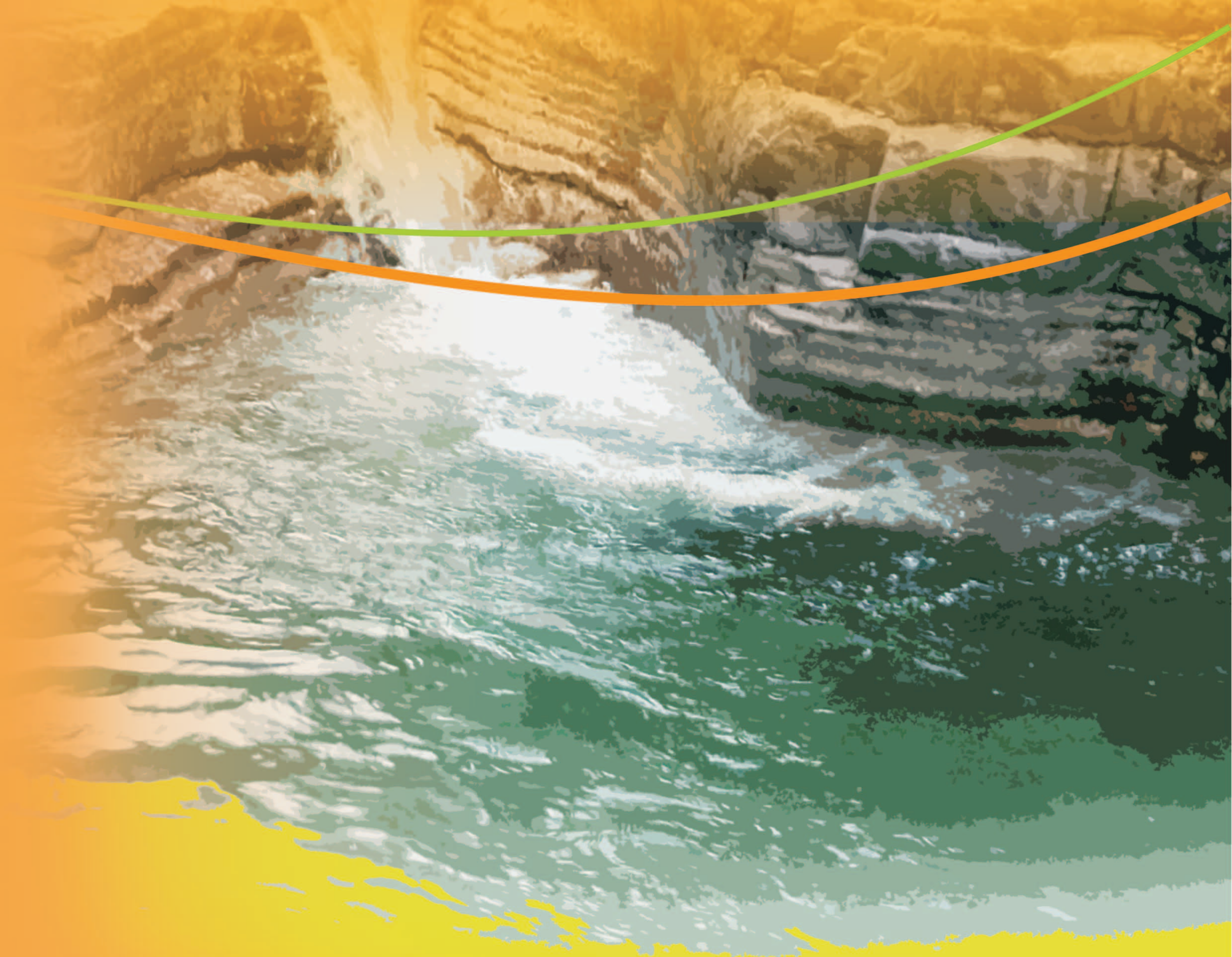

PUPILS' TEXTBOOK

FRESHWATER ECOSYSTEMS OF EUROPE

An Educational Approach

Education and Culture
Socrates

Produced by the EC funded project
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FRESHWATER ECOSYSTEMS OF EUROPE

An Educational Approach

Pupils' Textbook

COORDINATION

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PREFACE

Hi!

Freshwater resources are becoming more crucial than ever for the sustenance of life on the earth. This fact was recognized in the designation of the year 2003 as the World Year of Fresh Water. The ever-increasing human demands for water and rapid deterioration of water quality threaten freshwater ecosystems. The knowledge of the functioning of these ecosystems will help us understand the close connection between water quality and human life quality which will prove how critical and necessary is the conservation and sustainable development of these ecosystems.

Within the framework of the European project CONFRESH "Teaching Methods and Pedagogical Strategies for the Promotion to Schools of CONservation and Sustainable Development of FRESHwater Ecosystems", the present educational material under the title "FRESHWATER ECOSYSTEMS OF EUROPE: An Educational Approach" was produced. Its intentions were to spread the recent knowledge on European freshwater ecosystems to schools of Secondary Education and promote and enhance their protection and sustainability.

"FRESHWATER ECOSYSTEMS OF EUROPE: An Educational Approach" is available in printed and electronic form and consists of two parts:

Part A. Pupils' Package. It includes:

- Textbook
- Activities for the classroom
- Worksheets for the field
- Identification Cards of Aquatic Invertebrates for field guiding and lab activities
- CD Rom with a case study
- Evaluation sheets

Part B. Teachers' Package. It includes:

- Supporting material for teachers' training seminars
- Guidelines for the implementation of students' educational material in the class and the school curricula
- Evaluation sheets

We hope you enjoy your participation to the activities of this package!

Dr. Voreadou Catherina
Coordinator of CONFRESH project

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CHAPTER 1

WATER

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1. Water - the essential element for life

Fig. 1. Water is essential for life.

The most important element for all life is water. Water in the natural environment is defined as water in all its various states - in the atmosphere, on the land and in water bodies. The majority of processes in the nature depends on water or on the aquatic environment. Water creates and maintains life in every ecosystem. As a result, water is of primary importance to all living things (Fig.1).

1.1 Water molecule structure

Water is a tiny V-shaped symmetric molecule with the chemical formula H2O (Fig.2). It is the simplest compound made up of the two most common elements in the Universe - two hydrogen (H) atoms attached to a relatively heavy oxygen atom (O). Hence, the formula for water is H2O.

The side with the hydrogen atoms is positively charged, and attracts the oxygen side - of a different water molecule - which is negatively charged. The H2O molecule is electrically neutral, but the positive and negative charges are not distributed uniformly, as seen in Fig. 3 and Fig.5.

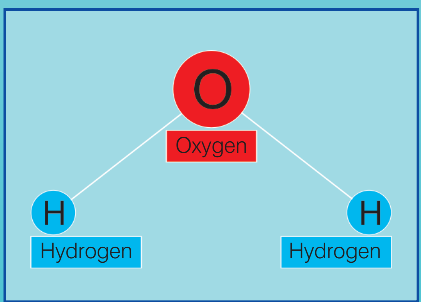


Fig.2. The scheme illustrates a water molecule. The larger oxygen atom attach to two smaller hydrogen atoms.

As a result, water is a molecular dipole and this influences how many substances dissolve in water. Water is called the "universal solvent" because it dissolves more substances than any other liquid. This means that wherever water goes, either through the ground or through our bodies, it carries along valuable chemicals, minerals, and nutrients.

1.2 Water's physical and chemical properties

Water is unique because it is the only natural substance that is found in all three states (Fig. 4, 5): liquid (water), solid (ice), and gas (water vapor, steam) - at the temperatures normally found on Earth.

Water is distinctive - among the more than 15 million known chemical substances - in that its solid form ice is lighter (less dense) than the liquid. This explains why ice floats on liquid water. The maximum density (weight) of water is reached at 4 degrees Celsius (Fig.6).

Heat is needed to break the hydrogen bonds between water molecules to enable them to vaporize. Commonly water vaporizes into steam at 100 degrees Celsius. When water molecules vaporize in this way, they carry with them a parcel of heat. On a grander scale, when water molecules vaporizes from the ocean surface they carry heat away from the ocean, and this helps to control and regulate the world's climate. Therefore, most of the water on Earth contained in the oceans and the high heat capacity of this large volume of water (1.35 million cubic kilometers) buffers the Earth surface from large temperature changes. The oceans absorb huge amounts of solar energy and ocean currents transport this heat from the equator toward the Poles.

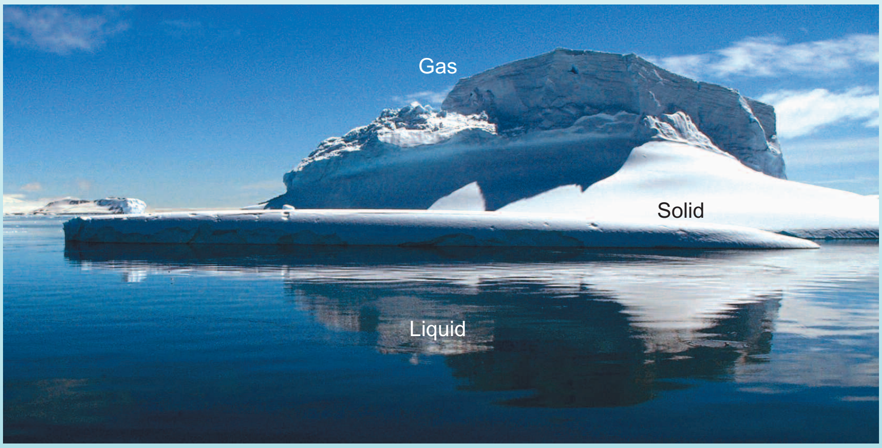


Fig. 4. Water occurring in three states in natural environment. Photo by P.Pinto

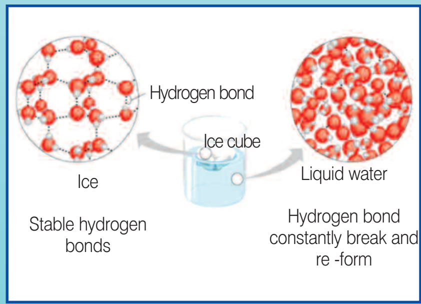


Fig. 5. Differing molecule states of water.

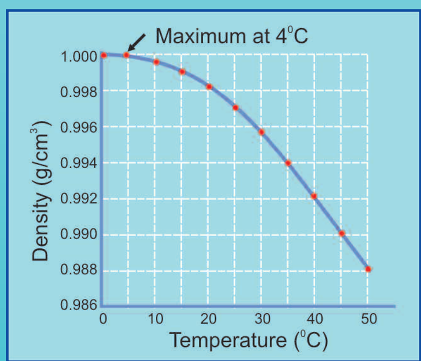


Fig.6. Relationships between the water density and the temperature.

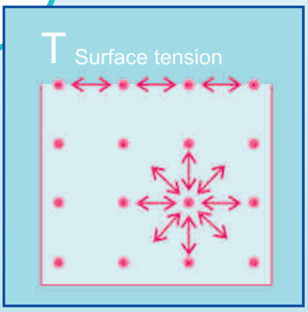


Fig. 7. A. Illustration of cohesive forces between water molecules, B. Pond scatter (aquatic bug from family Gerridae) walking on water surface.

The cohesive forces between molecules drawn into a liquid are shared with all neighboring water atoms but those on the surface have no neighboring atoms above and exhibit stronger attractive forces upon their nearest neighbors on the surface (Fig.7A). This is called surface tension. Water surface "film" can be used as a habitat for some aquatic insects, e.g. pond skater, because their weight is not enough to break through the surface (Fig. 7B).

Surface tension is also responsible for the shape of liquid droplets (Fig. 8). Although easily deformed, droplets of water tend to be pulled into a spherical shape by the cohesive forces of the surface layer and gravity.

The surface tension of water also decreases significantly as the temperature rises. Consequently, hot water is a better cleaning agent because the lower surface tension makes it a better "wetting agent" to get into pores and fissures.

Surface tension is also responsible for capillary action. Capillary action is the result of adhesion and surface tension. Adhesion of water to the walls of a vessel will cause an upward force on the liquid at the edges and result in a meniscus which turns upward. The surface tension (cohesion forces) acts to hold the surface intact, so instead of just the edges moving upward, the whole liquid surface is dragged upward (Fig. 9).

Fig. 8. Water droplets.

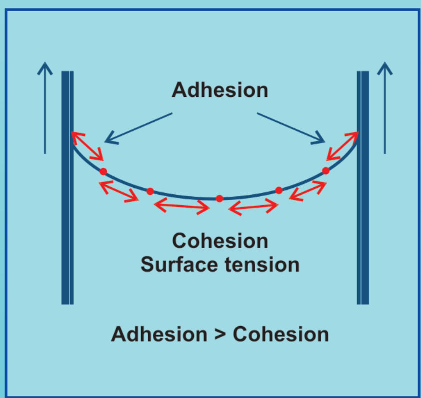


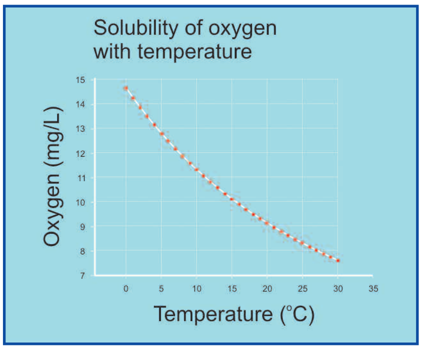
Fig. 9. The scheme illustrates the forces involved in capillary action. A liquid climbs up a capillary tube without external pressure - capillary action occurs when the adhesion to the walls is stronger than the cohesion forces between the liquid molecules.

BOX 1. THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF WATER

The results of any single measurement of a water's properties should be always considered over time (24 hours, a week, season, etc.) in the temporal scale, and and also in the natural hydrochemical background of the water body (e.g. pH of 5.5 is acid but it might be normal, seasonal state for a mountain creek).

pH is a measure of how acidic/alkaline water is. This means the relative amount of free hydrogen and hydroxyl ions in the water. Pure water has a neutral pH of 7. The range goes from 0 - 14. pHs of less than 7 indicate acidity (water has more free hydrogen ions), whereas a pH of greater than 7 indicates a alkalinity/basicity (water has more free hydroxyl ions). Since pH can be affected by chemicals in the water, pH is an important indicator of water that is changing chemically. Pollution can change water's pH, which in turn can harm animals and plants living in the water. pH can be accessed using litmus paper.

A lot of water is used for cooling purposes in power stations that generate electricity (water has a high specific index - can absorb a lot of heat before begins to get hot). The power stations generally release warmer water back to the environment. The temperature of the released water can affect habitats down stream.



Conductivity is a measure of the ability of water to conduct an electrical current. It is highly dependent on the amount of dissolved solids (such as salt) in the water. Pure water, such as distilled water, will have a very low conductivity, and sea water will have a high conductivity. Rainwater often dissolves airborne gasses and airborne dust while it is in the atmosphere, and thus often has a higher specific conductivity than distilled water. Specific conductivity is an important water-quality measurement because it gives a good idea of the amount of dissolved material in the water.

Turbidity is the amount of particulate matter that is suspended in water. Turbidity measures the scattering effect that suspended solids have on light: the higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include: clay, silt, fine organic and inorganic matter, soluble organic compounds, plankton, microscopic organisms, and pathogens.

Dissolved oxygen. although water molecules contain an oxygen atom, this oxygen can not be used by aquatic organisms for respiration. A small amount of free oxygen is actually dissolved in water (up to about ten molecules of oxygen per million of water). This dissolved oxygen is needed for respiration by zooplanktonic animals, invertebrates and fishes. Rapidly moving water, such as in a mountain stream or large river, tends to contain a lot of dissolved oxygen, while stagnant water contains lower concentrations. Bacteria in water can consume oxygen as organic matter decays. The pollution in our lakes and rivers can cause a reduction in the level of oxygen.

Photo by G. Kosmala

1. 3 Water for human health

Liquid water is essential for life. It is the most important element throughout the living world. In particular, we cannot live without water for more than about 100 hours, whereas other nutrients may be neglected for weeks or months.

Untill recently, water has been taken for many different, unlimited human applications and treatments, but no other element is more essential or needed in a great quantity.

Each day humans must replace 2.4 liters of water (Table 1). Then body water is distributed between the cells and the extracellular fluid. The excellent ability of water to dissolve so many substances allows our cells to use the valuable nutrients, minerals, and chemicals in all these biological processes.

1.4 Water as an environment for life

Water is of major importance to all living things. Water possesses particular properties that sustain life; therefore no other liquid can replace water in or outside an organism's body. These properties, as we stated, are connected with the physical and chemical structure of the water molecule and are brought about by the hydrogen-bonded environ-

BOX II. WATER FOR YOUR HEALTH

Without water, your body also would stop working properly. Your body is about two thirds water, and a person can't survive for more than a few days without it. Why? Your body has lots of important jobs and it needs water to do many of them. For instance, your blood, which contains a lot of water, carries oxygen to all the cells of your body. Without oxygen, those tiny cells would die and your body would stop working. Water is also in lymph, a fluid that is part of your immune system, which helps you fight off infection. You need water to digest your food and get rid of waste, too. Water is needed for digestive juices, urine (pee), and poo. And you can bet that water is the main ingredient in perspiration sweat. In addition to being an important part of the fluids in your body, each cell depends on water to function normally. Your body doesn't get water only from drinking water or milk. Lots of foods contain water, such as fruits and vegetables. When your body doesn't have enough water, you became dehydrated.

Water balance			
Water input, ml day^{-1}		**Water output, ml day^{-1}**	
Drinks	1500	Urine, faeces	1600
Food	700	From skin, sweat	500
Metabolic water	300	Respiration	400

Table 1. Water input and output values for an adult in a temperate climate (after Stirling & Parsons, 2000).

ment particularly evident in liquid water, such freshwater ecosystems (see Box III).

Water is also an invaluable resource to human societies - for cleaning and waste removal, for energy generation, for food production, for cooling and heating, for transportation, and for recreation. Rational water use, with a view to the long-term needs of other consumers, both human and otherwise, should be sustainable. Therefore, we have to study the role of water in our lives and learn more about the functioning of our freshwater ecosystems. Only with better knowledge and understanding we can undertake ecologically-sound tasks for water protection, and sustainable management.

BOX III. HOW WATER BEHAVES AT DIFFERENT TEMPERATURES IN LAKES?

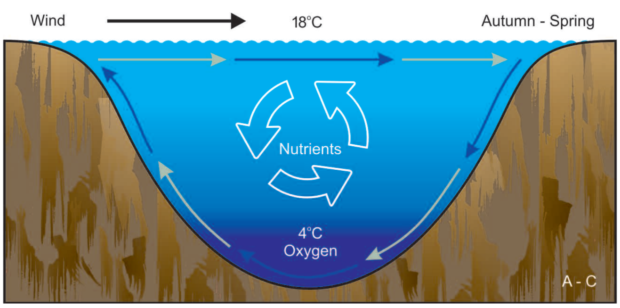
For the most part, as water increases in temperature it becomes less dense. Conversely, water becomes denser as it decreases in temperature. The exception to this rule is that water reaches its maximum density at approximately 4˚Celsius. Below 4˚C, as water cools, the number of water molecules joined together by hydrogen bonds increases to form loose clusters of ice. The molecules in ice form a very structured, open framework, so ice itself is less dense than water and, consequently float on it.

