River Water Quality

Section **2c**: Hydrology & Ecology of Running Waters

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Ευρωπαϊκή Ένωση
Ευρωπαϊκό Κοινωνικό Ταμείο

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ
ΕΚΠΑΙΔΕΥΣΗ ΚΑΙ ΔΙΑ ΒΙΟΥ ΜΑΘΗΣΗ
επένδυση στην κοινωνία της γνώσης
ΥΠΟΥΡΓΕΙΟ ΠΑΙΔΕΙΑΣ & ΘΡΗΣΚΕΥΜΑΤΩΝ, ΠΟΛΙΤΙΣΜΟΥ & ΑΘΛΗΤΙΣΜΟΥ
ΕΙΔΙΚΗ ΥΠΗΡΕΣΙΑ ΔΙΑΧΕΙΡΙΣΗΣ

ΕΣΠΑ 2007-2013
πρόγραμμα για την ανάπτυξη
ΕΥΡΩΠΑΪΚΟ ΚΟΙΝΩΝΙΚΟ ΤΑΜΕΙΟ

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Funding

- This educational material has been developed as part of the educational work of the teacher.
- The project "Open Academic Courses at Aristotle University of Thessaloniki" has only fund the remodeling of educational material.
- The project is implemented under the Operational Program "Education and Lifelong Learning" and co-funded by the European Union (European Social Fund) and national resources.

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Hydrology & Ecology of Running Waters

Freshwater Biota

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Introduction

- Water as a living environment does not have the same viscosity as air & contains very little oxygen to breathe

Freshwater biota:

✓ Withstand these conditions, survive & expand to new similar environments

✓ Possess structures & biological adaptions to life in wet environment

- Human interventions alter biotopes & introduce alien species
- The WFD emphasises (Annex V) the need to take into account the range of organisms (phytoplankton, phytobenthos, macrophytes, macroinvertebrates & fish) reflecting biological water quality
- Knowledge of basic ecological concepts is important for an understanding of the functioning of aquatic ecosystems

Flow of Energy

- Energy is the ability or capacity to do work
- All activities of living organisms involve work (energy expenditure)
- Energy contained in the food is reduced step by step (food chains) until all the energy in the system is dissipated as heat (unrecyclable)

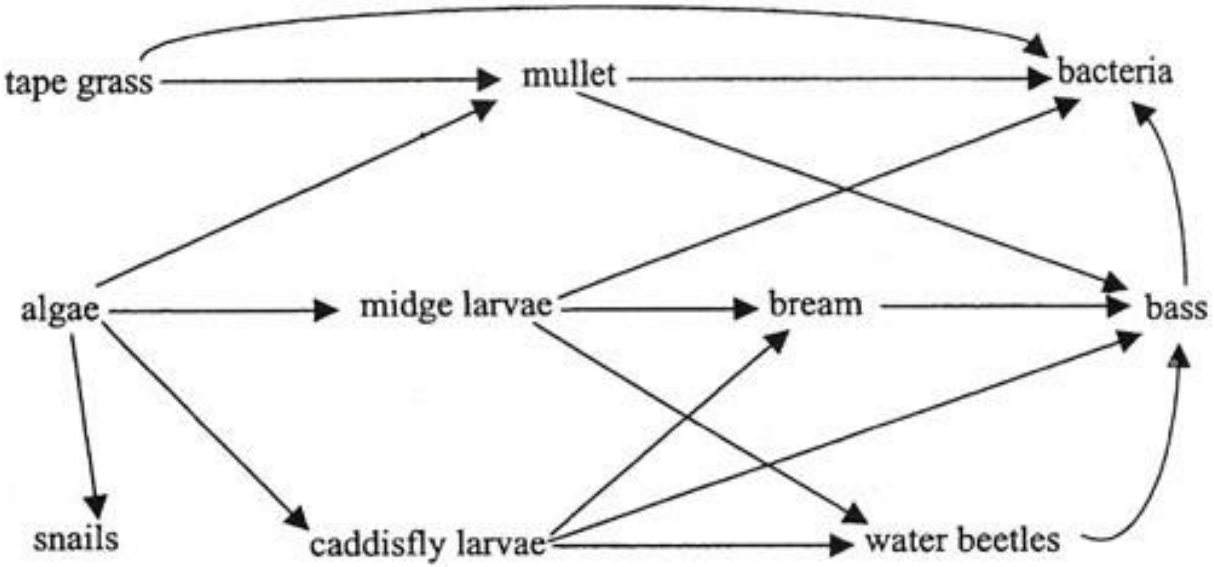
Organisms sharing the same general type of food in a food chain are at the same trophic level:

