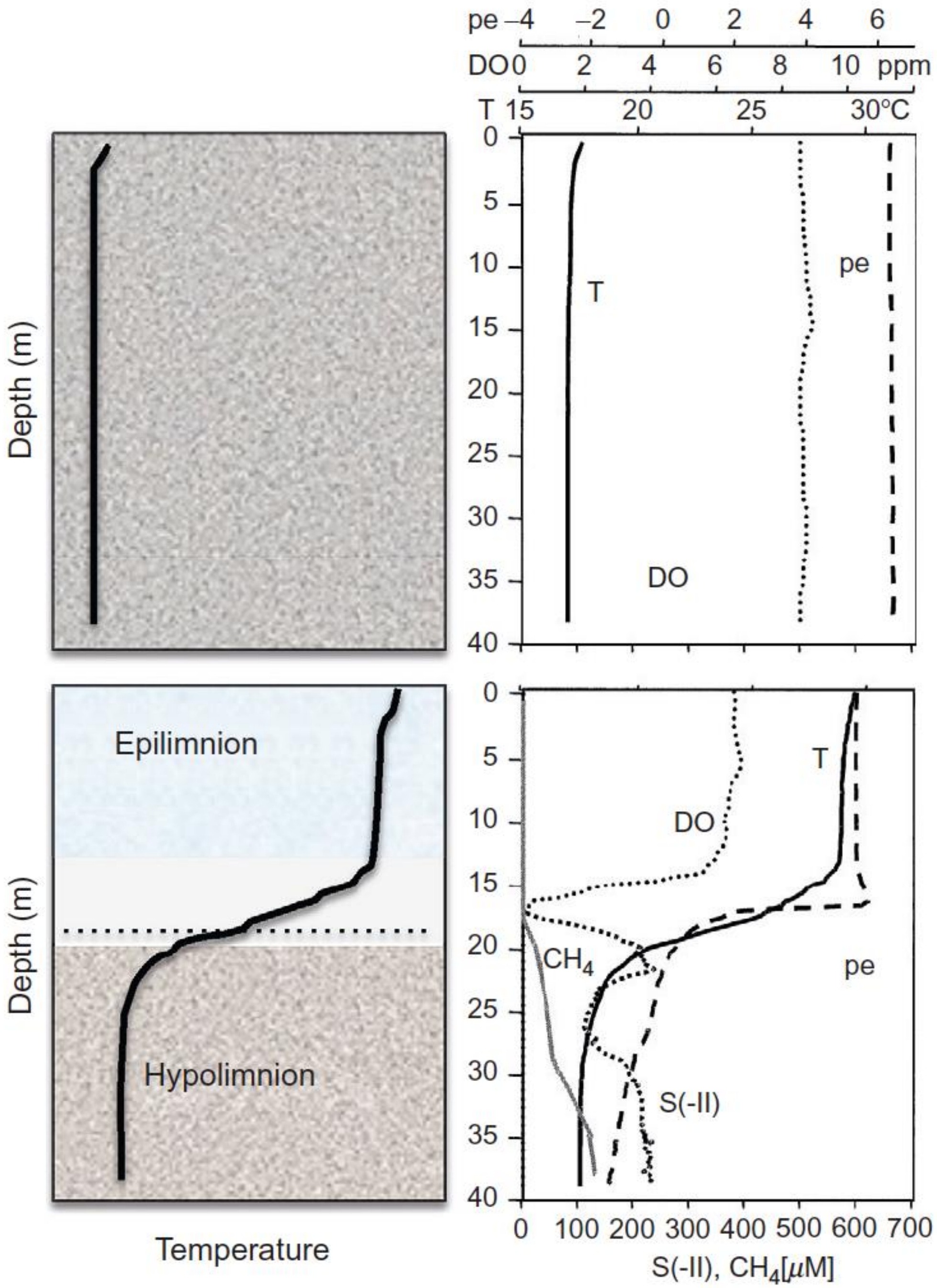


FIGURE 8.10 In the upper panels are shown a hypothetical and an actual lake temperature profile during winter (data from January). The lower panels show profiles during the period of summer stratification (data from July). The *dashed line* in the lower left panel indicates the lake thermocline. Depth profiles for temperature (T), dissolved oxygen (DO), redox potential (pe), total sulfide (S(-II)) and methane (CH_4) measured in the water column of Lake Kinneret in the Afro-Syrian rift valley during 1999. *Source: From Eckert and Conrad 2007. Used with permission of Springer.*

