ZOO-374

Aquatic Ecology

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Course contents:

Zoo 374 Aquatic Ecology 2 (1+1)

Introduction; properties of the aquatic environment; characteristics: physical characteristics (temperature, salinity, transparency and turbidity); chemical characteristics (dissolved oxygen, other dissolved gases, pH and hardness); aquatic ecosystem: aquatic plants and animals.

- An ecosystem is the basic functional unit in ecology, as it includes both organisms and their abiotic environment. No organism can exist without the environment.

- An aquatic ecosystem is an ecosystem in a body of water. The two main types of aquatic ecosystems are marine and freshwater ecosystems

- Marine ecosystems cover approximately 71% of the Earth's surface and contain approximately 97% of the planet's water. They generate 32% of the world's net primary production

- Freshwater ecosystems cover 0.80% of the Earth's surface and inhabit 0.009% of its total water. They generate nearly 3% of its net primary production

Types of Aquatic Ecosystems

- **Freshwater Ecosystems**
  - Standing Water- lakes & ponds
  - Moving Water- rivers & streams
- **Transitional Communities**
  - Estuaries
  - Wetlands- bogs, swamps, marshes
- **Marine Ecosystems**
  - Shorelines
  - Barrier Islands
  - Coral Reefs
  - Open Ocean





Characteristics of Aquatic Ecosystems

Fundamental Division: freshwater vs. saltwater(marine) based on:

- **Salinity,which is the amount of dissolved salts in water.**
- **Dissolved oxygen**
- **Light penetration**
- **Temperature**
- **pH**
- **Presence/absence of currents/waves**

1. Light

- Some incident sunlight is reflected from the water's surface.
- The lower the angle of the sun, the greater the reflectance.
- The amount of light that penetrates the water's surface varies with latitude, season.
- Light that does penetrate is absorbed by water molecules.
- Different wavelengths penetrate to different depths

E.g. for visible light:

Red: most rapidly absorbed

Blue: least rapidly absorbed > greatest penetration

- Suspended particles in the water also absorb and scatter light > reduces penetration even further

2. Temperature

- The temperature of water has extremely important ecological consequences.
- Temperature exerts a major influence on aquatic organisms with respect to selection/occurrence and level of activity of the organisms.
- All aquatic organisms have preferred temperature in which they can survive and reproduce optimally.
- For example, trout typically need cold water which may not be available in shallow waters during the summer.
- Temperature is also an important influence on water chemistry.
- Rates of chemical reactions also generally increase with increasing temperature.
- Temperature is a regulator of the solubility of gases and minerals (solids) or how much of these materials can be dissolved in water.
- The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases.
- For example, warm water contains less dissolved oxygen (DO) than cold water. Inversely the solubility of most minerals increases with increasing temperature.

