Ecology of Aquatic Environments

Lake Ecosystems

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Learning Outcomes

- To understand the principal abiotic factors impacting lake biota
- To apply recent knowledge of nutrient cycles and internal loading mechanisms to lakes
- To recognise the key organisms living in the sub-habitats of lakes

What are the Principal Abiotic Factors Impacting Lake Biota?

1. Light

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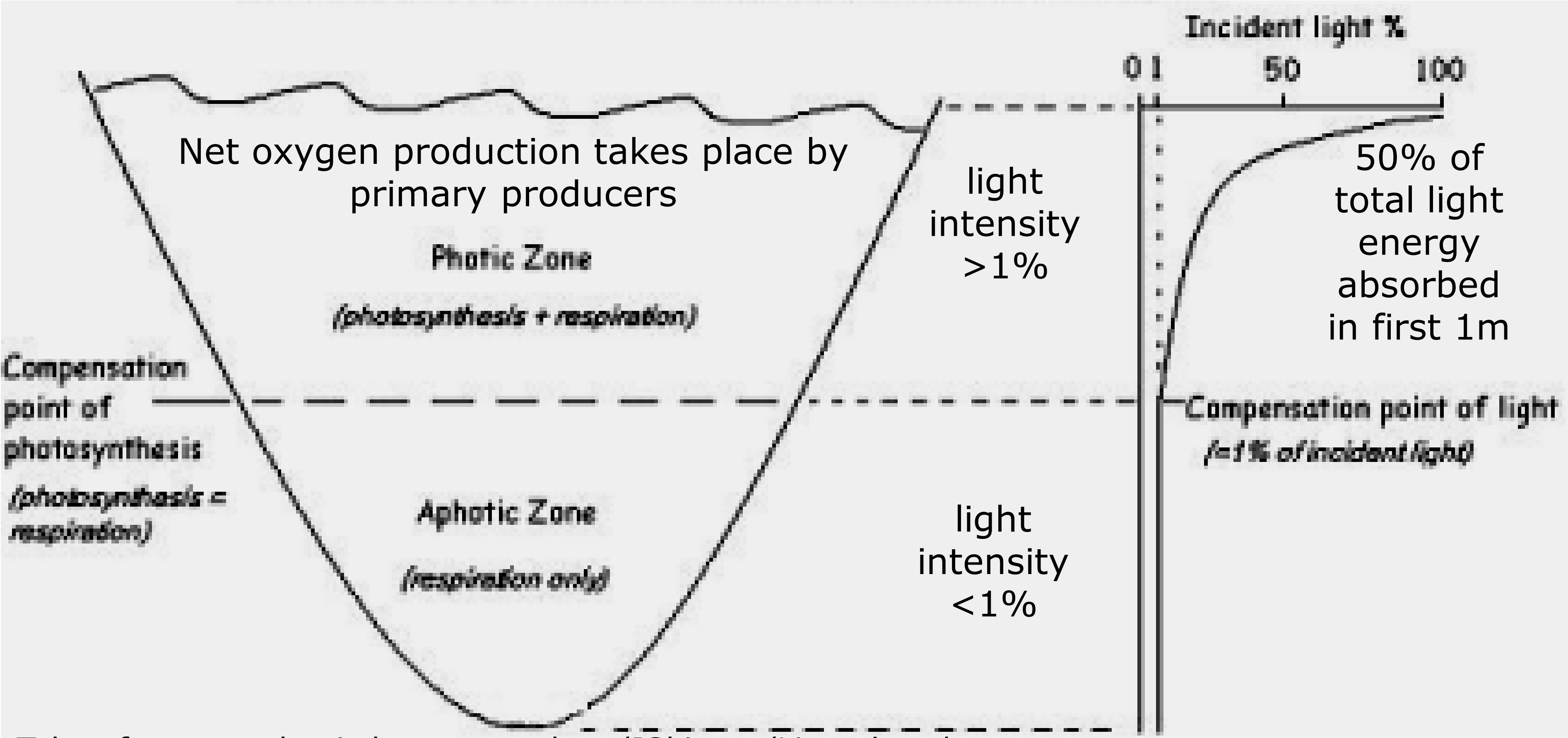


Taken from: academic.keystone.edu - /JSkinner/Limnology/

1. Light

Important for:

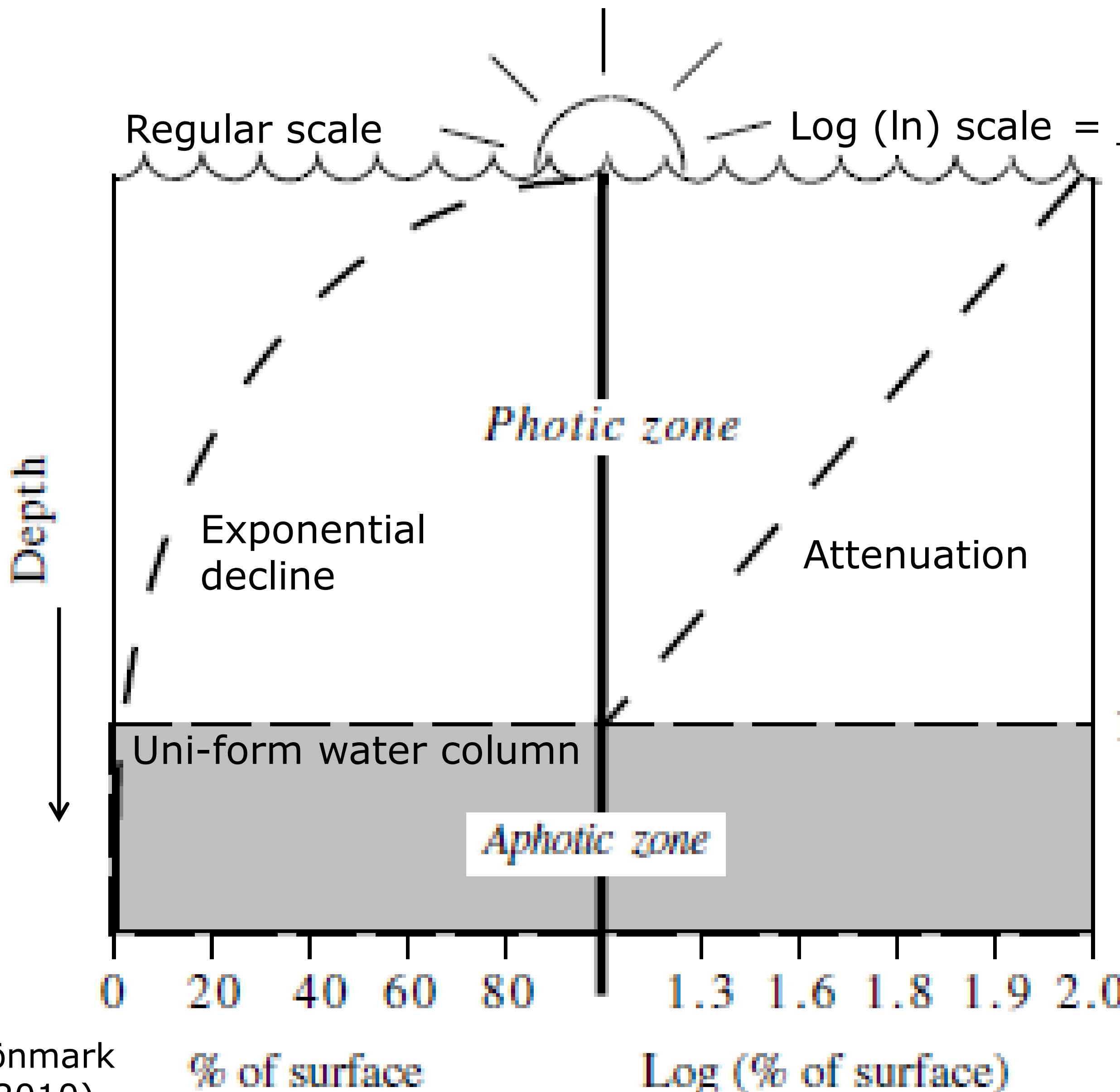
1. Photosynthesis (biochemical process) - constrains primary producers (algal and macrophyte growth) to the littoral zone
2. Organisms with eyes or light sensors use light as sensory cues - impacts on the movement and migration of many aquatic animals e.g. zooplankton and fish
3. Heats waterbody – solar energy
4. Stratification
5. Characteristic colour to lakes – blue, green, clear

