Part 1

Key Concepts on Biosphere Reserves and Designated Areas: their Special Characteristics, their Role and Value


Chapter 1

Ecological principles and function of natural ecosystems

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1.1 Introduction – Fundamental concepts

The term **ecology** was first used by Ernst Haeckel in 1869. It comes from the Greek words "οίκος" (oikos = house, home or, better, household) and "λόγος" (logos = knowledge) and refers to the science which deals with (speaks about) the function of 'home'. Other contemporary definitions of ecology describe it as the science of the relations of organisms with their natural environment. According to Howell & Bourliere (1964), ecology is the economy and sociology of nature, or put simply, it is the science which studies the function of living things in nature as an integral part of the whole: the ecosystem.

The definition of **ecosystem** was first articulated in 1935 by Tansley, who underlined that the word means not only the organisms which live in a certain area (biocommunity), but the sum of the inorganic natural factors which affect their survival and which compose the environment they live in (biotope). A few years later (1942) Lindemann restricted the term: ecosystem as "*a system comprising of physical- chemical- biological functions which act in a unit of space- time of whatever size*". Lindemann's definition does not address the limits or the size of the ecosystem. Instead, it introduces the combination of space and time. Indeed, most ecosystems are not marked by strict boundaries, but most often merge into each other through their biotic elements. For example, a migrating bird can belong to several, different ecosystems.

Although an ecosystem represents a real, non-fictional area in space, it cannot be pinpointed with accuracy i.e. on a map, because in reality it is but a concept that allows us to divide space into sections, which can be identified, with relative accuracy, by their individual conditions and characteristics.

Much later, Muller (1997) put forth that the ecosystem is the basic unit of study in the science of Ecology, while, according to Ulanowicz (2003), an ecosystem is considered to be the *"dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit."*

All ecosystems consist of **abiotic** and **biotic** elements: The term abiotic (non-living) refers to the physical and chemical characteristics or components of an ecosystem, such as sunlight, temperature, water, soil, and nutrients, etc., while he term biotic refers to its living organisms, such as plants, animals, fungi, bacteria, etc. **Population** refers to a group of organisms of the same species that live in an ecosystem and interbreed (e.g. deer population); while **species** is often defined as a group of individual organisms capable of interbreeding to produce fertile offspring. Populations are dynamic groups: the assemblage and interactions of different populations in an ecosystem comprise a **(bio)community.** The prescribed area of uniform environmental conditions in which a population or a community lives is called a **biotope.**

1. Rosemary and thyme in flower, *Luberon* massif, Provence, France
© Hélène Gille

1.2 Organisation and characteristics of ecosystems

Trophic relationships - Flow of energy and matter

There are various ways to study an ecosystem. One way is to examine the trophic (food) chain relationships within it. An ecosystem consists of producers and consumers: **Producers** or autotroph organisms (self-feeders) synthesize organic matter (mainly hydrocarbons or sugars, but also amino acids and proteins) from inorganic chemicals (CO_2, H_2O, nutrient elements) through a process called photosynthesis, wherein they capture a small proportion of the sunlight that penetrates into the ecosystem.

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2. Mediterranean ground cover with woodlands and shrubs, *Cuenta Alta del Río Manzanares BR*, Spain
©Thomas Schaaf

3. Purple loosestrife (*Lythrum salicaria*), *Lake Pamvotida*, Greece
©MB of Lake Pamvotida

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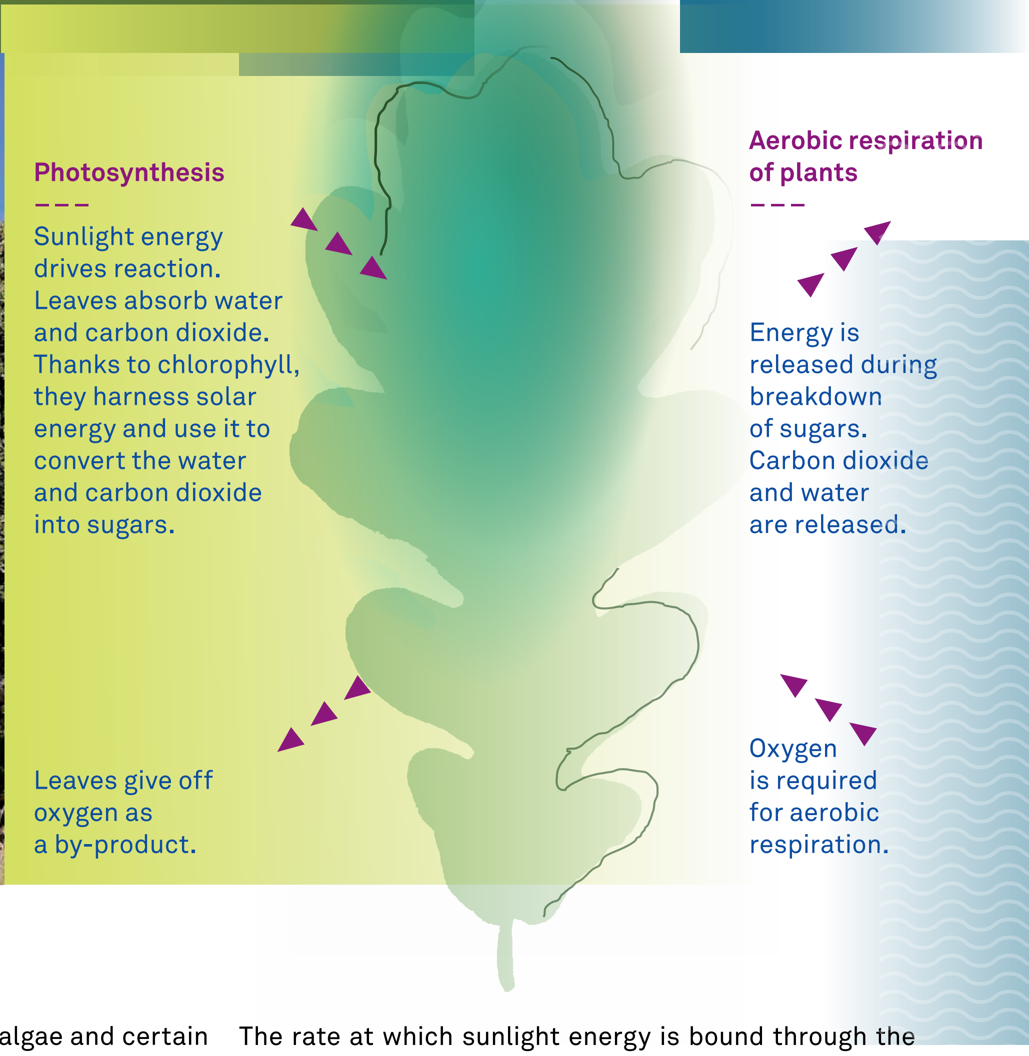
Typical Mediterranean woodland ecosystem

4. Holm oaks (*Quercus ilex*),
Trevélez region, Sierra Nevada BR, Spain



Photosynthesis takes place in plants, algae and certain types of bacteria. Energy from the sun is trapped inside the tissues of organisms, it is converted to chemical energy and stored as organic molecules, which are used to support the organism's metabolism and reproduction and to build new tissue, giving rise to the beginning of the food chain. Simultaneously, atmospheric carbon dioxide (CO_2) is captured and oxygen (O_2), a vital element to the evolution of all biochemical and chemical functions in living organisms, is released as a waste product. The process takes place in the chloroplasts, specifically using chlorophyll, the green pigment involved in photosynthesis. Photosynthesis occurs in two stages: in the first stage, light-dependent reactions or light reactions capture the energy of light and use it to make the energy-storage molecules ATP and NADPH. During the second stage, the light-independent reactions use these products to capture and reduce carbon dioxide.

In addition to photosynthesis, some production is conducted by **chemoautotrophic** bacteria, autotrophs that use energy stored in the chemical bonds of inorganic molecules, such as hydrogen sulfide, to produce organic molecules. This process also occurs in some Protista (one-celled living organism) Cyanobacteria and seaweeds.

In order for plants to form their structures, apart from carbon, oxygen and hydrogen the basic elements of the photosynthetic process, they also need other chemical elements, such as nitrogen, phosphorous and magnesium, sometimes silicon, sulphur and iron. The majority of photosynthetic terrestrial plants draw these additional chemicals from the soil. Aquatic plants absorb diluted inorganic compounds directly from their environment.

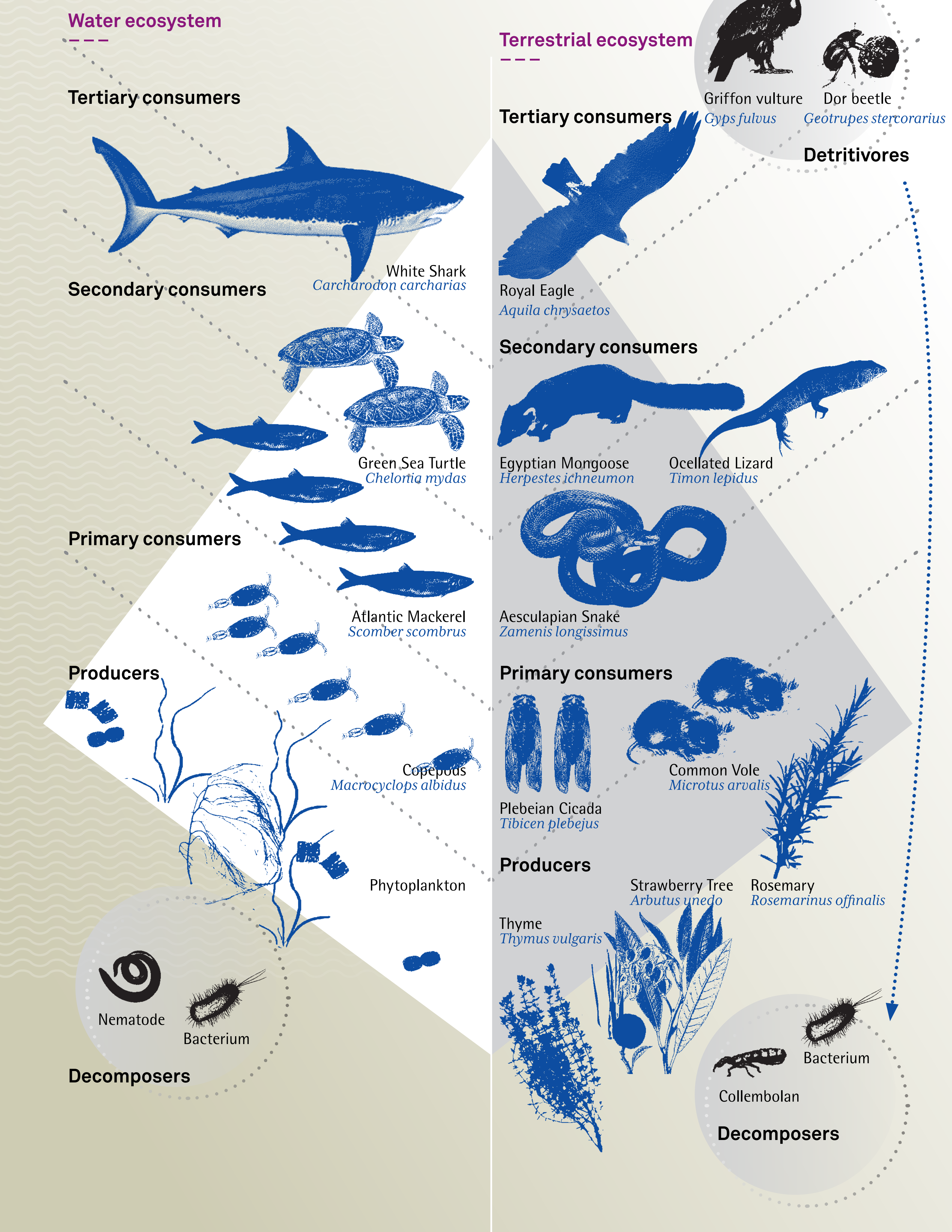
The rate at which sunlight energy is bound through the photosynthetic process and stored in the producer, is called **primary production** (estimated in kcal/sqm/day or in weight of biomass). The transformation of sunlight into chemical energy is the first step which initiates the circulation of matter and energy in the ecosystem.

Plants, as **primary producers**, form the first trophic level in most ecosystems. They are autotrophs as they get energy for all their needs and functions only from the sun through photosynthesis. In the second and tertiary level are the herbivores, omnivores, and carnivores (heterotrophs), relying on chemical energy captured in the plants of the first level. **Consumers** are divided into primary consumers (those who consume producers, herbivores) and secondary ones (omnivores who consume herbivores, and carnivores). The cycle "closes" with the detritivores (saprophytes, bacteria) which decompose dead organic matter and other metabolic products into inorganic materials.