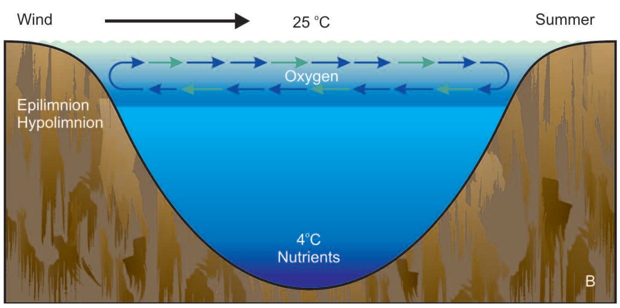
With this concept in mind we can consider seasonal or thermal stratification within lakes.

During the spring (A) - after the ice melts on a lake, the lake water is generally the same temperature from the surface to the bottom. Wind blowing across the surface encourages the water to circulate and mixing. Surface water is pushed to the lake bottom and bottom water rises to the surface. This circulation allows relatively large amounts of oxygen to reach the bottom of the lake. The mixing of lake water at this time of year is called the spring overturn.

During summer (B) - the surface water layer of the lake absorbs heat, and forms a heated layer called the epilimnion. This layer floats above the colder, deeper and denser water called the hypolimnion. In the summer, these layers remain distinct: only the water in the upper layer (epilimnion) benefits from wind driven circulation, leaving the lower layer (hypolimnion) almost stagnant. Without mixing to provide dissolved oxygen, the lake bottom, lacking enough light for photosynthesis to occur, tends to have a very limited supply of oxygen during the summer. Respiration by animals and bacteria can deplete the dissolved oxygen at the bottom of the lake even further. A stratified lake of this nature is said to be in the summer stagnation.

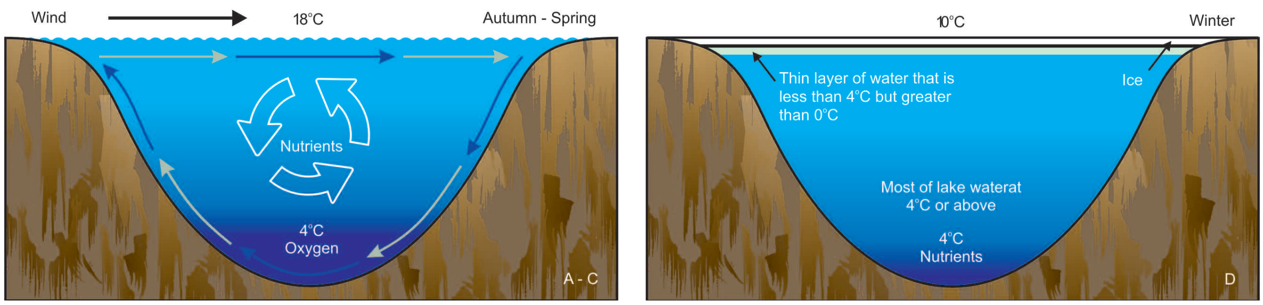
The lake water in the autumn (C) has generally uniform temperatures (about 4˚C), and wind can thoroughly mix the water. Surface water, which is in direct contact with the cold air, gets cooled faster than the water below. This cold, dense water sinks and further helps to mix the lake. Once more oxygen and nutrients are replenished throughout the water column. This process is called the autumn overturn.





During the winter (D) - the surface water is eventually cooled below 4˚ C. At this point, the water no longer sinks. The water molecules begin to align themselves (form more hydrogen bonds) to solidify. As water temperatures at the surface reach 0˚C, ice begins to cover the surface of the lake. Ice cover prevents mixing. However, stratification can occur.

A layer of low density water colder than 4˚C, but warmer than 0˚C forms just under the ice. Below this water, the remainder of the lake water is usually near 4˚C. At this point, a lake is said to be in the winter stagnation.



1.5 Earth's hydrosphere

The hydrosphere includes all water on Earth. The abundance of water on Earth is a unique feature that clearly distinguishes our "Blue Planet" from others in the solar system (71% of the earth is covered by water). Not a drop of liquid water has yet been found anywhere else in the solar system.

It is because the Earth has just the right mass, the right chemical composition, the right atmosphere, and is the right distance from the Sun (the "Goldilocks" principle) that allows water to exist mainly as a liquid. However, the molecular structure of water and the range of surface temperatures and pressures of our planet enable water to exist in all three states. The hydrosphere interacts with, and is influenced by, all the other earth systems, the lithosphere and atmosphere. The water of the hydrosphere is distributed among several different stores found in the other spheres (Fig. 10).

The living world, or biosphere, links all the other spheres enabling water to move between the hydrosphere, lithosphere and atmosphere mainly by transpiration, the movement of water though plants from root to leaves.

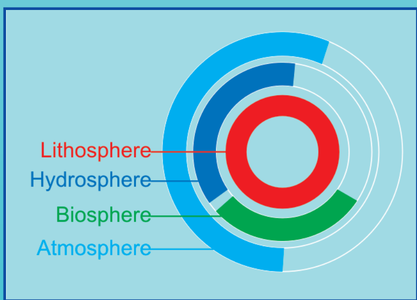


Fig. 10. Earth Spheres/Systems

1. 6 Earth's hydrosphere

About 97% of Earth water is distributed in oceans (Fig. 11). Freshwaters - as a result are a very precious resource, and there are many beneficial reasons to save the water.

Figure 12 shows the distribution of this three percent of freshwaters: (1) the majority - about 69 percent, is locked up in glaciers and icecaps, mainly in Greenland and Antarctica; (2) the remaining freshwater is ground water; (3) only about 0.3 percent is contained in rivers and lakes. As a result, rivers and lakes provide most of the water we use for our everyday lives.

1.7 The water cycle

The water cycle as a continuous circulation of water within the Earth's hydrosphere is driven by solar radiation. As water moves through the cycle, it changes state between liquid, solid, and gas phases (Fig. 13, Fig. 14).

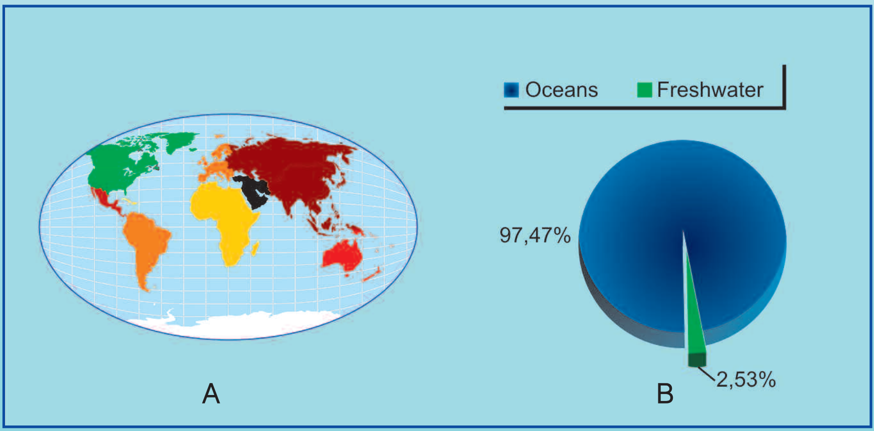


Fig. 11. Oceans (Pacific, Atlantic, Indian, Arctic) and continents (Europe, America, Africa, Asia, Australia, Antarctica).

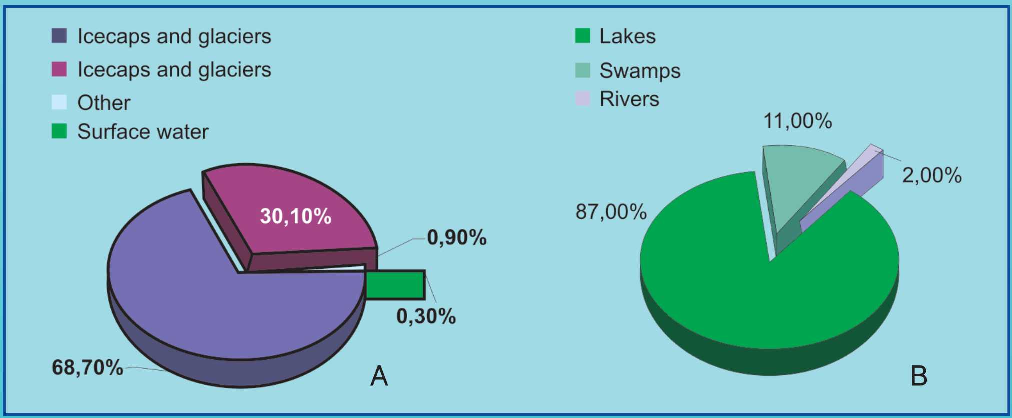


Fig. 12. Distribution of Earth's water. A. Global water distribution; B. Available fresh waters; C. Surface freshwater sharing.

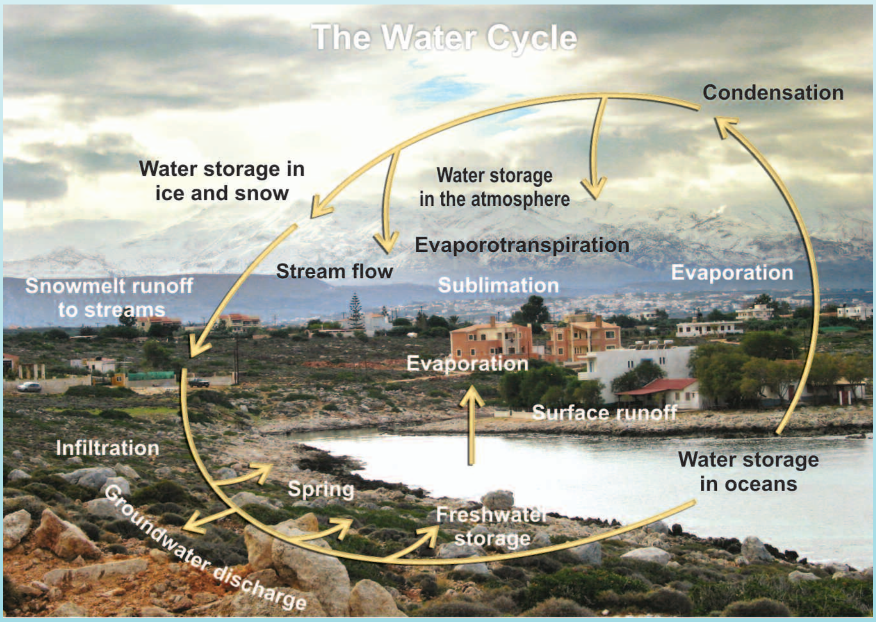


Fig. 13. The water cycle - showing the movement of water in the major processes.

Water begins the cycle in the oceans (Fig. 13). The energy from the sun evaporates some of this water. Evaporation removes water molecules only, leaving the salts in the oceans. As the water vapor rises into the atmosphere it cools and condenses into clouds. The clouds are then pushed by the wind, and under the right conditions they will produce precipitation (rain, snow, sleet). This collects to form rivers and lakes, and eventually infiltrates into the ground to become groundwater. However, the cycle can be completed in different ways, for example, before reaching the ocean, water may have evaporated, condensed, precipitated, and become runoff multiple times (Fig. 13, Fig. 14).

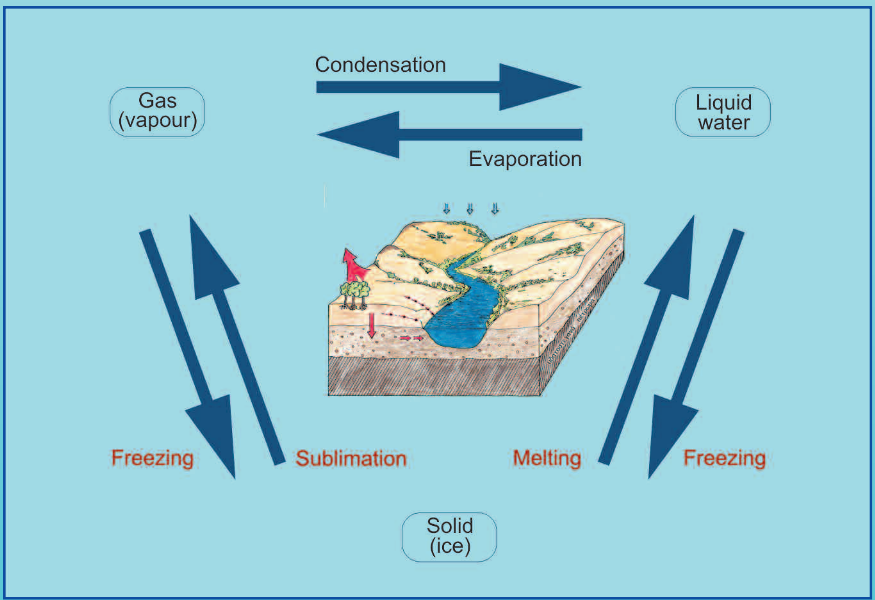


Fig. 14. The schematic outline of water cycle with including the main processes, contributed in three water states forming.

Components of the water cycle	Definition
Water storage in oceans	Saline water existing in oceans and inland seas (96,5% of the Earth's water).
Evaporation	The process by which water is changed from a liquid to a gas or vapor.
Sublimation	The conversion between the solid and the gaseous phases of matter, with no intermediate liquid stage. Sublimation is most often used to describe the process of snow and ice changing into water vapor in the air without first melting into water.
Evapo-transpiration	The process by which water is discharged to the atmosphere as a result of evaporation from the soil and transpiration by plants (the sum of evaporation and transpiration).
Water in the atmosphere	Water stored in the atmosphere as vapour, such as clouds and humidity. Evaporation and transpiration change liquid water into vapor, which ascends into the atmosphere due to rising air currents.
Condensation	The process by which water is changed from vapor to liquid. Condensation is responsible for the formation of clouds, which may produce precipitation - the primary route for water to return to the Earth's surface. Condensation is the opposite of evaporation.
Precipitation	The discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface - in the form of rain, freezing rain, sleet, snow, or hail. It is the primary connection in the water cycle that provides for the delivery of atmospheric water to the Earth. Most precipitation falls as rain.
Water storage in ice and snow	Freshwater stored in frozen form, generally in glaciers, icefields, and snowfields.
Snow melt run off to streams	Movement of water as surface run off from snow and ice to surface water.
Surface run off	Precipitation runs off which travels over the soil surface to the nearest stream channel.
Stream flow	Movement of water in a natural channel, such as a river.

Freshwater storage	Freshwater existing on the Earth's surface. Surface freshwater includes the streams (of all sizes, from large rivers to small creeks), ponds, lakes, reservoirs and canals (man-made lakes and streams), and freshwater wetlands. The definition of freshwater is water containing less than 1,000 milligrams per liter of dissolved solids, most often salt.
Infiltration	The downward movement of water from the land surface into soil or porous rock.
Ground-water storage	Water existing for an extended period below the Earth's land surface. Most of the water in the ground comes from precipitation that infiltrates downward from the land surface.
Ground-water discharge	Movement of water out of the ground. Ground water is a major contributor to flow in many streams and rivers and has a strong influence on river and wetland habitats for plants and animals.
Springs	Place where a concentrated discharge of ground water flows ate the ground surface.

Table 3. The water cycle. The key groups of physical processes

1. 8 Intensification of water cycle and climate changes

The Earth's climate has changed over the hundred years. Due to global warming over the past century - the water cycle has become more intense, with the rates of evaporation and precipitation is both increasing. There is new and stronger evidence that most of the warming observed in the last 50 years is attributable to human activities. Evolving computer models are predicting that, because of greenhouse gas emissions, temperatures should continue to rise over the 21st century (Fig.15).

Climate describes the total of all weather occurring over a period of years in a given place. This includes average weather conditions, regular weather sequences (like winter, spring, summer, and autumn), and special weather events (like floods).

Weather describes whatever is happening outdoors in a given place at a given time with regards to temperature, air pressure, humidity, wind, cloudiness and precipitation. The study of weather and its forecasting is called meteorology or climatology.

As a result, meteorological phenomena are observable weather events which are bound by the variables that exist in Earth's atmosphere. They are temperature, pressure, water vapor, and the gradients and interactions of each variable (Fig. 16), and how they change in time.

A weather station is a facility with instruments and equipment to make weather observations by monitoring atmospheric conditions. Typical weather stations (Fig. 17) have the following instruments:

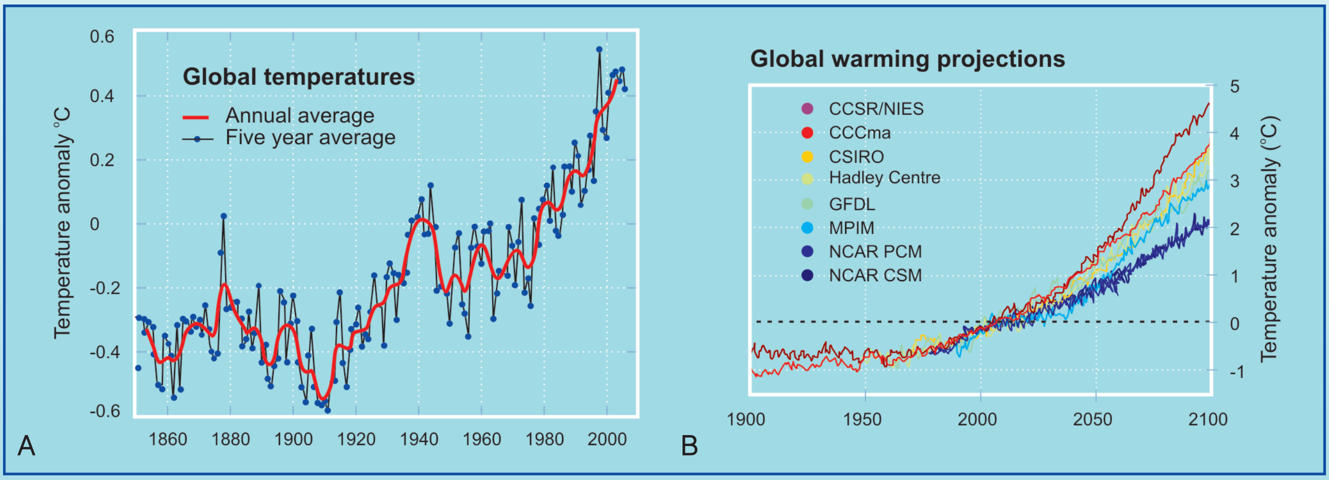


Fig. 15. A. Comparison of the average global temperature trends; B. Predictions of global warming from 8 different climate models.

- Thermometer: an instrument used to measure temperature;
- Anemometer: an instrument used to measure the strength and direction of wind, a wind gauge (Beaufort scale: Admiral F. Beaufort wrote the Beaufort scale to measure the speed of wind. His scale became the official method of ranking wind speed);
- Barometer: an instrument used to measure the weight or pressure of the atmosphere, indicate weather change. Barometric pressure is a measurement of how air pushes down. Cool air is heavier than warm air and pushes down with more pressure: high pressure. Warm air is lighter and is related to low pressure. As air moves faster, its pressure also drops;
- Hygrometer for measuring humidity;
- Rain Gauge: An instrument used to measure a storm's precipitation.