Light absorption is affected by:

- Amount of dissolved and suspended material
- Water clarity
- Wave type

1. Light

Light reduced at a fixed proportion at each depth increment



Considers reflection & absorption by water, dissolved compounds, suspended particles

Max depth photosynthesis can occur

Taken from Brönmark and Hansson (2010)

2. Temperature

Heating, cooling and movement of heat through the water determine water temperature

- In turn, controls the rates of biological activity (activity, behaviour, metabolic rate)

Thermal Stratification e.g. cold temperate lakes

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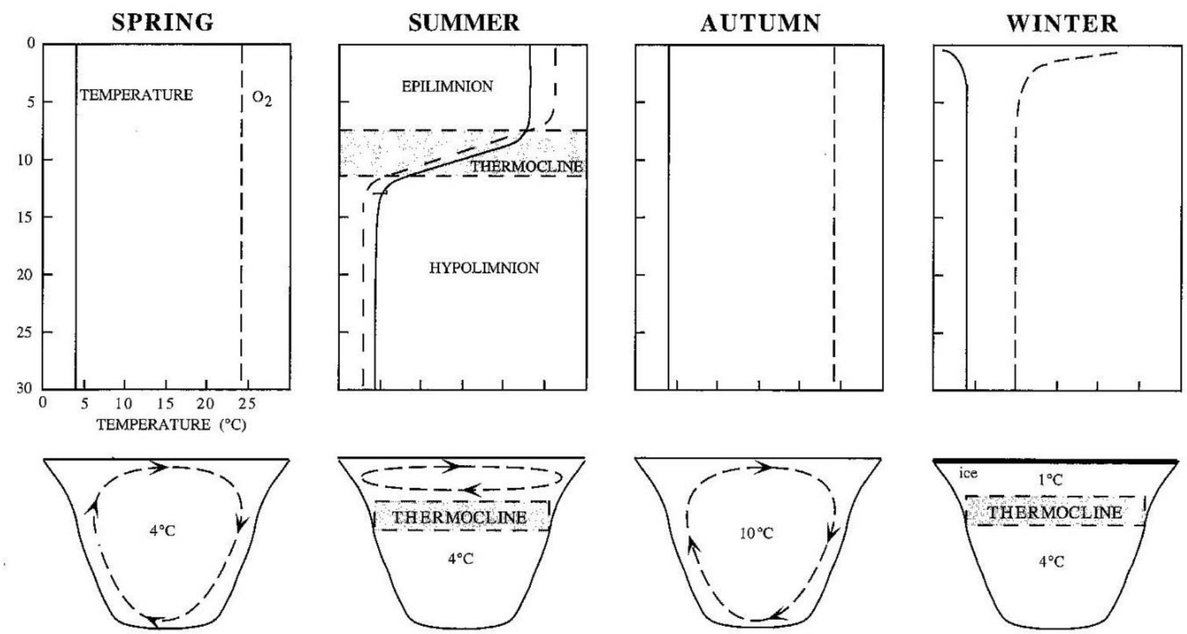


Solar radiation

Degree of vertical mixing

Brönmark and Hansson (2010)