- ✓ Plants = producers (autotrophs) – 1st trophic level
- ✓ Herbivores = eat plants – 2nd trophic level
- ✓ Carnivores = flesh eating consumers – ≥ 3rd trophic level

- At each transfer, 80 - 90% of energy is lost as heat & waste
- Aquatic food chains are commonly longer than those of land

Flow of Energy

- Interlocking of food chains forms a food web
- An organism in a food web may occupy ≥ 1 trophic levels
- Decomposers assure there is no waste in ecosystems

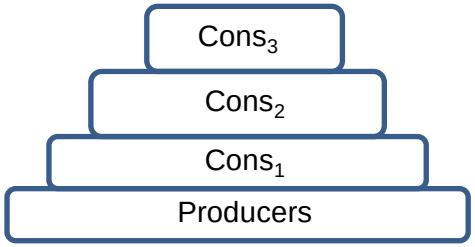


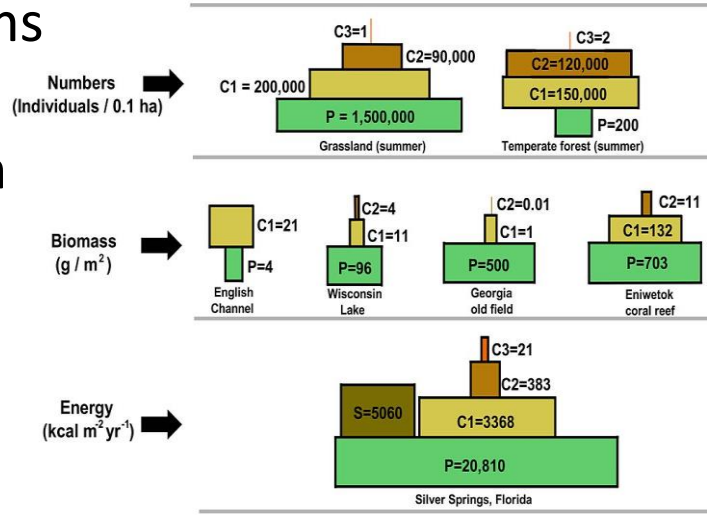
Paradigm of the form of a typical freshwater food web.

From: Spellman F.R. & Drinan J.E., 2001, 'Stream Ecology and self purification: An Introduction ' Technomic Publishing Company, Pennsylvania

Ecological Pyramids

- Less energy is available at higher trophic levels due to the loss caused by the transfer
- **Pyramids** must be larger at the base (2nd thermodynamics law & dissipation of energy)
- **Biomass pyramids –** in aquatic ecosystems are usually inverted. The amount of biomass in primary producers is less than that in larger, long-lived animals that consume primary producers
- **Pyramids of numbers** can have various shapes depending on the sizes of the organisms that make up the trophic levels.





Three different kinds of trophic pyramids (numbers, biomass, energy). From: http://en.wikipedia.org/wiki/File:EcologicalPyramids.jpg. in *Fundamentals of ecology*, Brooks Cole, pp. 598 ISBN: 9780534420666., Thompsma,CC-BY-SA

Pollution Response to Stress

- **Species diversity** - major factor that affects population stability or persistence
  - ✓ Shannon-Weiner Index – calculation of species diversity
- High diversity spreads the risk, whereas in stressed communities diversity tends to be reduced. The higher the species diversity, the greater the inertia & resilience of the ecosystem
- Change in ecosystems may result from natural occurrences (fires, earthquakes & floods) & from people-induced changes (deforestation, mining, pollution etc)