Except for those instruments requiring direct exposure to the elements (anemometer, rain gauge), the instruments should be sheltered in a vented box (usually a Stevenson screen) to

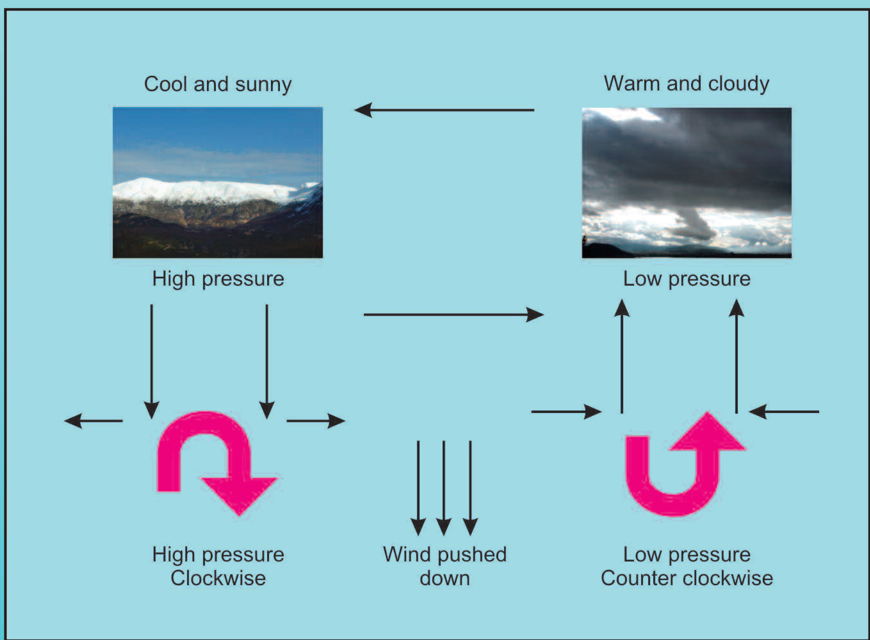


Fig. 16. The scheme to show general weather conditions: high air pressure means that air is being pushed down; air travels in a high pressure system clockwise; low air pressure means that air is being pushed up. The air that rises is warmer because hot air rises; air travels in a low pressure system - counter-clockwise.

Fig. 17. Meteorological station with instruments.

keep direct sunlight off the thermometer and wind off the hygrometer. The instrumentation (Fig. 17) may be specialized to allow for periodic recording otherwise significant manual labor is required for record keeping. Automatic transmission of data is also desirable as many weather stations' data is required for weather forecasting.

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Supporting references

Other thematic pieces of literature are available at following web sources:

Water

- Water - Learning and Living - teaching and learning resources about integrated water protection: water, catchments, biodiversity and human impact: http://www.watercare.net/wll/wc-watercycle.html
- Water Words Dictionary - a compilation of technical water, water quality, environmental, and water-related terms: http://water.nv.gov/Water%20planning/dict-1/ww-index.htm
- Water Science for Schools - http://ga.water.usgs.gov/edu/index.html
- H2O - The Mystery, Art & Science of Water - webside focused on the nature, properties, place, significance, importance, and role of water in Earth's life and culture; http://witcombe.sbc.edu/water/
- The Global Water Cycle - the webside page with the most important links related to GWC: http://www.usgcrp.gov/usgcrp/links/waterlinks.htm
- Water Resources of the U.S.A. - http://water.usgs.gov/
- Water resources in Europe - http://maps.grida.no/go/graphic/world_s_water_cycle_schematic_and_residence_time
- Chemistry of Water - http://www.biology.arizona.edu/biochemistry/tutorials/chemistry/page3.html
- UNESCO Water Portal: http://www.unesco.org/water/
- UNESCO-IHE Institute for Water Education: http://www.unesco-ihe.org/education/intro.htm
- UN Water: http://www.unwater.org/flashindex.html
- Schools resource on water rights: http://www.worldaware.org.uk/education/projects/water.html
- United Nations GEMS/Water Programme: http://www.gemswater.org/ http://www.gemswater.org/

Hydrospere and Global Water Cycle

- Hydrosphere: http://earth.rice.edu/MTPE/hydro/hydrosphere/hydrosphere_what.html
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- Visible Earth: http://visibleearth.nasa.gov/view_set.php?categoryID=629
- Oceans and Water Issues WebPages: http://www.publicforuminstitute.org/issues/oceans/index.asp
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- Water in School/educational page: http://www.epa.gov/highschool/water.htm

CHAPTER 2

WATER ENVIRONMENTS

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1. Europe

1.1 Location and boundaries

Europe is a continent geographically located between the 36o and the 71o of latitude. This position gives Europe great advantages as most of the region is in the temperate zone, with mild, wet climate.

Europe's boundaries are: the Arctic Ocean to the north, the Mediterranean Sea to the south, the Atlantic Ocean to the west and the crest of the Ural Mountains, together with the Ural River, to the north-eastern making its boundary with Asia. The Caspian Sea, Azerbaijan, Armenia, the Black sea, the Bosporus, the Sea of Marmara and the Dardanelles, complete the Asian boundary to the southeast.

Together with Asia, Europe forms a larger landmass, a supercontinent, known as Eurasia. Europe is close to Africa with only the Mediterranean Sea separating them. Europe, together with Africa and Asia are often referred to as "The Old World".

Europe is the third largest populated area after Asia and Africa. Its population in 2005 was estimated to be 728 million according to U.N. This is slightly more than one ninth of the world's population.

1. 2 European countries

Europe is made up of the following countries:

Eastern Europe: Belarus, Bulgaria, Czech Republic, Hungary, Moldova, Poland, Romania, Russian Federation, Slovakia, Ukraine

Northern Europe: Denmark, Estonia, Faroe Islands (Denmark), Finland, Greenland (Denmark), Iceland, Ireland, Latvia, Lithuania, Norway, Sweden, United Kingdom, (made up of England, Northern Ireland, Scotland and Wales)

Southern Europe: Albania, Andorra, Bosnia and Herzegovina, Croatia (Hrvatska), Cyprus, Gibraltar (UK), Greece, Holy See (Vatican City State), Italy, Fyrom, Malta, Montenegro, Portugal, San Marino, Serbia, Slovenia, Spain, Turkey

Western Europe: Austria, Belgium, France, Germany, Liechtenstein, Luxembourg, Monaco, Netherlands, Switzerland.

1. 3 Landscape

In terms of shape, Europe is a group of connected peninsulas. The two largest of these are "mainland" Europe and Scandinavia to the north, divided from each other by the Baltic Sea. Three smaller peninsulas-Iberian, Italien and the Balkans-emerge from the southern margin of the mainland into the Mediterranean Sea. Eastward, mainland Europe widens much like the mouth of a funnel, until the boundary with Asia is reached at the Ural Mountains. To the west, Europe begins to break into a series of islands, the largest of which are the UK and Iceland.

The topography of Europe shows great variation within relatively small areas, as a result of the strong geological forces that have acted in the region. The mountains in Europe today are remnants of three different mountain forming periods, and help describe its present physical geography:

Mainland Europe is mostly lowland, although the most important European mountain ranges are found in this area, located in the central and south part of the continent:

- Pyrenees, the natural border between France and Spain
- Alps, the famous mountains known for their spectacular slopes, which extend over 4 countries, France, Italy, Switzerland and Austria.
- Carpathians, a major mountain range in Central and Southern Europe, stretching from Poland to Slovakia
- Caucasus, which, like the Ural mountains, separate also Europe and Asia

In the North, a long length mountain range, the Scandinavian Alps, traverses the Scandinavian Peninsula, separating Norway from Sweden.

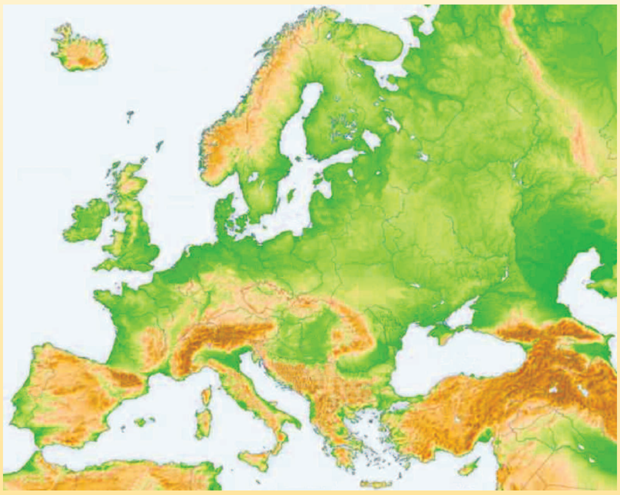

Fig. 1. Relief map of Europe.

In the West, the Iberian Peninsula is quite mountainous, and includes the more recently formed, high mountains such as Sierra Nevada, as well as lower, older, more eroded mountains such as Sierra Morena.

In the South, the Italian and the Balkan peninsulas are very mountainous, having been formed by the more recent Alpine mountain building phase (Alpine folding). Both Italy and Greece do have mountainous "backbones" called the Apennines and Pindos, respectively.

Among these mountains are some important plains. The Po Plain, between the Alps and the Apennines, the great Pannonian Plain of Hungary, southwest of Carpathians and the Galician Plain, northeast of Carpathians, are the greatest ones. Southern Europe tends to lack, or have small plateaux and plains due to the scattered land relief.

Europe is characterised by a great variety of natural landscapes. One can see high altitude mountains, big valleys, semi-arid lands and even areas covered with glaciers within the 10.180.000 km2 of the continent. Geographers have identified four main landscape regions that share common characteristics:

- The Northern European Lowlands
- The Western Uplands
- The Central Uplands
- The Alpine Europe

1. 4 Climate

As Europe extends approximately from the 30o to 70o latitude, it largely belongs to the temperate zone, with only a small polar zone. For this reason, its climate is mainly temperate but with some significant variations. On the west coast of France, night frosts are rare, but at the same latitude, 800km to the east, in the valley of Rhone, far from the sea, night frosts are normal. This proves that the most important regulator of the European climate is the Atlantic Ocean, along with the dispersed warm seas, like the Mediterranean Sea. The further a town or city is from the ocean, the colder the winters, and the warmer the summers will be.

European patterns of rainfall (precipitation) vary as well. Rainfall is more usual close to the Atlantic and reduces to the east. On the west coasts of Ireland and Norway, the annual rainfall reaches 1m in 200 days, while around Moscow it is slightly more than 40cm in 90-100 days. Europe also shows great variation in the seasons in which rain falls. In the Mediterranean, the rains fall mainly in the winter and autumn, in the Central and Western Europe it rains during autumn and spring, and in the Eastern Europe, during the summer period.

According to the above, Europe is divided in 5 geographic zones, each one including regions that share common climatic characteristics (major climatic zones), which are:

a) The Mediterranean countries, meaning the south-western Balkan Peninsula, Italy, southern France and the south-eastern Spain have the typical Mediterranean climate where the winters are mild and humid, average temperature around 5°C, and the summers are hot and dry, average temperature 25°C.

b) The Western Europe, made up of the northern coasts of the Iberian Peninsula, the greatest part of the north-western Europe and the British Isles, along with the northern and western coasts of Norway are characterized by the so-called maritime climate. This is strongly affected by the moderating influence of the Atlantic Ocean, with very mild winters and warm summers.

c) The whole Central Europe, far away from the coasts, to the Russian

Fig.2. The main landscape regions of Europe.

plain, and the south part of the Scandinavian Peninsula, belong to the transitional climate. Towards the coasts, it may be temperate but as we move to the east, it becomes continental, with harsh winters and hot summers.

d) The Northern Europe, made up of the Russian plain and a large part of the Scandinavia (including the Scandinavian Alps) have a typical continental climate. The winters are cold and the summers hot and humid. Generally, conditions are extreme with soil being frozen for between three to six months of the year. When the thaw comes, flooding occurs, carrying silt and mud over the land. The summers are hot and dry, and the wind whips up clouds of dust.

e) As we move north, to the Northeastern Europe, the climate becomes colder. But above 70° latitude, in the northern Finland and the part of Russia the polar climate is encountered. Here there are no seasons and the average monthly temperature is stable below 10°C. Rainfall is scarce. The landscape is a "frozen desert".

There is another also important think that we should consider that is based on altitude rather than latitude; all high mountains share a variation of the polar climate. The altitude reduces the temperature to freezing and many local conditions cause variations throughout the day.

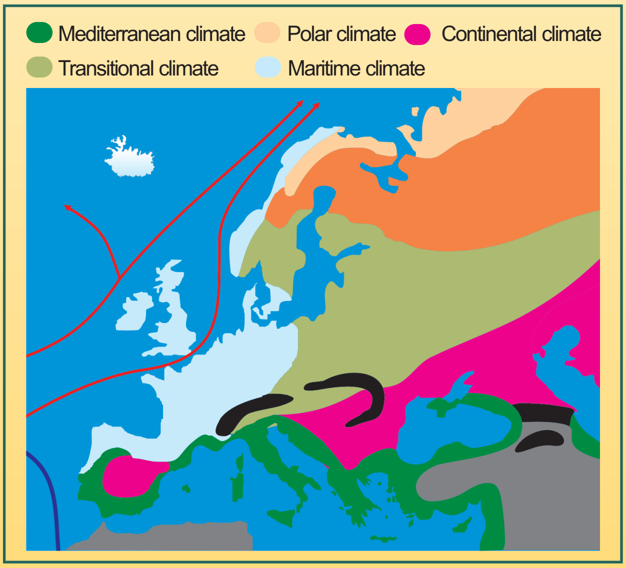

Fig.3. Climatic zones of Europe.

BOX I. THE MEDITERRANEAN CLIMATE

The Mediterranean Sea is the largest inland sea of the world. It is surrounded by the south-eastern part of the Iberian Peninsula, southern France, southern Italy and central and southern Greece.

The Mediterranean climate is a transitional regime between cold, temperate and dry, tropical climates. Apart in the mountains, snow rarely falls in the Mediterranean, but periods of hard frost do occur.

The main characteristics of the Mediterranean climate are:

a) The regional and local variation in temperature and rainfall regimes

b) Unpredictability: from one year to the next, between seasons of a given year and within the course of a single day, temperature extremes, rain precipitation, winds and other climatic factors can vary dramatically.

c) The various winds, as well as many local winds and variants, but as a rule, northerly winds predominate in summer when the overheated African continent creates a southward indraught. The opposite trend occurs in winter. Wind greatly increases evaporation, hence aggravating the effects of drought and high temperatures.

Given this unique combination of hot, dry summers and cool, humid winters, little or no surface water is available during the months when the sun is at its strongest. The main characteristics of Mediterranean freshwater ecosystems are the fluctuations in water levels and salinity, which reflect the large variation in rainfall both within and between years.

2. Freshwater ecosystems

Freshwater ecosystems are created by water that enters the terrestrial environment as precipitation and flows both above and below ground, towards the sea. These ecosystems include a wide range of habitats such as rivers and lakes, their catchment or drainage basins (see below) and the riparian zones associated with them. Their boundaries are constantly changing with the seasonality of the hydrological cycle. Their environment benefits and costs are distributed widely across time and space, through the complex interactions between climate, surface and groundwater and coastal marine areas.

Groundwater represents the largest single source of freshwater in the hydrological cycle (about 95% globally), greater in volume than all the water in rivers, lakes and wetlands combined (UNEP-GRID, 2003).

Freshwater ecosystems are unevenly distributed within Europe. The main factors that determine their distribution are the climate (solar radiation, wind and precipitation/evaporation ratio), landscape and geology (bed-rock).

2.1 Catchment or drainage basins

Catchment or drainage basin (see also chapter 5) is a natural unit of landscape, linking terrestrial and freshwater ecosystems. It is an area of land that drains water, sediment and dissolved materials to a common receiving body or outlet which can be a river, lake or estuary. The catchment basin links various biotic and abiotic components of the system, terrestrial and aquatic, plants and soils, atmosphere and vegetation, soils and water, animals and water. Catchment also includes groundwater that establishes close relationships with the superficial water. The shape, size and content of a stream or a lake depends on the quality of the environments traversed.

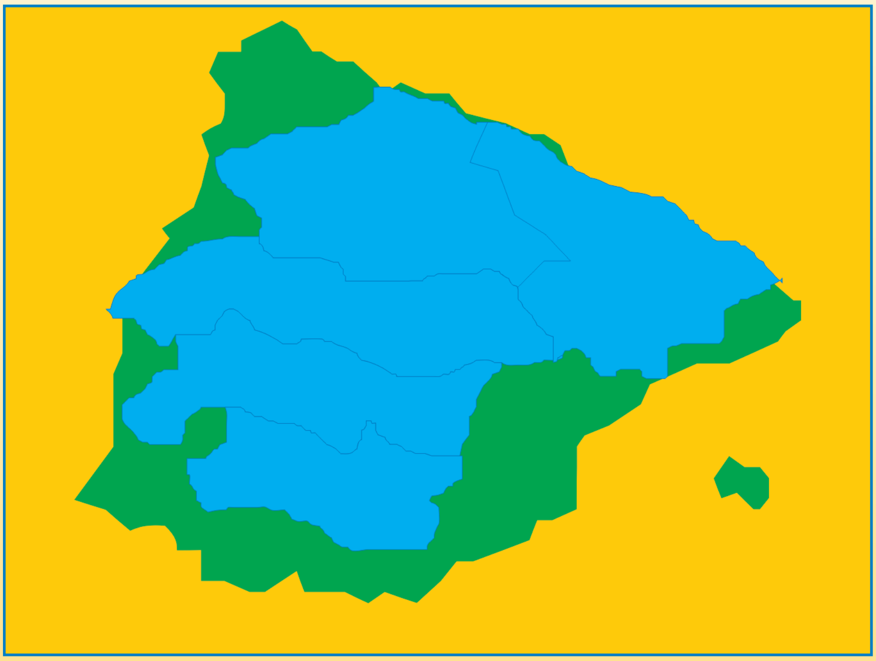

Fig. 4. Main drainage basins along Iberian Peninsula.

2.2 Lakes, Reservoirs and Ponds

Lakes cover less than 2% of Europe's surface. They are water bodies which are deep enough (greater than 2 m) to contain water for long periods of time (see also chapter 3) (Fig. 5). Some shallow water bodies, especially in the Arctic, are considered lakes simply because of their enormous surface area.

Fig. 5. Kastoria lake in Greece.

In contrast to the natural process of lake formation, reservoirs or artificial lakes are used to store water for various uses. Many of them were formed by the construction of a dam across a flowing river (Fig. 6). Reservoirs are used to generate hydroelectricity, to provide water for domestic and industrial use, fisheries, irrigation, transport, recreation or flood control. In Europe the number

Fig. 6. The reservoir of Nestos river (Greece) was formed by the construction of its dam.

of reservoirs is about 3350.

The distribution of lakes along the landscape regions of Europe is the following:

Northern European Lowlands

This landscape region includes the following ten (10) largest natural lakes of Europe.

Name	Country	Surface area (km²)
Ladoga	Russia	17700
Onega	Russia	9610
Vanern	Sweden	5585
Greater Saimaa	Finland	4377
Peipsi	Estonia-Russia	3550
Vattern	Sweden	1912
Ilmen	Russia	1410
Vygosero	Russia	1250
Malaren	Sweden	1140
Paijanne	Finland	1081

It also includes two (2) of the ten (10) largest reservoirs of the world.

Name	Country	Surface area (km²)
Samara	Russia	6450
Bratsk	Russia	5426

Western Uplands

Windermere is the largest natural lake in England. It is 17 km long, its width varies from 400 - 1500 m and its depth is about 65m. Lakes Lomond (Lough Lomond) (71 km²) and Ness (Loch Ness) (56 km²) are also big lakes in Scotland while Lake Neagh (Lough Neagh) (388 km²) is a big lake in northern Ireland.

Iceland: The biggest lake of Iceland is Thorisvatn situated at the southern highlands of the island. A number of volcanic lakes occur here. Iceland, like Azores, has a number of volcanic lakes. Azores: The nine (9) islands of Azores (Portugal), are hotspots in the world since each island sits on volcanoes or was born by a volcanic eruption some millions of years ago. The volcanic lakes of Sao Miguel are of unique beauty.

Central Uplands

The flat terrain of this landscape region is crossed by lakes and marshes (see below) mainly close to the Dutch borders with Germany and along the Frisian coast. Sandy Mecklenburg in northern Germany has many glacial formed lakes (see chapter 3) dating to the last ice age.