Thermal Stratification

Autumn Turnover

Winter Stratification

2. Temperature

Freshwater organisms experience a wide range of temperatures

- Seasonal and diurnal

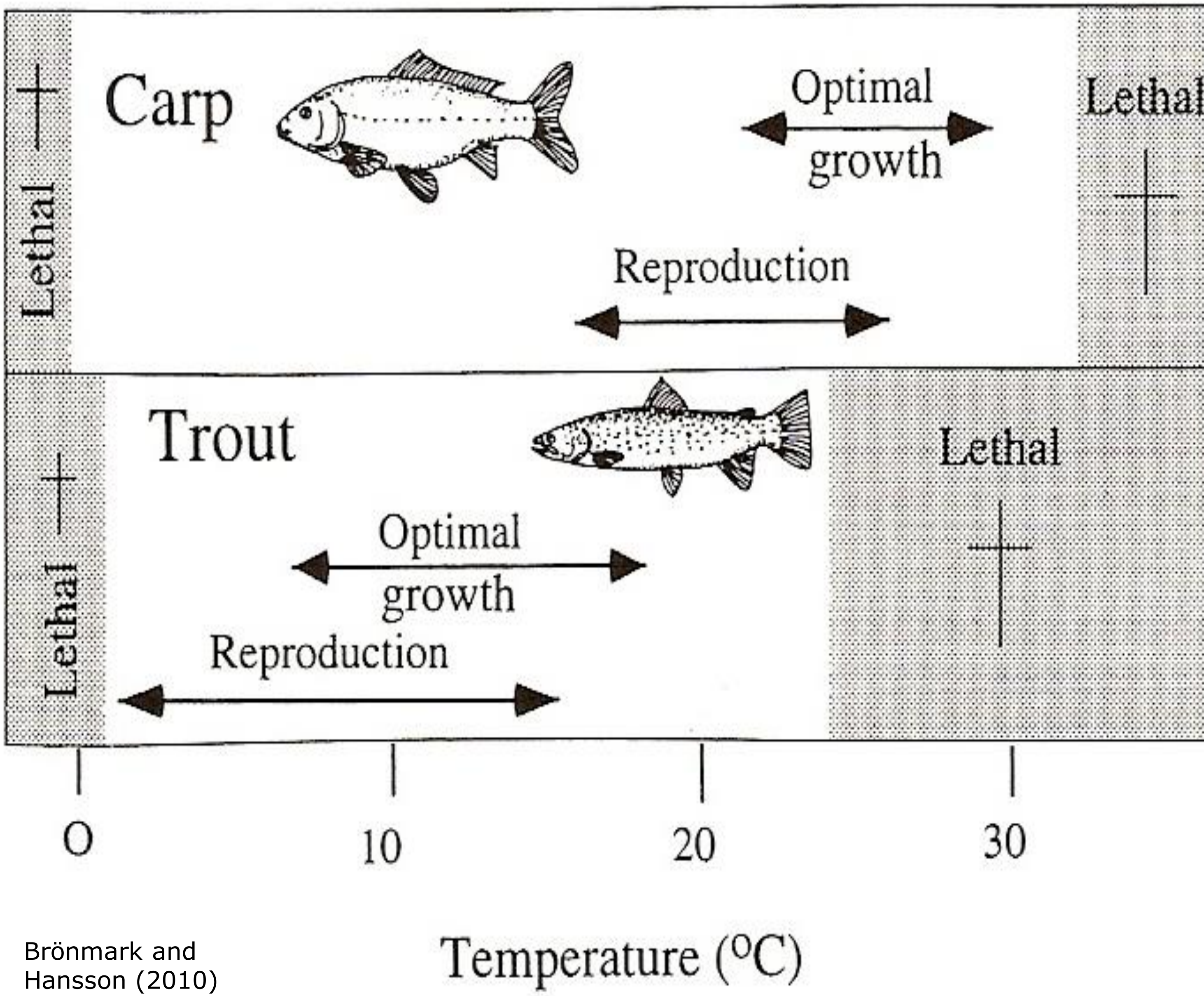
Different aquatic organisms have different temperature optima

E.g. Fish are classified as ‘cold’ and ‘warm’ water species based on temperature preferences

The optimum temperature range within which a fish spp. can survive and reproduce differs between spp.

- **Eurytherns** can tolerate a wide range of temps.
- **Stenotherms** have a narrow temperature range

2. Temperature



Brönmark and Hansson (2010)

2. Temperature

Biotic adaptations to changing temperature regimes:

1. Acclimatisation – where an organism acclimatises to a changing temp. regime

- E.g. *Chlorella* sp. showed maximum growth rates at 20^o, 26^o and 36^o
- Showed an acclimatisation of 16^o on optimal temps.

2. Resting stages – formed by many organisms under sub-optimal temperature conditions

- E.g. Algae form a thick-walled cyst that are morphologically different from the vegetative cells
- Functions as a time-dispersal system allowing rapid recolonisation following unfavourable environment conditions

2. Temperature

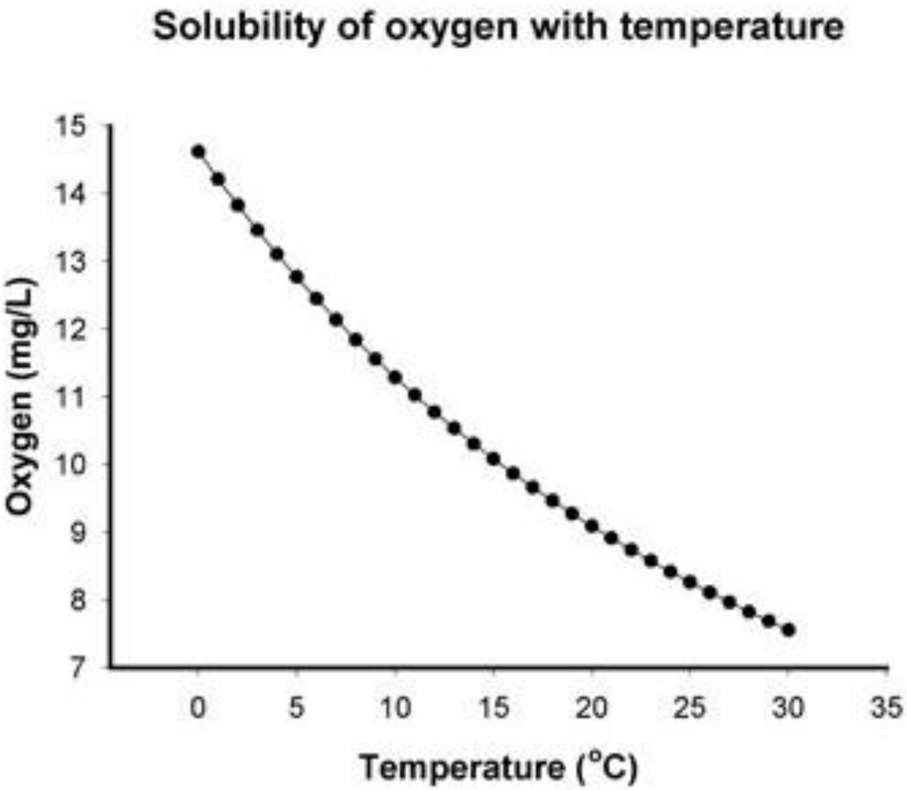
3. Temperature-Induced Hatching

- In *Rutilis rutilis* (Roach), eggs do not hatch at the same time each year
- Hatching date dependant on <u>accumulated temperature</u> on the days preceeding hatching
- Eggs hatch after a fixed degree-day threshold
- Hatching time varies due to between year variability in weather
- Availability of food and the activity of predators are also dependant on temperature
- Ensures resources are abundant for rapid growth

4. Behavioural thermoregulation

- E.g. Diel vertical migration displayed by phytoplankton, zooplankton and fish
  - Spend their days in the cold hypolimnion
  - Move up to the warmer epilimnion only during the night

3. Oxygen



High photosynthesis = oxygen supersaturated

Why?

High decomposition = reduced oxygen levels

Why?