Pollution Response to Stress

Stream Ecology

- Balance of the stream ecosystem = balance between population growth & reduction factors

Growth factors (biotic & abiotic) → ability to :

- ✓ Produce offspring
- ✓ Adapt to new environments
- ✓ Migrate to new territories
- ✓ Compete with species for food & space to live
- ✓ Blend into the environment (camouflage)
- ✓ Find food
- ✓ Defend against enemies
- ✓ Access favorable light, temperature, D.O., water level

Pollution Response to Stress

Stream Ecology

- Balance of the stream ecosystem = balance between population growth & reduction factors

Reduction factors (biotic & abiotic) :

- ✓ Predators
- ✓ Disease
- ✓ Parasites
- ✓ Pollution
- ✓ Competition for space & food
- ✓ Unfavorable conditions
- ✓ Lack of food – nutrients

Adaptations of animals to freshwater

- Physiological & Morphological adaptations occur for living in such environments
- Tracheal-gills & body/skin formations as gills for breathing
- Adaptations for locomotion (vibrating cells, fins, row-like limbs etc) & resistance against flow of water (flat shape, hooks, suction cups)
- Differences & variety of adaptations within a life-cycle: dormant stage-egg-larvae (nymph)-adult → to ensure the viability of the offspring & the stay in the water
- Clear sight is obscured (low transparency) → Growth of barbells
- Unclear sound perception → growth of stridulating organ

Adaptations of animals to freshwater

- Temperature variations = dissolved oxygen variations → breathing problem in risen temperatures & migration in freezing temperatures or physiological adaptations which enable species to survive in these special conditions
- Species dispersal depends on their life cycle characteristics- traits, their ability to reach terrestrial environment & the connectivity of neighbouring basins
- Barriers for these exchanges (dams, natural barriers or artificial constructions) affect the populations either by limiting colonization or by impoverishing the genetic potential of the species

Periphyton & Phytoplankton

Phytoplankton: The word is derived from the Greek term meaning "wanderer." The animals of this group are called zooplankton & the plants phytoplankton. Bacteria & fungi are often most abundant in association with particles, phytoplankton, or suspended sediments. Such free floating populations have been recognized in a wide variety of rivers of almost all sizes.

- Populations may be traced to inflows from standing waters in the catchment or dislodged from the benthos or from neither source. Various diatom species, or green algae (e.g. *Chlorella, Ankistrodesmus, Scenedesmus)* have been reported even though they generally require higher nutrient concentrations. Cyanobacteria, blue-green algae and others may also be present. (*Schizothrix, Rivularia & Tolypothrix - Ulothrix, Cladophora, Stigeocllonium, Rhizoclonium & Coleochaete)*
- Found In higher abundances in slow flowing reaches of the river, pools & still areas that can occur in a moderately flowing system.
- Unreliable indicators in river systems due to the lacking knowledge of river phytoplankton and to the fact that it is accumulated in lotic environments & stagnant waters.

Periphyton & Phytoplankton

Periphyton or Phytobenthos is divided to groups depending on where they grow:

- ✓ Epiphytes – grow on leaves of submerged plants
- ✓ Epilithic – grow on rocks & hard mineral surfaces
- ✓ Episammon – grow on sand grains
- ✓ Epipelic – associated with fine sediments or mud (may form mats)

Is a complex mixture of micro algae & associated bacteria, fungi & occasional protozoans which form communities (thick) held together by mucus

Diatoms is the most frequently used taxon in periphyton monitoring to assess the ecological status