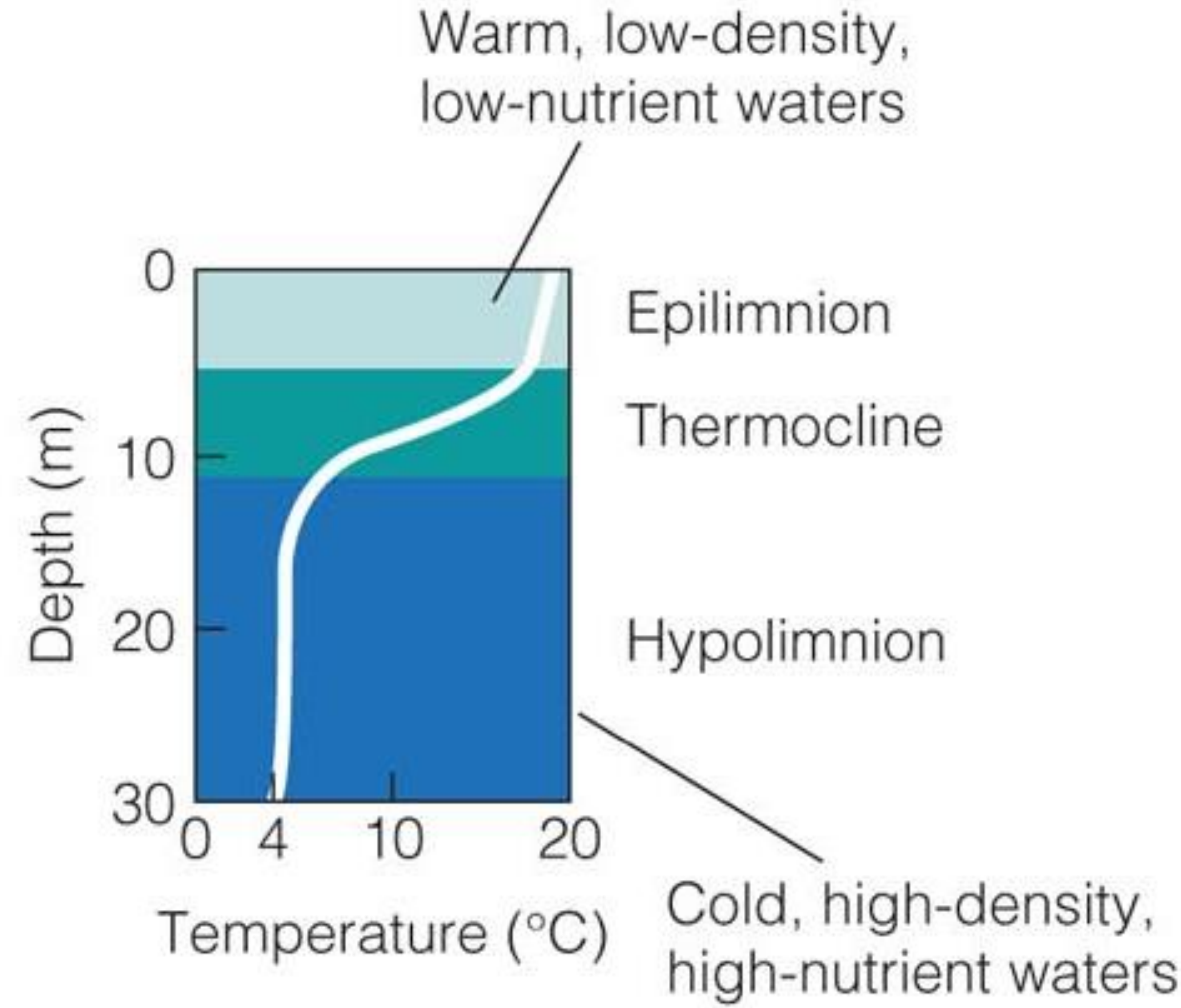
- Water is most dense at 4^{o}C.
- Lake in summer:

  temperature drops with increasing depth

  Stratification of water column

  - **Epilimnion:** warm surface water
  - **Thermocline**: rapid decline in temperature.

    Depth at which the rate of decrease of temperature with increase of depth is the largest.
  - **Hypolimnion**: cold, dense water (~4^{o}C)


Warm, low-density,
low-nutrient waters
0
10
20
30
Depth (m)
Epilimnion
Thermocline
Hypolimnion
0
4
10
20
Temperature (°C)
Cold, high-density,
high-nutrient waters

Seasonal Thermal Stratification

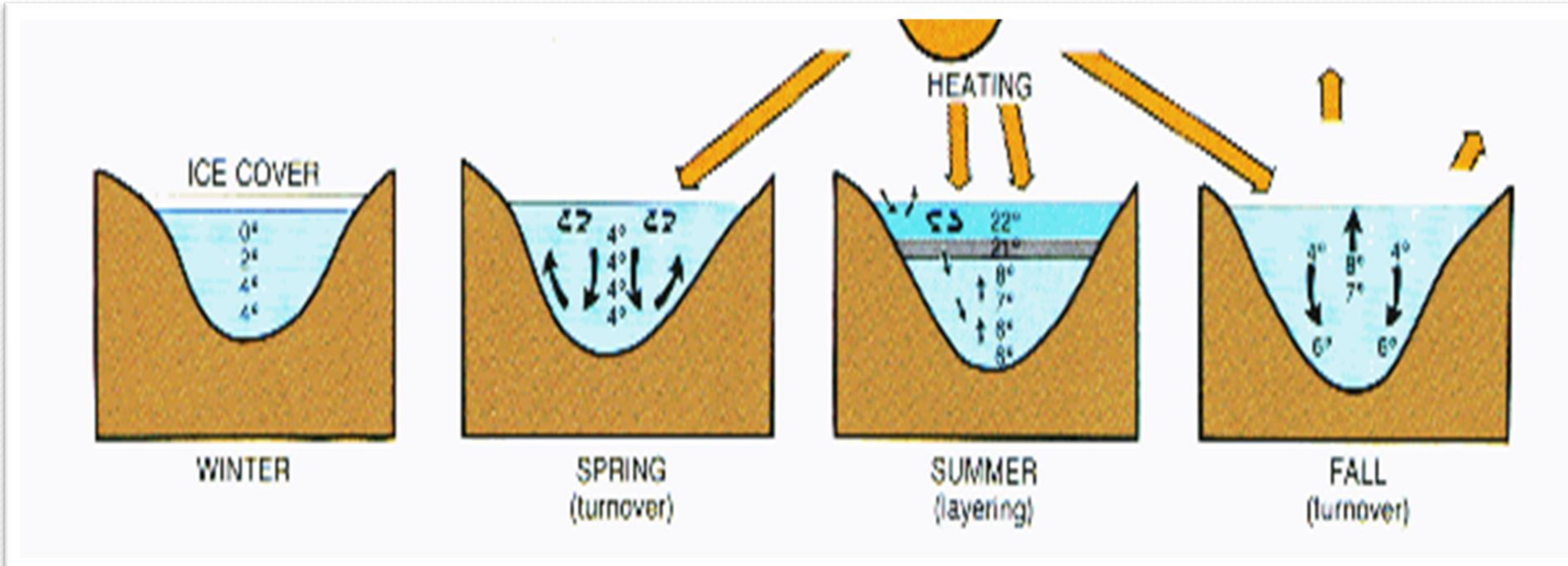
- Temperature changes sharply with depth (where sunlight penetrates)
- Summer: surface water heats up (becomes less dense) and deeper water is cooler so is more dense, creating a thermocline (temperature transition), more dissolved O_2 at cooler depths affecting fish distribution.