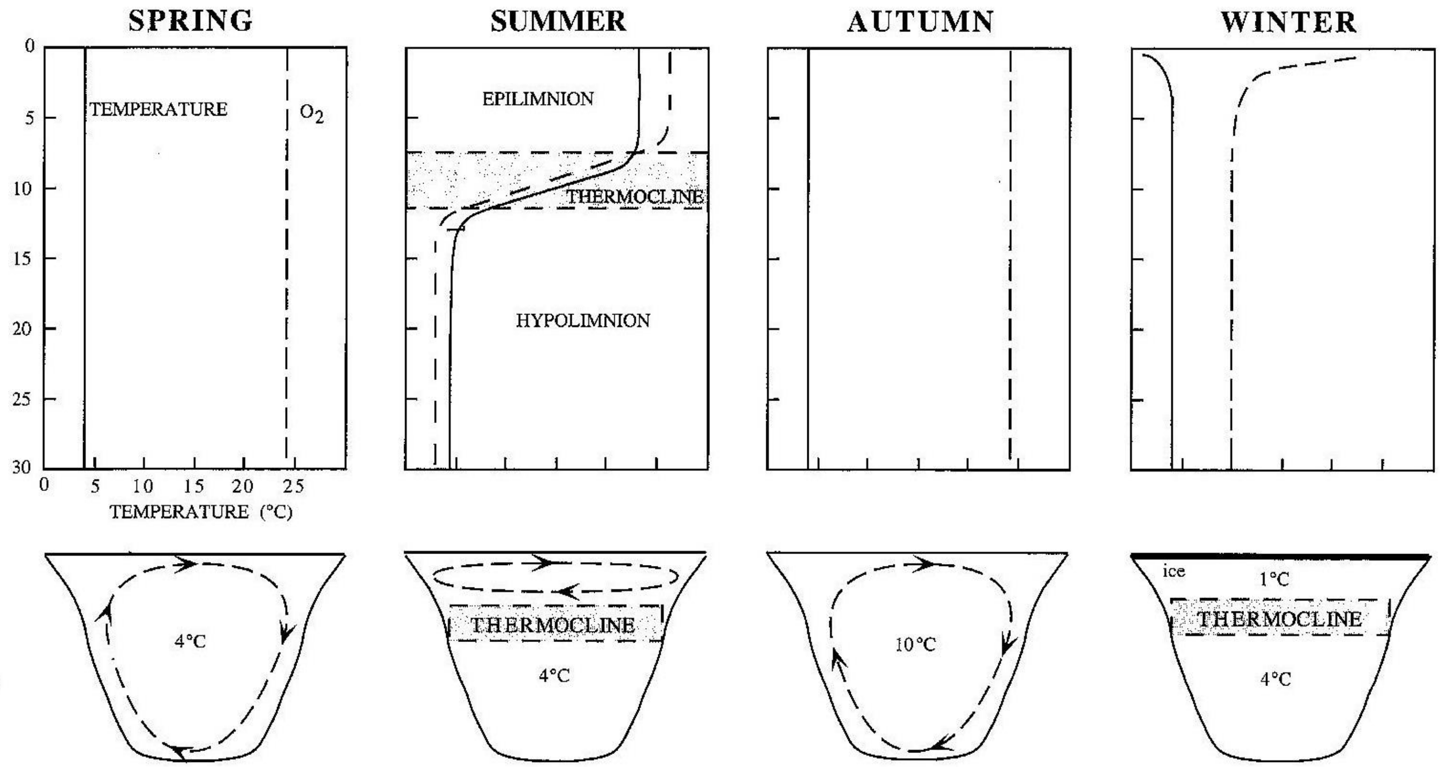
Availability of O_2 is sensitive to:

1. Physical processes e.g. mixing and wave action
2. Biological processes e.g. respiration and photosynthesis

3. Oxygen

Seasonal thermal stratification is a **key process** for understanding DO dynamics in lakes

Need a volunteer



Saturation levels ≥ 100%

Atmospheric O_2 (Epilimnion)

Anoxic (Hypolimnion)

Saturation levels ≥ 100%

Transparent Ice = algal growth

Snow and Ice = winterkill

Brönmark & Hansson (2010)

3. Oxygen

Biotic adaptations to low oxygen:

Macrophyte Morphological Adaptations

- See wetlands lecture & B&Z II lectures

Invertebrate Morphological Adaptations

Oxygen from water:

1. *Integumental respiration* – O_2 taken up directly across the body surface e.g. zooplankton, *Tubifex*
2. *Tracheal system* – transport of gases throughout the body e.g. aquatic insect larvae and nymphs
3. *Ventilatory movements* - increase the flow of oxygenated waters across the respiratory organs e.g. Ephemeroptera (gills), Trichoptera (cases)
4. *Rectal pump* – pump water in and out of their tracheated rectal chamber e.g. Odonata
5. *Fish gills*

3. Oxygen

Oxygen from air:

1. *Siphons/snorkels* - opened at the water surface e.g. water scorpion, water bugs
2. *Store air* – trap air beneath wings or with water repellent hairs
3. *Air bubbles* - carried underwater by organisms are replaced by O_2 in the water column via diffusion e.g. *Argyroneta aquatica*

Invertebrate Physiological and Behavioural adaptations

1. *Migrate* to more oxygen-rich habitats
2. *Haemoglobin (Hb)* – facilitates transport, diffusion and storage of O_2 e.g. crustaceans, chironomids

