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Ecological principles and function of natural ecosystems

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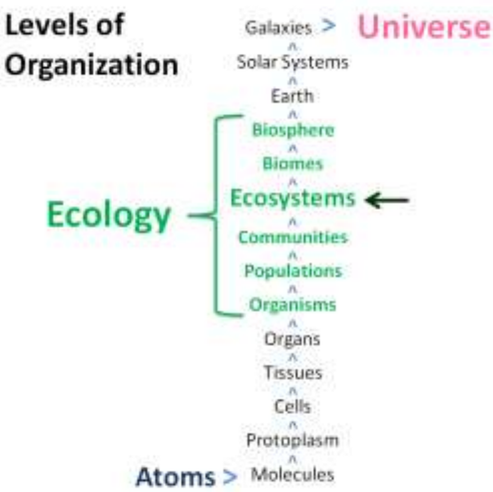
Summary

1. Hierarchy of living world

The larger objective of ecology is to understand the nature of environmental influences on individual organisms, populations, communities and ultimately at the level of the biosphere. If ecologists can achieve an understanding of these relationships, they will be well placed to contribute to the development of systems by which humans could sustainably use ecological resources.

This is an extremely important goal because humans are, after all, completely reliant on ecologically goods and services as their only source of sustenance.

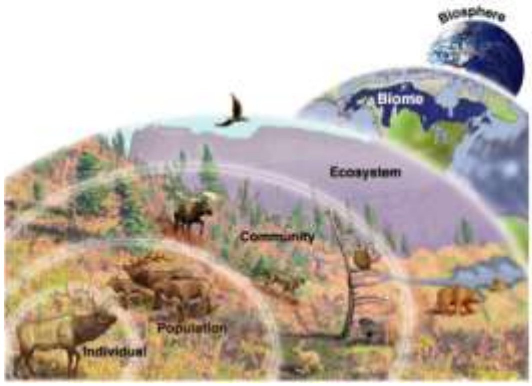


When studying the living world you may consider two levels of integration : the biological levels and the ecological levels :

• Biological levels
atoms ->molecules -> organelles -> cells -> tissues -> organs -> organisms

• Ecological levels :
populations -> communities -> ecosystems -> landscapes -> biomes -> biosphere

In both cases you have the same properties for each of the different levels: at every level of biological or ecological organization emerge new properties that were absent from the previous level. A level of any type represents a much larger entity than the sum of its parts.



This property invalidates predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behaviour, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision makers.

2. What is Ecology?

The word "ecology" ("Ökologie") was introduced in 1866 by the German scientist Ernst HAECKEL from two Greek words :οἶκος, "house"; -λογία, "study of". Ecology is the study of interactions among organisms and their environment, biological (biotic) or non biological (non biotic or abiotic). Ecology include many aspects: biological diversity (biodiversity), production and biomass, distribution of population (biogeography), as well as competition between them within and among ecosystems

An understanding of how biodiversity affects ecological function is an important focus area that seeks to explain the main mechanisms occurring at different levels of ecosystems:

- Life processes, interactions and adaptations;
- The movement of nutrients and energy through living communities;
- The successional development of ecosystems, and
- The abundance and distribution of organisms and biodiversity in various environments.
- Consequences of anthropic actions on various ecosystems and how to manage them.

Ecology is an interdisciplinary field that includes Life and Earth Sciences. Ecology is not restricted to environment, environmentalism, natural history, or environmental sciences but also includes evolutionary biology, genetics, ethology.

Ecology is a human science as well. There are many practical applications of ecology in conservation biology, natural resources management, urbanisation and urban ecology, community health, economics, basic and applied sciences.

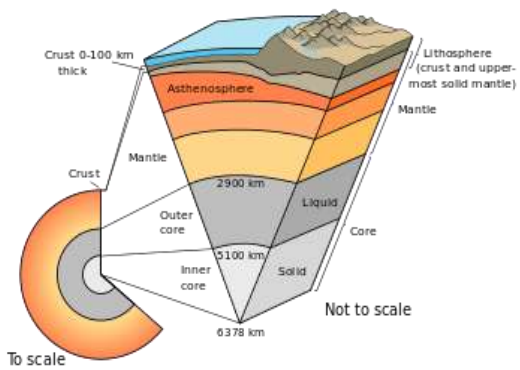
Organisms and resources compose ecosystems which, in turn, generate biophysical feedback mechanisms that moderate processes acting on living and non living components of the planet. Ecosystems produce animal and vegetal biomasses production), and sustain life-supporting functions through the regulation of climate, biogeochemical cycles, soil formation, water filtration, erosion limitations and the limitation of the greenhouse effect.