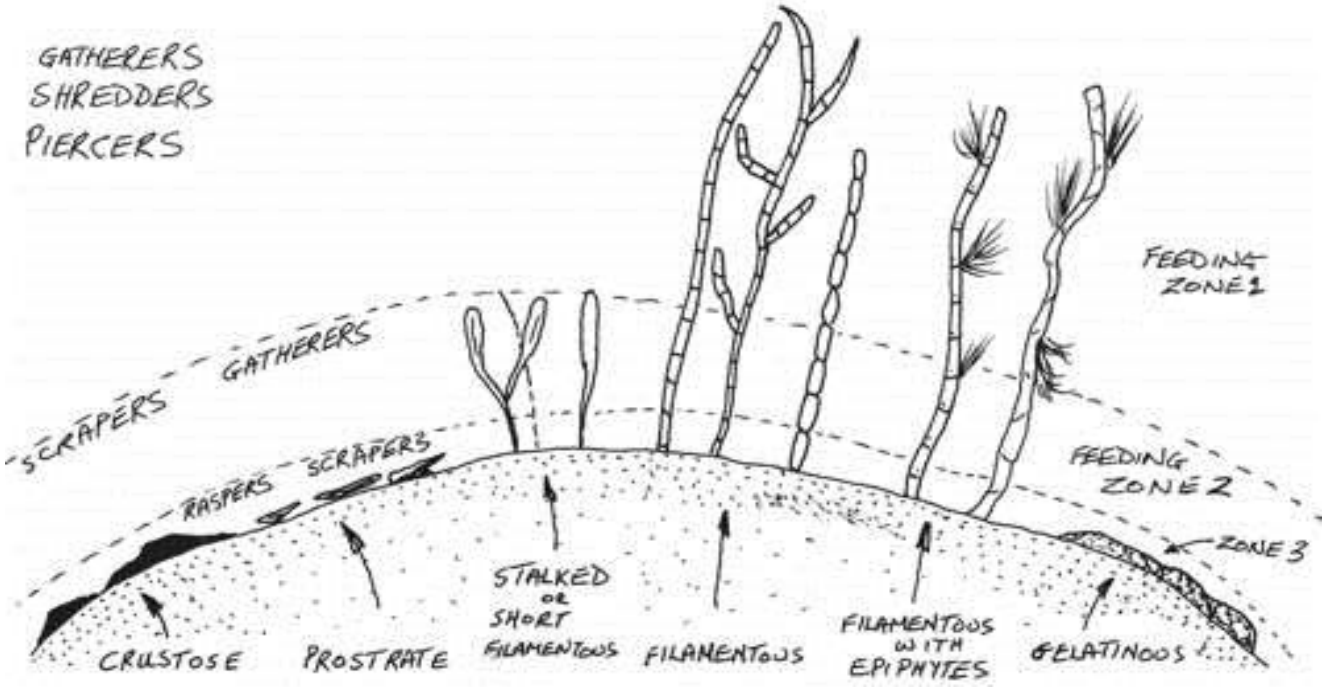
Periphyton & Phytoplankton

Diatoms (Periphyton) & water quality

- Sudied for >100 years, many indices devised, not standard-not intercalibrated (common base)
- Phytobentos is an essential element in the classification & its composition should be determined regularly (Annex V, WFD)
- Few species (of the several hundreds) act as quality indicators & grow on a variety of substrates
- Artificial substrata (posed in <1 m water, not in shade) are usually transported to the laboratory for observation
- Current of water, light, nature of substrate (pitted surface, silt), existence of grazing macroinvertebrates

Periphyton & Phytoplankton

Diatoms (Periphyton) & water quality



- A summary of the various growth forms on stones with the three zones of Periphyton directly related to the ability of the animals to consume the material (graze). From: http://www.lifeinfreshwater.org.uk/Web%20pages/Rivers/Prim%20Production.htm based on Steinmand (1992, from *Oecologia* vol. 91) after Gregory (1980, PhD Oregon State University). © 2014 Field Studies Council

Periphyton & Phytoplankton

Diatoms (Periphyton) & water quality

- Variations in activity depending on season with rise during spring-summer-autumn (photosynthetic organisms)
- In fast flowing rivers sloughing takes place (washed out) that leads to a cycle of growth – removal and recolonisation
- Standardized methodologies for field collection (),
- Various indices can be applied using species composition according to the river type & zones (e.g. Round 1993)
- Species identification can be achieved through keys & guides (e.g. Krammer & Lange-Bertalot 1986 – 1991, Round 1993, Cox 1996, Kelly 1998)

Macrophytes

- Diverse assemblage of taxonomic groups (angiosperms, pteridophytes, bryophytes) that dominate wetlands, shallow lakes, &streams

Divided in 4 categories based on their growth:

- ✓ floating unattached,
- ✓ floating attached,
- ✓ submersed (the plant is below the water surface)
- ✓ emergent (roots grow underwater, stems & leaves are above)

- Grow in association with standing & flowing water, at or above the soil surface
- Provide: oxygen, substrate for algae, shelter for invertebrates, aid in nutrient recycling, stabilization of banks, food & nesting habitats
- Used as bio-filters to reduce phosphorus & nitrogen concentration & to absorb substances & pollutants

Macrophytes

As water quality indicators:

- Respond to a great variety of abiotic characteristics (nutrients, light, toxic contaminants, metals herbicides, turbidity, water level fluctuation, salinity)
- Are easily sampled (transects or aerial photography)
- Do not require lab analysis
- Used for calculating simple abundance metrics
- Are integrators of environmental condition

Macroinvertebrates

- Species or groups with different tolerances to pollution whose presence and/or abundance can be used as quality indicators

Invertebrates that live:

- ✓ At the water surface (surface fauna),
- ✓ At the water column (pelagic fauna),
- ✓ At the bottom (benthic fauna - dwelling at substrate)
- ✓ As parasites

Macroinvertebrates

Surface fauna – pond skaters

- Spend all or part of their life at the surface of running or standing water like skaters
- Adaptations for staying on the surface (light, small bodied with large tarsi) and not being carried away (constant glide against the stream)
- Predators with abductor (front) legs & rostrum to suck on the pray
- 4 characteristic families with different sizes & habitats: Gerridae (larger), Hydrometridae (slim & smaller), Veliidae (water crickets) & Hebridae (small)

Pond skaters. Available at: http://www.flickr.com/photos/gails_pictures/4465462770/in/photostream/ Gailhampshire, 2009 CC-BY

Macroinvertebrates

Surface fauna – whirling beetles

- They hunt at the surface of the water, making circles
- Morphometry specified to spot & catch prey - Predators with abductor (front) legs & legs (middle & hind) like swimming paddles
- Compound eyes divided - allowing aerial & aquatic vision

'''Gyrinus substriatus''from Commanster, Belgian High Ardennes. Available at: http://en.wikipedia.org/wiki/File:Gyrinus.substriatus.-.lindsey.jpg James K. Lindsey 2005 CC-BY-SA

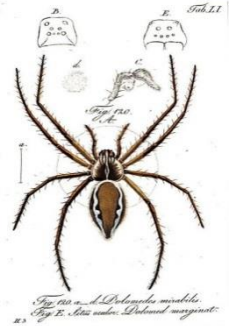
Surface fauna – springtails

- Tiny wingless insects feeding on minute pieces of dead plants that float
- Ability to jump when threatened by predators

Macroinvertebrates

Surface fauna – water spiders

- 2 types: Pisauridae (Dolomeds) & Lycosidae (Wolf-spiders)
- Hunt & chase their prey. Paralyzing venom through their chelicerae & exo-digest their prey
  - ✓ Pisauridae prey on frogs, toad-tadpoles & little fish
- When threatened hide underwater



A dolomed - *Pisaura mirabilis.* Available at http://commons.wikimedia.org/wiki/File:Pisaura_mirabilis_fem_Hahn_1834.jpg Dr. Carl Wilhelm Hahn (lat. Carolus Guilielmus Hahn) (* December 16, 1786 - † November 7, 1835)

A Wolf spider (Lycosidae). Available at http://commons.wikimedia.org/wiki/File:Wolf_spider_%28Lycosidae%29.jpg , Bidgee , 2010, CC-BY-SA

Macroinvertebrates

Pelagic fauna

- Is made up of Arthropods (Crustaceans & Insects) & Vertebrates

Crustaceans of the Decapoda Order can be found in pelagic of freshwater, brackish water & estuarine environments