Anthropogenic Influences

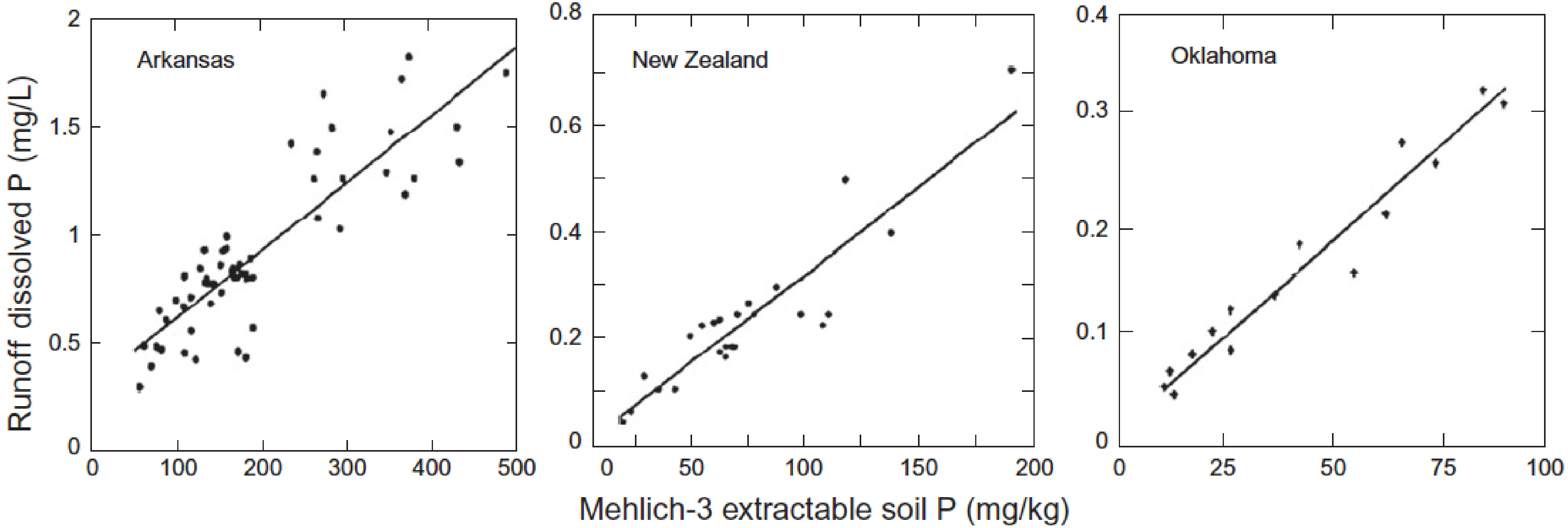
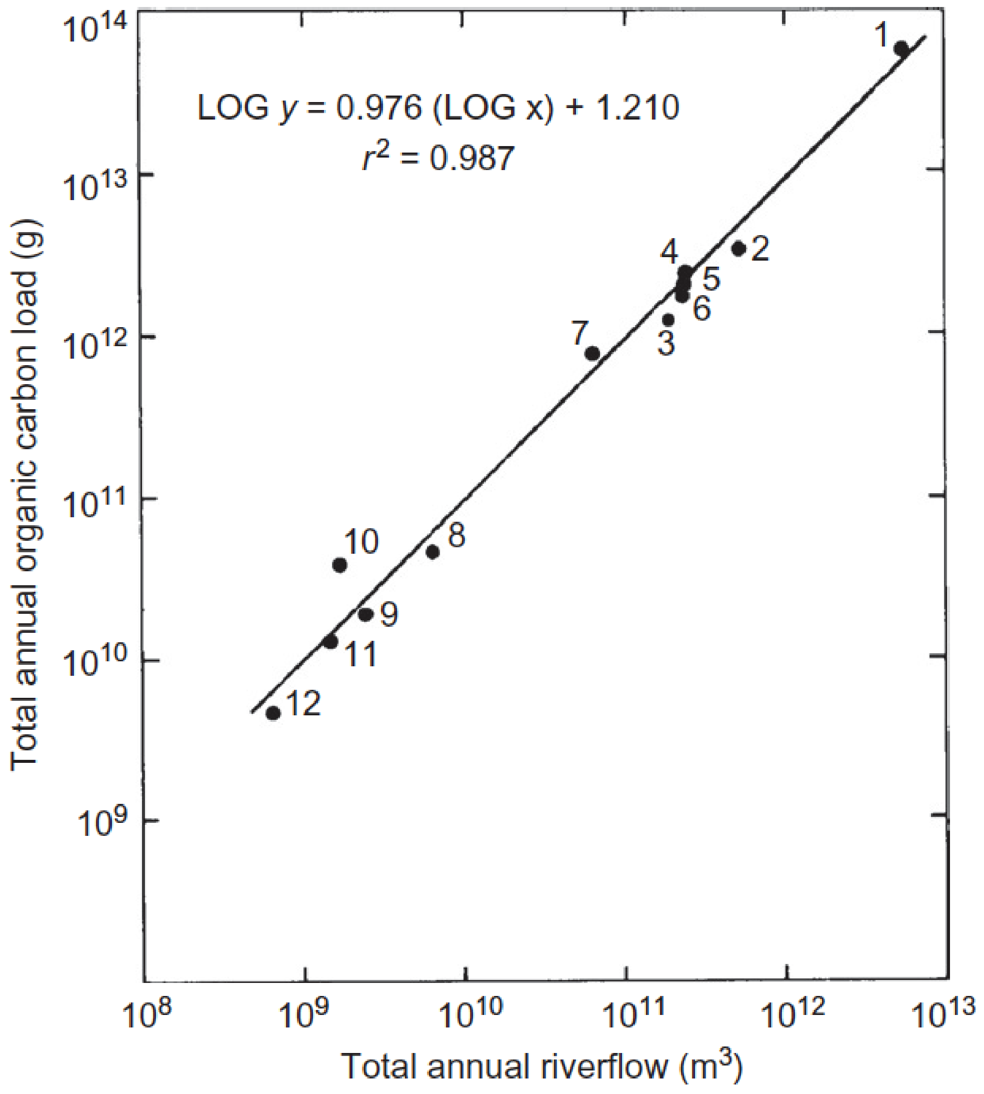