Seasonal Thermal Stratification

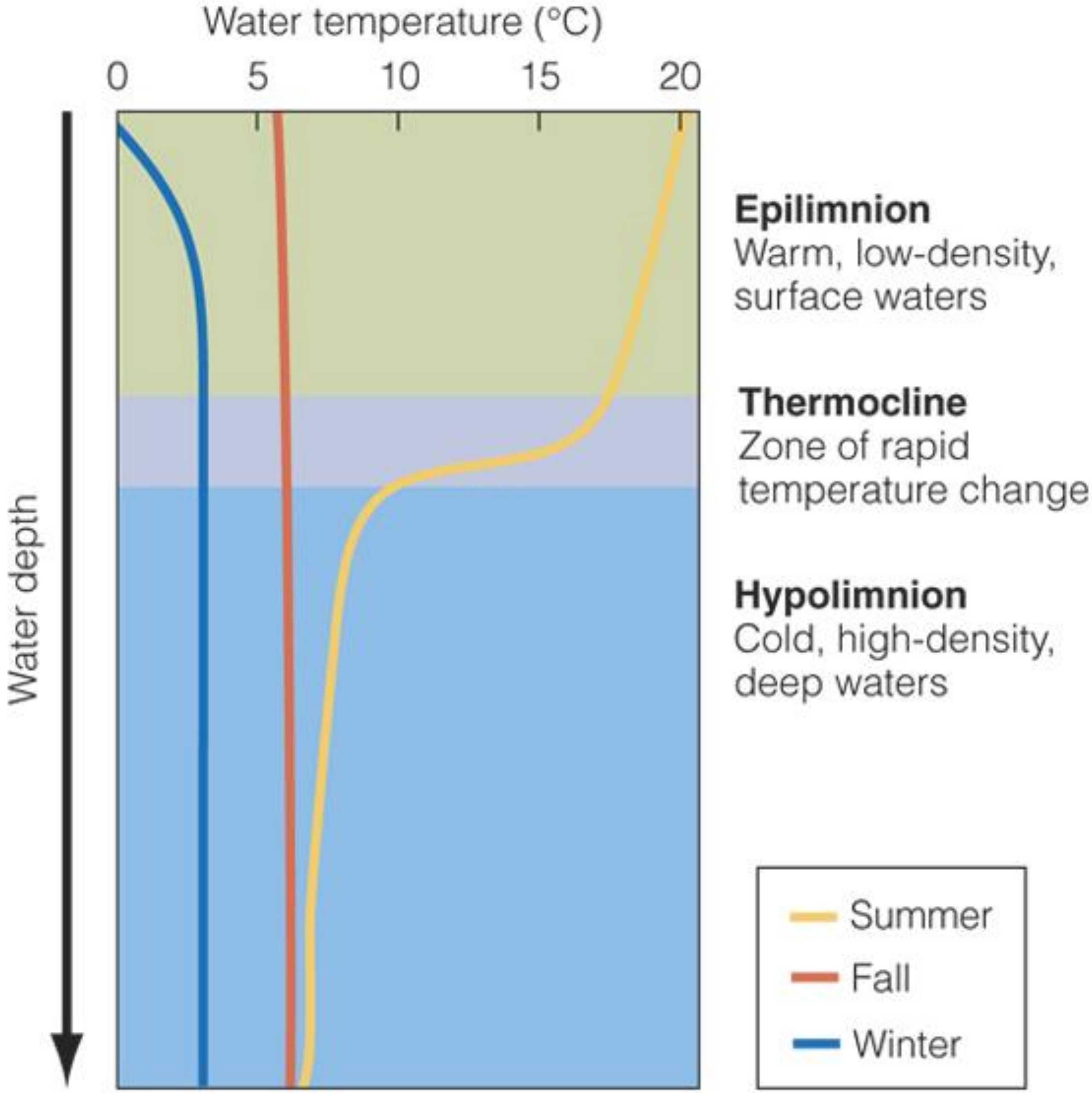
- Fall(Autumn): falling temperatures cause a mixing of the water layers known as fall turnover.
  - Surface water cools becomes more dense, sinks and displaces warmer water underneath.
  - This happens until a uniform temp. is reached.