Energy is transferred between organisms through their trophic relationships. These relationships are qualitative and quantitative. The graphic representation of these trophic relationships, i.e. the flow of energy from one organism to the next are called trophic chains (or food chains). In reality, however, these relations are not linear, as depicted by food chains, but more complex, and can be more thoroughly depicted by **food webs**, which are a set of interconnected food chains in which energy and materials circulate within an ecosystem.

An **ecological pyramid** (or **trophic pyramid**) is a graphical representation designed to show the biomass or productivity at each trophic level in a given ecosystem. **Biomass**

Figure 1
A representation of an energy pyramid with trophic levels in the Mediterranean region



pyramids show the abundance or biomass of organisms at each trophic level, while **productivity pyramids** show the production or turnover in biomass. Ecological pyramids begin with producers on the bottom and proceed through the various trophic levels, the highest of which is occupied by the secondary consumers.

In the first step the producers manage to capture 50% of the light energy and transform it into chemical energy stored in the biomass. From that step onwards, there is quite a significant loss due to the fundamental laws of thermodynamics. When energy is transferred to the next trophic level, typically only 10% of it is used to build new biomass, becoming stored energy; the rest is left unused or goes towards metabolic processes. This 10% is the **net production** of each step. This equals to the difference between the rate at which the plants in an ecosystem produce useful chemical energy (**Gross primary production**) and the rate at which they use some of that energy during respiration. The longer the food-chain, the more the trophic levels, the less the available energy in the form of biomass.

Bioaccumulation is the increase in the concentration of a chemical compound in the tissues of a biological organism over time, compared to the initial concentration of the compound in the environment. Compounds accumulate in living matter any time they are taken up and stored faster than they are broken down (metabolized) or excreted. Understanding the dynamic process of bioaccumulation is very important in protecting human beings and other organisms from the adverse effects of chemical exposure, and it has become a critical consideration in the regulation of chemicals. A clear distinction must be made between the terms bioaccumulation and **biomagnification**. **Bioaccumulation** refers to how pollutants enter and accumulate in one organism whereas biomagnification refers to the tendency of pollutants to concentrate through the food chain as they are transformed from one trophic level to the next. Both bioaccumulation and biomagnification are refered to as **bioconcentration**.

Apart from the basic mass and energy flow principles of an ecosystem, there are other fundamental laws, as well as a number of other important factors (ecological, abiotic, biotic) which are briefly described in the following section.

"Limiting" and "tolerance" factors

In order to survive and grow every organism needs certain environmental preconditions. These preconditions are not the same for all organisms but they are species and case specific.

Liebig's **law of the minimum**, that was introduced in 1840 by the German scientist, states that for every organism there is a minimum limit of necessary underlying conditions, and its growth is controlled by that environmental factor for which the organism has the narrowest range of adaptability or control. This factor is known as a limiting factor. For example, water (humidity) is a limiting factor in a desert, whereas in a lake dissolved oxygen or a nutrient could be the relevant limiting factors.

According to the **law of tolerance** of Shelford, an organism's degree of tolerance to changes in environmental parameters is not limitless. Every organism can only tolerate a certain range of changes in environmental conditions, and this varies from species to species.

Depending on whether it can tolerate small or big changes in a specific environmental parameter (temperature, humidity, salinity, and so on), an organism can be characterized as "eurytopic" (able to adapt to a wide range of environmental changes) or "stenotopic" (only able to adapt to a small range of environmental changes), accordingly. For example, organisms can be characterized as "eurythermal" when they can tolerate a broad range of temperatures and in the opposite case "stenothermal". Likewise they are considered "euryhaline" if they can tolerate a wide range of salinites or "stenohaline" if they tolerate a low salinity range.

Evolution and "succession" of ecosystems

The evolution and temporal change (succession) of ecosystems is a natural phenomenon sometimes mistaken as the result of external pressures and pollution. **Observation of ecosystems over time shows that bio-communities are not static but constantly in change as it concerns their size, structure and species composition in a manner which cannot be always predicted or predetermined.** Succession is due to changes that occur in the natural environment through the influences of the bio-communities themselves. The pace and general direction of succession are determined by the natural conditions of the biotope. All these changes tend to stabilize with the ecosystem at its maximum possible biomass. The first stages of this succession are called "primary" (precursors) and the most advanced ones, which correspond to stabilizing stages represent the "peak" or "climax". As an ecosystem evolves, it tends to increase its tolerance by acquiring a more complex structure, in order to protect itself from disruptions reaching a point where it is resilient to change and remains in a state of balance. This maintenance of stability and resistance to change and disruption can be thought of as a high degree of **homeostasis**.

Over the years environments, initially hostile to the majority of organisms, such as volcanic lava flows, river deltas, artificial lakes and sand dunes, are colonized in stages by a variety of plants and animals. Evolutionary changes which take place in areas lacking biotic factors are termed as **primary succession**.

An example of primary succession are the ecosystems that develop on volcanic lava flows. The first organisms that spread on the bare rocks are types of moss and lichens, forms of living organisms that are very resistant to sunlight, temperature fluctuations and drought.

5. Aleppo pine (*Pinus halepensis*) woodland,
Cassis region, France
© Hélène Gille

6. Trail in holm oak and pine woodland,
Aix-en-Provence region, France
© Hélène Gille

These "pioneer" species gradually break down the rock surface, forming a rudimentary soil. The "pioneer" decomposers, through biological functions catalyse favourable conditions for various other plants to follow. These new plants cover the moss and lichens, which in turn slowly disappear. The plants are gradually replaced by bushes, which are, in turn, replaced by trees, until finally a forest ecosystem is formed. The **balanced situation** characterised by a **"climax" community** is theoretically the final stage of primary succession because any ecosystem is a constantly evolving system. All these changes during the succession obviously induce changes in the structure and composition of the animal community in the area as well as in the community of decomposers. If the climate does not change substantially and there is no external interference, such as pollution, fire, or logging, subsequent changes in a natural forest ecosystem are small in terms of duration and space.

Once a balanced ecosystem is influenced by external factors, such as fire, deforestation, grazing, etc., then its primary succession comes to a halt and a new situation may be initiated, the **secondary succession**, which eventually leads the ecosystem to a new balanced situation. These disturbances form new conditions in ecosystems, and in most cases lead to the development of a new ecosystem, which may be slightly, quite, or even completely, different from the initial one. Because it occurs within an established ecosystem, the process of secondary succession is much shorter than that of primary succession.

A forest's soil functions as a "plant sperm bank" made of the seeds of the various plants that thrive in the forest. When a fire destroys the forest ecosystem the right conditions are in place for the seeds to sprout, and thus a mechanism of self regulation of the forest ecosystem is triggered so as to recover and reach a new balance. However, or serious inhibition if during this process of "natural restoration" and the crucial period of revival of the forest, other external factors affect the process, such as overgrazing or another fire, then the result will be the loss of this naturally induced balance and the degradation of the ecosystem.

Diversity and stability

Species diversity in a community is linked with the variety of the functions within it, as determined by the species themselves. Diversity is a measure of the ecosystem's capability to create mechanisms of self regulation. Higher diversity means longer and more complex trophic chains. As a first step, we could consider diversity to be the number of species within a bio-community. But we must also take account of the number of individual members of each species in our calculations. An ecosystem consisting of 100 organisms functions differently if it is made up of 4 species with populations of 25, 25, 25, 25 than if their populations are 97, 1, 1, 1 respectively. In order to have comparable measures of diversity, indexes of ecosystem diversity are used such as the Simpson or Shannon diversity appropriate index.[1]

Species diversity plays an important role in the stability of an ecosystem, i.e. its ability to return to its initial state of balance after the interference of externally induced "stress" or "disturbance". If stability is limited then a major disturbance may push the ecosystem to go beyond its tolerance range. In such case, it cannot return to its initial state of balance and as a consequence it is destroyed or degraded. High species diversity ensures increased stability because its large and complex network of energy flows provides many channels as well as safety valves for the flow of energy and matter in the ecosystem, absorbing thus the disturbance and maintaining stability.

Examples of agricultural systems with poor diversity and low stability are the usual cash crops monocultures (such as wheat, clover, fruit trees, etc.). Although such systems have high productivity rates, they have very low species diversity and are very sensitive to climatic changes or other alterations in their natural background situation. Monocultures are, for example, vulnerable to diseases or to considerable changes of abiotic factors.

1. Simpson's index of diversity: $D = -\log(ni/N)^2$ Shannon's index of diversity: $H = \Sigma(ni/N)\log(ni/N)^2$ where ni is the number of members of a particular species and N the total number of members of the bio-community.

7. Foggaras system of irrigation, *Timimoun* oasis, Algeria
©Olivier Brestin

8. Olive tree plantation (*Olea europaea*), *Khanasser Valley*, Syria
©Thomas Schaaf

In general, pollution drastically reduces species diversity in an area and renders the ecosystem more susceptible to degradation and less stable.

Abiotic (non-biotic) factors in ecosystems

Abiotic (more precisely "non-biotic") factors consist of all *non-living*, chemical and physical components within ecosystems. The key abiotic factors for the survival, development and evolution of various aquatic or terrestrial ecosystems are water, the bulk of all water-soluble salts (salinity, ionic strength), sunlight, temperature, soil or sediment texture, oxygen and other gases, acidity (pH), nutrients and trace elements. All these parameters are directly or indirectly connected to each other through complex mechanisms that are affected by the geomorphology of each system, soil type and composition, the circulation of water and air masses, seasonality, and so on. Overshooting of the natural limits within which these parameters function may be either the cause or the result of some kind of pollution.

Let us explore some basic abiotic factors:
Temperature: Due to the presence of water, which has a very high thermal capacity in all its phases and even more so in its liquid phase, planet Earth comprises a superb thermostatic system when compared to other planets.
Temperatures observed on the surface of the Earth very rarely exceed the range of –60 to +60°C. In aquatic systems and particularly in the seas the range is even narrower and usually between –2 to +35°C. The majority of organisms on Earth thrive within a relatively narrow temperature range, but there are some that survive in wider ranges. Big temperature variations introduce thermal stress which may cause damage to an ecosystem. Small variations on the other hand can often be beneficial and are directly linked to the life cycle and circulation of gaseous and aquatic masses in a specific system, whereas the variation limits define the degree of tolerance and evolution of ecosystems.

Thermal stress in a water body is often caused by "thermal pollution" as a result of extensive industrial emissions of water used for cooling purposes. Apart from the obvious thermal pollution and the potentially permanent effects on the local bio-community, the reduction of dissolved oxygen and of other gasses is dramatic, as is the stratification of the water column and the restricted oxygenation of the deeper layers, the increased solubility of sediment salts and of suspended particulates, increased rates of certain biochemical and chemical reactions, etc. For example, a 10°C increase of temperature doubles or even triples the respiration, whereas the incubation period of certain biochemical reactions is drastically reduced with unpredictable, yet often dire, consequences.
In most Mediterranean countries the legal maximum temperature for sewage and water coming from cooling towers is 40°C. This has been decided based on the likely rate of dilution and heat exchange.

Sunlight: This is the most important precondition for the development of the majority of life forms and, of course, for photosynthesis to occur. In aquatic ecosystems, available sunlight decreases substantially at increasing depths[2]. In depths greater than 100m, photosynthetic activity practically stops. In lakes, rives or coastal waters with high concentrations of suspended particulate matter or with high primary production and abundance of phytoplankton and zooplankton, the photosynthetic process is restricted to a surface thin water layer of just a few metres. The fluctuation

2. Red and blue wave lengths are fully absorbed while green is absorbed to a lesser extent by dissolved and particulate matter, e.g. chlorophyll, humic acids, etc.

9. *Karchaghbour River*,
Tsovak region, Armenia
©Olivier Brestin

10. *Lake Tonga*,
El Kala National Park, Algeria
©Olivier Brestin

of sunlight during the day or throughout the seasons frequently causes secondary phenomena, such as vertical movement of phytoplankton in the water column resulting in differentiated distribution of oxygen and of various chemical compounds at various depths.

Soil substrate: Terrestrial ecosystems cannot develop without soil of rudimentary fertility and stability. Soil erosion is a natural phenomenon, but also the result of destructive agricultural practices, livestock farming, and forest fires. All of them contribute to the destruction of the thin surface layer of fertile soil obstructing, thus, the accumulation of nutrients in it and reducing drastically the plant cover, both of which are critical factors for the development of various ecosystems.
In aquatic ecosystems unstable benthic sediments and waters full of suspended particulate matter discourage the development of benthic bio-communities and favours only the presence of bacteria and very few other organisms. Furthermore, suspended particles decrease the penetration of sunlight and photosynthetic activity, as well as the ability of fish to see and find their food and, protect themselves from predators. Finally, under such conditions, water is inappropriate for drinking purposes and sometimes even for industrial use.