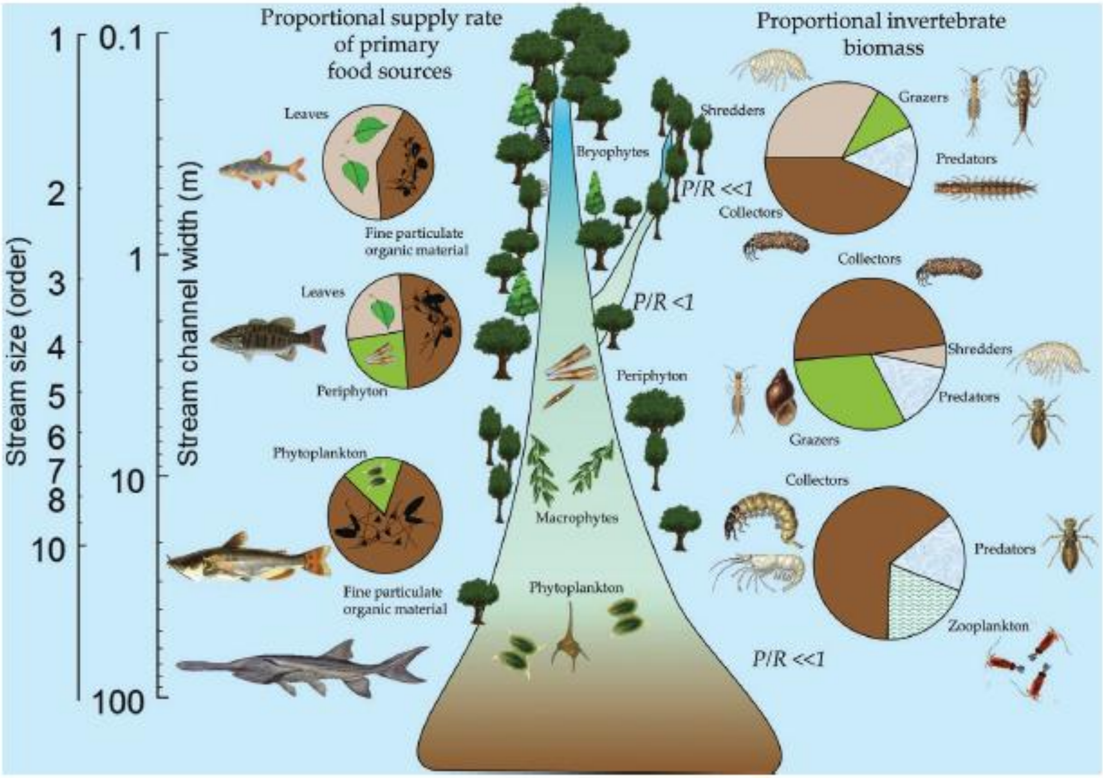
FIGURE 8.4 The nutrient content of surface waters reflect nutrient loading to their catchments. In A–C, the extractable soil phosphorus in agricultural watersheds is a good predictor of the concentrations of dissolved P in receiving streams. *Source: Sharpley et al. 1996. Used with permission of the Soil and Water Conservation Society.*