Seasonal Thermal Stratification

- Spring Turnover: occurs as ice melts, temp. of water increases to 4^{o}C at which time it sinks down (greatest density)
- Layers mix until a uniform temperature is reached. Turnovers (fall and spring) are really important because the cycle nutrients and oxygenated water, algal bloom usually follows.



HEATING
ICE COVER
0°
2°
4°
4°
4°
4°
4°
4°
4°
22°
21°
8°
7°
8°
8°
4°
8°
7°
4°
6°
6°
WINTER
SPRING
(turnover)
SUMMER
(layering)
FALL
(turnover)


Water temperature (°C)
0
5
10
15
20
Water depth
Epilimnion
Warm, low-density, surface waters
Thermocline
Zone of rapid temperature change
Hypolimnion
Cold, high-density, deep waters
Summer
Fall
Winter

- Oceans: never undergo complete turnover
- Winter: thermocline rises
- Summer: thermocline descends
- Bottom never mixes with top.

3. Turbidity

The word "turbidity" [Measured as nephelometric turbidity units (NTU)]has been used in a general sense to indicate the extent to which water lacks clarity.

- Turbidity in water bodies is caused by a heterogeneous (mixed) population of suspended particles, which may include clay, silt, finely divided organic matter (detritus), phytoplankton (microscopic free floating plants), and other microscopic organisms.
- Thus, the variations in measured turbidity may reflect the dynamics of phytoplankton growth as well as tributary runoff.

4. Dissolved Oxygen

- The concentration of dissolved oxygen [DO, units of milligram per liter ($mg \cdot L^{-1}$)] is perhaps the single most important feature of water quality.

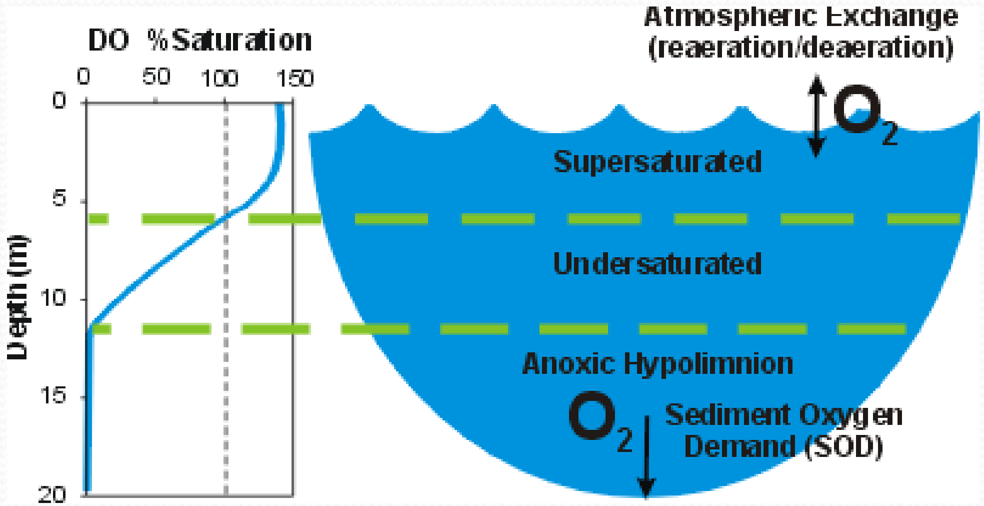
- It is an important regulator of chemical processes and biological activity. Most forms of aquatic life require oxygen (DO). For example, certain combinations of low temperature and high DO concentrations are required for the maintenance of a cold water sport fishery (such as trout and salmon).