Alpine Europe

On the long Alp mountain chain of Alpine Europe many alpine lakes (see chapter 3) are found, such as the alpine glacial lakes in Switzerland, the Lake Constance (Geneva), the lakes of Salzburg in Austria, and Lakes Como, Garda, Lugano and Maggiore in the area of Italy.

The southern part of Europe is characterized by dry, hot, nearly rainless summers and mild rainy winters. Only few and small freshwater bodies are found there.

A pond is a small shallow body of water less than 2 m deep. They are fed by rain runoff or small springs. Ponds are vulnerable to temperature changes freezing in winter and possibly drying in summer.

Well-known ponds in Europe are the Milicz ponds (77 km2) in Poland protected by Ramsar convention (see chapter 6). They are one of the most important resting places for migratory birds and Europe's biggest fishponds.

2.3 Running waters

Running waters are natural water courses, flowing over the surface in extended hollow formations (i.e., channels), which drain discrete areas of mainland with a natural gradient. In basic terms, the existence of a river depends on three factors: the availability of surface water, a channel in the ground and an inclined surface. In this sense, the term "river" includes all kinds of water courses, from the tiniest of brooks or creeks to a massive river the size of the Amazon, flowing over 6400 Km in length and reaching over 3 Km wide in places. The term "stream" is used interchangeably with river when describing the general physical changes that occur as one goes along a water course from small streams at the upper end to a lowland river and possibly an estuary at the lower end.
The 20 longest rivers of Europe are:

Name	Basin area (km²)	Length (km)
Volga	1380000	3690
Danube	817000	2860
Ural	231000	2428
Dnieper	503000	2290
Don	425600	1950
Pechora	322000	1809
Kama	522000	1805
Oka	>100000	1500
Belaya	>100000	1430
Dniester	72000	1352
Rhine	185000	1320
Elbe	148000	1165
Vistula	194000	1047
Loire	120000	1012
Sava	95719	945
Rhone	98000	810
Guadiana	66800	778
Guadalquivir	0	666
Po	74000	650
Garonne	57000	525

The distribution of rivers along the landscape regions of Europe is the following:

Northern European Lowlands and Central Uplands

The Northern European Lowlands is the richest landscape region of Europe in terms of big river basins. All the important European rivers, except Danube, rise in Russia and empty either in the Caspian Sea or in Black Sea. Only one, Pechora River, empties in Barents Sea of the Arctic Ocean. Volga River, which is the longest in Europe and Pechora River lie entirely within Russia. The others flow also through Kazakhstan, Belarus and Ukraine.

The main Northern European Plain hosts also the lower sections of other big rivers like Vistula, Oder, Elbe, Rhine, Seine, Loire, Garonne and Rhone. These rivers have already flown through the Central Uplands before reaching the main northern European plain.

Western Uplands

- Western Iberian Peninsula: Douro rises in the Sierra de Urbion in central Spain. Then it flows westwards across Spain and northern Portugal to the Atlantic Ocean.

Tagus is the longest river in the Iberian Peninsula. It rises in the Sierra de Albarracin of central Spain. Then it flows through Portugal where it empties in the Atlantic Ocean near Lisbon.

- United Kingdom and Republic of Ireland: Severn is the longest river in United Kingdom rising in the Cambrian Mountains. After becoming the Bristol Channel it discharges into the Atlantic Ocean (Irish Sea).

Thames in the UK is 346 Km long. It arises in the Cotswolds and flows eastwards through London eventually discharging into the North Sea.

Rivers Tay (Scotland), Bann (N. Ireland) and Towy (Wales) are also important river systems in the UK.

Alpine Europe

- The western part of Alpine Europe and the Balkan Peninsula: This part hosts the second longest river of Europe, the Danube. Rising from the Alps (Black Forest, Germany) it flows through mountainous areas for the third of its length before reaching foot hills and plains. It empties into the Black sea. Danube separates the Alps from the Carpathians and both of them from the Balkan Mountains.

River Sava rises in Alps and after flowing through four countries (Slovenia, Croatia, Bosnia and Herzegovina and Serbia), it joins the Danube River. It is the longest river of the Balkan Peninsula and the second longest tributary of Danube (after Tisa River).

Evros, together with Nestos and Strymonas, have their origin in the mountains of Bulgaria. Nestos and Strymonas flow south to Greece and discharge into the Aegean Sea. Evros flows to the south east. Then, its northern branch enters Turkey while its southern branch enters Greece and discharges also into the Aegean Sea.

Axios (Vardar) River rises from the Dinaric Alps and discharges also into the Aegean Sea.

- Eastern Iberian Peninsula: On the western part of the Alpine Europe, Guadalquivir and Guadiana are the main rivers. They rise from Sierra Morena Mountains and after flowing through Spain they discharge to the Atlantic Ocean.

▪ Italian peninsula: Po is the most important river of this area. It rises from the Alps. Its mouth is in the Mediterranean Sea (Adriatic Sea) after flowing through France, Switzerland and through its big plain (Po plain) in Italy. Arno and Tiber are also big rivers of Italy. They both flow from the north-central Apennines to the Tyrrhenian Sea.

2. 4 Estuaries

An estuary is a water body formed where saltwater from the sea mixes with freshwater from rivers, streams and creeks and groundwater (see also chapter 3). Estuaries and surrounding lands are transition zones from land to sea and from freshwater to saltwater. They are influenced by tides and protected from the full force of ocean waves, winds and storms by reefs, barriers, islands or fingers of land, mud or sand.

Finally, estuaries and coastal waters are among the most productive ecosystems on earth, providing numerous ecological, economic, cultural and aesthetic benefits.

Fig. 7. Nestos river, Greece.

2.5 Wetlands

Wetlands are areas where water covers the soil, or is present near the surface, during the whole year or for varying periods of time. For this reason they are transition zones between different habitats, getting the characteristics of both aquatic and terrestrial ecosystems. They vary widely due to regional and local differences, such as physical and chemical features, climate, landscape shape (topology), geology, movement and abundance of water and other factors. Wetlands are found from the tundra to the tropics and on every continent except Antarctica.

Fig. 8. Some countries crossed by Danube

Fig. 9. The extended Danube delta, covering an area of approximately 5800 km^2 .

BOX II. FRESHWATER ECOSYSTEMS IN NORTHERN EUROPE

The southern part of Europe is characterized by dry, hot, nearly rainless summers and mild rainy winters. Only a few, small freshwater bodies are found there. Despite their sparse distribution and small size, they are very important. These small lakes, streams or estuaries, influence the local climate and are important resting places for migrating birds.

The salt lakes of Cyprus are characteristic seasonal lakes: The Larnaca salt lake fills with water during the winter and it dries up in summer. It is used to yield salt which is scraped from its dried up surface. The Akrotiri salt lake together with the extensive Phasouri reedbeds and grazing marshes, salt marshes and open coastal areas, constitute a site of high biodiversity value.

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CHAPTER 3

LAKES RIVERS AND ESTUARIES

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1. What is the best way to classify such a variety of freshwater ecosystems, which vary in size, water permanence or flow regime?

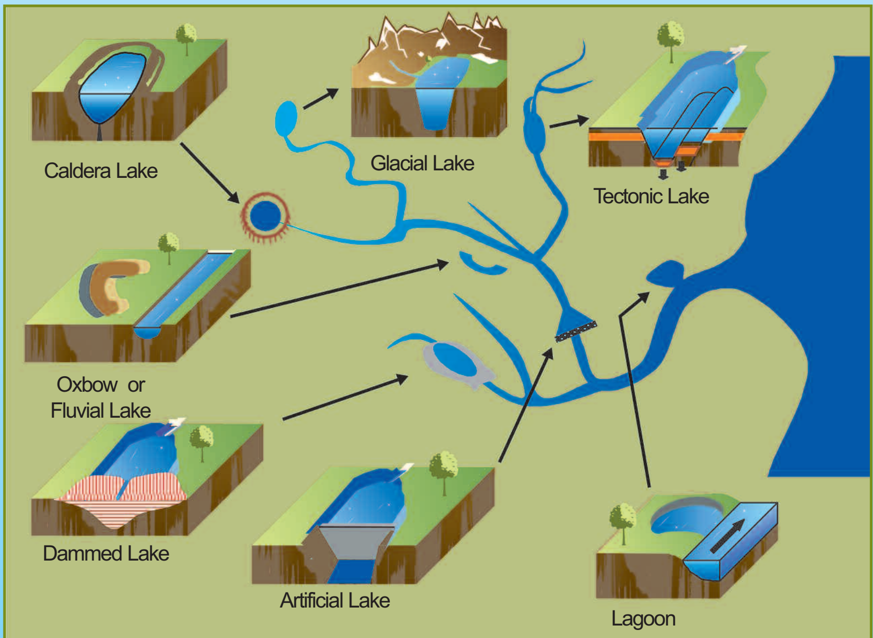

Fig. 1. The different origins of lakes.

We have chosen the distinction between standing water (e.g. lakes) and running water (e.g. rivers and streams); estuaries are also considered, because estuaries are transition zones from land to sea and from freshwater to saltwater.

1.1 How are lakes formed?

Geomorphology influences the physical and chemical characteristics of lakes, along with the local climate. While most lakes are formed by catastrophic events, others are created more gradually (Fig. 1).

1.1.1 Glacial lakes

The last glaciation was responsible for shaping the landscape of northern temperate regions. Glacial ice scoured

Fig. 2. One of the three glacial lakes on the top of Pindos Mountain, Greece. These glacial lakes are the southern ones of the northern hemisphere. They are called Drakolimnes (dragon lakes) since a lot of myths with dragons and gods have been raised around these lonely mountainous lakes.

the surface of relatively flat, mature rock causing the formation of a vast number of small lakes. These ice scour lakes are particularly common in mountainous regions where glacial movements have removed loosened rock material. When glaciers retreat, the rock basins formed fill with melt water. Such glacial scour lakes may be found on several places of Europe (Fig. 2).

1.1.2 Tectonic lakes

Tectonic basins are depressions formed by movements of deeper portions of the earth's crust. Foremost among these is Lake Baikal, in eastern Siberia, the deepest lake in the word, which is from the early Tertiary period. Lake Baikal and many other tectonic lakes are of particular interest because they contain a large number of ancient endemic species. Movements in the earth's crust causing moderate uplifting of the marine seabed have isolated several very large lake basins. The ancient marine basin of eastern Europe was lifted and divided by the formation of a Mountain ridge in the Miocene period. This isolated the Caspian Sea on one side and the Aral Sea on the other.

1.1.3 Naturally dammed lakes

This type of lake forms in river valleys behind a dam created by a landslide. Large quantities of unconsolidated rock material slide down to the valley floor, damming the river and creating a lake. This type of lake is often transitory, existing only for a few weeks or months. Many disastrous floods have resulted from the rapid removal of the dam material by the force of the flowing river.

1.1.4 Volcanic lakes

Catastrophic events associated with volcanic activity can generate lake basins in several different ways. Basins formed by the subsidence of the roof of a partially emptied magmatic chamber are called calderas. Lagoa das Sete Cidades in the Azores is the most spectacular example of such a lake (Fig. 3).

Fig. 3. A volcanic lake. Lagoa das Sete Cidades, Azores, Portugal. Photo by P.Pinto

Fig. 4. The doline of Kournas, Crete, Greece. Photo by A. Trichas

1.1.5 Karstic lakes

Most lakes are very common in limestone regions of the world, notably in the karst regions of the Adriatic, especially in the Balkan Peninsula, and in the Alps of Central Europe. Karstic basins are usually almost circular and conically shaped sinks, called dolines, which develop as the soluble limestone is gradually dissolved (Fig.4). Usually, the depressions created are sufficiently deep to extend well into the groundwater table and permanently contain water.

1.1.6 Oxbow or fluvial lakes

Many lakes were formed along large rivers when sediments carried from the main river were deposited as layers across the mouths of tributary streams (Fig. 3). As a result, the tributary flooded its valley, forming a lateral lake. Flow continued until the side valley was flooded and a lateral lake was formed. These kinds of lateral lakes occur especially in the upper portion of the drainage catchment area.

As a river meanders along its flood plain, greater turbulence causes erosion to occur on the concave side of the river bend, while deposition occurs on the convex side, where currents and turbulence are reduced. In time, the main course of the river cuts a new, more direct channel, leaving behind the isolated loop, referred to as an oxbow lake.

1.1.7 Lagoon or Coastal lakes

Marine coastal lakes commonly result from the formation of a bar of sediment across the mouth of an old estuary. River discharge and tidal currents are sufficient to prevent complete separation of the lake from the sea. Thus, on any day, the lake may contain freshwater, brackish water or salt water, depending on the tides.

1.2 How can we classify running waters?

Running water, streams and rivers, occur under widely differing conditions of vegetation, topography and geology. However, they are all linked by the effect of precipitation and evaporation that affects their drainage basins. It is useful to classify running water according to the availability of water in terms of predictability and permanence. On this basis, rivers can be classified from the least predictable and least permanent, ephemeral and episodic systems to the most predictable, seasonal, permanent or perennial systems.

1.2.2 Episodic streams

These are dry during most of the year with rare and very irregular wet phases that may persist for months.

1.2.3 Intermittent streams

These are alternately wet and dry, but less frequently and less regularly than seasonal streams (Fig. 4).

1.2.4 Seasonal streams

These are alternately wet and dry every year, according to the season (Fig. 5). They usually fill during the wet part of the year, and dry in a predictable way. The surface water persists for months, long enough for some macroscopic plants and animals to complete the aquatic stages of their life cycles.

1.2.5 Permanent or Perennial

These are permanently filled, although water levels may vary. Most of their living communities cannot tolerate desiccation (Fig. 8).

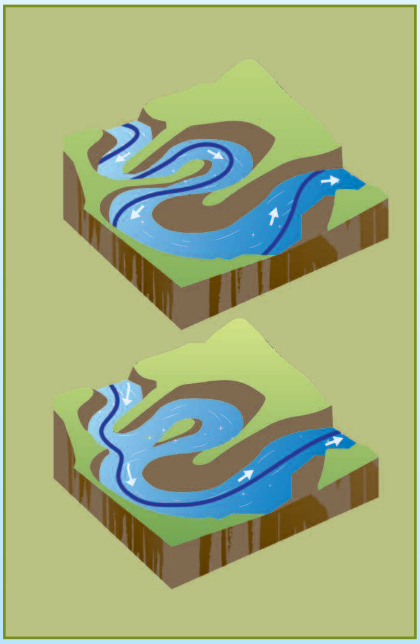

Fig. 5. Formation of an oxbow or fluvial lake.

Fig. 6. An intermittent stream. Krathis stream, Crete, Greece.
Photo by M.Morais

1.3 How can we classify estuaries?

Estuaries are divided into four types, depending on how they are formed (Fig. 9).

Fig. 7. A seasonal temporary stream in southern Portugal. Pardiela stream belonging to Guadiana basin.
Photo by M.Morais

1.3.1 Coastal plain estuaries

These are formed when the sea level rises and fills an existing river valley.

11.3.2 Tectonic estuaries

These are formed by the folding or faulting of land surfaces.

1.3.3 Bar-built estuaries

These are formed when a shallow lagoon or bay is protected from the ocean by a sand bar or barrier island.

1.3.4 Fjords

These are a very special type of estuary formed by flooding U-shaped glacial valleys. Fjords are found in areas with long histories of glacier activity, like northern Europe, Alaska and Canada.

Fig. 8. Kalamafkianos. A permanent stream, Crete, Greece.
Photo by C. Voreadou

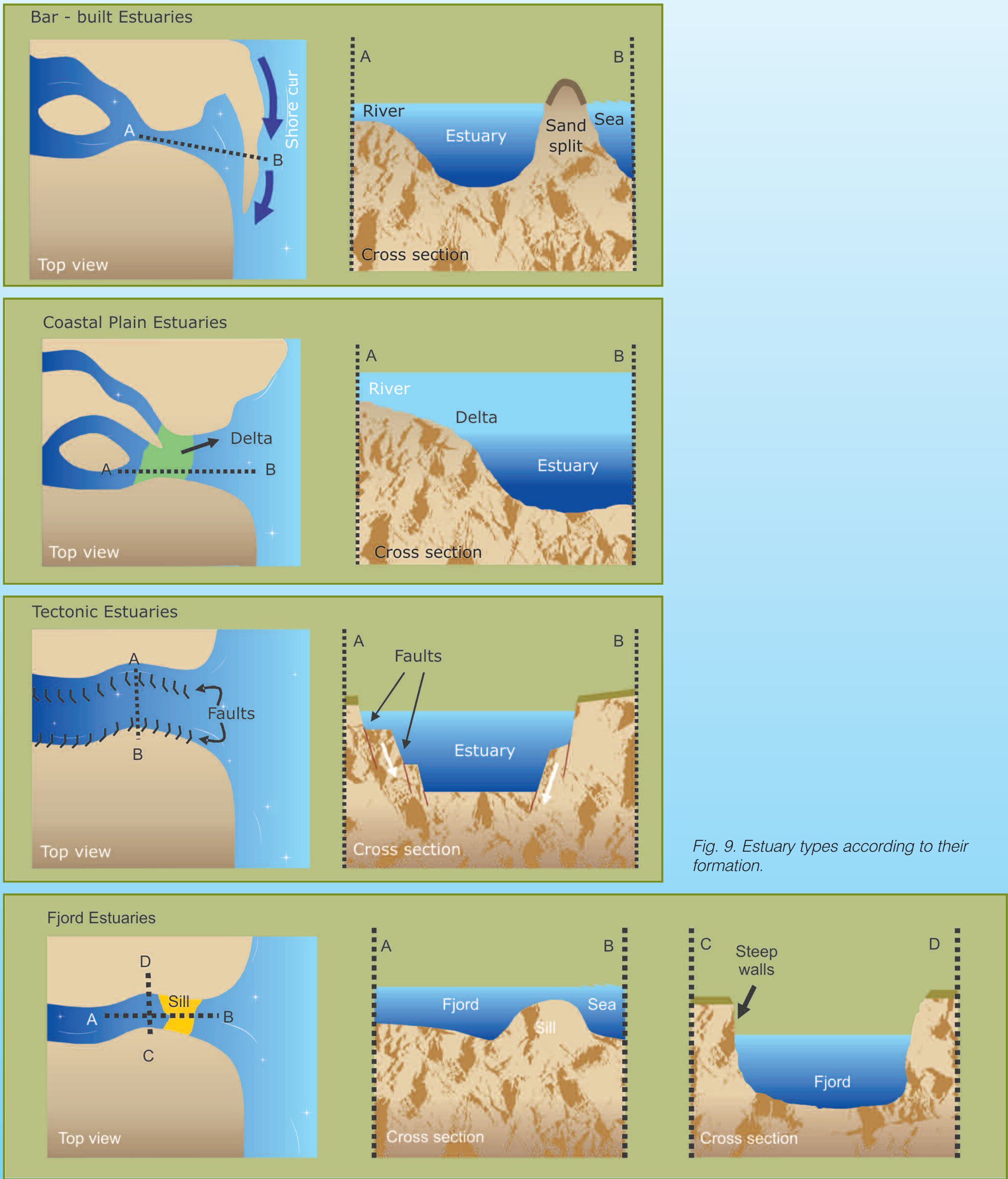

Fig. 9. Estuary types according to their formation.