Typical families: Palaemonodae & Atyidae

Insects of the pelagic fauna belong to 2 Orders: Hemiptera & Coleoptera

Macroinvertebrates

Pelagic fauna - Insects

- Breathing: go up to the surface to renew air supplies (Dytiscidae) & other adaptations as breathing tubes (Nepidae) that reach the surface or as cavitation covered with hydrophobic hairs that form an air bubble-supply (Notonectidae)
- Feeding: the majority is carnivorus but there are exceptions of herbivores (Corixidae scrape & suck small particles of algae). They can be either active hunters (ability to swim fast with flattened posterior legs - Notonectidae) or ambush hunters (forelegs like grasping organs - Nepidae). The larvae of large bodied species (Dytiscus, Hydrous, Hydrophilus) attack preys larger than them

Macroinvertebrates

Benthic fauna

The sum of organisms associated with the bottom (collectively as benthos). These include all forms found in or upon submerged substrates.

- Hidden (endofauna) or present at the surface (epifauna or epibenthic fauna) has an extreme variety of representatives from Sponges to Vertebrates.

Macroinvertebrates

Benthic fauna - Sponges

- < 10 species in freshwater.
- Small in running waters (few cm^2), large in still waters (>m^2)
- Prey on insects larvae (Neuroptera)

Benthic fauna - Cnidaria

- < 20 species in freshwater. The majority belongs to genus Hydra
- Small tube-like bodies (<10 mm) with 4-10 tentacles
- Remain attached but has the ability to move
- Prey on small crustaceans & worms
- Reproduce sexually by hermaphrodite or separately sexual individuals or by buds which develop on their body

Macroinvertebrates

Benthic fauna - Flatworms

- Representatives of the phylum Platyhelminthes – the majority is parasitic. The class Turbellaria (planarians) has free living organism

Turbellaria has 30 species in 10 genus in 3 families

- Small, unsegmented, flat bodies (<30 mm) with no body cavity & under-surface covered with vibrating cilia to glide on surfaces
- Reproduce sexually by hermaphrodite individuals which produce eggs & spermatozoa to fertilise one another
- The eggs in a capsule attach to substrates
- Ability to regenerate themselves
- Feed on small live or dead animals

Macroinvertebrates

Benthic fauna - Crustaceans

18 orders from 5 classes → many representatives

Order: Amphipoda

Drawing of a typical Gammaridae

- Freshwater shrimps
- Flattened from side to side, with curved body
- Feed on organic matter & on small animals
- Separately sexual individuals lay eggs
- Hatching young look like the adults (not larvae form)
- The females lay eggs up to six times during a year.
- The life cycle lasts from 1 to 2 years.

Macroinvertebrates

Benthic fauna - Crustaceans

Order: Isopoda

- Freshwater lice (1 family-Asellidae)
- Flattened dorsoventrally
- Symmetric limbs to each segment
- Feed and feed on all kinds of decaying organic matter (scavengers)
- Separately sexual individuals lay eggs
- Hatching young look like the adults (not larvae form) & remain attached to the mother
- The females lay eggs up to six times during a year.
- The life cycle lasts from 1 year

Drawing of a typical Asellidae

Macroinvertebrates

Benthic fauna - Crustaceans

Order: Mysidacea

- Small shrimp-like
- Swim free or rest on the surface

Order: Decapoda

- 2 groups: Crayfish (Macroura) & True Crabs (Brachyura)
- Mainly carnivorous, some omnivorous
- Crayfish live in running waters & some in burrows dug in the banks
- Crayfish do not have planktonic larvae (eggs attached to abdominal appendages)
- True crabs belong to 2 families with few representatives
- True crabs do not have planktonic larvae (eggs attached to abdominal appendages)

Macroinvertebrates

Benthic fauna - Insects

- The largest invertebrate taxon
- Has aquatic groups during their larval stage & some during their adults stage
- Presence, abundance & species composition = water quality indicator
- Representatives belonging in many orders

Macroinvertebrates

Benthic fauna - Insects

Order: Ephemeroptera (Mayflies)

- Have numerous larval stages (12 to 20)
- Larval life lasts from 1 to 3 years
- Found both in still & running water
- 3 long tail appendages
- Legs equipped with a single claw
- Lateral tracheal-gill on the side of each abdominal segment
- Feed on vegetable matter (large species are carnivorous)
- Last larval stage has wings but cannot copulate
- Brief adult life- from hours to days
- females lay eggs dropping them into the water or crawl & deposit on submerged ojects