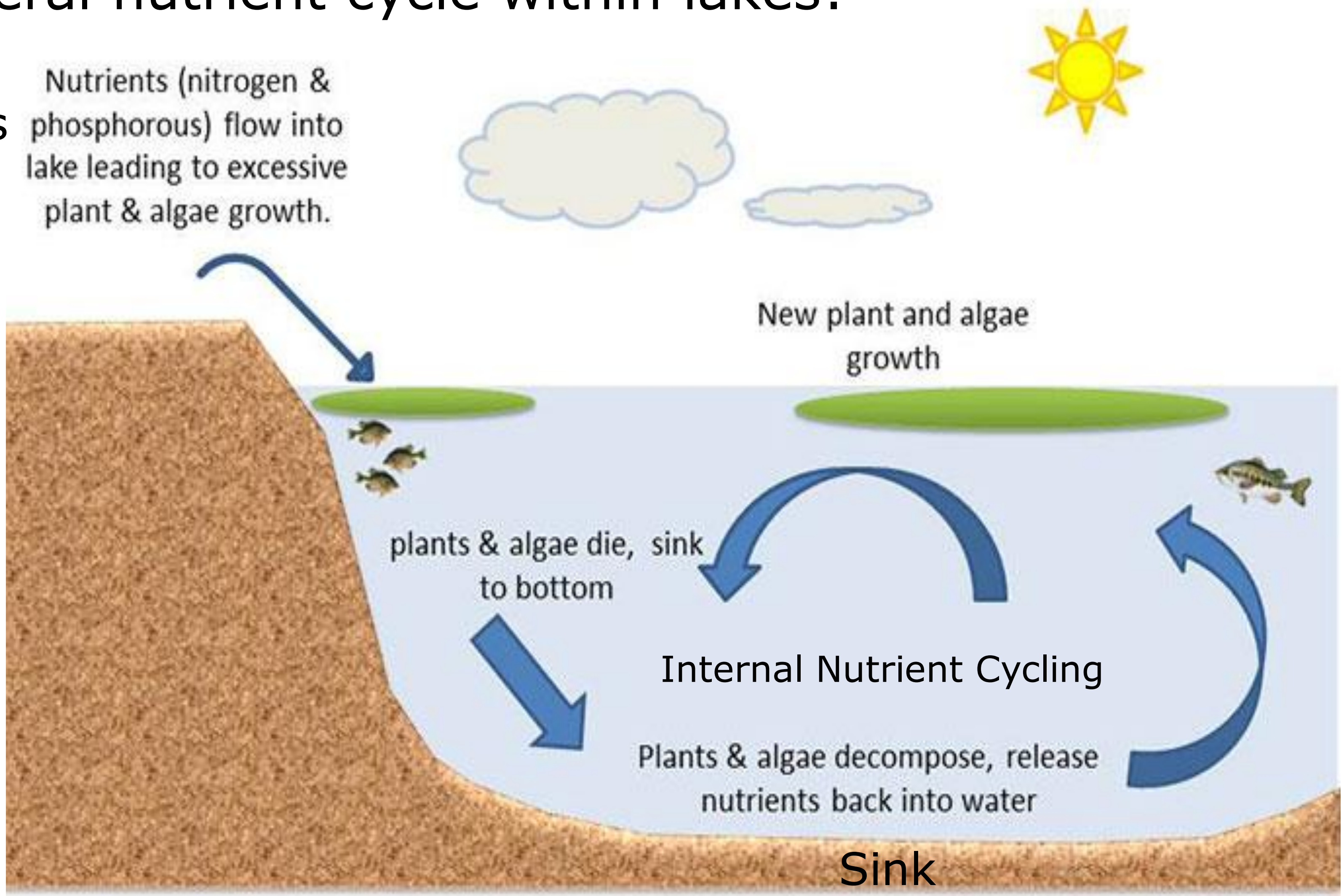
To apply recent knowledge of nutrient cycles and internal loading mechanisms to lakes

What do we know?

Nutrient Cycles within Lakes

General nutrient cycle within lakes:

Inputs

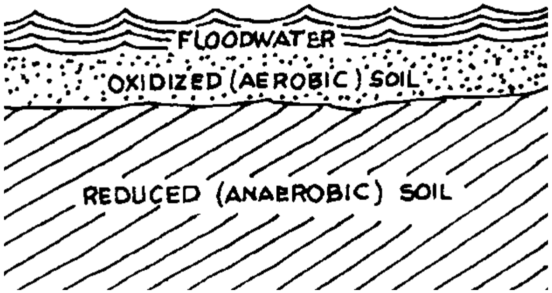


Outputs

Nutrient Cycles within Lakes

Decomposition of OM occurs between the **water-sediment interface**

- Nutrients available for organisms in the water column



A **<u>key phosphate interaction</u>** is with **Iron (Fe)** (Søndergaard et al. 2003)

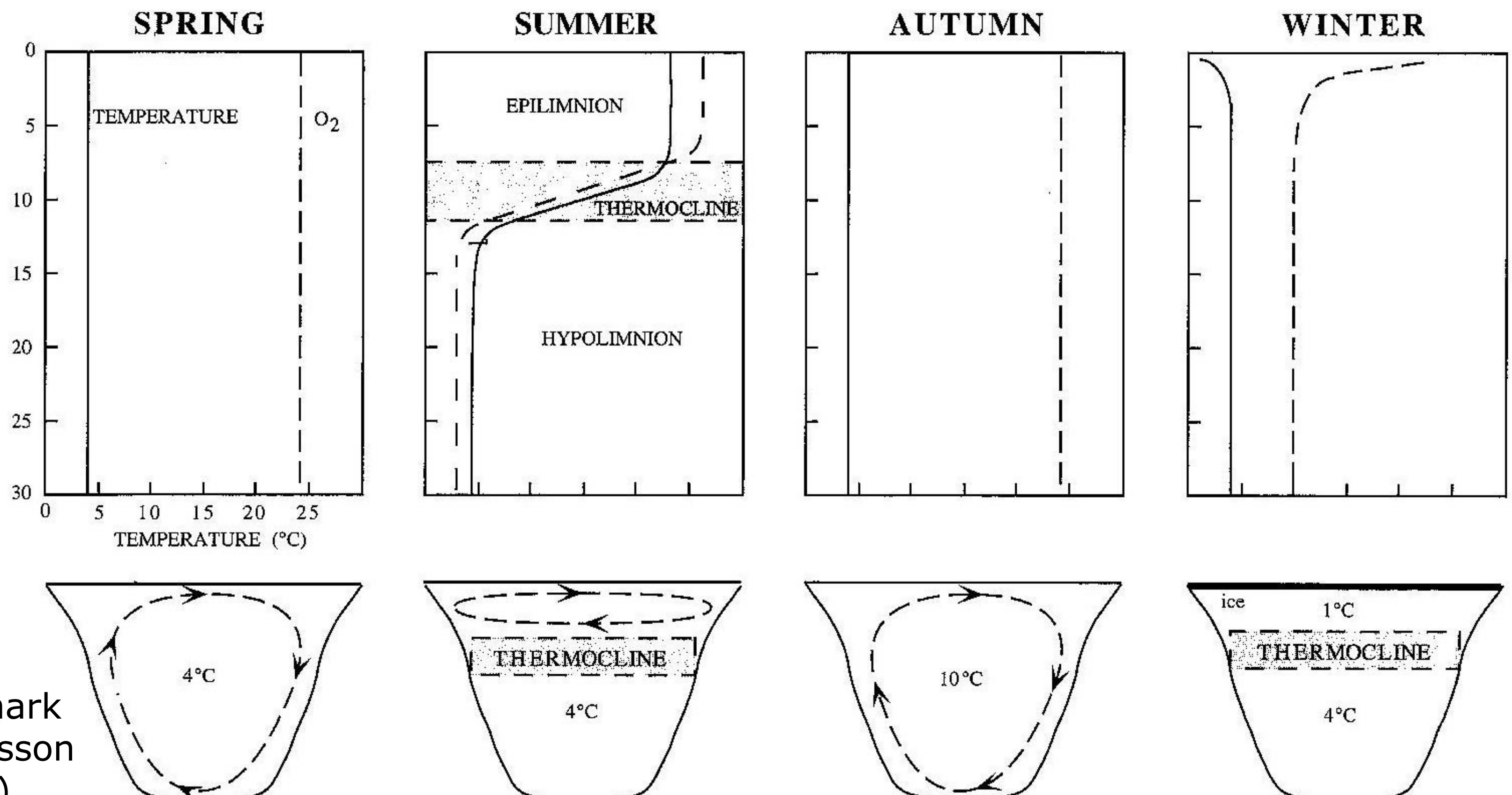
$Fe^{3+}(OH)_3 + PO_4^{3-}$ (sorbed) ⇔ $Fe^{2+}(OH)_2 + PO_4^{3}$(bioavailable)