Salinity: The concentration of soluble salts in water and their fluctuation is fundamental for the existence of various organisms. Areas with frequent and broad variations in salinity, such as river deltas, give rise to ecosystems with special features ("euryhaline" ecosystems). Most seas, with concentrations of sodium chloride (NaCl) in the range of 0.5M which represents 35g per kg of sea water, have a highly concentrated solution of salts (electrolytes) which behave very differently from fresh water as far as physicochemical properties and biological processes are concerned.

Acidity(pH): Acidity is one of the most important abiotic parameters influencing directly and indirectly ways the various ecosystems. The major reason for the acidity is the dilution of carbon dioxide from the atmosphere into water. Similarly, other gaseous oxides such as sulfur and nitrogen oxides which are common pollutants, mostly from combustions (from energy production, heating, travel or industry) also contribute to acidity.

The rainwater is normally acidic (pH~6) while in polluted atmospheres it can be as low as pH~3. The river and lake waters are almost neutral (pH~7) while the marine waters are alkaline (pH>7 up to 8-2). This allows the dissolved metals (e.g. the most abundant iron) to precipitate in the mixing (buffering) zones of acidic/neutral with alkaline waters in the form of mixed oxides-hydroxides of iron co-precipitating with a series of other metals and, eventually, other pollutants. Therefore, the differences in acidity play an important role in depolluting certain ecosystems and/or polluting certain others by accumulating in precipitating metal oxides and other pollutants in the sediments of narrow strips of coastal areas particularly in lagoons, wetlands and river deltas.

1.3 Biogeochemical cycles

The transport and transformation of nutrients, water or chemical elements through both biotic and abiotic compartments of an ecosystem are collectively known as biogeochemical cycles. The most important natural bio-geo-chemical cycles are those of water, carbon, and nutrients such as nitrogen, phosphorus and, in aquatic ecosystems, silicon. The cycles of elements, such as sulphur and iron are also important.

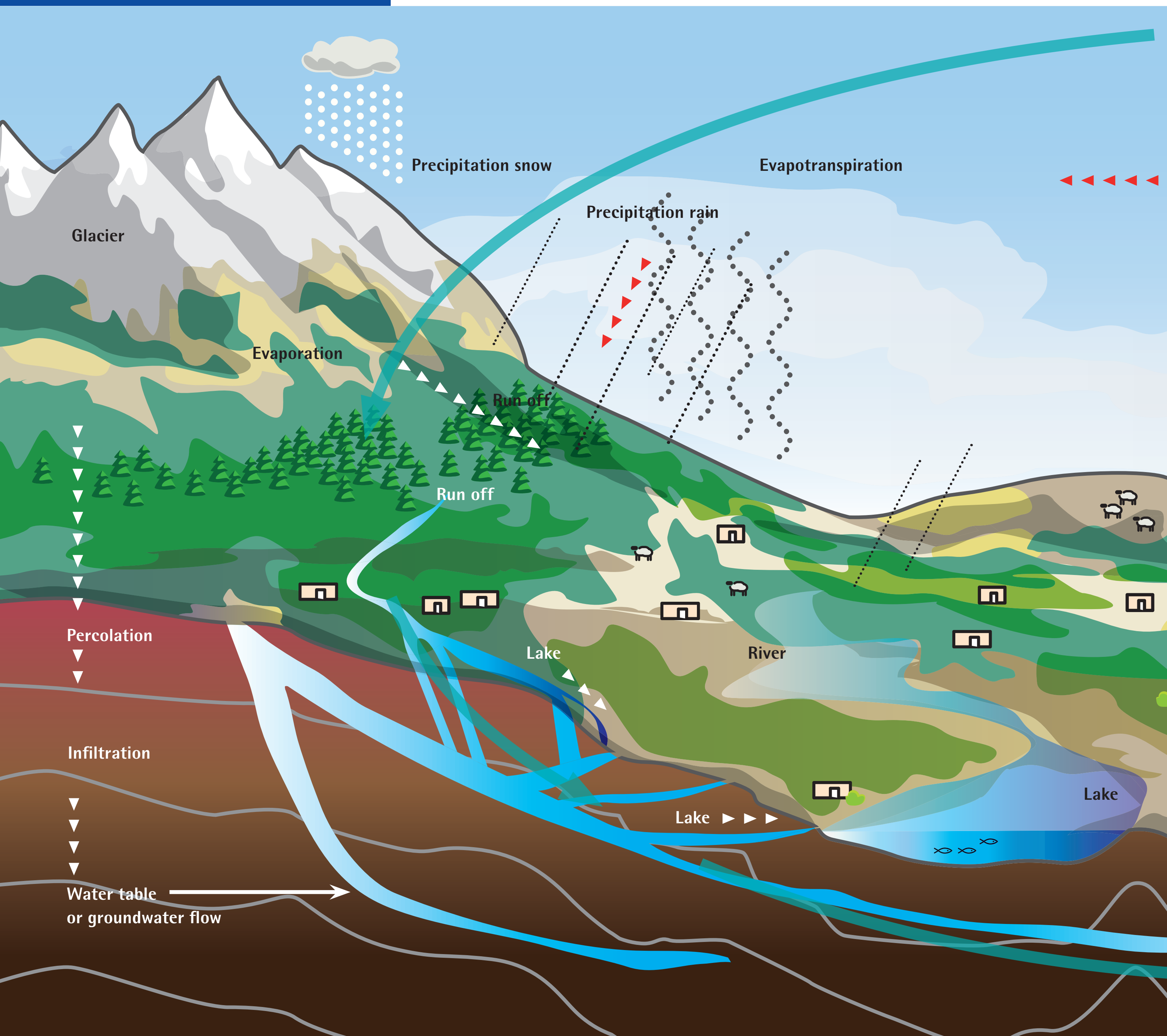
The water cycle

Around 97% of the planet's water is found in its oceans. The remaining 3% is fresh water, of which the 2/3 is frozen and locked up in the Polar Regions, glaciers and in deep inaccessible aquifers. In other words, all the water in the planet's rivers, lakes, soils and plants, its accessible groundwater and the moisture in its atmosphere constitute a mere 1%. From this, only a small part is readily accessible for human consumption and is mostly surface water and shallow groundwater that can be easily pumped.

Although the balance of water on Earth has remained for Millenia fairly constant water circulates continuously within a "closed system" the **hydrological cycle**. The hydrological cycle describes this transfer of water from the oceans and land into the atmosphere through evaporation and then back to the oceans and land via precipitation (in the form of rain, snow, hail, etc.).

The cycle "begins" with the evaporation of surface waters. As moist air is lifted, it cools and water vapour condenses and forms clouds. Moisture is transported around the globe until it returns to the surface as precipitation. Plant transpiration is another process through which water vapours are transferred into the atmosphere. Once water reaches the oceans and the ground it may evaporate back into the atmosphere. The water that remains on the earth's surface is run-off, which empties into lakes, rivers and streams and eventually into the oceans, in a never ending cycle. An-

Figure 2
The water cycle

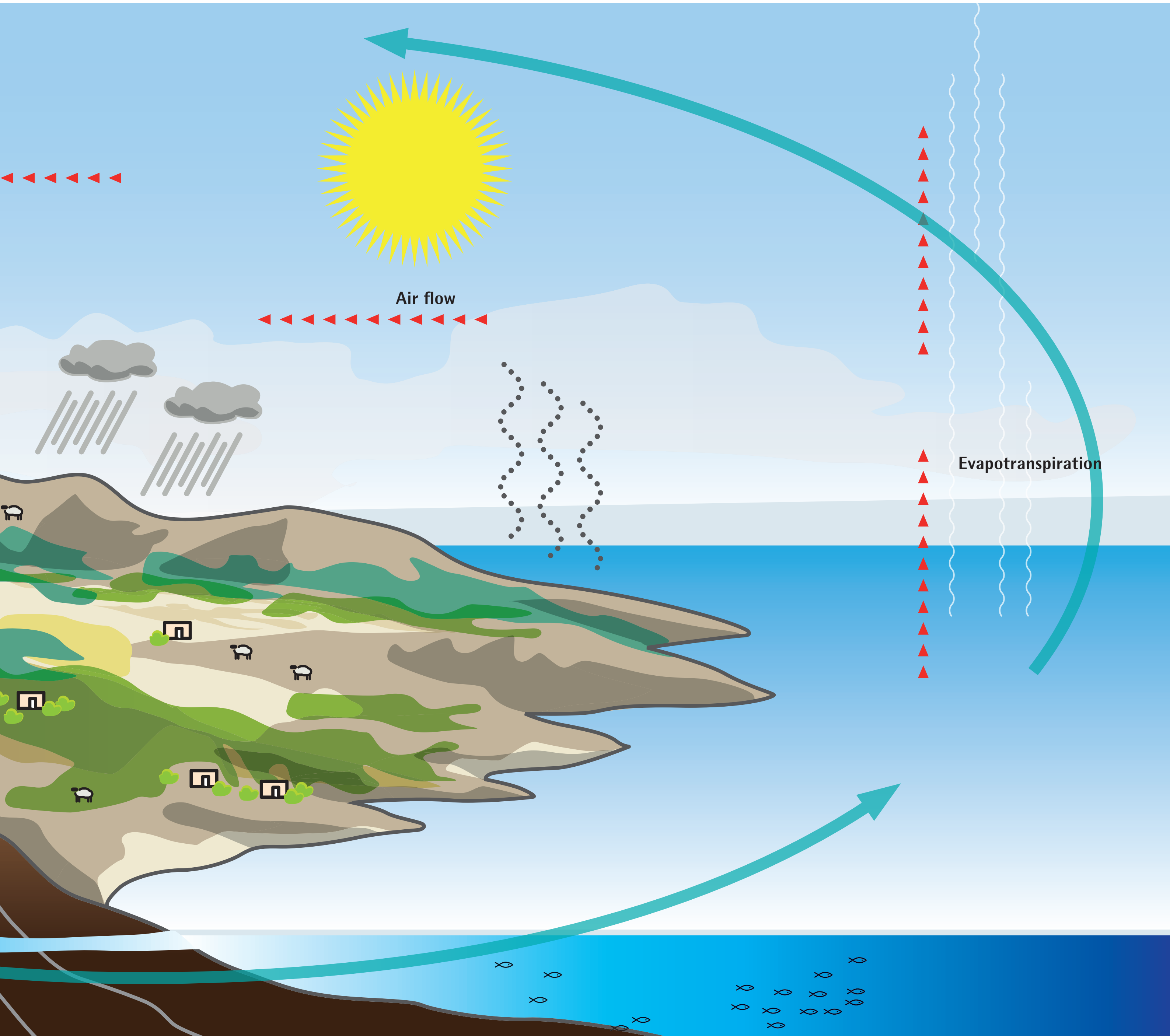


other part of water is filtered into the soil, either to be absorbed by plants or to percolate to form underground rivers, lakes and aquifers. Typically, an underground water table stores large amounts for a long period of time. Some of this water eventually finds its way back to the surface (geysers, water springs in lakes and oceans) to re-enter the cycle.
Water that is trapped in impermeable underground reserves is known as **fossil water.** Many such reserves around the globe have already been tapped into and since they are not renewable they will soon be exhausted. A typical example is a major Sahara desert's fossil aquifer, pumped systematically by Libya.

The hydrological cycle should also be viewed from a spatial and temporal perspective, as certain areas on Earth receive much higher precipitation, than others where, evaporation is more prominent.

The Mediterranean area is a typical example of uneven water distribution over time and space, where scarcity is frequent, at least at its southern and eastern coasts.

Unfortunately, in recent decades **human interventions**, especially those linked to the intensification of agriculture and, to lesser extent, to urbanisation, energy production and tourism have seriously affected the hydrological cycle. Such interventions include:
- Large dam construction and river diversion,
- Over-pumping of ground water mostly,
- Large scale drainage projects,
- Land reclamation and draining of wetlands,
- Cities' expansion and sealing of soil surfaces (by asphalt, concrete) related to rapidly expanding infrastructures (roads, airports, etc).
- Waste water treatment and discharge (artificial river outflows).