- Plant photosynthesis produces oxygen within the region below the water surface with adequate light (photic zone). Microbial (for example, bacteria) respiratory and organic decay processes consume oxygen. Near the reservoir surface, oxygen can move between the water and air.

- Oxygen is moderately soluble in water. The solubility limit, or saturation concentration of DO is largely regulated by temperature.

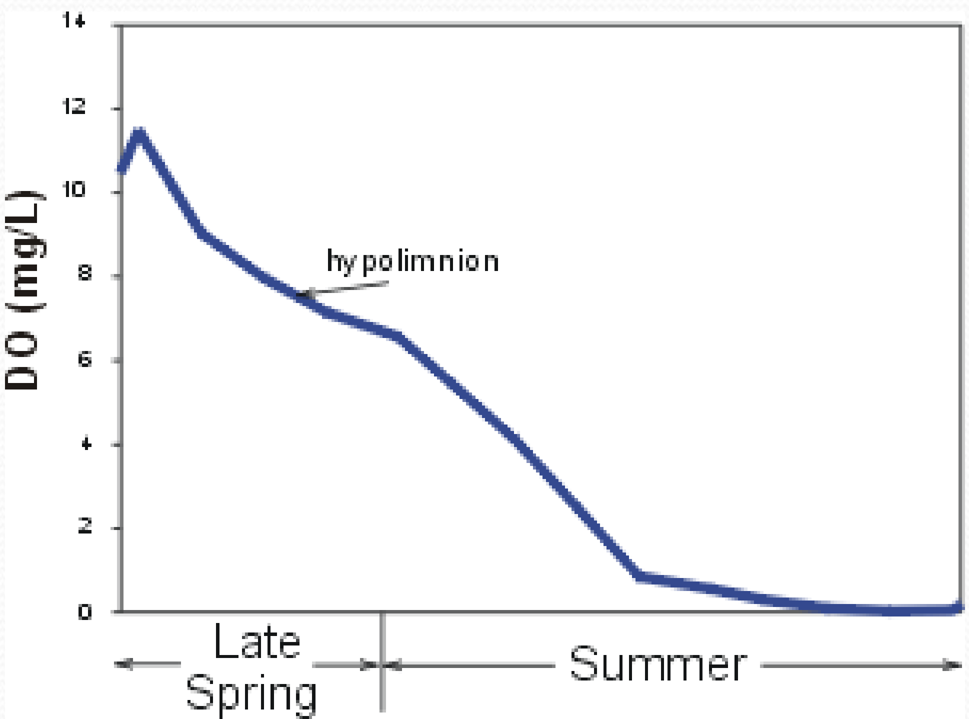
- Concentrations that exceed the saturation value are described as supersaturated. Such conditions reflect high photosynthetic activity (i.e. during an algal bloom).

- Undersaturated conditions prevail when the DO concentration is less than the saturation value, indicating oxygen-demanding processes exceed the sources of DO.

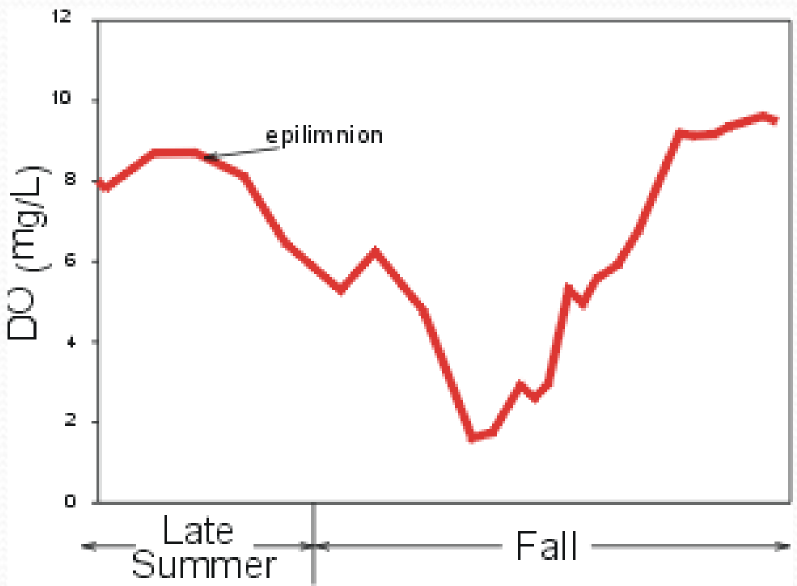


Depletion in the Bottom Waters

Upon the onset of thermal stratification the hypolimnion (see thermal stratification) becomes isolated from sources of oxygen. DO is widely observed to decrease progressively in the hypolimnion over the period of stratification, because the demand for oxygen associated with respiration and decay exceeds the sources. This is illustrated by the time plot of DO concentration in the hypolimnion



Oxygen concentrations are replenished in the lower layers during fall turnover. Reductions in oxygen concentrations may be observed in the upper waters of a lake during this interval if very low DO levels developed in the hypolimnion, reflecting the outcome of mixing of high (for example, saturated) and low (from the oxygen-depleted hypolimnion) DO concentrations. A particularly sever case of such dynamics for DO in an eplimnion is illustrated by the time plot on the right.