Oxic & pH < 8 Anoxic & pH > 8

- Controlled by levels of pH and oxygen availability
- In <u>presence of oxygen</u>, phosphate precipitates with ferric iron (Fe^{3+}) = ferric phosphate $FePO_4$ = deposition of P in sediments (sink) = reduces phosphate availability to phytoplankton
- In <u>anoxic conditions</u>, Fe^{3+} transforms back to soluble Fe^{2+} = P is released from the sediment = phosphate available to phytoplankton

Nutrient Cycles within Lakes

Impact of lake stratification on internal nutrient loading



Brönmark & Hansson (2010)

Well mixed nutrients = bioavailable

Storage of nutrients in hypolimnion

Well mixed nutrients = bioavailable

Storage of nutrients in hypolimnion

Who are the key organisms living in the sub-habitats of lakes?

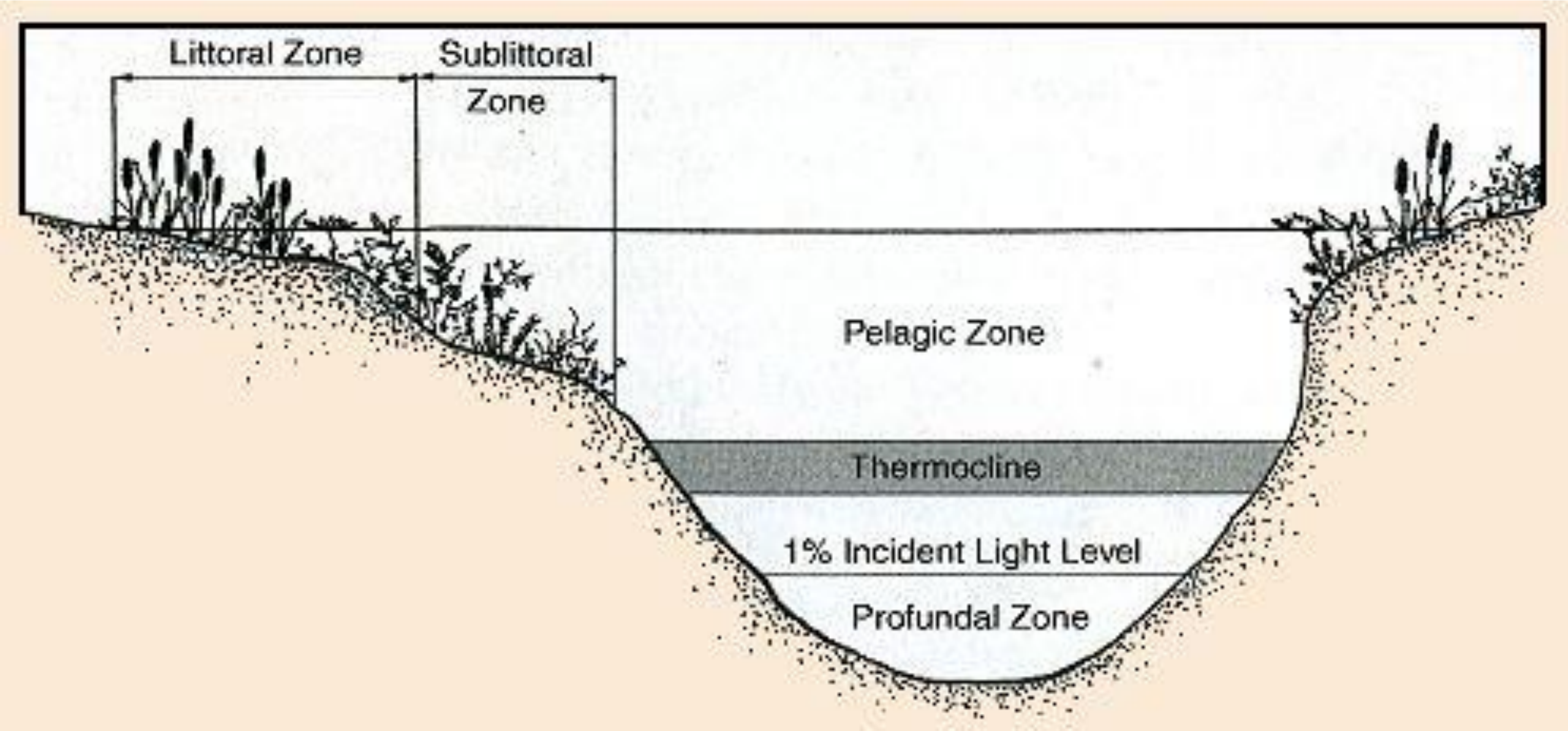
What is a sub-habitat within a lake?

Who might live there?

Lentic Sub-habitats

Divided into three distinct sub-habitats/zones:

- Determined by the size and shape of the lake



Life in the Littoral Zone

Key players:

1. Phytoplankton (free-living)
2. Periphyton
3. Macrophytes

- Rely on photosynthesis for their nutrition
- All have similar resource requirements e.g. nutrients (N & P), CO_2, light

What do we already know?