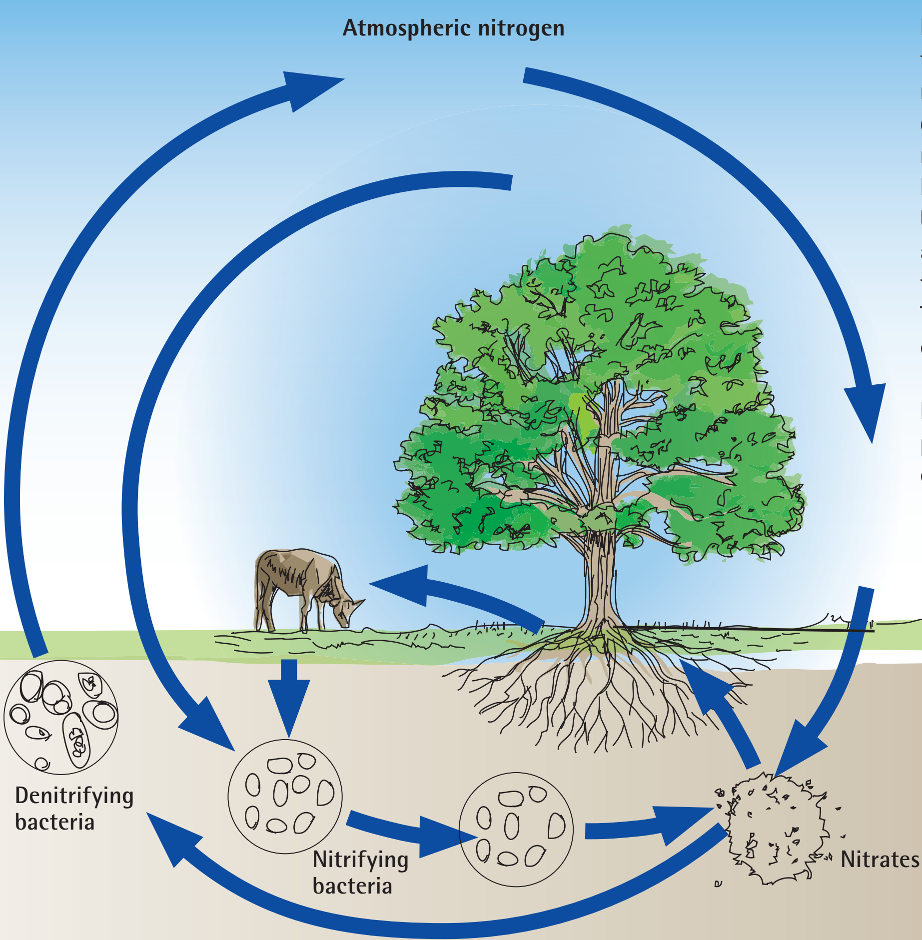
Acid rain: When water evaporates, most of its dissolved chemicals and salts do not, so when it returns as rainwater it is relatively clean. Naturally occurring carbon dioxide in the atmosphere dissolves in rain and makes it slightly acidic compared to water in rivers and lakes, which are almost neutral, and sea water which is alkaline. It is atmospheric pollution that can transform otherwise clean rain into a highly acidic solution. The burning of fossil fuels (coal, lignite, etc.) apart from carbon dioxide also releases sulphur dioxide into the atmosphere. Meanwhile, atmospheric air contains nitrogen oxides and many suspended particulates (e.g. soot) released from vehicle exhaust fumes and many other anthropogenic activities. Sulphur dioxide and nitrogen oxides in combination with rainwater form two very strong acids: sulphuric acid and nitric acid. In this way evaporated clean water can return to the surface in the form of acid rain. Acid rain "attacks" soil and sediment extracting substances which are transferred into water bodies / used by trees in forests causing severe damage. Acidic waters can exterminate large populations of fish in rivers and lakes while they corrode the surface of marble monuments and oxidise large infrastructures (e.g. bridges).

The Aswan dam: an example of human intervention on the water cycle

The Aswan dam, 17 times bigger than the Great Pyramid of Cheops, was constructed far from the delta of the Nile River forming an artificial lake 70 metres deep, 550 km long, 35 km at its widest, with a surface area over 5.000 square km. This massive structure was to serve many purposes in Egypt: to produce electricity (10 billion KW/year); to provide water for irrigation especially during the dry periods; to control the flow of the Nile, which used to flood extensively, from time to time causing serious damage. However, the dam itself has caused considerable damage as well:

– The artificial lake submerged agricultural land.
– A huge volume of water is lost due to evaporation (estimated ~10 km^3 per year).
– As the dam retains the suspended matter, it blocks large amounts of mud that for centuries would end up in the Delta, to form natural coastline barriers between the sea and brackish water lakes. Without the transported silt, the Nile's water erodes rather than stabilizes these barriers.

Figure 3
The nitrogen cycle



Falling with rain as a light form of citric acid, nitrogen is mobilized by nitrifying bacteria from the soil which convert nitrogen compounds into nitrates. Plants absorb nitrates (nitrogen-containing molecules) via their roots. Animals obtain nitrogen by eating plants or animals that eat plants.

What happens is bacteria like *Rhizobium* invade the deep roots of leguminous plants (beans, peas, red clover, alfalfa in different regions) and form nitrogen-fixing nodules on them. The nitrogen is then incorporated into the proteins of the plant, which distributes it through its roots, making it available to other plants.

Nitrifying bacteria from the soil also convert nitrogen compounds from dead plant and animal matter into nitrates. In turn, other denitrifying bacteria absorb nitrates and release nitrogen into the atmosphere. The nitrogen cycle is then completed.

Nitrogen is an important part of the proteins that cells need to survive.

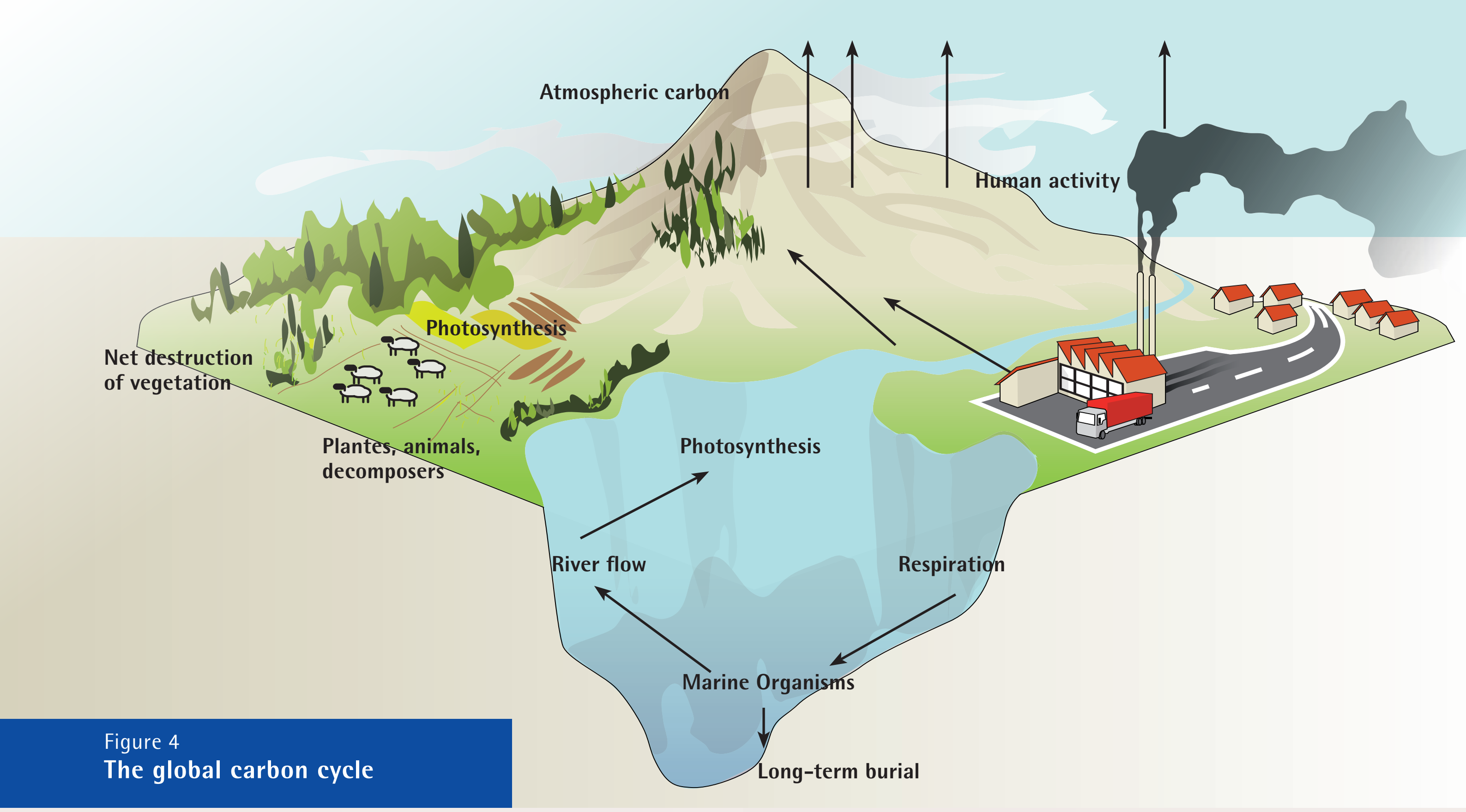


Figure 4
The global carbon cycle

– The fertile silt which used to function as a natural fertilizer once spread into the fields during the annual floods now accumulates at the bottom of the dam reducing its depth never reaching the fields. This has caused agriculture production to rely on the use of chemical fertilizers.

– The absence of the fertile silt and nutrient salts has disturbed the food chain. The quantities of fish (anchovy, sardine, etc.) that used to nourish the population around the Delta have been reduced substantially.

– The increased population of a gasteropode species along the banks of the reservoir and irrigation channels has supported the growth of the parasite bilharzia which causes a serious and sometimes fatal disease to humans. This disease has affected ¾ of the river's rural population.

– The irrigation network extending outward from the Nile and spreading over many kilometres has penetrated into the subsoil gradually releasing large amounts of water. This waterlogging has dissolved the large salt deposits that exist in solid form. The subsoil layers absorbed these salts causing decreased yields. Many freshwater reserves and wells are also threatened with degradation by these salts.

– A more far reaching problem is visible offshore the Delta. The reduction of the volume and surface of river water plume is not allowing it to play any longer its role at the entrance of the neighbouring Suez canal. In the past the low salinity in the Nile water plume presented a natural "barrier" between the Mediterranean and the Red sea water thus not allowing species from the Red Sea to migrate into the Mediterranean. Now many more alien species migrate to the north, disturbing seriously the biodiversity in the Mediterranean.

– The socioeconomic and political consequences and relationships between upstream and downstream countries are a constant source of concerns and problems not fully addressed.

– The Aswan Dam also has another characteristic which is almost the opposite of what we observe elsewhere. In the vast majority of rivers the downstream communities "suffer" from water retention or pollution by the up-stream ones. They develop, therefore, a "victim" syndrome towards their upstream neighbours who "hold" the water. This may or may not be justifiable as many of the downstream communities develop irrigated agriculture, tourism or coastal settlements with high water demands.
This is actually very true for the case of the Nile.

The Aswan Dam experience, despite its many important short and medium term benefits, is yet another example of how a big-scale human intervention upon a natural ecosystem without adequate integrated impact assessment may have severe long-term consequences.

Carbon, nitrogen and phosphorus cycles

Carbon is found in all organic compounds that form biological macromolecules. Carbon enters ecosystems in the form of carbon dioxide (CO_2) mainly from the atmosphere, is taken up by primary producers and through photosynthesis is transformed into organic matter. Organic matter is oxidized by producers, consumers and decomposers (through the process of cellular respiration) producing energy which is used for the needs of the organisms themselves, releasing CO_2 into the atmosphere as waters.

The senseless exploitation and use of fossil fuels (coal, petroleum and natural gas) has resulted in the release of large amounts of CO_2 into the atmosphere. The problem is exacerbated by the destruction of primary producers (e.g. forests) that function as carbon sinks. It is estimated that CO_2 concentrations in the atmosphere have increased by 80% between 1970 and 2004 (IPPC, 2007).

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11. Quinoa of different sizes, shapes and colours, Bolivia,
© Thierry Winkel, IRD

12. Flowering meadow, poppies and daisies, *Saint-Etienne-les-Orgues*, France
© Olivier Brestin

13. Children in *Benni Yenni*, *Kabylia*, Algeria
© Olivier Brestin

14-15. Mediterranean monk seals (*Monachus monachus*), *Northern Sporades*, Greece
© MB of the Northern Sporades Marine Park/ Vasilis Kouroutos

16. Hive and bees, *Mirador del Río Leza Valles del Jubera*, *Leza*, *Cicados y Alhama BR*, Spain
© UNESCO / O. Brestin

17. Camargue bull, *Saintes-Maries-de-la-Mer*, *Camargue BR*, France
© UNESCO / O. Brestin

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Nitrogen is a very important element for a large number of biomolecules (such as amino acids, the building blocks of proteins). Although it exists in abundance in the earth's atmosphere, it cannot be used in this form by plants and animals. Nitrogen enters the food chains of ecosystems through the **nitrogen fixation process,** which is the biological process by which nitrogen from the atmosphere is captured and converted into ammonia, nitrite and nitrate ions, which are compounds that can be used by producers. Plants use nitric (nitrate) ions for synthesising their own nitrogen compounds, such as nucleic acids and proteins. The amino acids of producers are transported through the food chain to the consumers so they can in turn produce their proteins.