2. Which are the aquatic inhabitants of freshwater ecosystems?

a) Plankton community is the living fraction of material which floats in the water and is moved passively by wind or current. It is composed of microscopic plants - the phytoplankton - which are the primary producers of organic matter in aquatic habitats. The nutritionally dependent animal component constitutes the zooplankton. The phytoplankton thus stands on the base line of food webs in aquatic environments. It is in turn dependent on the activities of other microbial organisms, mainly bacteria, which convert organic material into the inorganic nutrients required by plants. Members of phytoplankton are classified as algae.

b) Algae can also growth upon substrate, in the littoral zone and constitute, together with other communities like fungi and bacteria, the periphyton.

c) Macrophytes are aquatic plants. They are described as aquatic if the plant parts involved in photosynthesis are submerged or float on the water surface either permanently or at least for several months each year. The term "macrophytes" refers to all plants large enough to be visible to the naked eye - not only flowering plants but also ferns, bryophytes and algae.

d) Benthic macroinvertebrates live in the sediment at the bottom of the lake. These aquatic mini beasts are larger than a pin-head (that's about five microns). Like bacteria, these organisms are important for processing and transforming organic matter into sources of food for other aquatic life.

e) Fish communities: These are vertebrates and the best-known inhabitants in freshwater systems. Fish are the major predators in lakes. This is no doubt connected with their importance as food. Freshwater fisheries are important for domestic use and commercially worldwide.

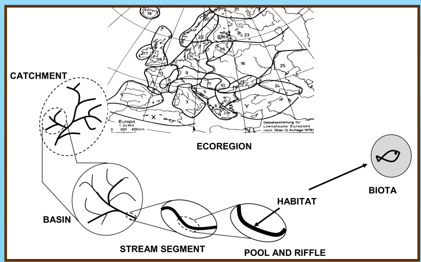

Fig. 10. Complexity and different landscape scales of a catchment. This scale is pertinent to physical, chemical and blotic processes, because processes are scale-dependent.

3. Are there common ecological features among freshwater ecosystems?

Freshwater-ecosystem communities are dynamic, reflecting changes in many variables. The trophic state of any aquatic system depends on nutrient inputs from the catchment and the riparian zone (mainly branches, leaves, soil). When a dead leaf (CPOM-Course Particulate Organic Matter) falls into a stream, it may be carried along for a distance, until it sinks in a pool or is trapped by a rock. Within 1-2 days, dissolved organic matter (DOM) leaches out of the leaf and may form fine particulate organic matter (FPOM). Meanwhile, the leaf has formed a substrate for microbes. Microbes improve leaf palatability for invertebrate decomposers by partially digesting leaf tissue. Nutrients are also important input elements from catchment basins to freshwater ecosystems. How they enter though freshwater ecosystems? Which are their pathways and how aquatic organisms are involved in these pathways? Answers to these questions are included i the figures below (Fig. 10, 11 &12).

In ecosystems, competition between organisms for space, light and food is balanced over space and time through the interaction of producers and consumers. The first consumers in the base of a food web can be zooplankton in lakes and estuaries and macroinvertebrates in rivers and streams. According for their trophic characteristics, which means their feeding preferences, the macroinvertebrates can be divided into scrapers, collectors, shredders and predators (BOX I).

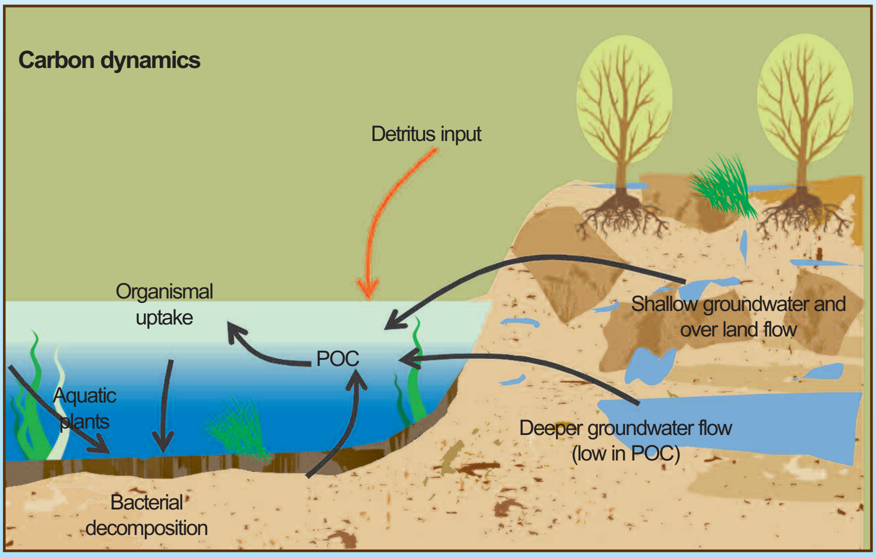

Fig. 11. Major pathways of carbon dynamic in lakes. The diagram shows the importance of allochthonous carbon coming from drainage basin (trees and groundwater).

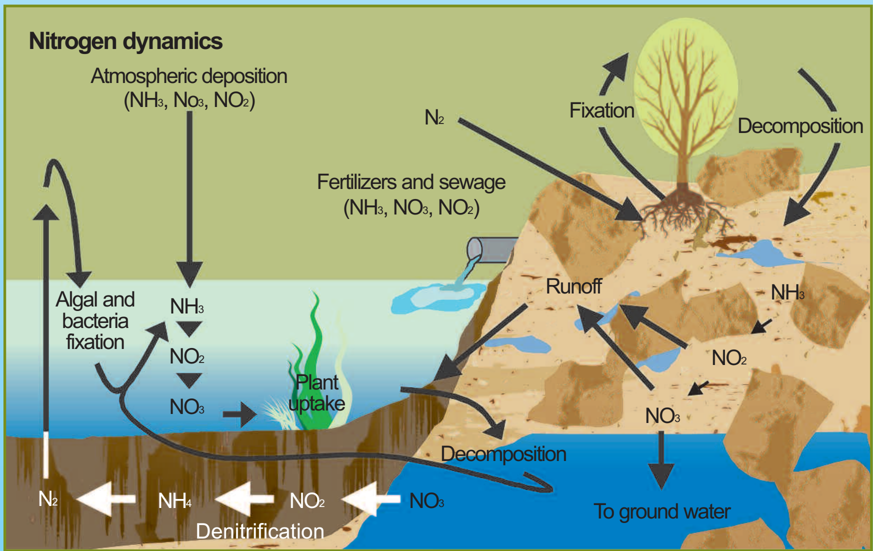

Fig. 12. The nitrogen dynamics, showing the major pathways and the different habitats involved.

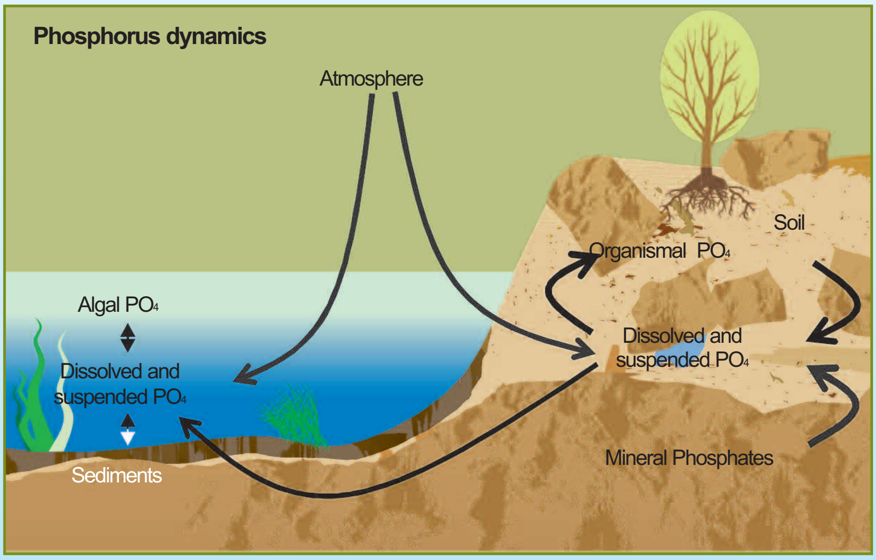

Fig. 13. The phosphorus dynamics, showing the major pathways and the allochthonous dependence.

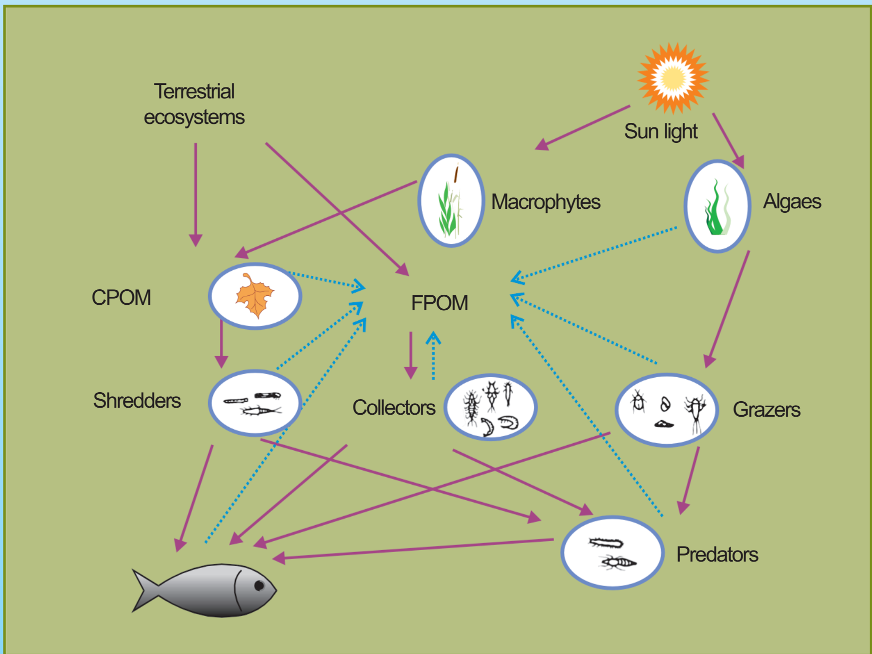

Fig. 14. Simplified model of a stream's ecosystem, showing the principal biological components, energy sources and material pathways. The relative importance of the pathways will differ from stream to stream and from segment to segment in the same stream according to their positions along the longitudinal course. Larger blue arrows correspond to the contribution of the terrestrial environment. Blue arrows correspond to the direct flux of energy along the food web. The brown dotted lines show the different ways FPOM is generated (CPOM partition or animal faeces).

Nutrients are released from excreta and decomposition. Rooted plants recycle nutrients from the sediments and release nutrients for producers (algae and large plants). Grazers vulnerable to predators depend on plants for refuge. Predators control these grazers, avoiding excess plant consumption at destructive levels. These grazers, shredders and collectors are consumed by predatory amphibians, fish and birds (Fig. 11).

To summarise, the basis of this web is the conversion of the sun's energy into food energy by plants. When the plants die and decay at the end of the growing season, protozoa and other microorganisms coat the dead plant material. Small invertebrates, which feed on this detritus, are themselves eaten by fish, which in turn may be eaten by birds and mammals (Fig. 12).

Fig. 12. Food chain. Light from the sun is fixed by photosynthesis in plants that are eaten (alive or in decomposed forms) by small invertebrates. These invertebrates serve as food for fish that may themselves eventually be eaten by birds. The energy trapped by the primer producers flows along the food chain, being finally exported to the terrestrial ecosystem by birds. Organisms are not represented to scale.

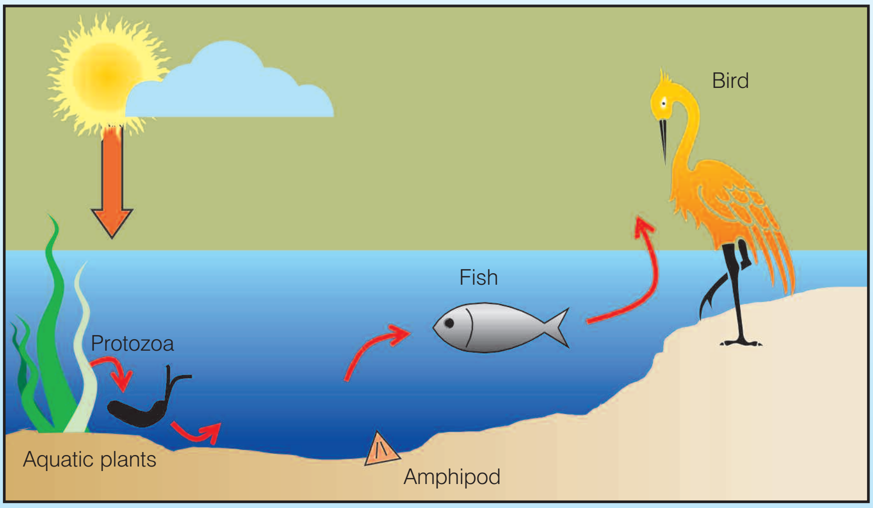

Fig. 15. Food chain. Light from the sun is fixed by photosynthesis in plants that are eaten (alive or in decomposed forms) by small invertebrates. These invertebrates serve as food for fish that may themselves eventually be eaten by birds. The energy trapped by the primer producers flows along the food chain, being finally exported to the terrestrial ecosystem by birds. Organisms are not represented to scale.

BOX I. FUNCTIONAL FEEDING GROUPS OF INVERTEBRATES

CPOM-Course Particulate Organic Matter
FPOM-Fine Particulate Organic Matter

Feeding group	Food resource	Feeding mode	Examples
Shredder	Leaf litter (CPOM), green water plants	Chewing and mining	Caddisflies, some beetles, some chironomid midge larvae, some crustaceans
Collector-filterer	Suspended FPOM	Filter-feed using specialised setae, nets or secretions	Net-spinning caddisflies, blackfly larvae, some chironomid midge larvae
Collector- gatherer	Deposited FPOM or biofilm on rocks and other hard substrates	Brushing biofilms, burrowing in soft sediments	Many mayflies, stoneflies, caddisflies, true flies, oligochaeta worms, some crustaceans
Scraper or Grazer	Algal biofilm	Scraping and browsing	Some mayflies, caddisflies, snails, beetle larvae
Predator	Animal prey	Bitting and piercing	Dragonflies and damselfliaes, flatworms, some caddisflies, true flies, true bugs and beetles

4. River Continuum Concept: a model to explain the distribution of aquatic organisms

Standing-water communities are organized according to the vertical axis of light penetration. Thermal stratification, which contributes to lake structure, is a direct result of heating by the sun. Thermal stratification is the phenomenon by which lakes develop two discrete layers of water of different temperatures: warm on top (epilimnion) and cold below (hypolimnion) (Fig. 13). This vertical gradient is a key environmental factor, affecting distribution patterns, behaviour and metabolic rates of freshwater organisms. For example, nutrients may be cycled repeatedly between the water layers, plankton and sediment organisms, as the system alternately stratifies and mixes before ultimately being exported (see chapter 1).

Running water is distinguished from other freshwater ecosystems due to its unidirectional flow. This means that downstream reaches are influenced by upstream ones. The transport of dissolved or particulate organic matter occurs from source to mouth and there is a close linking of the stream with the surrounding terrestrial ecosystem. This link is largely one-way, from land to water, in headwaters, but two-way, between water and floodplains, in lower reaches. In running water, the cycling process is superimposed on the longitudinal movement of the water to produce nutrient spiralling (Fig. 14).

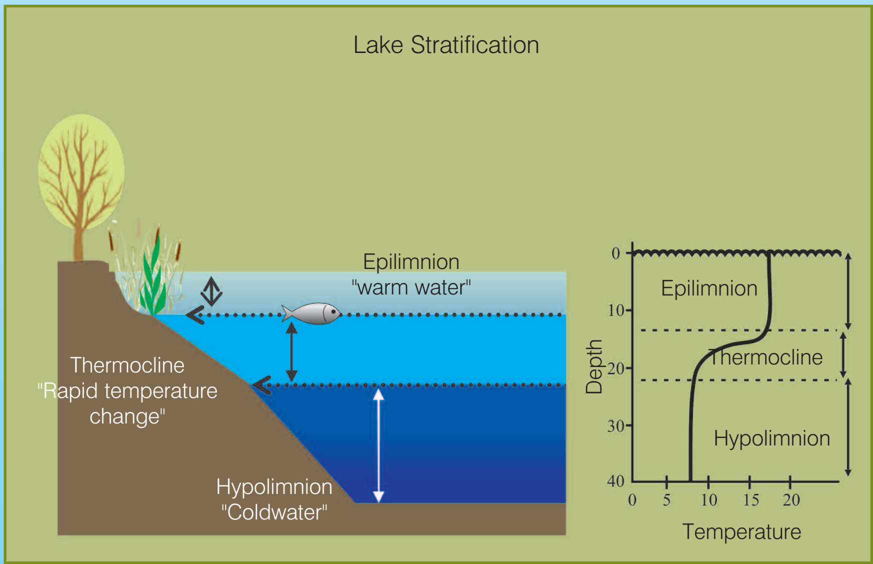

Fig. 16. Vertical temperature profile, showing stratification and the epilimnion and the hypolimnion zones.

As ecologists began to think of stream ecosystems in terms of energy sources or as functional systems capable of processing organic matter, models were developed to describe the longitudinal pattern in such processes. The most popular of these models is the River Continuum Concept (RCC) and it represents a bold attempt to construct a single synthetic framework to describe the functioning of lotic ecosystems from source to mouth (Fig. 15).

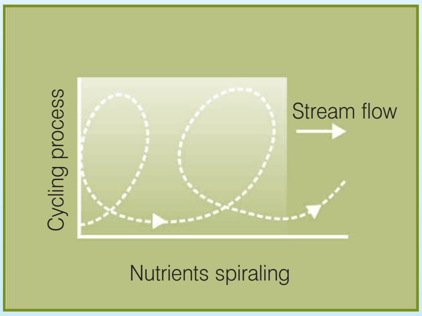

Fig. 17. Nutrient spiralling in running waters. Spirals lying together indicate high retention such as in oligotrophic conditions or in upland streams with coarse substrate. Loose spirals with broader diameters represent low retention, characteristic of eutrophic systems with excess of nutrients.

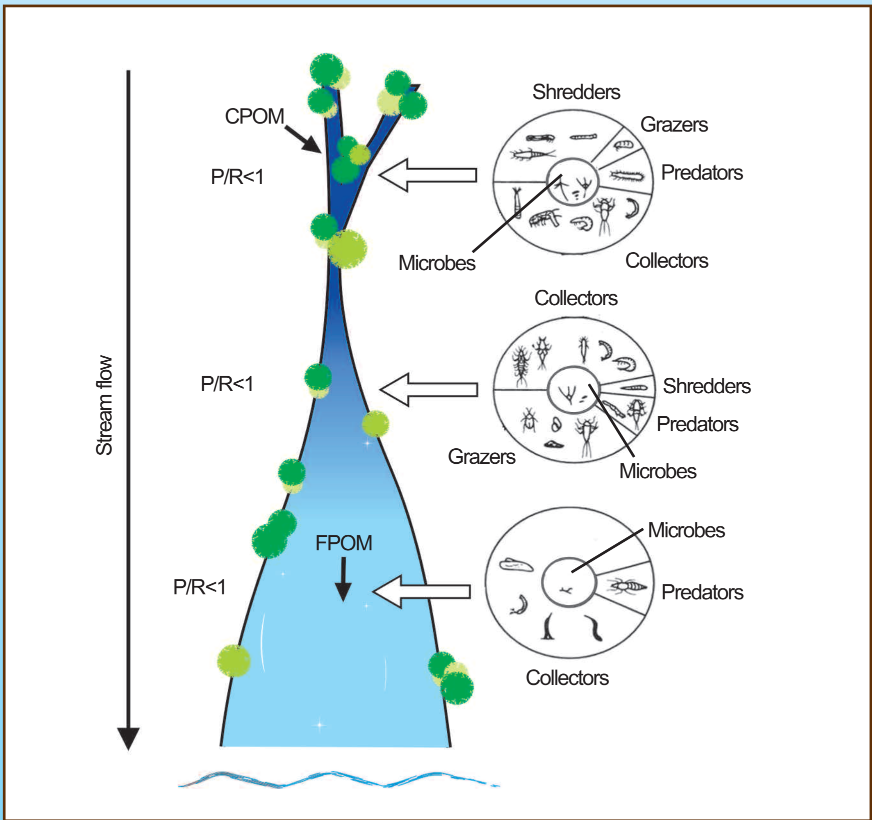

Fig.18. Relationship between stream size (order), energy sources and ecosystem function predicted under the River Continuum Concept (from Vannote et al., 1980).