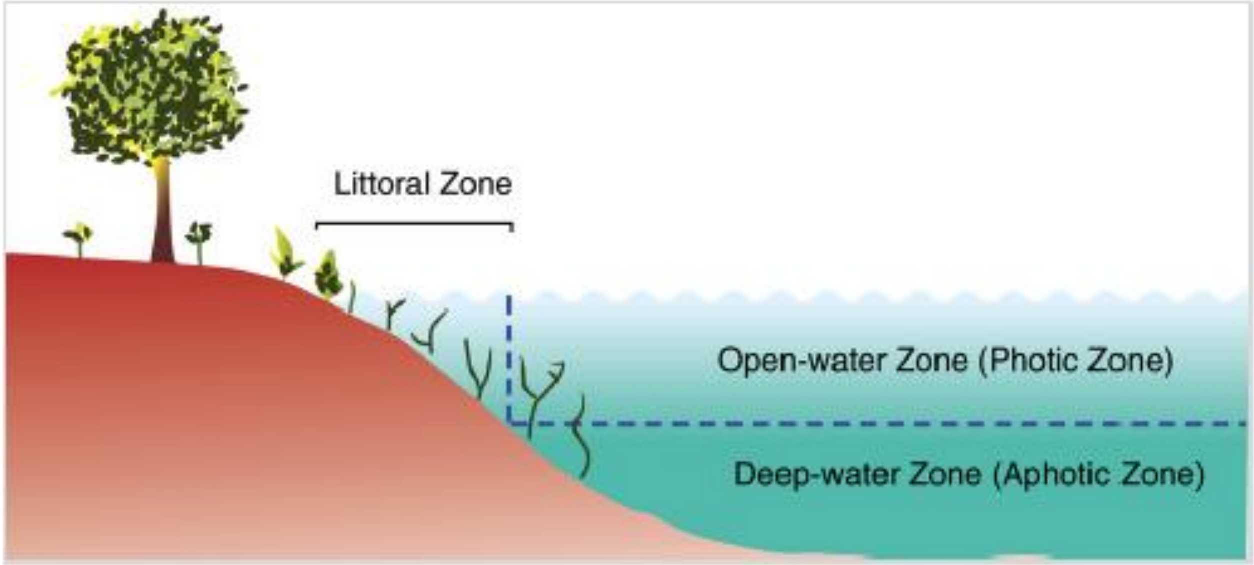
Rivers 1–7 are among the 50 largest.
1 = Amazon; 2 = Mississippi; 3 = St. Lawrence;
4 = MacKenzie; 5 = Danube; 6 = Volga; 7 = Rhine