The excessive use of nitrogen fertilizers in agriculture has affected the nitrogen and phosphorus cycles by "enriching" the system with large amounts of nutrients which are not absorbed readily by plants and therefore, they are carried away by runoff or percolation, ending up in aquatic ecosystems (lakes, rivers, seas) and contributing to the phenomenon of eutrophication or contaminate around waters and aquifers.

Decomposers break down dead organic matter (dead leaves, plant and animal matter, etc) or faeces (urea, excrements) and produce carbon dioxide (CO_2) or -in absence of oxygen- methane, (CH_4), ammonia (NH_3) and phosphoric acids. Ammonia is converted into nitrates by soil-living bacteria and other nitrifying bacteria and thus the cycle closes. Partial re-entering of nitrogen into the atmosphere occurs through denitrifying bacteria, which through complex reactions transform nitrate and ammonia ions under anaerobic conditions into molecular nitrogen (N_2).

All organisms require **phosphorus** for synthesizing nucleic acids (DNA and RNA), phospholipids and other compounds. Phosphorus is mainly found in water, soil and sediments, as well as in the atmosphere –in the form of fine dust particles. Plants predominantly use the phosphate salts of the soil that enter the system when phosphate rocks are eroded by rainfall, weathering and runoff. The phosphate salts are absorbed by phytoplankton through the roots of plants and used to make organic compounds. As animals eat the plants, phosphorus is passed up the food chain. The decomposition of these animals or the excretion of organic phosphate returns phosphorus into the soil or water thereby completing the cycle. Once in the ocean, phosphorus accumulates to a large extend on continental shelves in the form of insoluble deposits.

1.4 Biodiversity

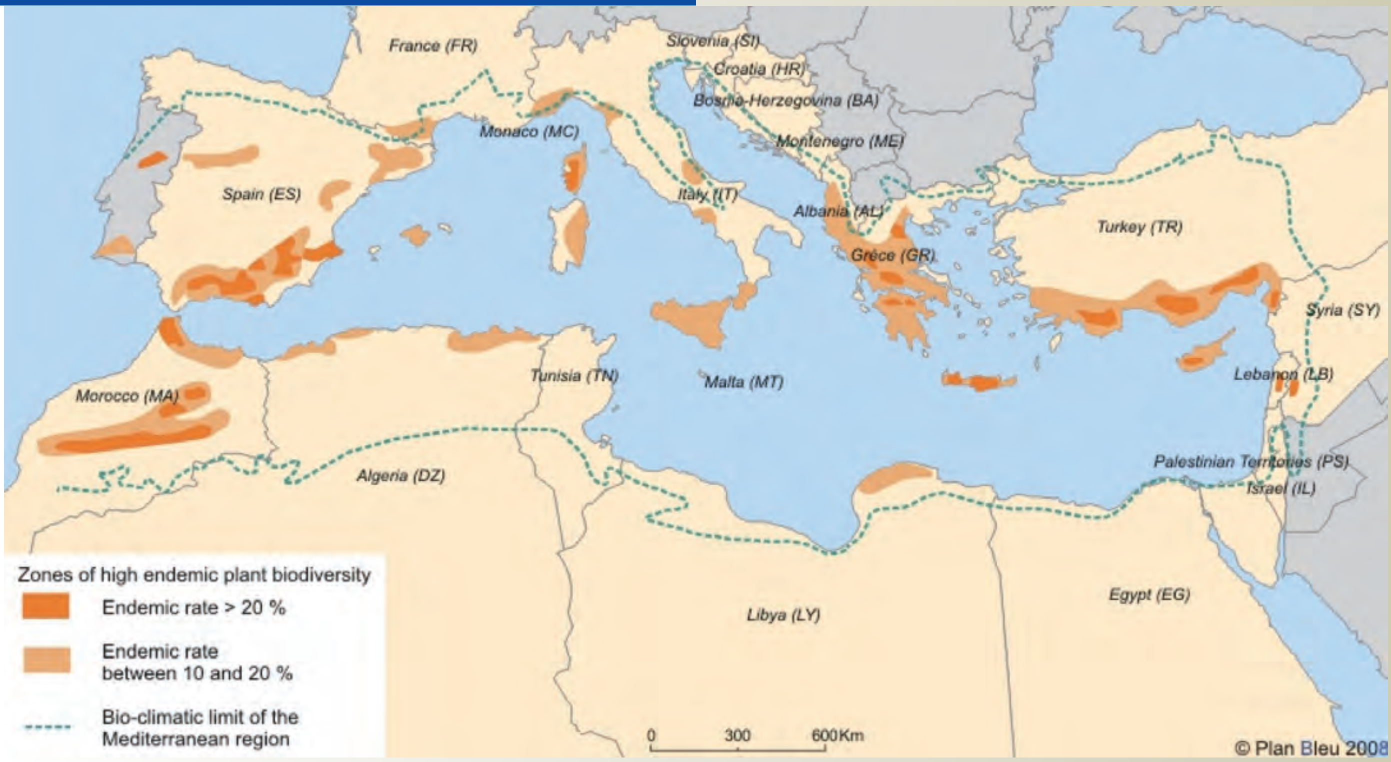
Biodiversity plays a vital role in human well-being and in maintaining the life support system on Earth. It refers to the degree of variation of life forms within a given ecosystem. The term began to receive widespread use especially after the United Nations Conference on Environment and Development (Earth Summit of Rio, 1992) and the signing of the Convention on Biological Diversity (CBD). For many years, there wasn't a precise, functional, commonly accepted definition of the term, mainly due to the multiple approaches of diversity across the levels of organization of ecosystems. Researchers generally accept three levels of biodiversity: **genetic**, **species**, and **ecosystem**.

Genetic biodiversity is the variety at the level of genes. More genetic diversity in a species or population means a greater ability for some of the individuals (and therefore, the population/species in question) to adapt to changes in the environment, such as natural disasters, epidemics and climate change. Less diversity leads to uniformity, which is a problem in the long term, as it increases the possibility that all or most of the individuals in a population will be unable to adapt to changing conditions. Natural species have an inherently larger genetic pool that helps them tolerate change and ultimately survive, compared to the genetically modified ones.

The flora of the Mediterranean basin is unique. Its approximately 12,500 mostly endemic plant species are more than four times the number found in all the rest of Europe; the region also supports many endemic reptile species. However, populations of threatened species are increasingly fragmented and isolated to make way for resort development and infrastructure, as the region is a popular tourist destination. The Mediterranean monk-seal, the Barbary macaque and the Iberian lynx, which are "Critically Endangered", are among the region's imperilled species.

Species biodiversity is expressed by the number (population) of species of plants and animals which are found in one specific area or ecosystem. High species biodiversity in an ecosystem leads to higher stability of the ecosystem, unhindered flows of energy, biomass and nutrient recycling and effective return mechanisms. Various studies estimate that between 5-10 million species have been identified world-wide, whereas 14 million appears to be an estimate that is commonly quoted in the literature (UNEP, 2001). Of these, only 1.4 million have been properly recorded and named to date. The number of species in an area is frequently used as a measure of its biodiversity. But recently, more precise estimation of species variety has been based on the study of the variety of taxonomic groups ("taxa") which constitute a bio-community. For example, an island with two bird species and one reptile species is taxonomically more diverse than another island with three bird species and no reptiles. Also, although more species live on land than in the sea, terrestrial species do not present higher species variety, because they are closely connected to each other phylogenetically (evolutionary relatedness). As a result, biodiversity in marine ecosystems, when estimated on the basis of variety of genetically distant taxonomic groups, is higher than terrestrial diversity.

Figure 5
Riparian countries and areas with a high level of endemic plant biodiversity in the Mediterranean bio-climatic zone



Source : Zones of high endemic plant biodiversity according to Médail & Quezel, in Annals of the Missouri Botanical Garden, 84 (1997)

Species biodiversity varies in different regions of the world: It is higher in the tropics and at the Equator and reduced in the Polar Regions. Other factors which affect species biodiversity are altitude, rainfall and the abundance of nutrients.

The location of the Mediterranean basin, at the intersection of two major landmasses, Eurasia and Africa, has contributed to its high diversity and spectacular scenery. The region boasts mountains as high as 4,500 meters, peninsulas and one of the largest archipelagos in the world. The climate around the basin is dominated by cool, wet winters and hot, dry summers, with rainfall ranging from as little as 100 mm to as much as 3,000 mm. (Conservation International). All these results to a terrestrial biodiversity of great value: the Mediterranean flora accounts for 25.000 species which is 10% of known species in the biosphere, and more than half of them are **endemic**.

Ecosystem biodiversity is expressed as the number of combinations of plant and animal species (bio-communities) in a defined area (ecosystem). The number of separate ecosystems (such as forests, wetlands, and so on) and the way they are arranged and distributed in space forming a larger ecosystem (such as an island) constitute a **landscape**. Apart from their ecological importance, landscapes encompass significant aesthetic and cultural values largely because they embody the historical evolution of land use throughout the ages.

Species and ecosystem biodiversity is a prerequisite for the survival of life on Earth. Estimating the value of biodiversity is very difficult because the **services** provided to humans by ecosystems are multiple and cannot be estimated only on the basis of economic criteria. Indeed, apart from the goods it provides directly (such as food, pharmaceuticals, and construction materials), biodiversity offers a series of services essential for supporting life: nutrient cycling; carbon storage; pest regulation and pollination; sustaining agricultural productivity; retention, purification and distribution of freshwater; mitigating climate change impacts (such as floods, storms, and extreme weather phenomena), and much more. Also, the study of biodiversity offers opportunities for research and education (scientific and educational value), contributes to human psychological and spiritual well being (aesthetic, cultural and spiritual value) and provides the opportunity for the development of an area for tourism and recreation use through the observation of wild life, climbing, walking, diving, fishing and other activities. Finally biodiversity has been always the source of “admiration” of nature and of “inspiration” of man of all cultures.

Cultural diversity refers to the variety of human societies, or cultures in a given region. Apart from the obvious cultural differences that exist between people, such as language, dress and traditions, there are also significant variations in the way societies organize themselves, in their shared value system and in the way they interact with their environment. Just like biodiversity, is considered essential to the survival of life on earth, it can be said that cultural diversity may be vital for the long-term survival of humanity. The Universal Declaration on Cultural Diversity states that *«...cultural diversity is as necessary for humankind as biodiversity is for nature"* recognizing for the first time, cultural diversity as *«common heritage of humanity»* and considers its safeguarding to be a concrete and ethical imperative inseparable from respect for human dignity. (UNESCO, 2001)

Links between cultural and biological diversity: There is a growing recognition that reduced diversity makes the world and its inhabitants increasingly vulnerable to natural and human-induced changes. During the past decades have seen a rise of interest in the approach of link between these two, and the role this link plays in sustainable development and human well-being, worldwide.
The notion of the 'inextricable link' (UNDP, 2004) implies not only that biological and cultural diversity are linked to a wide range of human-nature interactions, but also that they are co-evolved, interdependent and mutually reinforcing. Each culture possesses its own set of representations, knowledge and cultural practices which depend upon specific elements of biodiversity for their continued existence and expression. Cultural groups develop and maintain significant ensembles of biological diversity, with knowledge and practice as the media for their management.
Considerable work has been done to better elucidate the areas of interdependence between biological and cultural diversity. Characteristic examples include the areas of linguistic diversity, material culture, traditional knowledge and technology, natural resource use, social relations including gender, etc. (UNESCO, 2008)

Biodiversity loss: Since the industrial revolution the planet's biodiversity has been decreasing, and even more rapidly during the last few decades. A view shared by many scientists is that biodiversity services are declining and natural resources are diminishing at a pace which poses serious threats to the ability of ecosystems to support future generations. The number of species endangered by human activites and the number of natural or semi-natural habitats being destroyed, fragmented or changed are constantly growing, thus destabilizing ecosystems, causing the loss of vital resources together with genetic and cultural impoverishment.

18. Tuscan landscape with vineyards and cereal crops, *San Gimignano* region, Italy
©Hélène Gille

This is the result of unsustainable developmental activities (such as intensive agriculture, exhaustive logging, overfishing, draining wetlands, overgrazing, mining and mass tourism), pollution (soil, water, air), desertification, extensive land use changes (construction, infrastructure development, creation of roads for transportation), combined natural and man induced disasters (fires and floods), invasion of alien species and climate change.