5. Which are the peculiar characteristics of estuaries?

Water mixing in estuaries is complex, being affected by geology, topography and fresh water discharge. River water carries dissolved salts and particles, and this loading, plus the physical mixing, leads to very active biological transformations. For instance, deltas occur in estuaries where the sediment load carried by the river is so large that accumulations of sediment near the river mouth grow towards the sea. The shores of the complex channels that form in deltas provide extensive protected shallow habitats that invariably support dense vegetation of vascular plants. Estuaries and coastal waters often contain various mixtures of fresh and salty water, which create physiologically and ecologically challenging circumstances for organisms. The often-changing mixtures of fresh and seawater create difficult osmotic gradients that greatly affect organisms.

Circulation of water in the near shore is complex and results from a complex combination of factors: differences in density between freshwater and sea water; differences in water temperature; tidal forces; wind-driven circulation; the effects of the earth's gravitational field. Less dense or warmer water tends to remain in the surface layers of a water column, while denser, colder water remains in a layer below, and the water column is therefore stratified. Winds and tides, however, may mix the water column, causing a vertical exchange between surface and deeper layers (Fig. 16).

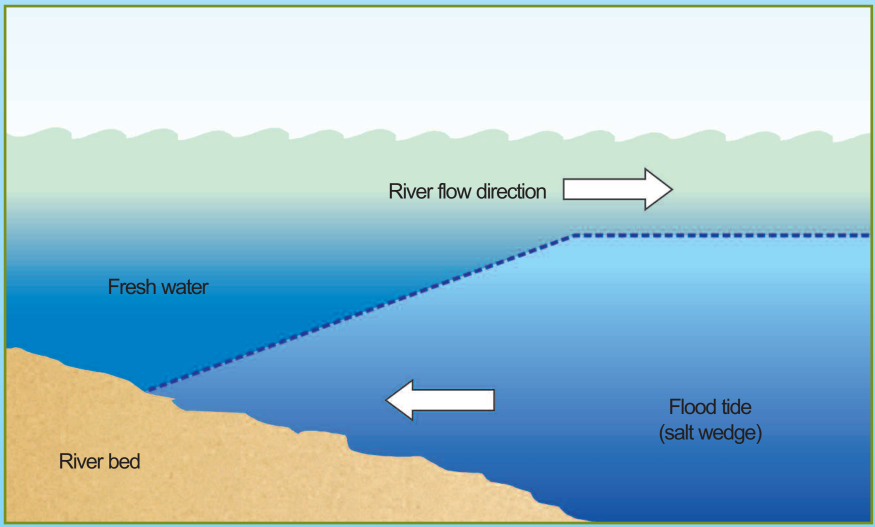

Fig. 19. Water mixing in an estuary. Fresh water and salt water mixing inside an estuary. Density stratification is observed. Salt water, being denser, tends to penetrate inside the estuary near the bottom. Fresh water, which is less dense, tends to stay in the upper layers of the water column.

CHAPTER 4

ASSESSING THE ECOLOGICAL STATUS OF FRESHWATERS

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1. Why we have to protect the water? A new water management strategy under the European Water Framework Directive (WFD).

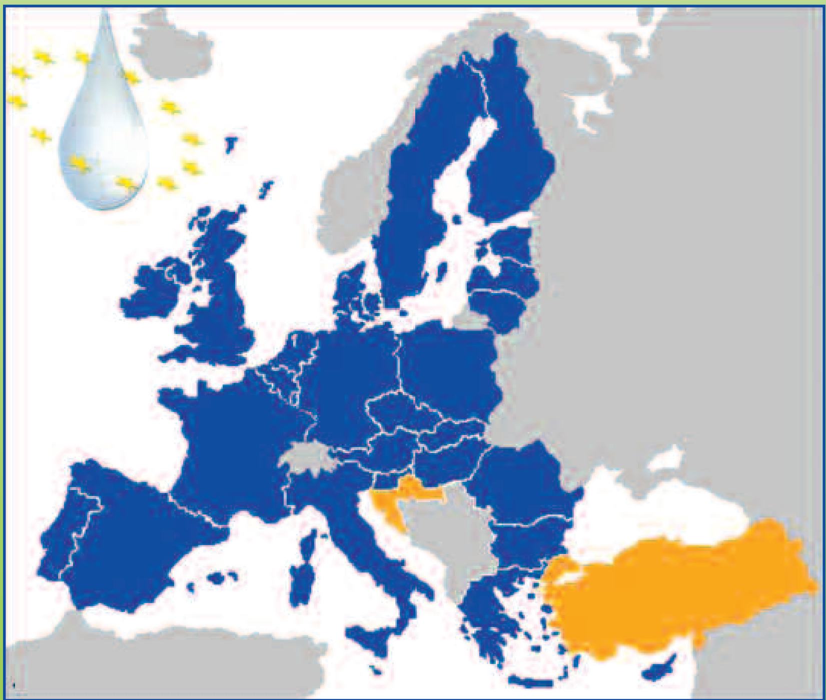


Fig. 1. The water policy scene of the European Union (on the upper left - a logo of the EU-WFD implementation in the EU states; the 27 EU countries highlighted by blue background).

The critical decline of biological diversity and water quality at the global scale was sobering evidence that valid water management requires effective tools and standard methodology to control excess pollutants, nutrients, organic materials and specific substances being transferred into freshwater ecosystems.

A new regulation for the European Community action in the field of water policy - the Water Framework Directive (WFD) (2000/60/EC) was agreed by the European Parliament and Council in September 2000, and came into force on 22nd December 2000 - as part of an general re-structuring of the European Union water policy.

Nowadays, the WFD is the most influential legal instrument on the EU level for water protection and management (e.g. Jungwirth et. al. 2000; Butterworth et al., 2001; Statzner et al., 2001; Bis, 2002; Bis & Usseglio-Polatera, 2004; Furse et al., 2006).

One of the main aims of the WFD is to establish a formal background for the protection of all European water types: inland surface waters, transitional waters, coastal waters and groundwaters.

secondly, all environmental targets of the wfd are strictly directed to enhance and protect biological diversity, and ecological integrity of aquatic ecosystems in europe.

The WFD requires the new organisation of all national water monitoring systems in EU states, in terms of moving away from simple pollution level evaluation (based only on hydrochemical measurements) - to assessing THE HEALTH OF THE AQUATIC ECOSYSTEM overall.

The health of animals and plants that live in waters will now be the main indicators of the quality state of water bodies.

As a result, the major objective of the Water Framework Directive aims at:

- preventing any deterioration in the existing status of water bodies,
- maintaining 'high status' of all water types where it exists, and
- achieving at least 'good quality status' in relation to all European water types by 2015.

The added values of the WFD are to:

- enhance protection of aquatic ecosystems - together with terrestrial ecosystems and wetlands - directly dependent on aquatic ecosystems;
- promote long-term protection of available water resources based on sustainable water use;
- establish a register of 'protected areas' - areas designated for protection of habitats and/or species;
- provide for enhanced protection and improvement of the aquatic environment by reducing emissions of hazardous substances;
- provide for sufficient supply of good quality surface water and groundwater as need for sustainable, balanced and equitable water use.

Fig. 2. The water environment for biodiversity protection

Fig. 3. Freshwaters around Europe.

2. How water bodies should be manage under the European Water Framework Directive?

All water bodies in Europe, including

- inland waters: surface and groundwaters,
- transitional and costal waters

should be now artributed to the basic management units - to the river basin districts (Fig. 3).

Therefore, any management goals undertaken by regional water authorities have to consider the River Basin's scale of potential impact, particularly in the case of the transboundary river systems (encompassing some administrative borders and flowing by different countries).

3. How surface water bodies should be managed under the European Water Framework Directive?

The WFD established three main categories of SURFACE water bodies:

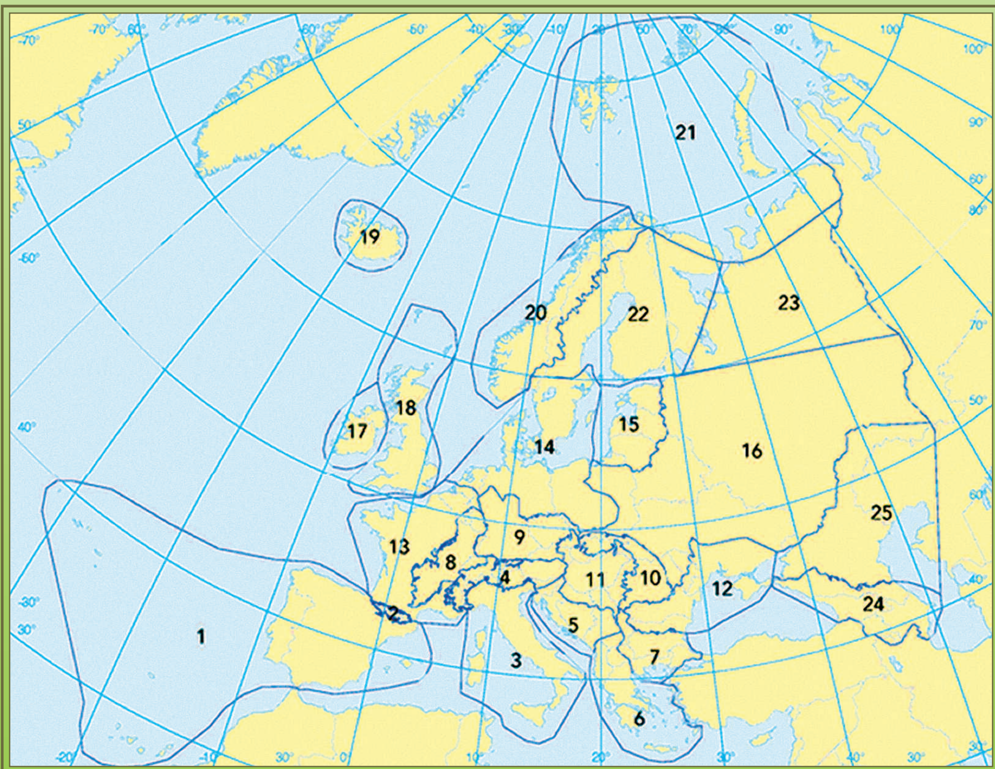
- natural surface water bodies:
  - ✔ rivers
  - ✔ lakes
  - ✔ transitional waters
  - ✔ coastal waters
- heavily modified surface water bodies (with heavily physical alterations by human activity);
- artificial surface water bodies.

The divisions of surface water bodies with a separation of heavily modified and artificial waters - is connected with the proper water management procedures (the quality of these waters should be effectively improved). For these purposes, there is also important to recognize the dominated stressor type and its intensity (e.g. organic pollution, canalization), different planned water uses (e.g. drinking water) and local protected areas (e.g. Natura 2000 sites).

4. How European river systems should be characterized and managed under the Water Framework Directive?

As we stated, according to the WFD objectives - all the European river basins are water management units - and are grouping within BIOGEOGRAPHICAL ECOREGION (Fig. 4). As a result, ecoregions correspond to the typical environmental variability of European aquatic ecosystems, based on type-specific biocenosis, and also geological settings, and hydrological regime.

▪ The EU-member states for the key characteristics of all river basins will use some obligatory parameters:
▪ ecoregions, which covering the studied river basin (Fig.4);
▪ geographic location of the river system: latitude and longitude (for the studied river section),
▪ altitude as defined by the elevation of the source, or the elevation of the river section being assessed (mountain rivers >800m above see level; upland rivers 200-800m a.s.l.; low-



Ecoregions for rivers and lakes:

1. Ibero - Macaronesian region
2. Pyrenees
3. Italy, Corsica and Malta
4. Alps
5. Dinaric western Balkan
6. Hellenic western Balkan
7. East ern Balkan
8. Western highlands
9. Central highlands
10. The Carpathiens
11. Hungarian lowlands
12. Pontic province
13. Western plains
14. Central plains
15. Baltic province
16. Eastern plains
17. Ireland and Northern Ireland
18. Great Britain
19. Iceland
20. Borealic uplands
21. Tundra
22. Fenno - scandian shield
23. Taiga
24. The Caucasus
25. Caspic depression

Fig. 4. Ecoregions are based on fauna communities living in European inland surface waters (the data was published as a map in Annex XI, Water Framework Directive, in Official Journal of the European Communities).

land rivers <200m a.s.l.),
- river basin size, as defined by catchment area,
- geology of the river basin (calcareous, siliceous, organic).

However, the EU-member states can applied other complementary criteria that identify as important for defining the regional characteristics of river systems.

5. Why the river reference conditions with high ecological status should be established for the water quality assessment?

The identification of reference onditions - defined as the best conditions of a given stream-type (e.g. lowland or mountain streams) with a minimal degree of modification - is a rigid requirement for assessing the ecological quality of European waters.

To establish the main WFD goals, directed to the ecological status improvement - an understanding of a water body's reference conditions, in unimpacted state - is strictly needed. When reference conditions are established (as a control/benchmark system), they can be used to assess environmental impacts, conservation status, or biodiversity modifications at any water type.

BOX I. REFERENCE CONDITIONS UNDER THE WFD

Reference conditions (RC) - do not equate necessarily to totally undisturbed, pristine conditions. They include very minor disturbance which means that human pressure is allowed as long as there are no or only very minor ecological effects; as results

◆ RC are equal "the high ecological status" (no or only very minor evidence of disturbance for each of the general physico-chemical, hydromorphological and mostly biological quality elements);

◆ RC shall be established for each water body type, and for each quality elements and should be revised every 5 years;

◆ There are two primary approaches for selecting reference conditions (having no or minimal impact) at surveyed sites:

▪ Selection of reference sites based on a definition of reference site criteria - is used when a sufficient number of pristine or unimpacted rivers and/or reaches exist;

▪ Determination of reference condtions based only on the best conditions, which can be actually found in the given water type range -is used when few reference sites exist or are not suitably defined.

6. How the ecological status of surface waters should be assessed under the WFD?

The WFD specify that the ecological status of the surface water is defined as " an expression of the quality of the structure and functioning of aquatic ecosystems associated with water-type" (WFD, 2000; Furse, at al., 2006).

Consequently, the ecological status assessment should evaluate how the biological structure and ecosystem functioning are altered in response to different anthropogenic pressures (e.g. nutrient loading, acidification, toxic and hazardous substances, physical habitat alterations, etc.).

All the WFD requirements are a novel approach in the European water policy, which in the past was based on the evaluation of emission values - but now is focused on the strict control of the allowed impacts on the recipient ecosystems. this conceptual approach is directly connected with EU nature conservation legislation such as the 'Birds Directive' (79/409/EEC) and the 'Habitats Directive' (92/43/EEC) - which have established a legislative framework for protecting and conserving Europe's wildlife and habitats (creation of a coherent ecological network of protected areas across the EU - NATURA 2000). According to the WFD, there are three basic QUALITY ELEMENTS applicable to assessing ecological status (Fig. 6):

1. Biological quality elements;
2. Physico-chemical quality elements; and
3. Hydromorphological quality elements (river channel and its valley conditions).

It is very important to note that now under the WFD the hydromorphological and the general physico-chemical conditions are ONLY supporting elements for the biological elements assessment.

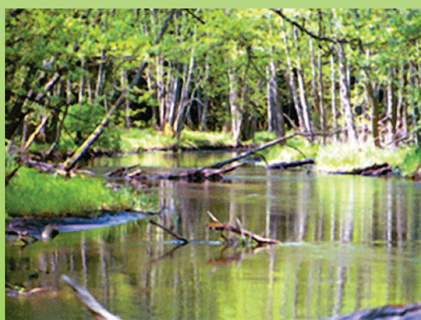


Fig. 5. An example of reference conditions for small-sized mountain streams, and middle-sized lowland rivers.
Photo by B.Bis

Biological Quality Elements	Hydrochemical Quality Elements	Hydromorphological Quality Elements

Phytoplakton (only in large rivers and lakes) Phytobenthos Macrophytes Benthic macroinverte-brates Fish fauna	Oxygenation conditions Nutrient concentration Salinity Termal conditions Acidification status pH Hazardous substances	Morphological conditions Hydrological regime River continuity

Fig. 6. Three basic quality elements of the ecological status assessment: (1) biological quality elements (algae, phytoplankton, macrophytes, macroinvertebrates, fishes); (2) hydromorphological assessment of river channel and its valley; (3) physico-chemical quality elements - with quality standards for hazardous substances.

BOX II. THE WFD CONSEQENCES FOR WATER MANAGEMENT

The ECOLOGICAL STATUS of natural waters:

- ◆ needs to be determined using primarily BIOLOGICAL quality elements (BQE: phytobenthos/phytoplankton; macrophytes; macrozoobenthos; fish)
- ◆ Biological assessment is the basis for the water body CLASSIFICATION;
- ◆ Ecological classification sets the principal WATER MANAGEMENTS GOALS for the River Basins.

7. Harmonized class boundaries in Europe

Each EU country should define and establish the five quality classes (Fig. 7) related to the environmental modifications - separately for all biological quality components (BQC) and water body types (e.g. WFD CIS 10, 2003; UKTAG, 2005; Urkiaga et al., 2006).

The WFD gives definitions of the different quality class as follows:

- High status: reflect undisturbed conditions and no or only very minor evidence of alteration;
- Good status: Low level of human-impacted alterations and only slight deviation from undisturbed conditions;
- Poor status: High level of deviation and alteration.

As a result - the outcomes of the monitoring system of the EU-Members should be established on the class values for each biological quality elements (e.g. invertebrates or diatoms communities).

This central concept is the most innovative for the EU-WFD principles. In the past - each standard monitoring system was based on the hydrochemical quality assessment and the class boundaries were easy to determine. Now, the class boundaries for all groups of the indicative organisms (diatoms, macrophytes, benthic invertebrates, fishes) and their responses on the stressor type must be established. It is much more difficult for determining, but is directly connected with the optimalisation of aquatic ecosystems protection.

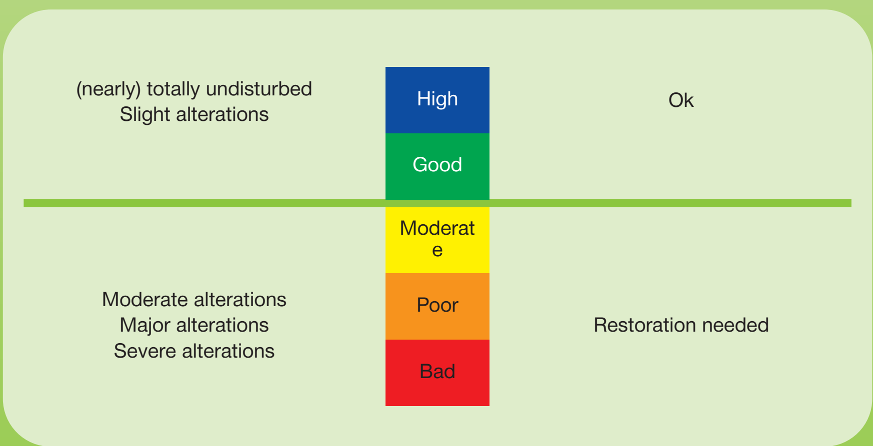


Fig. 7. Diagram of the five quality classes - under the WFD - based on the ecological status assessment (biological, hydrochemical and hydromorphological quality elements) - with a brief interpretation of human impact, and the indication of responsibility for the river restoration tasks.