3. The Biosphere

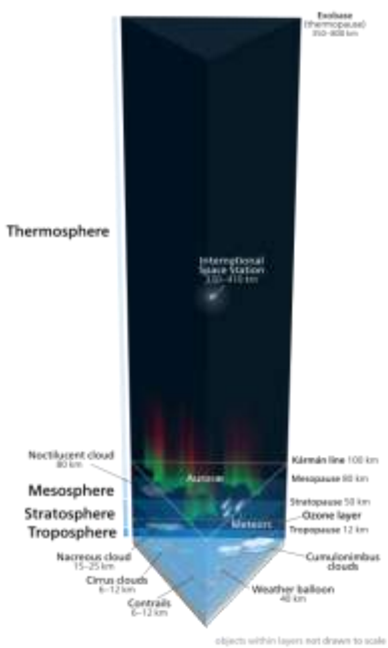
The **biosphere** is the global sum of all ecosystems. It is a closed system (apart from solar and cosmic radiation and heat from the interior of the Earth), and largely self-regulating. The biosphere is postulated to have evolved, beginning with a process of biopoesis, a process by which living organisms are thought to develop from non living matter, and the basis of a theory on the origin of life on Earth and biogenesis, life arising from pre existing life. Life should have appeared at least some 3.5 billion years ago.

The biosphere is the global ecological system integrating all living beings and their relationships, including their interaction with the elements of the lithosphere, hydrosphere and atmosphere.

- **lithosphere** : the rigid outermost shell of our rocky planet . The lithosphere includes the crust and the uppermost mantle, which constitute the hard and rigid outer layer of the Earth. The lithosphere is broken into tectonic plates.



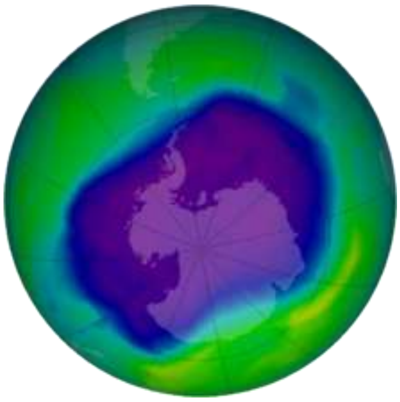
- **atmosphere**: the atmosphere is a layer of gases surrounding the planet and retained by Earth's gravity. The atmosphere protects life by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night (the diurnal temperature variation). By volume, dry air contains 78% nitrogen, 21% oxygen, 1% argon but only 0,04% of carbon dioxide. Air also contains a variable amount water vapour, on average around 1%. Several layers can be distinguished in the atmosphere, based on characteristics such as temperature and composition (troposphere, stratosphere, mesosphere, thermosphere, exosphere) and life is only known to be found in troposphere.



Until the Earth's protective atmosphere was formed, there was no life on Earth except in the seas. The atmosphere is vital for life. However, the quality of the air is damaged by gases from our daily activities like driving cars, heating houses and manufacturing products in factories. Besides the atmosphere, almost all living things need freshwater. Yet humans pollute and waste it recklessly. The quality of freshwater resources is declining due to pollution and the availability of water poses serious problems in large parts of the world. More than a fifth of the world's population does not have enough.

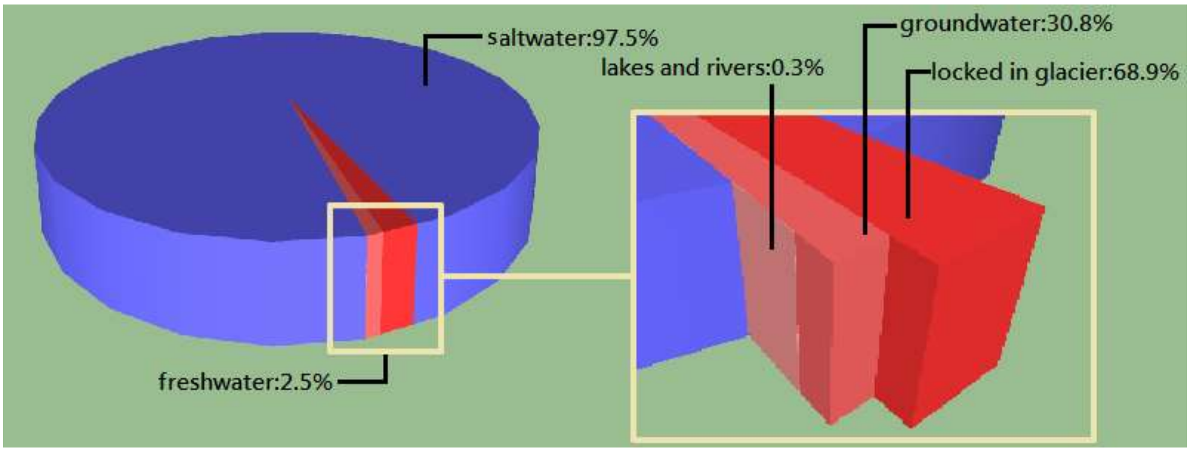
-> Depletion of the Ozone Layer

The Ozone Layer is a layer in the upper atmosphere where a form of oxygen, ozone or trioxygen (03) is found. This layer protects us from harmful ultraviolet (UV-B) radiation from the sun. In the seventies was observed a "hole" in this layer at the poles. The cause of this hole turned out to be the use of substances which destroy ozone, in particular the chlorofluorocarbons (CFCs). As a result of the reduction of this layer the UV-B radiation that reaches the Earth increased with an increase of skin cancer risks and eye problems.