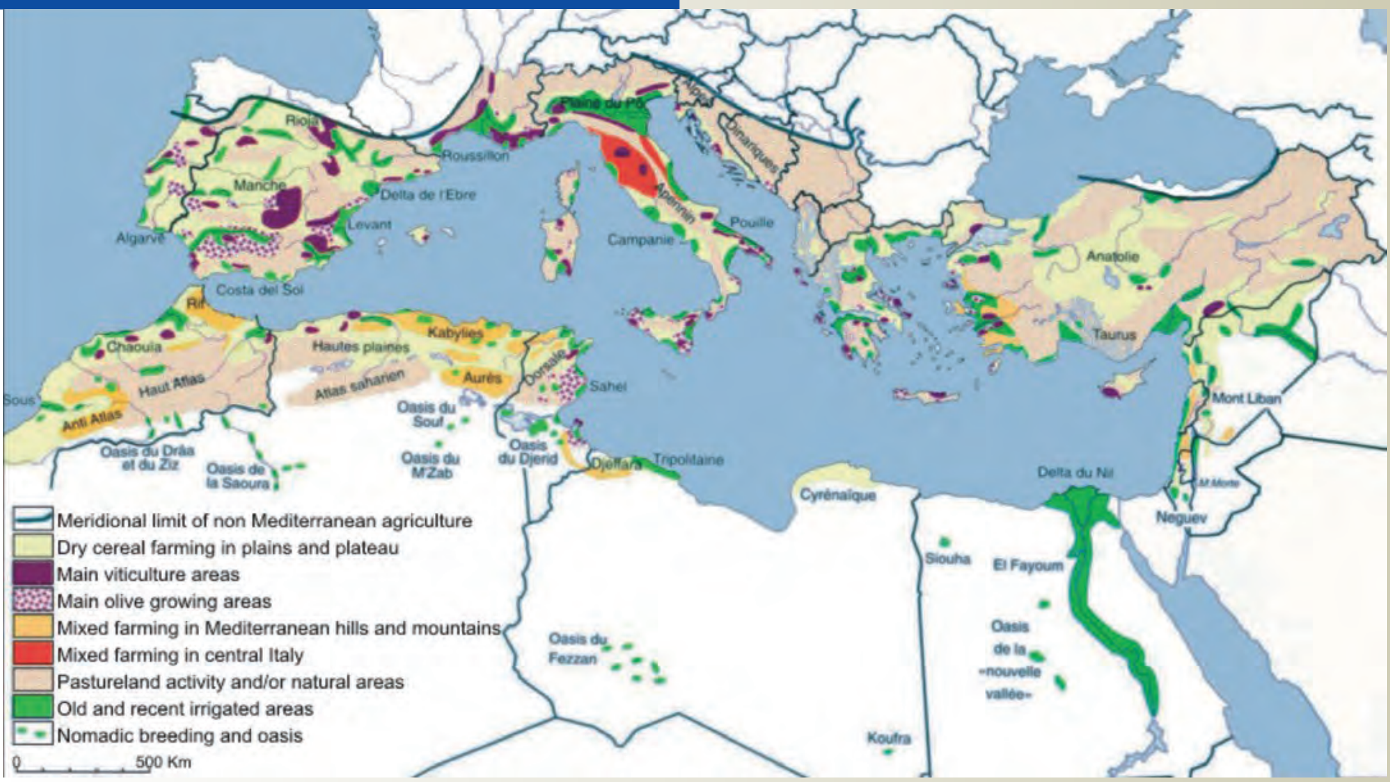
The extent and role of all these pressures is area specific, and frequently the final impact is due to a combination of pressures. Demographic explosion and increased production and consumption in a globalized economy exert further pressure on ecosystems and their biodiversity. To these one must add ineffective governance and the incapacity of traditional economies to recognize and incorporate the economic value of natural resources and ecosystem services.

To this end, there is systematic refusal by many governments to acknowledge biodiversity loss in their sectoral policies (in agriculture, transport, energy and even in education). The concept of biodiversity is usually viewed as a purely environmental issue linked to nature protection. The low level of understanding of the value of biodiversity and the threats and pressures imposed on ecosystems all these years, is also attributed to insufficient information and awareness raising as well as lack of proper education.

In the Mediterranean region civilizations have 'domesticated' or transformed the milieu and shaped landscapes and the environment significantly over a prolonged period. Almost everywhere the primary vegetation has been replaced by landscapes affected by humans, in some cases degraded, in others improved, abandoned or re-conquered. Because of these changes a number of animal and vegetable species have disappeared or are under threat (some Felidae, certain antilopes, a number of birds such as birds of prey and limicolous birds). However, agricultural diversity which has been enriched over the ages –with many variables of cereal, vegetables, fruits plus horned cattle, sheep and goats) has put the Mediterranean into the top eight most important dispersion centres for cultivated plants. This rich genetic heritage is experiencing a remarkable change and is now facing a serious threat as a result of the abandonment of traditional practices.

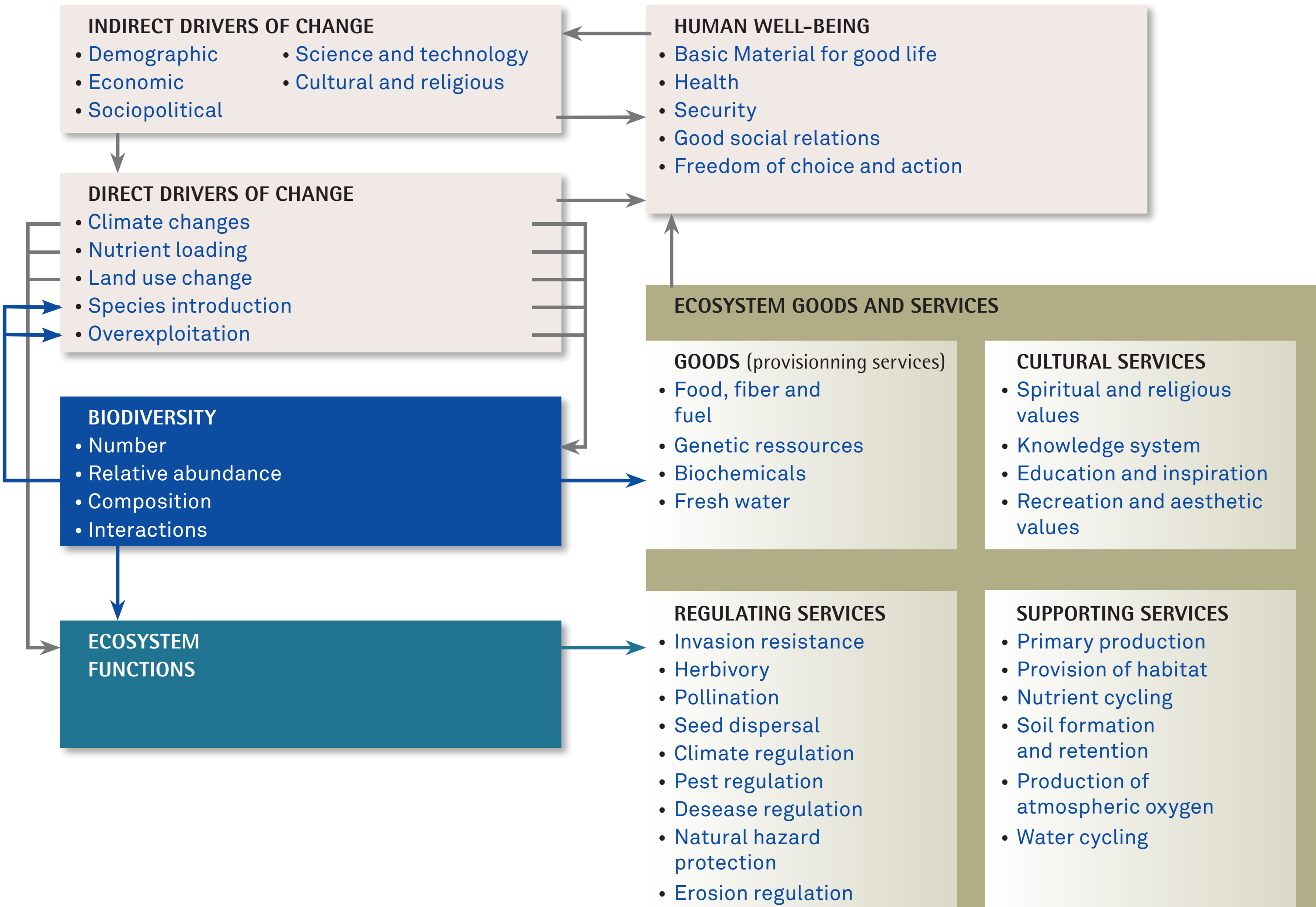
In 2000, the UN Secretary-General Kofi Annan called for the **Millennium Ecosystem Assessment** (MA). Initiated in 2001, the objective of the MA was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being.
The MA has involved the work of more than 1,360 experts worldwide. Their findings provide a state-of-the-art scientific appraisal of the condition and trends in the

Figure 6
The main agricultural and natural systems in the Mediterranean



Source : Geographic revue of the Mediterranean countries, Tome 97 « 40 years of Mediterranean geography, 2001

Chart 1
Biodiversity, ecosystem functioning, ecosystem services, and drivers of change



Source: CBD Global Biodiversity Outlook 2, 2006.

Biodiversity is affected by drivers of change and also is a factor modifying ecosystem function. It contributes direcly and indirectly to the provision of ecosystem goods and services. These are divided into four main categories by the Millenium Ecosystem Assessment: goods (provisioning services) are the products obtained from ecosystems; and cultural services represent non-material benefits delivered by ecosystems. Both of these are directly related to human well-being. Regulating services are the benefits obtained from regulating ecosystem processes. Supporting services are those necessary for the production of all other ecosystem services.

world's ecosystems and the services they provide (such as clean water, food, forest products, flood control, and natural resources) as well as the options to restore, conserve or enhance the sustainable use of ecosystems.
A major finding is that relatively limited information exists about the status of many ecosystem services and even less information is available about the economic value of non-marketed services. Moreover, the costs of the depletion of these services are rarely tracked in national economic accounts. Basic global data on the extent and trends in different types of ecosystems and land use are surprisingly scarce. Models used to project future environmental and economic conditions have limited capability for incorporating ecological "feedbacks", including nonlinear changes in ecosystems, or behavioural feedbacks such as learning that may take place through adaptive management of ecosystems.
Until recently, appropriate models for assessment of the net economic consequences of inaction and of actions to reduce the biodiversity loss were not available. In a G8+5 meeting held in Potsdam in 2007, the German government proposed that a study on the worldwide economic significance of the global loss of biological diversity should be undertaken.

The study entitled **The Economics of Ecosystems and Biodiversity** (TEEB) initiated in 2007 evaluates the costs of biodiversity loss and the associated decline in ecosystem services, and compares them with the costs of effective conservation and sustainable use. It is intended to sharpen awareness of the value of biodiversity and ecosystem services and facilitate the development of cost-effective policy responses, notably by preparing a 'valuation toolkit'. The TEEB initiative has resulted in four UNEP reports during the period 2008-2010, the last of which was released during the 10th Conference of the Parties to the Convention on Biological Diversity (CBD COP-10) in Nagoya, Japan, in October 2010.