8. Why are biological quality elements (BQEs) the basis for ecological classification?

Ecological indicators can be used to assess the condition of the environment, to provide an early-warning signal of changes in the environment, or to diagnose the cause of an environmental problem. Ideally the suite of indicators should represent key information about structure, function, and composition of the ecological system (Markert et al., 2003).

Ecological indicators need to capture the complexities of the ecosystem yet remain simple enough to be easily and routinely monitored. As a result, ecological indicators should meet the following criteria:

- be easily measured
- be sensitive to stresses on the system
- respond to stress in a predictable manner
- predict changes that can be averted by management actions
- be integrative
- have a known response to disturbances, anthropogenic stresses, and changes over time

Algae as biological indicators

As primary producers - algae and aquatic plants (macrophytes) are considered as early-warning system groups, that distinctly react on hydrochemical disturbances (e.g. eutrophication = nutrient richness of any type of stagnant waters - mainly lakes and lagoons). Periphyton are benthic (attached) algae that grow attached to surfaces such as rocks or larger plants. The periphyton, mostly diatom assemblages - serves as a good biological indicator due to:

(1) a naturally high number of species;
(2) a rapid response-time to both disturbance and ecosystem recovery; (3) ease of sampling, requiring few people;
(4) tolerance or sensitivity to specific changes in environmental condition are known for many species.

By using algal communities in association with macroinvertebrate and fish data, the significance of biological assessments is optimized.

Fig 8. Macrophytes. Photo by P.Pinto

Aquatic and terrestrial plants as biological indicators

Macrophytes are aquatic plants, growing in or near water that are either emergent, submergent, or floating. Macrophytes - as a primary producers (organisms in an ecosystem that produce biomass from inorganic compounds; autotrophs) - are excellent indicators of water body status because they:

- respond to nutrients, light, toxic contaminants, metals, herbicides, turbidity, water level change, and salt;
- (2) are integrators of environmental conditions (e.g. nutrients, soil composition; ground waters).

Macroinvertebrates as biological indicators

Aquatic invertebrates, involved in bioassessment, live in the bottom parts of our waters. They are also called benthic macroinvertebrates, or benthos (benthic = bottom, macro = large, invertebrate = animal without a backbone) and are indicators of water quality because they:

- live in the water for all or most of their life;
- stay in areas suitable for their survival and their occurance is not limited by seasonal changes (macrophytes, algae);
- are easy to collect;
- differ in their tolerance to amount and types of pollution;
- are easy to identify in a laboratory;
- often live for more than one year;
- have limited mobility;
- are the best biological integrators of environmental conditions.

The role of macroinvertebrate assemblages in aquatic food web as primary consumers of producers (i.e. periphyton) and decomposers (i.e. heterotrophic bacteria and fungi), as prey for secondary and tertiary consumers (i.e. fish) make this group of organisms important for the holistic assessment of streams: the community's total integrity of the system, and multiple-stress indication (all stressor types and its intensity: chemical contaminations, organic pollution, acidification, morphological and biotic degradation).

The utility of macroinvertebrates assemblage structure for describing the integrity of aquatic ecosystems and diagnosis of the anthropogenic stress

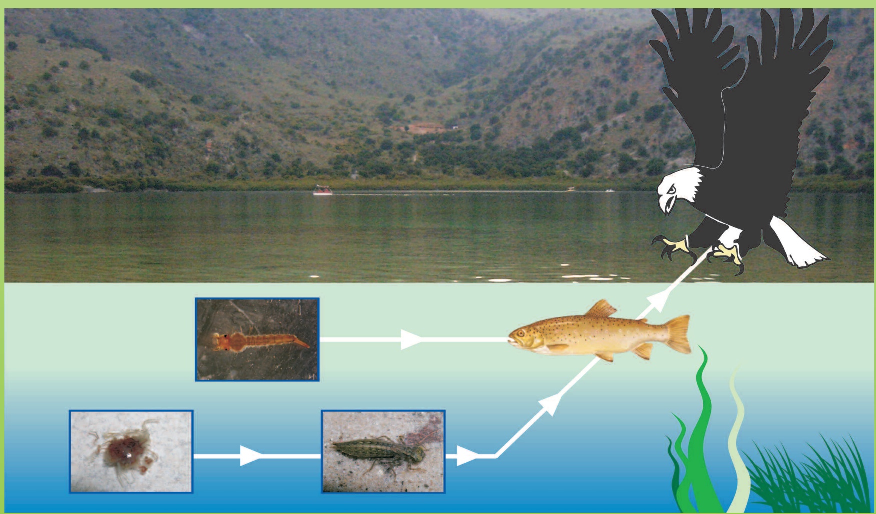


Fig. 9. The role of macroinvertebrates in the aquatic food chain, showing structural and functional importance of this group in the aquatic system (marked by yellow frames).

has been widely recognized. More than one hundred different bioassessment methods exist in Europe, two thirds of which are based on macroinvertebrates (e.g. Rosenberg and Resh 1993, Verdonschot 1990, 2000).

Fish as biological indicators

Fish are excellent indicators of watershed health because they:

- live in the water all of their life;
- differ in their tolerance to amount and types of pollution;
- are easy to collect with the right equipment; live for several years;
- are easy to identify in the field.

Generally, fish are very good bioindicators of river assessment at basin-scale, particularly morphological properties of river systems (habitat structure, refugia), and also very good bioindicators for marine and costal monitoring system. Hydrochemical conditions are secondary/additional determinants of their distribution in river systems - therefore this group of biota is mainly used to ecotoxicological studies. In conclusion, the ecological integrity approach, directly corresponding to WFD philosophy (2000), and the investigations of potential human impact at all levels of biological organization and different geographic scales are of importance to assess the ecological risk and any potential restoration undertakings/tasks (e.g., Lanz & Scheuer, 2001).

BOX III. WHY IS MAINTAINING BIODIVERSITY SO IMPORTANT?

Biodiversity is the variety of all living things. All organisms rely on other life forms for their existence. Organisms that use oxygen for respiration rely on plants for oxygen production. Their food comes from plants, animals and fungi. Any change in the numbers of one species will affect other species, and ecosystem functioning.

The term biodiversity is also often used to describe the diversity of organisms within a particular area. The 'local' biodiversity is of concern when human activity encroaches on habitats. This often pushes one or more species out of the area, and in some cases, it may also cause local or the complete extinction of a species.

Worldwide, more than 10,000 species become extinct every year and while precise calculation is difficult, it is certain that this rate has increased alarmingly in recent years. The central cause of species extinction is the destruction of natural habitats by human beings.

Biodiversity is priceless.

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Supporting references

Other thematic pieces of literature are available at following web sources:

Water Framework Directive

- The EU Water Framework Directive - integrated river basin management for Europe: http://ec.europa.eu/environment/water/water-framework/index_en.html
- Implementation of the EU-WFD: http://ec.europa.eu/environment/water/water-framework/implementation.html
- Common Implementation Strategy for the Water Framework Directive: http://www.eeb.org/activities/water/Common%20EU%20Strategy%20for%20WFD%20Implementation.pdf
- WFD page at EMWIS website: http://www.emwis.org/WFD/WFD.htm
- Environmental Agency - the WFD: http://www.environmentagency.gov.uk/aboutus/512398/289428/655695/
- CIRCA Forum Implementing the WFD: http://forum.europa.eu.int/Public/irc/env/wfd/home
- Join Research Centre - Institute for Environment and Sustainability http://www.jrc.cec.eu.int/default.asp@sidsz=our_organisation&sidstsz=ies.htm

Freshwater Protection and Sustainable Management

- European Rivers Network: http://www.rivernet.org/
- WaterWeb: http://www.waterweb.org/resources.php
- Freshwater Life: http://freshwaterlife.info/index.jsp
- WWF - Freshwater Work: http://www.panda.org/about_wwf/what_we_do/freshwater/index.cfm
- Euro-Mediterranean Information System on the Know-how in the Water Sector - EMWIS: http://www.emwis.org/
- US Environmental Protection Agency - http://www.epa.gov/
- International Year of Freshwater 2003: http://www.wateryear2003.org/en/ev.php-URL_ID=1456&URL_DO=DO_TOPIC&URL_SECTION=201.html;
- European Environmantal Bureau Hanbook: http://www.eeb.org/publication/chapter-4_5.pdf

Freshwater Protection, Biological Indicators and Biomonitoring in Education

- CEH's School Net - is the educational section of CEH Web, and is intended to be used as a resource by teachers of primary and GCSE-aged school children: http://schools.ceh.ac.uk/
- EEK! Environmental Education for Kids: http://www.dnr.state.wi.us/org/caer/ce/eek/teacher/index.htm
- Educational Materials: http://www.ucar.edu/learn/1_1_2_1t.htm
- Stream Biomonitoring Unit - Key to Aquatic Macroinvertebrates: http://www.dec.state.ny.us/website/dow/stream/index.htm
- Digital Key to Aquatic Insects - North Dacota: http://www.xerces.org/CD-ROM%20for%20web/id/index.htm
- Freshwater Macroinvertebrates - Oregon http://www.nwnature.net/macros/
- EPA - Biological Indicators of Watershed Health: http://www.epa.gov/bioindicators/html/invertebrate.html
- Stream Biomonitoring http://www.yni.org/yi/monitoring/stream_biomonitoring.html
- ACD Technical Assistance - Stream Monitoring http://www.anokaswcd.org/tech_assist/monitoring/biomonitoring.htm
- Drinking Water and Groundwater Kids Stuff http://www.epa.gov/safewater/kids/kids_9-12.html
- NSW Water Bug Survey - Bugasaurus Explorus!: http://www.bugsurvey.nsw.gov.au/

CHAPTER 5

DISTURBANCES

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1. Disturbances

Disturbance is regarded as an event of intense environmental stress occurring over a relatively short period of time and causing large changes in the affected ecosystem. Disturbance can result from natural causes (natural disturbance) such as fires, floods, droughts, volcanic eruptions, hurricanes, tornadoes, soil erosion, earthquakes and over geological time, glacial advance and retreat. It can also result from human activities (man made or anthropogenic disturbance) which include logging, deforestation and drainage of wetlands, clearing for cultivation, elevated water withdrawals for irrigation, water pollution or the introduction of foreign species, sometimes referred to as alien or invasive species.
Disturbance can occur over varying time scales. The most extensive disturbances involve landscape scale events, such as glaciations, which can affect entire continents. Some disturbances, however, are much more local in their effects for example flooding and landslides.

Whenever an ecosystem is affected by a substantial disturbance event, individuals and even entire species may be weakened or killed. Other ecological damage may occur, such as changes to a water course and hydrologic processes or soil contamination. However, once the actual disturbance event has finished, a process known as succession begins, which may eventually produce a similar ecosystem to the one that existed prior to the disturbance. Biological diversity depends on natural disturbance. Usually the success of a wide range of species, from all taxonomic groups, is closely tied to natural disturbance events such as fire, flooding and windstorm.

2. Natural disturbances

Unpredictable (episodic or sudden) droughts and floods are the most common natural disturbances for freshwater ecosystems. Droughts are caused by insufficient rain fall, precipitation, over an extended period of time and should be considered relative to some long-term average condition of balance between precipitation and evapotranspiration (evaporation + transpiration) in a particular area. Other climatic factors such as high temperature, high wind and low relative humidity are often associated with drought. With the onset of a drought there is a sequential decline in precipitation, run off, superficial stream flow, soil moisture and groundwater levels. In severe droughts whole sections of streams may loose any trace of surface water (Fig. 1). Streams and rivers loose their connection with each other and the ground water flow. Stream channels may become fragmented to a series of pools which can be either permanent and keep water during the whole drought period, or temporary and dry up. With reduced flow from inflowing rivers, estuaries can become disconnected from the sea and form lagoons, with low water quality which can deplete populations of estuarine organisms.

Sudden droughts are unpredictable in timing and duration and thus are more difficult for organisms to deal with. Organisms tend to be killed by these extreme events rather than being able to adapt to them over time, evolving coping strategies. Aquatic communities are characterised by adaptations to their watery environments. Since droughts are followed by falling water levels, the amount of habitats available for most aquatic species, are reduced. High densities of freshwater animals can be trapped in pools where factors such as high water temperatures, low oxygen and low availability of food, can be lethal for them.

Nowadays human action such as extended withdrawal of water together with climatic change, have resulted in long term droughts, which are common events in several places on earth today. Occasional or episodic floods also cause severe changes in the freshwater animal communities. A flood is a high flow or overflow of water from a stream, river or similar body of water. Flash or episodic floods are quick-rising floods that usually occur as the result of heavy rains over a short period of time, few hours or less. Several factors contribute to flooding. The two key elements are rainfall intensity and duration. Intensity is the rate of rainfall and duration as in how long the rain continued. Topography, soil conditions and ground cover, play an important role in predicting where flooding may occur. Floods can be devastating for aquatic communities as was seen when two streams in Spain, La Rambla del Moro stream, belonging to Segura river, and Matarranya stream, belonging to the Ebro river catchment, flooded. In each case the population of aquatic macroinvertebrates was reduced by 97 -99 % and the number of taxa, plant and animal groups, was reduced to 32-40% of what had been present before.

Human action has worsened the consequences of excessive rainfall. Urbanisation, tarmac and paved sur-

Fig. 1. Dry channel of Bramianos stream and of Koronia lake.
Photos by C. Voreadou, R. Jaskula

faces along with general building sprawl, is one of the main aggravating factors of present day flooding. Many homes have been built on flood plains and rain no longer has access to the soil and can not sink into ground water. Town and country planning regulations, and the urgent need for more homes, has often leaded to the use of flood plains for construction. Forty years ago such sites would never have been used and many countries have experienced dramatic flooding in such developments in recent years. Deforestation, clearing land for cultivation and fires, have also worsened the consequences of excessive rainfall. Over the coming years we may see more erratic weather patterns and more flooding as the effects of climate change become known (Fig. 2).

Fig. 2. Flooding after fire in summer 2006, Halkidiki, Greece.

BOX I. THE MEDITERRANEAN AREA

In the area around the Mediterranean Sea, there are periodic seasonal droughts and floods (Fig. 3). Most of the streams there are also seasonal (see also chapter 3) with a drought period during summer time and flood period during autumn, winter or spring. These seasonal droughts and floods are not counted as disturbances because freshwater animals and plants can survive either phases due to physiological, morphological, behavioral or life-cycle adaptations. These cyclical droughts and floods are very important for Mediterranean streams. Just as in the case of permanent streams which can suffer the sudden episodic drought, some members of a seasonal stream fauna may be killed if stream fails to go dry one year or if the duration or sequence of the dry period is somehow altered substantially.

Fig. 3. Seasonal drought (with accumulation of leaf litter) and flood in a Mediterranean stream, Crete, Greece.

3. Man made disturbances

Human activities cause a large set of effects such as the "greenhouse effect", the acid rain or the disposal of different organic and toxic pollutants to the water. In parallel the elevated water withdrawals for domestic, industrial and irrigation purposes together with the construction of dams or reservoirs can cause severe disturbances to freshwater ecosystems.

Fresh waters naturally contain chemicals dissolved from the soils and rocks over which they flow. The major inorganic elements include calcium, magnesium, sodium, potassium, carbon, chlorine, and sulphur as well as plant nutrients, such as nitrogen, silicon, and phosphorus. Organic compounds derived from decaying biological materials may also be present. Chemicals resulting from human activities that increase the concentration of specific compounds above natural levels may cause water pollution problems and are called pollutants. Pollutants can be taken up by plants and animals through contact with contaminated sediments, or directly from the water.

Modern agriculture depends on chemical fertilizers, pesticides, and irrigation to produce high-quality crops for animal and human consumption. To maximize the crop yield, nitrogen-based fertilizers are spread on the land. In addition, phosphorus and other essential minerals also may be applied where they are lacking or have been depleted in the soil. To improve production, herbicides (to kill weeds) and insecticides (to kill insects) are frequently applied to crop lands. Not all of the fertilizers and pesticides stay where

Fig. 4. Eutrofication in lake Kournas, Crete, Greece.

Fig. 5. Eutrofication in Aposelemis intermittent stream, Crete, Greece.

they are applied; consequently, some are released to the atmosphere, seep into groundwater, or are carried to lakes and streams as runoff, causing pollution problems. Pesticides, herbicides, and insecticides can cause toxicity, while fertilizers, which contain large amounts of nutrients (nitrogen and phosphorus) compounds, can result in eutrophication (Fig. 4, 5), the excessive growth of aquatic plants and algae. When these die and decay, breakdown of their bodies uses all the oxygen dissolved in the water, reducing the amount of oxygen available to fish and other aquatic life.

Industry is mainly responsible for the build-up of carbon dioxide and other gases in the atmosphere which is known as the "greenhouse effect" and which results in climatic change (Fig. 6). The accumulation of these gases is believed to have altered the earth's protective cover, resulting in more of the sun's heat being absorbed and trapped inside the earth's atmosphere, producing global warming. The higher temperatures and other factors, such as melting polar ice, will raise sea level. The sea is a tremendously important resource for us and some of the world's largest cities are on the coast. A change in sea level will affect these cities and coastal ecosystems like river deltas, wetlands, swamps, and low-lying forests, which play an important role in providing services for mankind, in addition to housing biological diversity.

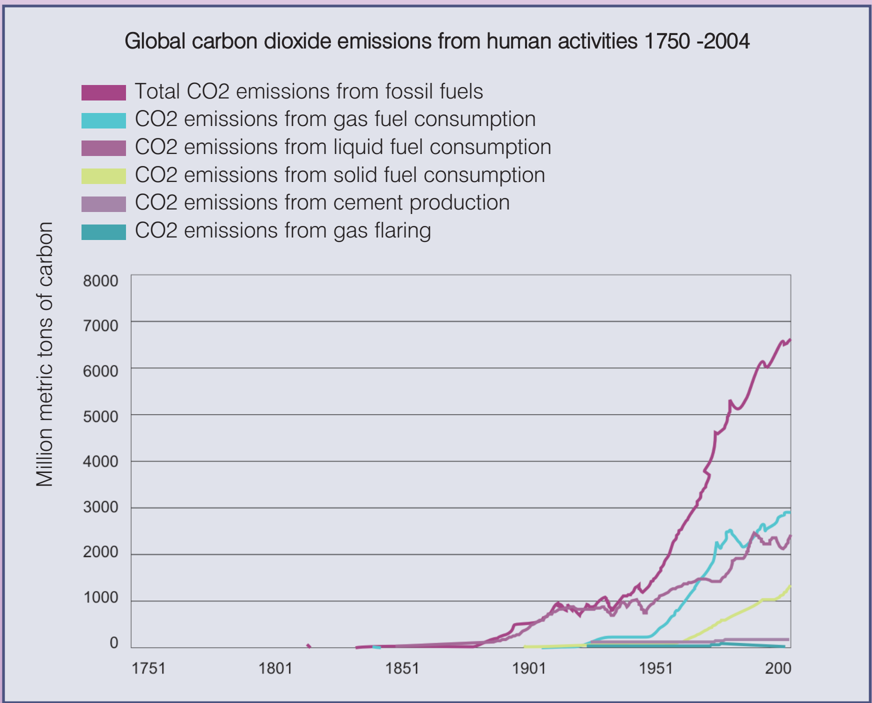

Fig. 6. Global CO_2 emissions from human activities from 1750 till 2004.