Drawing of a typical Ephemeroptera

Macroinvertebrates

Benthic fauna - Insects

Order: Odonata (Dragonflies)

Drawings of two typical Odonata: Anisoptera & Zygoptera

- 2 subgroups: Anisoptera & Zygoptera
- Have numerous larval stages (8 to 15)
- Larval life lasts from 1 to 5 years
- Found mainly in still water
- Predators that devour other insects
- Typical mask created by the labium (is shot forward to secure the prey)
- 3 flat leaf-like tracheal-gills at the tail-end of Zygoptera
- A bulb (like tracheal-gill) formed in the posterior part of the digestive tract receives water through the anus at Anisoptera (used to propel themselves in case of danger)
- Adults live in terrestrial biotopes near the water bodies

Macroinvertebrates

Benthic fauna - Insects

Order: Plecoptera (Stoneflies)

Drawing of a typical Plecoptera

- Have numerous larval stages (6 to 20)
- Larval life lasts from 6 months to 3 years
- Found mainly in rapid stream water
- Lack of tracheal-gills
- Mainly vegetarian, they eat algae and leaves of higher plants
- Presence of only two long tail appendages
- Ends of the legs equipped with two claws
- Adults stay mainly in the water-side vegetation
- Adults are not all able to eat (some feed on lichens and other plants)

Macroinvertebrates

Benthic fauna - Insects

Order: Megaloptera (Alder-flies)

- Only 1 genus in Europe
- Have 10 larval stages
- Larval life lasts from 2 to 3 years
- 7 lateral pairs of tracheal gills on the abdomen part with a terminal one
- The wings-buds miss (holometabola)
- Carnivorous that attack & seize small animals
- Fully developed larva crawls out of the water into the mud or the vegetable debris nearby (3 months)
- Adults stay near the water

Macroinvertebrates

Benthic fauna - Insects

Order: Neuroptera (Sponge-flies)

- Usually a terrestrial insect, can be found in freshwater biotopes
- Larvae live at surface & cavities of freshwater sponges
- Feed on juices of sponges
- Lace-wings larvae live at the hedge of streams &
- Feed on small larvae blood
- Characteristic lengthened & frayed mandible & maxilla

Macroinvertebrates

Benthic fauna - Insects

Order: Trichoptera (Caddis flies)

- >100 genuses from 20 families in this order
- 2 types of larva: eruciform & campodeiform
- Eruciform form a case of silk, spun from labial Glands,covered by pieces of sticks, stones, sand-grains, snail-shells
- These cases are characteristic for each kind of larva
- Feed mostly on plants & some on animal matter
- Campodeiform are found mainly in running water
- Spin a net attached to the underside of stones or on plants to catch small animals

Drawing of typical Trichoptera, eruciform &campodeiform

Macroinvertebrates

Benthic fauna - Insects

Order: Coleoptera (Beetles)

Drawings of typical Coleoptera

- Numerous species from 10 families in this order
- Each family has its own behaviour.
- Larvae lack tracheal-gills (except Gyrinidae),
- Larvae lack wings-buds
- Presence of strong mandibles

Macroinvertebrates

Benthic fauna - Insects

Order: Diptera (Two-winged flies)

Drawings of typical Diptera

- Numerous species from 20 families in this order
- Each family has its own behaviour.
- Larvae & pupas live in all kinds of freshwater
- Lack of limbs & non-existent cephalic capsula

Macroinvertebrates

Benthic fauna - Molluscs

- About 70 representatives from 2 classes : Bivalvia & Gastropoda
- Molluscs are large invertebrates with distinctive shells
- Gastropoda - Snails have coiled shells & Limpets have conical shells
- Mussels & Cockles have two shells

Macroinvertebrates

Benthic fauna - - Molluscs

Class: Gastropoda

- Water snails occur in all water types (not in very acidic waters)
- Found in clean, plant-rich, lowland waters
- 2 subclasses :Prosobranchia & Pulmonata
- Prosobranchia: the aperture of the shell can be closed by a flat lid called the operculum
- Breathe through a feathery comb like gill
- Pulmonata: breathe atmospheric air via an internal lung opened to air when the snail is at the surface
- Feed on organic matter or on plants