Table 1
The last TEEB report, "Mainstreaming the Economics of Nature" (Japan, Oct 2010, COP-10) estimates the cost of some widely applied unsustainable patterns.
More examples can be found at (www.teebweb.org)

ACTIVITY	ANNUAL COST	SOURCE (of TEEB)
Over-exploitation of global fisheries. Competition between highly subsidized industrial fishing fleets coupled with poor regulation and weak enforcement of existing rules has led to over-exploitation of most commercially valuable fish stocks, reducing the income from global marine fisheries by US$50 billion annually, compared to a more sustainable fishing scenario.	**US$ 50 billion**	(World Bank & FAO, 2009)
Insect pollinators are nature's multi-billion providers. For 2005 the total economic value of insect pollination was estimated at Euros 153 billion. This represents 9.5% of world agricultural output for human food in 2005.	**€ 153 billion**	(Gallai et al., 2009)
The annual value of human welfare benefits provided by coral reefs. Although just covering 1.2% of the world's continent shelves, coral reefs are home to an estimated 1-3 million species including more than 1/4 of all marine fish species. Some 30 million people in coastal and island communities are totally reliant on reef-based resources as their primary means of food production, income and livelihood.	**US$ 30 billion - US$ 172 billion**	(Allsopp et al., 2009). Gomez et al., 1994, Wilkinson, 2004) (Estimates of the value of human welfare benefits)provided by coral reefs range from US$ 30 billion (Cesar et al., 2003) to US$ 172 billion annually (Martinez et al., 2007)
The benefits of tree planting in the city of Canberra. Local authorities in Canberra, Australia, have planted 400,000 trees to regulate microclimate, reduce pollution and thereby improve urban air quality, reduce energy costs for air conditioning as well as store and sequester carbon. These benefits are expected to amount to some US$20-US$67 million over the period 2008-2012, in terms of the value generated or savings realized for the city.	**US$ 20 million - US$ 67 million** (over 4 yrs)	

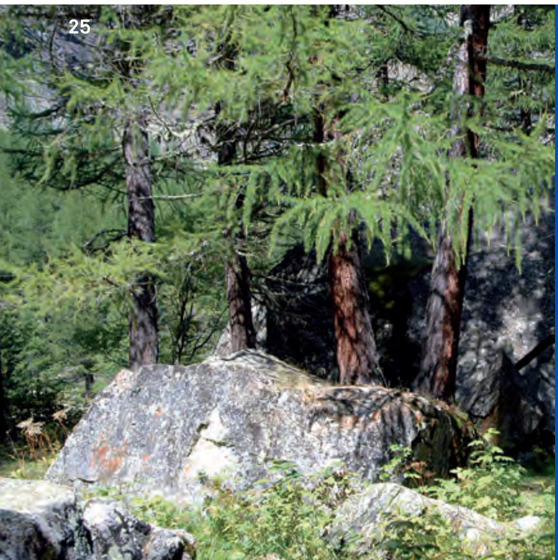
1.5 Types of flora and fauna in the Mediterranean

PLANTS (adapted from Conservation International)
Although much of the Mediterranean area was once covered by evergreen oak forests, deciduous and conifer forests, 8,000 years of human settlement and habitat modification have distinctly altered the characteristic vegetation. Today, the most widespread vegetation type is the hard-leafed (sclerophyllus) **maquis**, which includes representatives from the plant genera *Juniperus, Myrtus, Olea, Phillyrea, Pistacia*, and *Quercus*. Some important components of Mediterranean vegetation (species of the genera *Arbutus, Calluna, Ceratonia, Chamaerops*, and *Larus*) are relicts from the ancient forests that dominated the basin two million years ago. Frequent burning of maquis results in depauperate vegetation dominated by Kermes oak (*Quercus coccifera*), *Cistus* spp. or *Sarcopoterium spinosum*, all of which regenerate rapidly after fire by sprouting or mass germination. Shrublands, including maquis and the aromatic, soft-leaved and drought phrygana of *Rosmarinus*, *Salvia*, and *Thymus*, persist in the semi-arid, lowland, and coastal regions.

Overall, of the 22,500 species of vascular plants in the Mediterranean region, approximately 11,700 (52%) are found nowhere else in the world. The endemics are mainly concentrated on islands, peninsulas, rocky cliffs, and mountain peaks.

The Mediterranean region harbors a high degree of tree richness and endemism (290 indigenous tree species with 201 endemics). A number of trees are important flagships, including the cedars (i.e. the cedar of Lebanon, *Cedrus libani,* has been exploited since the rise of civilization in the Fertile Crescent); the argan tree (*Argania spinosa*), a species found in southwest Morocco; oriental sweet gum (*Liquidambar orientalis*); and Cretan date palm (*Phoenix theophrasti*) in Greece and western Turkey. The only palm native to the Mediterranean, *Phoenix theophrasti*, is found in a tiny part of Crete and on Turkey's Datca Peninsula, two areas experiencing substantial tourism development.

BIRDS (adapted from Conservation International)
A total of ~500 bird species are found in the Mediterranean basin, and many more migrate through the region, crossing the Mediterranean at Gibraltar, Sicily, the Bale-



19-22. and **26.** Prickly juniper (*Juniperus oxycedrus*), myrtle (*Myrtus communis*), cretan rockrose (*Cistus creticus*), holm oak (*Quercus ilex*), olive tree (*Olea europaea*), *Sóller* Botanic Garden, *Mallorca*, Spain ©Hélène Gille

23. Tuscan landscape with vineyards and olive trees, ©Hélène Gille

24-25. Larch needles (*Larix decidua*) and clump of larches (*Larix decidua*) on a rocky scree, *Valnontey*, *Aosta Valley*, Italy ©Michel Le Berre

27. High mountain pasture with monk's rhubarb (*Rumex alpinus*) in foreground, *Little St Bernard Pass*, France
©Michel Le Berre

28. Chamois (*Rupicapra rupicapra balcanica*), *Mount Olympus*, Greece
©MB of the National Park of Olympus/P. Charitakis

aric Islands, Corsica, Sardinia, Crete, and Cyprus. About 25 of these species are endemic, and several are threatened, including: the Spanish Imperial eagle (*Aquila adalberti*), thought to number around 350 mature individuals, Raso Island lark (*Alauda razae*), which occurs only on the uninhabited Raso Island in the Cape Verdes; Balearic shearwater (*Puffinus mauretanicus*), which breeds in the Balearic Islands; and the Madeira or Zino's petrel (*Pterodroma madeira*), which has an estimated breeding population of 20-30 pairs in the central mountain massif of Madeira.

The destruction and degradation of Mediterranean wetlands threaten widespread species such as the Dalmatian pelican (*Pelecanus crispus*), which winters in the eastern parts of the region, marbled teal (*Marmaronetta angustirostris*) and ferruginous duck (*Aythya nyroca*). These wetlands are also important for wintering and migrating species like the slender-billed curlew (*Numenius tenuirostris*), which travels between Africa and its Siberian breeding grounds each year.

MAMMALS (adapted from Conservation International)

The Mediterranean Basin is home to more than 220 terrestrial mammal species, of which 25 are endemic (11%). A number of large mammal species, like the lion (*Panthera leo*) and the scimitar-horned oryx (*Oryx dammahl*), have been extirpated from the region in the last few thousand years as the result of human habitat alteration and hunting pressure.

Among notable flagship species are the Mediterranean monk seal (*Monachus monachus*), of which less than 400 individuals remain in the wild; the Barbary macaque (*Macaca sylvanus*), the only native monkey known from Europe confined to several small, disparate fragments of habitat in the mountain ranges of Morocco and Algeria and on the island of Gibraltar; the Barbary deer (*Cervus elaphus barbarus*), represented by a few hundred individuals in a small forest on the Algerian/Tunisian border; and the Iberian lynx (*Lynx pardinus*), the most threatened felid in the world with no more than 250 individuals remaining in the wild.

Biodiversity in Mediterranean mountains:
(Regato & Rami, IUCN, 2008)
The high diversity of the Mediterranean mountain flora is attributed to a synergy of factors including the significant number of distinct elevation belts, the high geological diversity, the sharp latitudinal gradients, the broad oceanic-continental gradients from the coast to the inner mountain regions, and the frequent isolation of mountains. Almost all centres of plant diversity and endemism in the Mediterranean region are continental and island high-mountain areas. Rates of endemism of above 20% occur in the Betic–Rifan complex on either side of the Strait of Gibraltar, in the Middle Atlas and High Atlas in Morocco, in the Iberian Sistema Central, on the islands of Corsica, Sardinia and Sicily, in the Pindos Mountains of Greece, in Crete, Cyprus, the southern mountains of Turkey (Taurus and Amanus) and the Lebanon mountain range.

Mediterranean mountains are home to many endangered animal species, such as felines: the few viable populations of the Iberian lynx (Lynx pardina) are found in the mountains of SW Spain; the few leopards of the Middle Eastern subspecies (Panthera pardus jarvisi) survive in the deserts of Israel and in Sinai (Egypt); the Anatolian Leopard (Panthera pardus tulliana) persists in the western Taurus (Turkey); while the last remaining specimens of the Atlas leopard (Panthera pardus panthera) are confined to the Atlas mountains in Morocco. Mediterranean mountains are also home to several endemic species and subspecies of large herbivores, most of which are rare or endangered: the mouflon (Ovis orientalis), ancestor of the domestic sheep, is represented by a number of subspecies that live in some of the most pristine forest areas of Sardinia, Corsica, Cyprus and Turkey. High mountains and rocky outcrops are home to the Nubian ibex (Egypt, Israel, Jordan), the Spanish ibex (Spanish sierras), the Bezoar ibex (Taurus and Anti-Taurus, Turkey), the Abruzzo chamois (Italy), and the Eastern Anatolian chamois, which spend the winters in wooded areas at lower elevations.

29. The bridge of *Noutsos* (1750), *Vikos Gorge*, Greece
©Cultural Association of Vradeto

30. Green frogs (*Pelophylax esculentus)* , *Kotychi-Strofylia wetland*, Greece
©MB of Kotychi-Strofylia wetland

REPTILES (adapted from Conservation International)
There are more than 225 reptile species in the Mediterranean, nearly 80 (34%) of which are endemic. There are also four endemic genera, namely *Algyroides, Trogonophis, Macroscincus,* and *Gallotia (*the last being a genus of lizard unique to the Canary Islands).
The family Lacertidae, characterized by small, long-tailed lizards, is represented in the region by more than 60 species, ¼ of the world total, and the family Viperidae, stocky venomous snakes, is represented by nearly 20 species. The family Testudinidae is represented by five tortoises: spur-thigh or Greek tortoise (*Testudo graeca,* VU); Hermann's tortoise (*Testudo hermanni*); marginated tortoise (*Testudo marginata*); the Endangered Egyptian tortoise (*Testudo kleinmanni*), and Weissinger's tortoise (*Testudo weissingeri*), an endemic species.

AMPHIBIANS (adapted from Conservation International)
There are nearly 80 amphibian species in the Mediterranean Basin; nearly 30 of these are endemic (31%), such as the families of the Discoglossidae and the Salamandridae. Eleven of the world's 12 recognized species of disc-tongued frogs (*Discoglossidae*) are found here, seven of which are endemic. The Palestinian painted frog (*Discoglossus nigriventer*), known from Israel, has not been recorded since 1955, although there are recent tantalizing reports of the species having been seen in Lebanon. The region's 23 species of Salamandridae account for over a third of the world's representatives from this family. The fire salamander (*Salamandra salamandra*) is one of the largest salamanders in the world; its range includes most of Europe, a portion of North Africa, and the Middle East. Of the 17 species of threatened amphibians present in the Mediterranean, the most threatened is probably *Rana holtzi*, which is endemic to two lakes (Karagol and Cinegol), no more than 500 meters apart, in the Taurus Range in Turkey.

FRESWATER FISHES (adapted from Conservation International)
The freshwater fishes of the Mediterranean basin are small subsets of the rich Eurasian and African fish faunas from which they are isolated. Although there are only less than 220 species, more than 60 are endemic, including six endemic genera. There is also one endemic family, Valenciidae, the tooth carps of the Iberian and Greek peninsulas. These two peninsulas contain about 86% of the entire Mediterranean's endemic fishes.

1.6 Types of ecosystems in the Mediterranean

Natural terrestrial ecosystems
The Mediterranean natural and semi-natural terrestrial ecosystems consist of forest (according to the FAO definition, areas of land where canopy cover by large trees exceeds 10%), other wooded land (bush, scrub, matorrals, wooded steppe) and natural pastoral areas (mountain pastures, mountain steppes, predesert steppes, alfa grass steppes, etc.).

According to UNEP/MAP (2009) there is currently a significant disparity between the situations prevailing on the two banks. To the north, following a period of major overexploitation and regression over the 18th - 19th century, the forests are now making a comeback in many areas, due to the abandonment of farming and grazing on soils having a low productivity. Conversely, pressure to the south is generally still very strong- over-exploitation of firewood, over-grazing and erosive ploughing- but tending to stabilise. To the east, a midway situation prevails. Several major reforestation programmes have been implemented to the north as well as in the south and east.

Mountain ecosystems
To a large extend mountains constitute the backbone of the whole Mediterranean region. It is often hard to draw the limit between mountains and lowlands, as where

31. Hikers, *Kyra Panagia Island*, Greece
© MB of the Northern Sporades Marine Park

32. *Dragon Lake* (*Drakolimni*), *Epirus*, Greece
© MB of Vikos-Aoos-Pindos National Park/ K. Zisides

steep mountain slopes plunge sharply into the sea. This is the case on several mountainous islands (Corsica, Dalmatian Islands) and in long stretches of continental coastline. Seven Mediterranean countries are among the top 20 mountainous countries in the world, and half of the countries in the region have at least 50% of their land classified as mountain areas.

There are several definitions of mountains based on various criteria, such as topography, climate, vegetation, constraints on agriculture, or length of growing seasons. UNEP (2002) based its definition on topographic features, such as slope, ruggedness of the terrain and absolute altitude, establishing a lower limit of 300 metres.
Mountains play a key role in the water cycle, influencing climate and precipitation regimes and modulating the runoff regime. Mountain vegetation and soils store rainfall water and regulate the gradual flow of water and sediments downstream, which fertilises lowland plains, replaces coastal sediments, and recharges groundwater aquifers in lowland areas, where the demand from population centres, agriculture and industry is high. Healthy mountain systems are therefore vital not only for their inhabitants –humans and wildlife– but also for the prevention and mitigation of risks from natural hazards, such as landslides and avalanches, for the maintenance of ecological processes, and for the provision of goods and services to lowland users.