Water pollution covers a large set of adverse effects upon water bodies such as lakes, rivers, oceans, and groundwater caused by human activities. Water pollution has many causes and characteristics. Sewage disposal causes also pollution problems to freshwater bodies since it also contains nutrients and toxic elements.

Industries discharge a variety of pollutants in their waste water including heavy metals, organic toxins, oils, nutrients and solids, resulting in water toxicity. Industry is also mainly responsible for acid rain or more accurately acid precipitation which is commonly used to mean the deposition of acidic components in rain, snow, dew, or dry particles. Acid rain occurs when sulphur dioxide and nitrogen oxides are emitted into the atmosphere, undergo chemical transformations, and are absorbed by water droplets in clouds. The droplets then fall to earth as rain, snow, mist, dry dust, hail, or sleet. This increases the acidity of the soil, and affects the chemical balance of lakes and streams. Acid rain causes a cascade of effects that harm, reduce or kill individual species and populations.

Another big issue for freshwater ecosystems are the elevated water withdrawals by humans for commercial, domestic, industrial and irrigation purposes. Irrigation is the largest category of water use worldwide. The excessive demand for water fuels the need to build dams, dig wells, and make withdrawals from our natural water bodies. New technologies in the industrial sector that require less water, improved, more efficient, industrials processes, increased water recycling, higher energy prices, and changes in laws and regulations, will all result in decreased water use. The enhanced awareness, by the general public, of water resources and active conservation programs in many countries both contributed to reduced water demands.

BOX II. POLLUTION AND MEDITERRANEAN AREA

The area around Mediterranean Sea is quite dry and rainfall over much of the land is highly variable, with extended drought periods during summertime. Surface fresh water bodies which are quite scarce, have a limited volume and quite often a temporal flow. Both surface and groundwater, although in many cases directly interlinked, have been severely degraded by human use. Pollutants from agricultural (Fig. 7), urban and industrial sources such as nutrients, chemicals, fertilizers and pesticides, have altered ecosystems' balance and have resulted in algal blooms with toxic effects and acute or chronic toxicity. Unfortunately, pollutants are not diluted in the Mediterranean area, as rainfall is minimal, so they have a more pronounced effect on fresh water ecosystem than would be the case in countries with more rain fall. For these reasons an intergraded management plan in accordance with the initiatives of the Water Framework Directive 60/2000 is essential for the Mediterranean.

Fig. 7. Olive oil mill wastes in a Mediterranean stream, Crete, Greece.

CHAPTER 6

PROTECTION AND SUSTAINABILITY OF FRESHWATER ECOSYSTEMS

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Fig. 1. Campanula pelviformis, an endemic species in Crete, growing close to rivers.

Freshwater ecosystems are the most endangered of all ecosystems. They are very rich in habitats and species and include many endemic species, especially in river systems, which, in geological terms, and unlike most lakes, are ancient habitats. Many species are endemic to specific wetlands or to a region, and many are rare and threatened (Fig. 1,2). Freshwater ecosystems have lost more of their biodiversity, than ecosystems on land or in the oceans and are, moreover, in greater danger of further losses.

The vulnerability of freshwater ecosystems comes from the fact that they depend on fresh water and fresh water, in many areas, like the Mediterranean, is becoming a scarcer Artificial drainage, the excessive extraction of groundwater, the construction of dams, are only a few of the threats.

Fig. 2. Pelophylax cretensis, endemic to Crete.

BOX I. BRINE SHRIMP AND FLAMINGOS

Plants and animals that inhabit wetlands are often dependent on a particular water regime. The Brine shrimp (Artemia salina), for example, needs water with low salinity at the beginning of the winter season, low enough to ensure that its cysts (eggs) hatch, so that should they hatch, the young ones will have a chance to grow into adults and produce cysts themselves (Fig. 3). If the Brine shrimp cysts do not hatch it means that the flamingos, which normally feed on the brine shrimp, will have no food and they will need to move on elsewhere - if they can. So if sufficient freshwater does not reach the salt lakes, the flamingos will have no food.

Fig. 3. Brine shrimp cysts (eggs) on the shores on Larnaca Salt Lake. When they hatch they provide food for the flamingos and other birds.

BOX II. EUTROFICATION

Fertilizers, running off the catchment basins to the lowest points - the rivers and lakes. Fertilizers can cause enrichment of water bodies, enhance the excessive growth of algae and cause eutrophication (Fig. 4), which can result in oxygen depletion, anoxic conditions and, eventually, habitat and biodiversity losses.

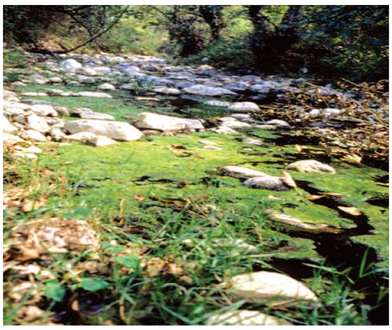

Fig. 4. Excessive growth of algae in a stream, Crete, Greece.

BOX III. INVASION OF ALIEN SPECIES

The Nile perch is a large freshwater fish, which can grow up to 200 kg and two metres in length. It was introduced to Lake Victoria in 1954 where it has contributed to the extinction of more than 200 endemic fish species through predation and competition for food. Procambarus clarkii is another alien species which has invaded many water bodies in Cyprus (Fig. 5).

Fig. 5. Procambarus clarkii.

BOX IV. PROTECTION

Ramsar Convention recognizes wetlands as ecosystems that are extremely important for biodiversity conservation in general and for the well-being of human communities. The Convention was adopted in 1971 in the Iranian city of Ramsar and entered into force in 1975. As of 1 May 2003 it had 136 Contracting Parties. More than 1280 wetlands have been designated for inclusion in the List of Wetlands of International Importance, covering some 108.7 million hectares (1.87 million km2), more than the surface area of France, Germany, and Switzerland combined.

The MedWet Initiative operates under the Ramsar Convention, and is a long term, collaborative effort towards the conservation and wise use of Mediterranean wetlands.

Two Ramsar sites have been declared in Cyprus: The Larnaca Salt Lake (Fig. 6) and the Akrotiri (Limassol) Salt Lake. Both are seasonal lakes which usually host thousands of flamingos as well as other waterfowl.

Fig. 6. Larnaca Salt Lake was the first Ramsar site in Cyprus.

Environment in danger! - what can we do?

Be a journalist! Do your own survey!

Your freshwater environment is in danger. What can your classroom do then?

Schedule your actions step by step!

For ideas make your own journalistic survey. Search the last year newspaper or magazine articles. Surf in the Internet. Ask the scientists. Select the ideas you find more interesting and try to fit them in your environment. Make your own proposals to the local authorities.

Just think that you can do a lot. And remember! Adults will listen carefully to your ideas!

CHAPTER 7

THE GUARDIANS OF WATER

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There are too many issues non clarified regarding the quantity and the quality of the available water, as well as questionable individual and collective behaviours in its management. Since environmental education is quite conscientious of the problems and is an active way for changes, we propose a methodology based on the conflict between the "enemy" and the "guardian" of the water, characters that we all assume in our single and collective daily behaviours, resulting from this conflict.

We are aware of the fact that we don't have the power to simultaneously solve problems assigned to the water management. But we can give a first fundamental step to identify some of these problems and sensitize our community for them. Our objective is to identify obvious situations, easy to characterize, to quantify and to transmit.

Let's create a team of guardians to fight the enemies of the water. These enemies are caricatures of the different problems. They are:

- Walter Flush, for domestic water consumption;
- Joe Philpot, for public water consumption
- General Nitrate, for the contamination of the aquifers
- Urban Kaos Architect, for superficial flowage and non recharge of the aquifer
- Mr Globus Eucalyptus, for the bad wood management
- Miss Bulldozer Overuse, for the bad use of the machinery
- Dr. Smelly Swine, for the contamination of superficial waters

We believe that through artistic expressions is possible to reach serious problems without causing resentment to any of the society sectors involved in the problematic. The "Guardians of the Water" offer their services to all the institutions in order that, together, they can beat the enemy.

Concerning the contents, the Guardians want to promote a reflexion that would led each of us to the origin of the water problems, that is to say, to be aware of environmental issues inherent to our model of society. The Guardians can contribute for the creation and development of values, attitudes and auto - limitation behaviours.

Those are some of the concerns of the guardians of the water:

- The water consumption in schools and private houses
- The water wasting in sprinkling green public areas
- The use of plants with big needs of water in the Mediterranean
- The exaggerate consumption of products that use in their production an huge amount of water
- The focus of our society in the efforts of recycling instead of doing the same for the reducing

Fig. 1. Walter Flush, cartoon, by the students of the EB2,3 Ibne Ammar Intermediate school, Lagoa, 2004.

The Enemies of the Water

The orientation line approches the conflict between the "enemies of the water" (characters below designed as caricatures of specific problems of water management and use) and "the guardians of the water" (to be created for each of the enemies, capable of realize and implement specific measures to fight them).

Our town has been invaded by a group of enemies of the water who want to make it disappear completely. The only way to fight them is through little gestures that we can do in our daily life, such as turning the tap off while brushing the teeth and this would be to fight Walter Flush or not to let Joe Philpot wet the asphalt instead of watering plants in public places. If we act all together as "guardians of the water" we will manage to save it.

Walter Flush

Implacable gangster (Fig. 1) who wastes an enormous quantity of water by flushing it down the toilet. He leads to families' ruin, due to the payment of very expensive bills. While people brush their teeth he turns on the taps, fills the bathtubs with water and starts the washing machines without them being totally full.

Joe Philpot

Terrorist responsible for huge public waste of water: during the night he waters the gardens and washes himself in the puddles (Fig. 2).
He turns the sprinklers to the road, where the water forms large puddles. He also waters the gardens when it is hotter and when it rains. He moves within the municipal water network, damaging it and giving rise to great loss of the water for private consumers' expenditure. As he moves very quickly, he can act at the same time in several places.

Fig. 2. Joe Philpot, cartoon, by the students of the EB Elementary School of Castro Marim, 2003.

Fig. 3. General Nitrate, cartoon by the students of the Secondary School, Dra Laura Ayres, Quarteira, 2002.

General Nitrate

Very dangerous mercenary (Fig. 3) paid by agro industry to destroy the underground water and to poison the population. He strikes in a more violent way in some areas of intensive agriculture.

Miss Bulldozer Overuse

Japanese "She-Rambo" (Fig. 4) who, without the foresters taking any notice, enters the river basin and destroys important riverain. She also destroys Mediterranean maquis of our mountain hills. In spite of her destruction she likes referring to her job as "CLEANING".

Fig. 4. Miss Bulldozer Overuse, cartoon by the students of the Secondary School Dra Laura Ayres, Quarteira, 2002.

Urban Kaos architect

Dissident architect who works for a powerful multinational (Fig. 5). He spreads uninterruptedly an endless layer of concrete all over the territory. He calls his "raids" of "DEVELOPMENT".

Fig. 5. Urban Kaos Architect, graffiti by the students of the Intermediate School EB2, 3 de Vila do Bispo, 2004.

Mr Globus Eucalyptus

Criminal vegetable who comes from Australia, green blood, internationally known for its voracious thirst, he's been sucking up all the water from the best springs of our land (Fig. 6).

Dr Smelly Swine

Famous terrorist, who, during the dark rainy nights, opens criminally without the owner's knowledge, the gates of the piggery's tank effluents, allowing its waste content to contaminate the brooks (Fig. 7). Some places have been frequently attacked by him. He's an expert in camouflage and it is thought that his hiding place is somewhere in the middle of the arbutus tree woods of the south of Europe.

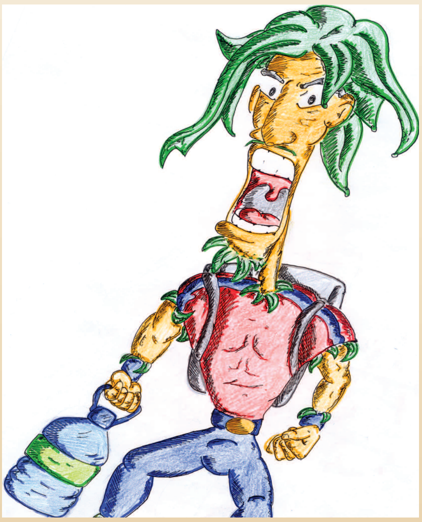

Fig. 6. Mr Globus eucalyptus, cartoon by the students of the Secondary School Dra Laura Ayres, Quarteira, 2002.

Fig. 7. Dr Smelly Swine, cartoon by the students of the Secondary School Dra Laura Ayres, Quarteira, 2002.

How to be a Guardian?

The methodology concerning the following activities puts into practice a sequence of drama group techniques about the topic of domestic water management which can be applied to specific behaviours.

Some of those activities, by their nature, imply that amongst the entire participants one assumes the role of coordinator or several of them can form a jury.

The subject for the session should be the first decision. For the present example we will choose one of the problems we mentioned above: the private water consumption.

Stage 1: sensitization

Distributed in groups of five, enumerate trough a rain of ideas the highest possible number of daily behaviours that at home can help us fighting against potable water waste. Start by the verb, for instance: to fix tap that leak or to turn off the tap while you soap your hands. The time for the game is five minutes.

A jury is formed to receive the written results of each group and analyses the behaviours. The group that gathers the highest number of behaviours considered correct wins.

Alice in the Water land

All participants form a circle and each one introduce himself / herself using a composition in rhyme using is name and a word related with water like "Alice in the Water land". When he/she says his/her rhyme, he/she should step forward and gesture, then should step backwards and take his/her place in the circle. Afterwards all participants should imitate him/her. The exercise can be repeated just with choreographic movements and music.

The chairs game

In the centre of the room you put less number of chairs than the number of participants. The coordinator asks everyone to walk around the chairs using the body to express his proposals, e.g., walk as if you were rain drops touching dry land. When the coordinator claps, it means "sit down". Participant(s) that didn't manage to sit on a chair will not play again, and this will be repeated successively until two chairs remain in the room and thus you decide who the winner is. Suggestions for the "walk" between the chairs: Persons could be:

- water drops falling down rapidly from a not properly turned off tap
- showering and while soaping themselves the tap is turned off
- water drops being evaporated at noon
- water drops "travelling" through conducts that unify a dam to the tap of the science lab of the school
- high pressured water drops sprayed from a break in a distribution conduct

Stage 2: create characters

Brain storming

Each participant, individually, selects one of the behaviours referred by the group in the first exercise and records it in a piece of paper, for instance, to fix taps that leak.

Afterwards he/she writes down the first ideas that come to his/her mind about a character that is obsessed by that behaviour or by an opposite one, for instance, by the idea of fixing taps that leak or by placing leaking taps, according to the next list:

name, nickname, age, religion, physical and psychic characteristics, why is the character worldwide known, which was the childhood trauma that has determined his / her "obsession", the name of his / her worst enemy, where he/she is now and doing what.

There is no problem if some of the participants cannot answer all the parameters: the goal of this technique is to originate ideas to build up a character and his/her enemy. Ideas originate others, they're all good and the more different they are, the better. The first character to be created, the "enemy" or the "guardian", the "good" or the "bad",

is determined by its author that introduces him / her to the class. The second character can be deeply characterized when the story is being brought up. Making up a character can be done through analogy: to select a famous duo hero / villain, to characterize it according to the parameters mentioned above, and at the same time, to create a strong and coherent new duo related to the message you want to work on.
When everybody is done, each participant introduces his/her character.

For instance, Walter Flush is a big and fat flusher who has fun flushing water down, therefore he spends his whole day pushing his own button... He feels very proud to know that he is responsible for the biggest waste of potable water in the house! He is the only one to face Captain One Litre and a Half that with his bottle shaped body throws himself inside Walter Flush to make him save one and a half litre in every flushing down.

creative language games

To find creative names for the characters:

In a rain of ideas write down words that are related to the place associated to the image to be transmitted. For instance, if it's about "fixing leaking taps" one has to do a rain of ideas with places where there are taps, such as the bathroom. E.G: wash basin, bidet, water flush, brush, shampoo, shower, soap, light, toilet brush, towel, and so on.

Then a selection and association of the words could be done, e.g. Miss Little Tap; it is also possible to divide them and put different parts together, e.g. Don Show Shower.

Stage 3: create products of artistic expression with a message

Participants are organized into groups according to the topic affinities of their characters. In each group there is:
1. a clear and determined message; 2. characters; 3. conflict; 4. space/time;5. script; 6. means of expression.

Example:

1. clear and determined message: to reduce the waste of water by putting a bottle of one litre and a half inside the flushing.

2. characters: Captain One Litre and a Half (Fig. 8) and Walter Flush

3. the conflict: Captain One Litre and a Half with his bottle shaped body throws himself inside Walter Flush, forcing him to save one litre and a half in each discharge of water (Fig. 9)

4 . space and time: in our own house

5. the script: action sequence, from the time that Captain One Litre and a Half arrives home, goes to the bathroom and manages to open the upper cover of the Walter Flush without him noticing it...

6. means of expression: radio, theatre and cartoon

To tell a tale in group

After the definition of the above mentioned parameters each group has a story to tell collectively. The different parts of the tale are attributed to each participant and they tell it in group, forming a circle, randomly distributed between the presents in the session.

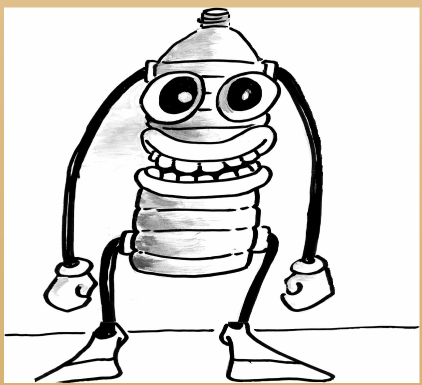

Fig. 8. Captain One Litre and a Half, School EB2,3 de Vila do Bispo, 2002.

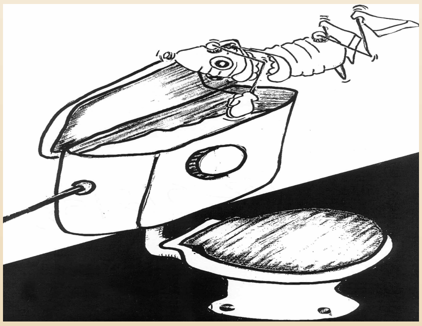

Fig. 9. Captain One Litre and a Half with his bottle shaped body throws himself inside Walter Flush, forcing him to save one litre and a half in each discharge of water, School EB2,3 de Vila do Bispo, 2002.

Stage 4: suggestion for intervention/ public presentation and respective evaluation.

The group defines behaviours for each of the elements and the way it will be disseminated to obtain results.

In this example, the participants commit themselves to put a bottle of water in their flushing and to create a leaflet and mail it to all the houses of their town. In this leaflet is suggested the use of the bottle and subsequent record of the number of discharges of water during one week. It is requested that the filled in leaflet would be sent to the school for a calculation of the volume of saved water.

Stages 5 and 6: presentation/ work discussion/ conclusion

The work is presented, discussed and selected according to a strategy of local intervention defined by the group. For instance, a session of tales is presented to the community, where the created tales and their results obtained from concrete actions regarding the savings of the water are presented.

Conclusion

The mentioned methodology helps, firstly, to raise the awareness, that means, to the self discovery of the reference boards of the participants before a determined environmental topic.

Secondly, there is the discussion of what path to follow and suggest it to ourselves and the others as a way of changing. That is the message being handled creatively and the artistic product that comes out is presented to the community.

Finally, the evaluation is done and the results disseminated.

When the participant presents an artistic project, he / she feels as being part of the group getting an identity, a place, a value. By performing and suggesting an action towards sustainability, the group becomes a social intervener.