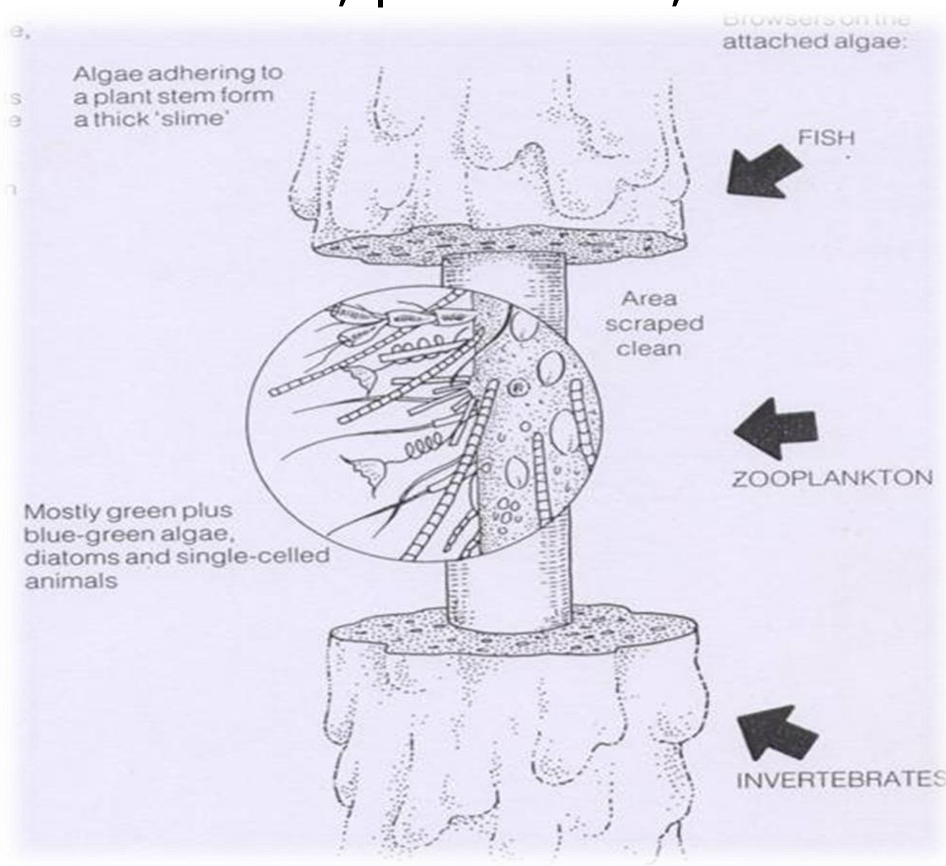
1. Phytoplankton

- Free-living phytoplankton most important in large lakes
- Play an important role as bioindicators of water quality (WQ) and trophic status (TS)

Life in the Littoral Zone

2. Periphyton refers to the microalgae growing on or attached to any submerged surface

- Slippery, greenish-brown layer
- Composed of algae (diatoms, chlorophyta, cyanophyta), fungi, bacteria, protozoans, small invertebrates



Role as bioindicators:

- Integrates physical & chemical disturbances
- Naturally high numbers
- Rapid response time to exposure and recovery
- Ease of sampling and ID
- Tolerance/sensitivity of many species well known e.g. diatoms – Trophic Diatom Index

Life in the Littoral Zone

Wetzel 1983; Trifonova 1988; Reynolds et al. 2002 & Bellinger and Sigee 2010 suggest the following as reliable indicators of WQ and TS:

- **Oligotrophic**: Dinoflagellates; Diatoms – *Tabelleria*, *Cyctotella*; Desmids (acidic) – *Staurodesmus*, *Staurastrum*; Chrysophycean - *Dinobryon*

- **Mesotrophic**: Dinoflagellates – *Peridinium*, *Ceratium* sp.; Cyanophyta – *Merismopedia*; Chlorophyta – *Pediastrum; Diatoms - Tabelleria*, *Cyctotella*

- **Eutrophic**: Cyanophyta - *Anabaena*, Euglenophyta; Chlorophyta - *Spirogyra*; Diatoms – *Fragilaria*, *Asterionella, Synedra*, *Melosira, Nitzschia*

Life in the Littoral Zone

3. Macrophytes as bioindicators: What do we already know?

- Respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, water level changes
- Easily sampled
- Easy to determine richness and abundance metrics (Mean Trophic Rank)
- Knowledge of the trophic requirements and ecological tolerances of macrophytes – can infer the trophic status of a lake (Smith 2012)
  - **Oligotrophic**: *Isoetes lacustris* (quillwort), *Lobelia dortmanna* (water lobelia)
  - **Eutrophic**: *Lemna* spp., *Ceratophyllum* spp., *Ranunculus aquatilis* (water crowfoot), *Rorippa amphibia* (greater yellow-cress), *Sagittaria sagittifolia* (arrowhead), *Glyceria* spp., *Typha latifolia*
- Community changes can indicate sources and quantities of pollution
- Absence = water quality problems, excess turbidity, presence of herbicides, metals, lack of fish or waterfowl
- Overabundance = high nutrients = low aesthetic value

Life in the Pelagic Zone: Slum or Paradise?

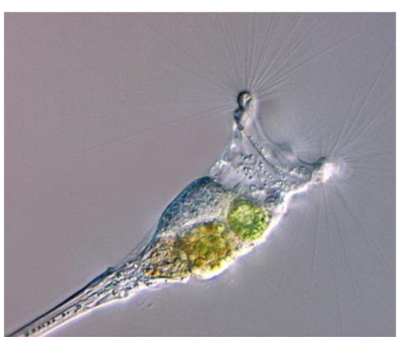
Key players:

1. Protozoa and Fungi (see B&Z I notes)
2. Phytoplankton (see previous slides)
3. Zooplankton (L&O notes)
4. Fish

Who do we already know?

3. Zooplankton

- Rotifers & crustaceans dominate
- Others freshwater jellyfish, flatworms, gastrotrichs and mites
- Carnivorous and typically suspension feeders
- Indicate productivity levels in water