Carbon dioxide

- Carbon Dioxide is present in water in the form of a dissolved gas. Surface waters normally contain less than 10 ppm free carbon dioxide, while some ground waters may easily exceed that concentration. Carbon dioxide is readily soluble in water. Over the ordinary temperature range (0-30 C) the solubility is about 200 times that of oxygen. Calcium and magnesium combine with carbon dioxide to form carbonates and bicarbonates.
- Aquatic plant life depends upon carbon dioxide and bicarbonates in water for growth. Microscopic plant life suspended in the water, phytoplankton, as well as large rooted plants, utilize carbon dioxide in the photosynthesis of plant materials; starches, sugars, oils, proteins. The carbon in all these materials comes from the carbon dioxide in water.
- When the oxygen concentration in waters containing organic matter is reduced, the carbon dioxide concentration rises.

The rise in carbon dioxide makes it more difficult for fish to use the limited amount of oxygen present.
To take on fresh oxygen, fish must first discharge the carbon dioxide in their blood streams and this is a much slower process when there are high concentration of carbon dioxide in the water itself.

Influence of carbon dioxide on alkalinity:

Carbon dioxide can change the pH of water. This is how it works:

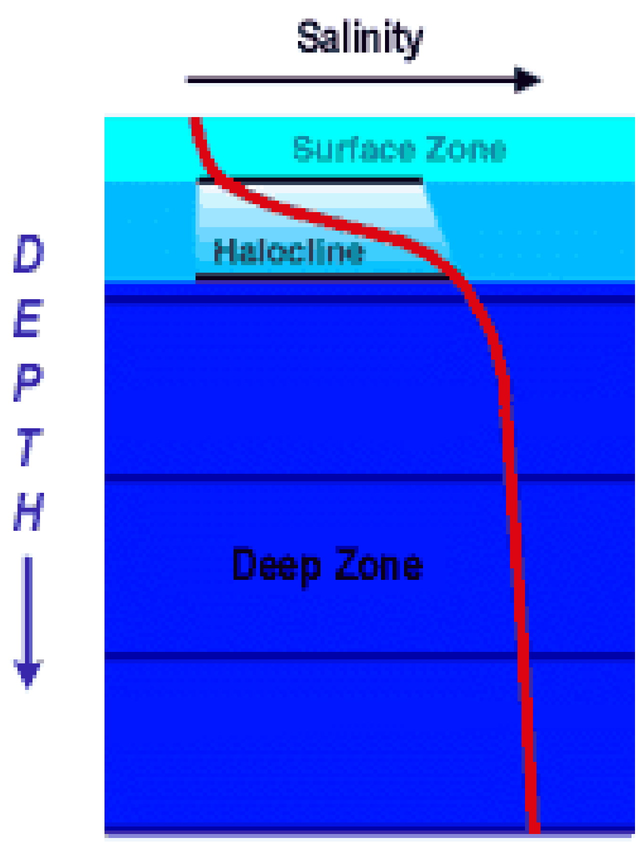
Carbon dioxide dissolves slightly in water to form a weak acid called carbonic acid, H_2CO_3, according to the following reaction:
$CO_2 + H_2O \dashrightarrow H_2CO_3$

After that, carbonic acid reacts slightly and reversibly in water to form a hydronium cation, H_3O+, and the bicarbonate ion, HCO^3-, according to the following reaction:
$H_2CO_3 + H_2O \dashrightarrow HCO_3^- + H_3O^+$

This chemical behaviour explains why water, which normally has a neutral pH of 7 has an acidic pH of approximately 5.5 when it has been exposed to air.

5. Salinity

Salinity is a measure of dissolved salts in sea water. Although salinity generally increases with depth, there is a distinct layer where salinity increases sharply called the **Halocline**.



- Flow of rivers into ocean: dissolved materials increase over time
- Concentrations cannot increase beyond maximum solubility limite.e

eg. Ca^{2+} forms $CaCO_3$ (limestone)

e.g. Cl^- - highly soluble (max. 360 g/L)

- Total concentration of all salt in ocean: 3.5% or 35 ppt
- Fresh water 0.065 to 0.3 ppt .