FIGURE 8.8 Total annual load of organic carbon shown as a logarithmic function of total annual riverflow for major rivers of the world. *Source: From Schlesinger and Melack 1981 with a revision of the data for the St. Lawrence derived from Pocklington and Tan (1987). Used with permission of the Ecological Society of America.*

Streams



Lakes



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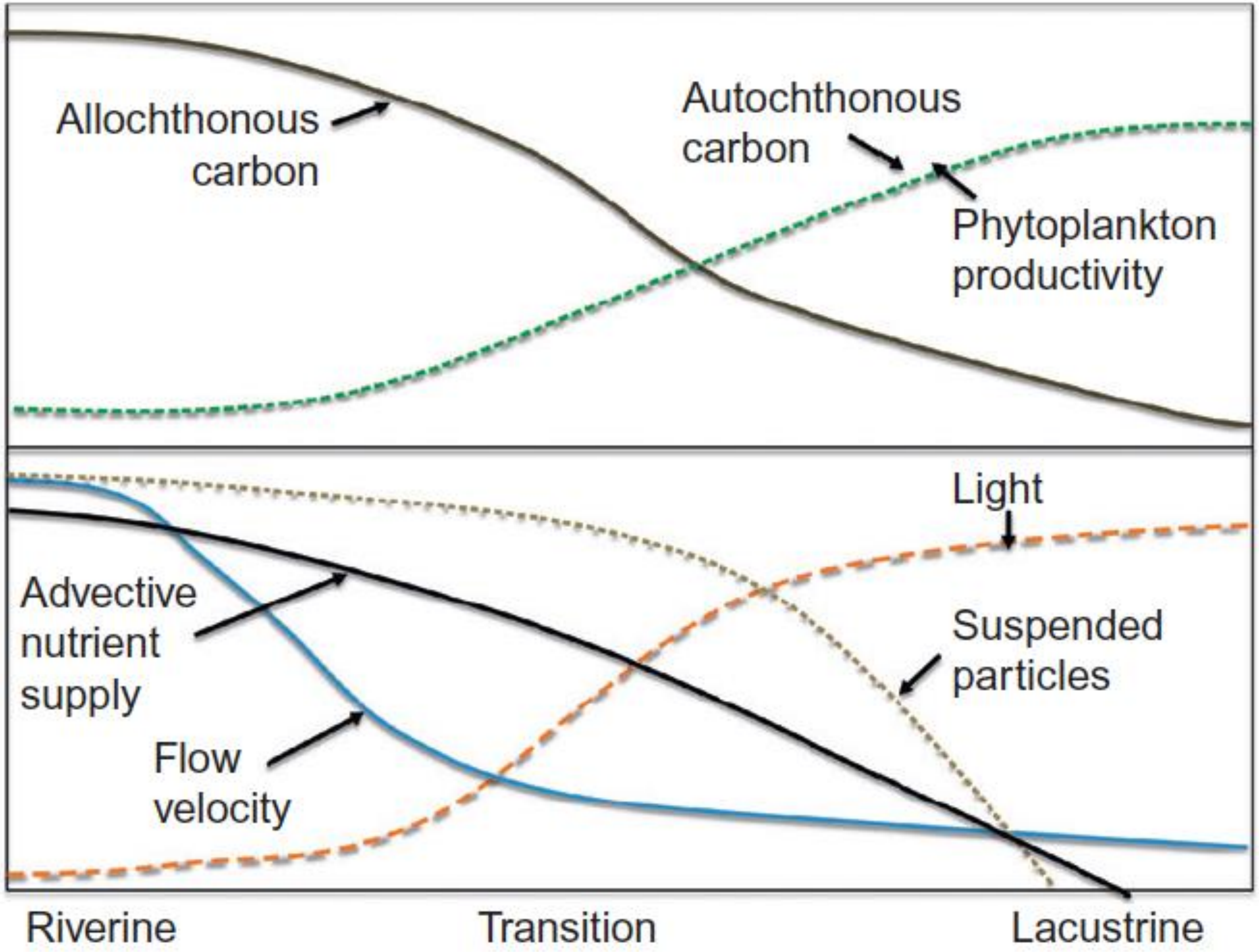

FIGURE 8.19 Commonly observed shifts in flow, light, nutrients, and sources of organic matter in the transition between rivers and lakes.