Mediterranean mountain BRs larger than 150,000 ha, which may constitute functional landscape systems:
- Southern Morocco Oasis BR: 7,185,371 ha, extending from the lowland desert oases to the High Atlas summits;
- Inter-continental Mediterranean BR: 894,135 ha, including a network of protected mountain areas in southern Andalusia and in the northern Morocco Rif chain;
- Dehesas of Sierra Morena BR: 424,400 ha of extensive and very unique sylvo-pastoral landscapes in the western mountains of Andalusia;
- Velebit BR: 200,000 ha of a mountain range parallel to the Adriatic coast in Croatia;
- Cazorla/Segura BR: 190,000 ha (Andalusia, Spain)
- Cilento & Vallo di Diano BR: 181,000 ha of coastal mountains south of Naples (Italy);
- Luberon BR: 179,600 ha in southern France;
- Sierra Nevada BR: 171,646 ha of Iberia's highest mountain range (Andalusia, Spain).

Aquatic ecosystems

Aquatic ecosystems are categorised in various types to facilitate on the one hand their description and study and on the other their management. To a large extent the classification of the existing legislation, is based on the European Directive 2000/60/EE, known also as the **Water Framework Directive.** According to this Directive aquatic ecosystems are divided into coastal and transitional (seas and lagoons), internal (lakes and rivers) and wetland ecosystems, which are placed between the aquatic and terrestrial ecosystems.

Coastal and transitional: seas and lagoons

The conditions in the marine environment are extremely varied and as a result form a great variety of ecological environments: from the surface waters, rich in oxygen and sunlight, to the waters of the abyss with complete darkness, extremely high pressures, low temperatures and in many cases lack of oxygen. It is no wonder that this variety of conditions resulted in the development of great diversity in the adapted organisms (from unicellular algae to big mammals).

Marine ecosystems are distinguished based on their depth, geomorphological characteristics and the type of their seabed (rocky, sandy, muddy). Marine ecosystems are thus divided into the following zones: shallow bays, sandbanks which are slightly covered by sea water all the time, river estuaries and reefs.

Shallow bays are protected by wave action, have a big variety of substrata and sediments, they are rich in biodiversity and have benthic communities with distinct zoning.

Sandbanks slightly covered by sea water all the time consist of sandy sediments that are permanently covered by shallow sea water, usually at depths of less than 20m. They are typically colonised by a burrowing fauna of worms, crustaceans, bivalve molluscs and echinoderms. Apart from the benthic communities they host many migratory birds.

River estuaries (deltas) are areas with shallow semi-saline waters where fresh water comes into contact with sea water. Sunlight easily penetrates the water column reaching down to the bottom, while their substratum is mostly muddy from the depositions of rivers. They are generally eutrophic ecosystems whose vegetation includes benthic seaweeds, phanerogame meadow and areas with densely populated bio-communities of invertebrates and many birds seeking food.

Reefs are rocky substrata, either submerged or standing out of the sea surface with characteristic zones of benthic bio-communities of fauna and flora. Many organisms cover the rocks in a crust-like formation. Characteristic photofila algae e.g. *Cystoseira* can be found on the surface of reefs, whereas in the shady crevices and bigger depths one finds red algae corals. Reef fauna comprises mostly of invertebrates such as mussels, sponges, bryozoa, thysanopoda and crustaceans.

Posidonia seagrass beds named after the ancient Greek god of the sea, Poseidon, are protected habitats which have a fundamental role for the health and productivity of Mediterranean marine ecosystems. The endemic to the Mediterranean Sea angiosperm *Posidonia oceanica* forms widespread meadows or clusters on sandy bottoms, near coastal areas in depths ranging from 1 to 40 metres. It has 50 cm long strip-like leaves and produces flowers and fruit while its roots are fixed in the sand, stabilizing the sediment. Just like land-based plants, Posidonia beds photosynthesise absorbing carbon dioxide from the atmosphere (carbon sink) there by mitigating the effects of global warming. At the same time, due to their high rates of primary production, they generate large quantities of oxygen and organic material. One square metre of posidonia produces 20 litres of oxygen in 24 hours.

Posidonia meadows are of significant ecological importance because of their high rates of primary production and because they control sediment movement stabilising the sea floor and develop mats that eventually build up reefs which protect coastal areas from erosion induced by wave motion and coastal streams. They provide habitat for a great variety of marine species, a place for the reproduction and development of many young fauna species, thus contribute to the maintenance of biodiversity. Posidonia meadows are resistant to changes in temperature and water currents, but are vulnerable to salinity variations and pollution. They are also threatened by pollution and other human interventions, such as trawler fishing which can uproot large sections of seagrass, pleasure boat anchoring.

The **Mediterranean Sea** is a rich store of endemic flora and fauna containing 7% of the world's marine species. The marine biodiversity is concentrated in the limited areas with shallow waters (38% of the invertebrates and 75% of the fish and nearly all seaweeds). The natural heritage with its biodiversity and its vital role in the food chain, in purifying water and hosting the public has a significant ecological and social value. A survey has indicated high economic value of the environmental benefits supplied by the coastal environments especially: This exceptional value of coastal wetlands is explained by the multiplicity of services rendered: natural purifying capacity of an environment that is both receptive to and propitious for dozen of fish and waterflow species and millions of migratory birds to reproduce, climate and water cycle circulation, erosion prevention, biological control, food and raw material production, fisheries, aquaculture and leisure activities, genetic capital and, knowledge, landscape and cultural heritage.

33. Posidonia seagrass (*Posidonia oceanica*) with Pinnidae (*Pinna nobilis*)

Lagoons are formed in river estuaries or coral reefs. A necessary requirement for their formation is the absence of intense wave and tidal activity. This is the reason why lagoons are mainly found in closed seas such as the Mediterranean, rather than oceans. Lagoons cover approximately 10% of global coasts and are of very high ecological and commercial value.

From the sea's entry points to the most remote inland locations, a variety of lagoon habitats host large numbers of hydrophilic plant species, rich benthic communities and plankton as well as animal species including many types of fish, amphibians, reptiles, insects and small mammals. Lagoons are usually part of broader river deltas with occasional fresh water surges, reed beds, brackish swamps, all of which contribute to a very rich variety of fauna and flora.

Fish in lagoons are divided into non migratory, which spend all their life in the lagoon, and migratory, which visit the lagoon usually just to lay their eggs. In the Mediterranean a "lagoon phase" is the general rule for the young members of all marine species of fish.
Until the mid 20th century, lagoons in the Mediterranean were often afflicted by malaria epidemics, bearing extensive, large-scale aquaculture (*valicultura*) as the only viable commercial activity. Many lagoons were therefore drained and exploited for agricultural purposes. The development of modern aquaculture techniques led to intensive and semi intensive exploitation of lagoon fish stocks, rendering them commercially attractive. These practices are to a certain extent compatible with the preservation of the ecological wealth of lagoons.

Nevertheless, lagoons are not just threatened by draining, but also by other anthropogenic activities, such as river deviation linked to the construction of dams resulting in decreased organic matter in river estuaries. The dynamic equilibrium between rivers bringing organic matter into the lagoon and the sea distributing this matter is disrupted. As the sand belts gradually dissolve the lagoon may transform into a bay, losing its unique physical and biological characteristics.
In general, marine degradation imposes several negative socioeconomic pressures on various other economic sectors such as tourism and commercial fishing with subsequent loss of jobs and income.

According to UNEP/MAP, marine pollution in the Mediterranean has increased. On its shores there exist 584 big cities, 55 refineries, 180 thermoelectric power stations, 238 desalination plants. In addition, the Mediterranean Sea is burdened by the chemical pollution carried from the rivers of Central Europe; is the recipient of 17% of global oil pollution; and endures the implications of intensive coastal activities which degrade its coasts and beaches. On top of that 30% of the world's maritime transport is carried out in its waters.

34. Aerial photo of the Lighthouse of the Navy on the *Aphrodite's isle*, *Axios Delta*, Greece
© MB of Axios-Loudia-Aliakmonas rivers/George Chatzispyrou

35. Aerial photo of the meandering formations,
Evros Delta, border between Greece and Turkey

Ecosystem of internal waters: lakes and flowing waters

Key factors in any **lake**'s ecosystem include its size, shape and volume, its average and maximum depth, the length of its shoreline, the geology of the watershed[3] it belongs to, the climate, as well as the commercial activities within. A critical factor for the lake's living organisms is the distance from the shore.
In lakes, just as in seas, water masses can be oligotrophic, that is, with low biomass quantities and low concentrations of nutrients, or eutrophic, with a surplus of nutrients and high biomass productivity.

Natural eutrophication of lakes (opposite to the anthropogenic one) is a natural process: From the moment of its birth, a lake follows a series of phases, with the last one being its "death", meaning its disappearance. Due to accumulation of organic matter rich in silt carried by rivers and rain, a lake's depth gradually decreases. Biocommunities of plants and animals evolve and the productivity of the water body gradually increases. In this way the geological history of every lake starts with low productivity (oligotrophic), continues with medium productivity (mesotrophic) and results in high productivity (eutrophication). This aging process is very slow and can last hundreds or even thousands of years, depending on morphometric, soil and climatic features. Eutrophication accelerates the siltification of lakes little by little transforming them into swamps until they finally disappear. This is not necessarily the fate of every lake but rather the most likely outcome of evolution.

Anthropogenic eutrophication caused by human intervention is a major problem for most lakes in temperate plains, which have rapidly deteriorated in the last decades. In most cases agriculture has been mostly applied lacking proper planning and impact assessment on the aquatic environment. As a result, the growing demand for water combined with the increasing fertilizer and pesticide runoff exert pressure on lake ecosystems. The increased urbanisation and industrialisation worsen the situation. However, anthropogenic eutrophication is a phenomenon that can be reversed. Proper management of the ecosystem that makes use of the existing knowledge of the environmental functions and the best available technology can solve many problems, and even lead to certain benefits.

Flowing water ecosystems are characterized by permanent or seasonal surface flowing water, such as rivers and flood streams. The configuration or arrangement of the natural stream courses in a specific area is called a hydrographic network. It is related to local geologic and geomorphologic features and history. Groundwater has its own basin of drainage, which does not necessarily coincide with that of the basin's surface water.
Along the course of a river, from its source downstream, the physical parameters (width, depth, water velocity and volume, temperature) constantly change. Inevitably,

3. A watershed can be defined as the area of land that drains to a particular point along a stream or a system of streams

habitats along the longitudinal stream gradient of a river also vary and can be thought of as a "continuum" along which the river's bio-communities are in a dynamic balance. Where species are reduced due to an external factor there is a tendency for more effective use of the available food sources, thus minimising the losses. Contrary, new species may be introduced in the habitat where food is abundant. If a dominant species disappears because of a fluctuation in an environmental parameter (such as a change in temperature) it will be replaced by another. It is evident that such variations in species distribution are to be expected throughout the year.

Each flowing stream has its own specific features, and classification on the basis of its bio-communities that live in it is difficult. Nevertheless, efforts have been made to categorize parts of streams and rivers in zones-sections with similar environmental conditions, defined by the presence of certain indicator species.

Wetlands
A wetland is an area that is covered by shallow waters or is saturated by water. The prolonged presence of water creates conditions that favour the growth of specially adapted plants (hydrophytes).

According to the Ramsar Convention on Wetlands they are defined as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed 6 metres ... Wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than 6 metres at low tide lying within the wetlands".

Wetlands can be natural or artificial, coastal or inland. Coastal wetlands are usually associated with river deltas and estuaries. Inland wetlands are most common on floodplains along rivers, lakes and streams. Artificial wetlands are linked with anthropogenic interventions such as dams, mineral mining (e.g. quarries and salt mines), as well as with specific cultivation practices (e.g. rice fields).

Wetlands are a valuable resource for the planet because of their rich biodiversity and productivity. They host many important species of fauna and flora (e.g. plant species and invertebrates) while providing refuge to many migrating fish and birds, plenty of food and favourable wintering conditions. Their hydro-regulating role is significant as is their effect on climate and on bio-community composition. Wetlands contribute in controlling water flow and fluctuation levels and many commercial fish species rely on them for reproduction.

Their rich biodiversity is essential for improving crops and livestock breeding; scientific research, particularly in medicine; for technological innovation and advancement in various economic sectors that use live organisms. They also provide water for agricultural and drinking purposes, they recharge the water table, they minimise the effects of floods and other extreme weather phenomena (heat waves, frost), they support fish stocks, they feed the livestock, they function as filters by diluting pollutants. Finally, they offer the opportunity for recreation, sport, tourism, education and research, and they are intrinsically linked with local history, mythology and traditions.

36. Pink flamingos, *Camargue*, France