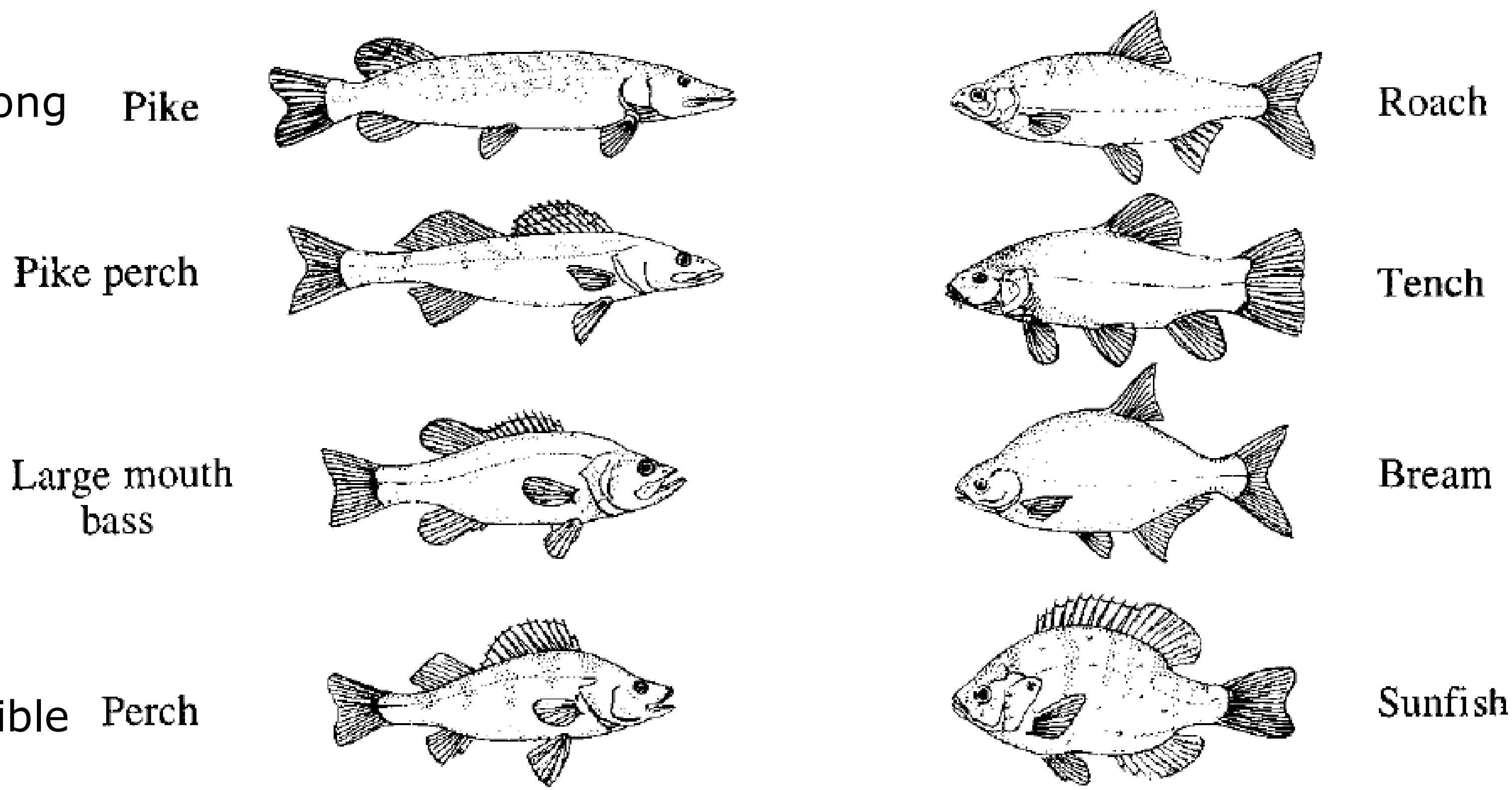


Life in the Pelagic Zone: Slum or Paradise?

4. Fish

- Diverse group including generalists, omnivores and specialists
- Have distinctive body shapes based on feeding habits

Strong



Flexible

Bronmark and Hansson (2010)

Life in the Pelagic Zone: Slum or Paradise?

Fish undergo **ontogenetic niche shifts** – as they grow they change their diet and habitat use

- E.g. *Perca fluviatils* (European perch)
  - Feeds on zooplankton as a juvenile in the littoral zone
  - Benthic macroinvertebrates
  - Piscivorous in the pelagic zone

"**Fish are the prime determinants of community structure in shallow lakes"** Why?

Cascade effect (Top-down effects)

- Fish predate on invertebrates = grazing invertebrate density decreases = increases in periphyton biomass = decrease in nutrients

Life in the Profundal Zone – What Lurks in the Dark?

Key players:

- Bacteria
- Protozoans
- Ciliates
- Insect larvae e.g. *Chaoborus & Chironomus*
- Bivalves
- Oligochaetes
- Nematodes

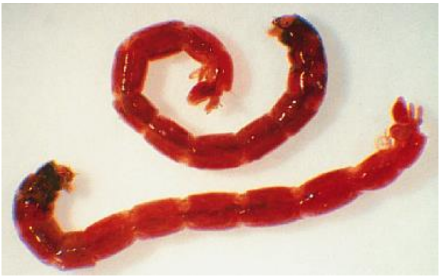
- Dependent on OM (energy source) from above overlying layers = all heterotrophs
- Low diversity of species
- Depends on O_2 status
- Production levels are high = high bacterial activity = anaerobic conditions

Life in the Profundal Zone – What Lurks in the Dark?

Chaoborus fluvicans (Phantom midge larvae)

- Dipteran larvae
- Voracious carnivore/Predator of zooplankton
- Transparent body with two air sacs (buoyancy aids)
- Diurnal feeding habits (Malinen et al. 2001)
- Eggs laid in late summer by adult midge
  - 1st instar appears in plankton in Sept
  - 2nd and 3rd instars spend time in plankton and sediment
  - 4th instar in following spring
  - Pupation and emergence occur in July

Life in the Profundal Zone – What Lurks in the Dark?



Chironomus anthracinus

- Dipteran larvae
- Detritivore
- In May: eggs are laid on water surface between sunset/sunrise
- In June: Eggs hatch to form instars <2 mm long
  - Rapid growth occur to form 1st and 2nd instars
  - 1st instar is transparent and moves beneath the sediment surface, swallowing sediment as it moves
  - 2nd instar is more muscular, lives in a tube in the sediment and develops haemoglobin
    - 1.5cm long and bright red
  - Coincides with a ready supply of food falling from the pelagic zone e.g. phytoplankton
- In July: 3rd instar may have reduced growth if O_2 levels drop
- In Sept.: 4th instar
- In 2nd year: pupa floats to surface in cocoons
- Hatch into imagos (adults)
- Live for 2-3 days feeding on phytoplankton and detritus

Life in the Benthic Zone

Key players:

1. *Chironomus* spp. live closest to the sediment surface
   - Better food quality

2. Oligochaetes – Family Tubificidae
   - Deep in the sediments
   - Process material that has already been ingested and defaecated
   - Least vulnerable to fish predation

Remember !

The littoral and pelagic zones are the kitchens

The profundal and benthic zones are the lavatory and sewage works

Moss (2010)

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Thank you