Drawings of typical Gastropoda

Macroinvertebrates

Benthic fauna - Bivalvia

Class: Bivalvia

Drawings of typical Bivalvia

- Range in size from 2mm - 180mm
- 2 equal valves, hinged at the top by an elastic ligament
- Breath & feed through a current of water is drawn through the mantle-cavity, and then expelled. Particles Are fed by ciliar action to the mouth
- Small bivalvia are hermaphrodite & large have distinct sexes
- Can reproduce by means of larvae (glochidium) which live as parasites on fish before settling on the substrate

Macroinvertebrates

Parasitic fauna

Leaches: (Class Hirudinea) common in all freshwaters.

- Flattened oval body, no bristles,
- Pair of suckers (small at the end of head, large at the rear).
- Blood-suckers, excrete through salivary glands an anti-coagulator (hirudin)
- Hermaphrodite with sexual reproduction
- Eggs laid in cocoon attached to submerged matrixes

Water Mites: (Phylum Chelicerata)

- Active little animals, swimming rapidly among water-plants
- After hatching search for host (aquatic insects) & spend larva stages
- Nymphs & Adults are free moving fierce predators

Macroinvertebrates

Parasitic fauna

Fish lice: (Class Branchiura)

- Only European genus is *Argulus*
- Swim free in search of host - fish
- Attaches itself outside the host & sucks blood

Flukes: (Phylum Platyhelminthes- Class Trematoda)

- Mostly internal parasites of vertebrates
- Adults are flattened or cylindrical with one or more distinct suckers
- 2 subclasses:
  - ✓ Monogenea - simple life cycle, young develops on the same host
  - ✓ Digenea - complex life cycle involving several stages, with both parasitic & free living stages

Macroinvertebrates

Parasitic fauna

Tapeworms: (Phylum Platyhelminthes - Class Cestoda)

- Mostly internal parasites of vertebrates
- Long chains of reproductive units budded off from a head attached to the wall of the host's intestine
- Complex life cycle involving several stages
- Can be transferred to humans (up to 6 m in intestine)

Hairworms: (Phylum Nematomorpha)

- Adults - Very thin & long worms fold up in masses
- Larvae are internal parasites in insects until the insect is fully occupied internally & killed

Fish

- A homogenous group of water vertebrates with 7,000 freshwater species (≥200 found in Europe)
- 2 systematic groups: Actinopterygians (Chondrosteans) & Teleosteans (all other kinds)
- Majority is sedentary, some are migratory
- The presence of fish communities is water-quality indicator
- Distinct zonation from headwater to estuary - Different areas inhabited by characteristic fish communities
- Feed differently according to species & localization in water (detritus, minute organisms, plankton, terrestrial insects, benthic dwellers or piscivores).

Fish

Trout zone – *Salmo spp.*

Grayling zone – *Thymallus, Phoxinus, Leuciscus spp.*

Minnow zone

Barbel zone – *Barbus, Rutilus, Esox, Perca spp*

Bream zone – *Abramis, Tinca, Cyprinus spp*.

Fish

Freshwater fish main families:

- **Sturgeons** (Acipenseridae) – big size with side-lines of osseous plates along the body.
- **Eels** (Anguillidae) – snake-shaped & deprived of pelvic fins
- **Carps** (Cyprinidae) – pectoral fins in low position & pelvic fins clearly at the back of the body. (2 - 4 barbels usually)
- **Loaches** (Cobitidae) – fins in the same position as carps, & bear 6 barbels
- **Trouts, Salmons** (Salmonidae) – rayless fin behind the dorsal fin
- **Cat-Fishes** (Ictaluridae) – same dorsal fins as Salmonidae & bear 8 barbels.
- **Sticklebacks** (Gasterosteidae) – 3 - 9 spines in front of the dorsal fin
- **Pikes** (Esocidae) – dorsal & anal fins above each other
- **Perca, Lucioperca** (Percidae) – 2 dorsal fins (the first is spiny)