6. pH

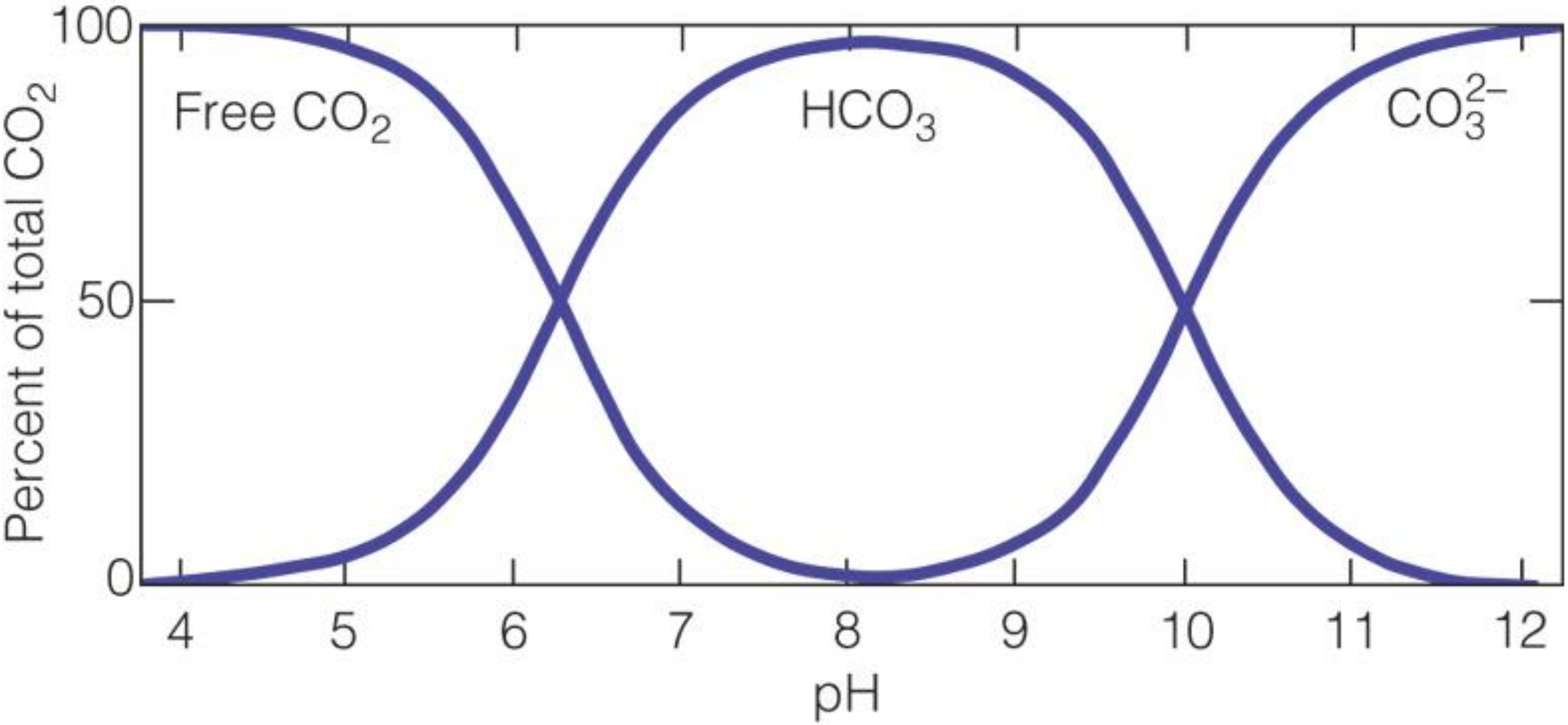
- **pH is defined as: pH** = - $\log_{10}$ $[H^+]$where $[H^+]$ = concentration of H^+

- The pH scale ranges from 0 to 14, that denotes various degrees of acidity or alkalinity.

- A value of 7 is neutral; values below 7 and approaching 0 indicate increasingly acid conditions (higher H^+ concentrations), while values above 7 approaching 14 indicate increasing alkalinity.

- The temporal and vertical patterns of pH in lakes and reservoirs are mediated through the dynamics of photosynthetic consumption and respiratory/decomposition production of carbon dioxide (CO_2).

- Photosynthetic uptake of CO_2 tends to increase pH (e.g., during phytoplankton blooms) while decomposition/respiration tends to decrease pH.



100
50
0
Percent of total CO_2
Free CO_2
HCO_3
CO_3^{2-}
4
5
6
7
8
9
10
11
12
pH

Factors affecting pH

- Fresh water: underlying rock is important
  - Limestone:
    - raises pH
    - buffers against changes
  - Sandstone, granite
    - Lowers pH
- Oceans: Na^{+}, K^{+}, Ca^{2+} raise pH
  - pH ~ 7.5-8.4

7. Alkanity and Water Hardness

- Alkalinity and hardness are both important components of water quality. However, these two aspects of water chemistry are commonly confused. The confusion relates to the term used to report these measures, ppm CaCO3 (same as mg/L).

- Total alkalinity indicates the quantity of base present in water -- bicarbonates, carbonates, phosphates, hydroxides, etc. Hardness represents the overall concentration of divalent salts (calcium, magnesium, iron, etc.) but does not identify which of these elements is/are the source of hardness. It is important to recognize the difference between hardness and total alkalinity when farming aquatic animals.

- Water hardness is important to fish culture and is a commonly reported aspect of water quality. It is a measure of the quantity of divalent ions (for this discussion, salts with two positive charges) such as calcium, magnesium and/or iron in water. However, calcium and magnesium are the most common sources of water hardness.

- The hardness of a water sample is reported in milligrams per liter (same as parts per million, ppm) as calcium carbonate (mg/l CaCO3).

The determination of whether water is acid, neutral or base is defined by pH. However, alkalinity measures the total amount of base present and indicates a pond's ability to resist large pH changes, or the "buffering capacity." The most important components of alkalinity are carbonates and bicarbonates. The total alkalinity concentration should be no lower than 20 mg/L CaCO3 in production ponds.

Calcium and magnesium are essential in the biological processes of aquatic animals, for example, bone and scale formation in fish. The critical component of total hardness is the calcium concentration, or "calcium hardness."

Environmental calcium is crucial for osmoregulation, that is, maintaining precise levels of internal salts for normal heart, muscle and nerve function. Calcium is also important in the molting process of shrimp and other crustaceans, and can affect the hardening of the newly formed shell. Aquatic animals can tolerate a broad range of calcium hardness concentrations. A desirable range would lie between 75 and 200 mg/L $CaCO_3$.

EQUATION 5. HARDNESS AND ALKALINITY.

$$\underset{\text{limestone}}{CaMg(CO_3)_2} \Longleftrightarrow \underbrace{Ca^{++} + Mg^{++}}_{\text{(hardness)}} + \underset{\text{(alkalinity)}}{2CO_3^{=}}$$

Which are the limiting factors for aquatic life?

Aquatic environments have many advantages.

- Water has many properties and because of that it is a unique kind of environment to live in.
-
Water pressure provides physical support.

- Temperature fluctuations are very limited, which reduces the risk for aquatic animals to become overheated or to dry out.

- The required nutrients are readily available, because they are dissolved in water.

- When toxins enter the water they are quickly converted or dispersed.

However, there are also factors that limit aquatic life. Factors that determine which life forms can be sustained in an aquatic life zone are:

1)Temperature: **The water temperature usually falls with water depth, because less sunlight will penetrate the water at a greater depth. Most aquatic organisms have a limited range of tolerance to temperature changes. However, when sudden temperature changes do occur it will have a significant effect on the performance and survival of aquatic organisms.**

2)Access to sunlight: **Sunlight can only penetrate the water up to a depth of about 30 metres below the surface. Producers need sunlight to produce oxygen and other required substances that will sustain consumers. Production can only occur in the zone where sunlight can penetrate. Suspended matter may interfere with the penetration of sunlight into water. This may decrease the size of the zone in which production takes place**

3) Dissolved oxygen concentrations: **Oxygen enters the aquatic ecosystem from the atmosphere and on account of production by (phyto)plankton. Dissolved oxygen concentrations deriving from atmospheric oxygen are influenced by water temperatures. When dissolved oxygen levels fall below 3 ppm many consumers, such as fish and zooplankton, will die. Oxygen levels, like temperatures, also decrease with depth. This makes dissolved oxygen and water temperature very important limiting factors in aquatic life zones.**

4) Availability of nutrients, such as nitrogen and phosphorus: **Nutrient supplies are usually satisfactory in freshwater ecosystems. However, in open oceans nutrients are often in short supply. They are an important limiting factor for productivity in aquatic life zones. Phosphorus is the main limiting nutrient in freshwater life zones, whereas nitrogen is the main limiting nutrient in saltwater life zones.**