The depletion of the ozone layer is a clear example that the environment does not have national boundaries. CFCs were used in industrialized areas, but its effect concentrated at the polar areas.

- **hydrosphere** refers to the combined mass of water found on, under, and over the surface. A scientific assessment estimates that there are about 1400 millions km3 of water on earth. This includes water in liquid and frozen forms in continental waters, glaciers and oceans. Saline water accounts for 97.5% of this amount and Fresh water for only 2.5%. Besides the atmosphere, almost all living things need freshwater. Yet humans pollute and waste it recklessly. The quality of freshwater resources is declining due to pollution and the availability of water poses serious problems in large parts of the world. More than a fifth of the world's population does not have enough.



4. What is an ecosystem

An **ecosystem** is a community of living organisms, the biocenosis, (plants, animals and microbes) in conjunction with the non living components (air, water and mineral soil), the biotope, interacting as a system. These biotic and abiotic components are regarded as linked together through nutrient cycles and energy flows. As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment, they can be of any size but usually encompass specific, limited spaces (although some scientists say that the entire planet is an ecosystem).

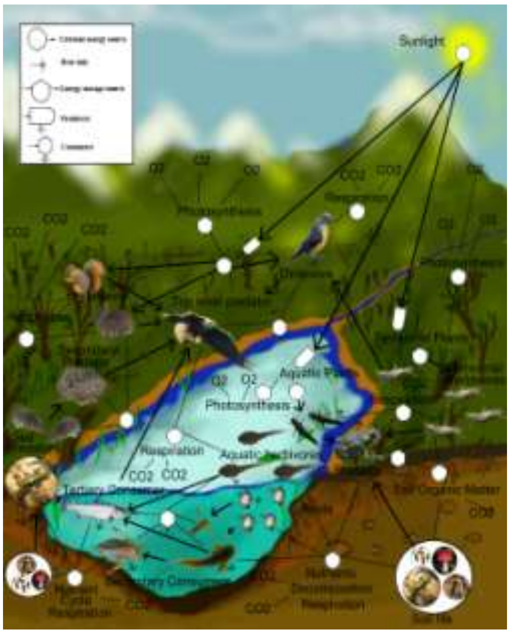
Ecosystems are composed of dynamically interacting parts including organisms, the communities they make up, and the non-living components of their environment. Ecosystem processes, such as primary and secondary productions, cycle of nutrients, pedogenesis, etc. regulate the flux of energy and matter through ecosystems.

The "species" is the ecosystem basis. This term refers to all organisms of the same kind that are potentially capable, under natural conditions, of breeding and producing fertile offspring. The members of a species living in a given area at the same time constitute a population. All the populations living and interacting within a particular geographic area make up a biological (or biotic) community. The living organisms in a community together with their non living or abiotic environment make up an ecosystem. In theory, an ecosystem (and the biological community that forms its living component) can be as small as a few insects living in a rain puddle or as large as the American prairie stretching across thousands of kilometres.

Energy, water, nitrogen and soil minerals are other essential abiotic components of an ecosystem. The energy that flows through ecosystems is obtained primarily from the sun. It generally enters the system through photosynthesis. By feeding on plants (called primary producers) and on one another, animals (secondary producers) play an important role in the movement of matter and energy through the system and influence the quantity of plant and microbial biomass present. By breaking down dead organic matter, decomposers release carbon back to the atmosphere and facilitate nutrient cycling by converting nutrients stored in dead biomass back to a form that can be readily used by plants and other microbes.

Ecosystems are dynamic entities controlled both by external and internal factors. External factors such as climate, soil, topography, control the overall structure of an ecosystem and the way things work within it, but are themselves more or less influenced by the ecosystem.

Internal factors not only control ecosystem processes but are also controlled by them and are often subject to feedback loops. While the resource inputs are generally controlled by external processes like climate and parent material, the availability of these resources within the ecosystem is controlled by internal factors like decomposition, competition or shading. Other internal factors include disturbance, succession and the types of species present. Although humans exist and operate within ecosystems, their cumulative effects are large enough to influence external factors like climate.



The scale of ecological dynamics can operate like a closed system, such as a pond, to broader scale influences, such as ocean or atmosphere. Hence, ecologists classify ecosystems hierarchically by analysing data collected from finer scale units to the largest ones.

• Ecozone :

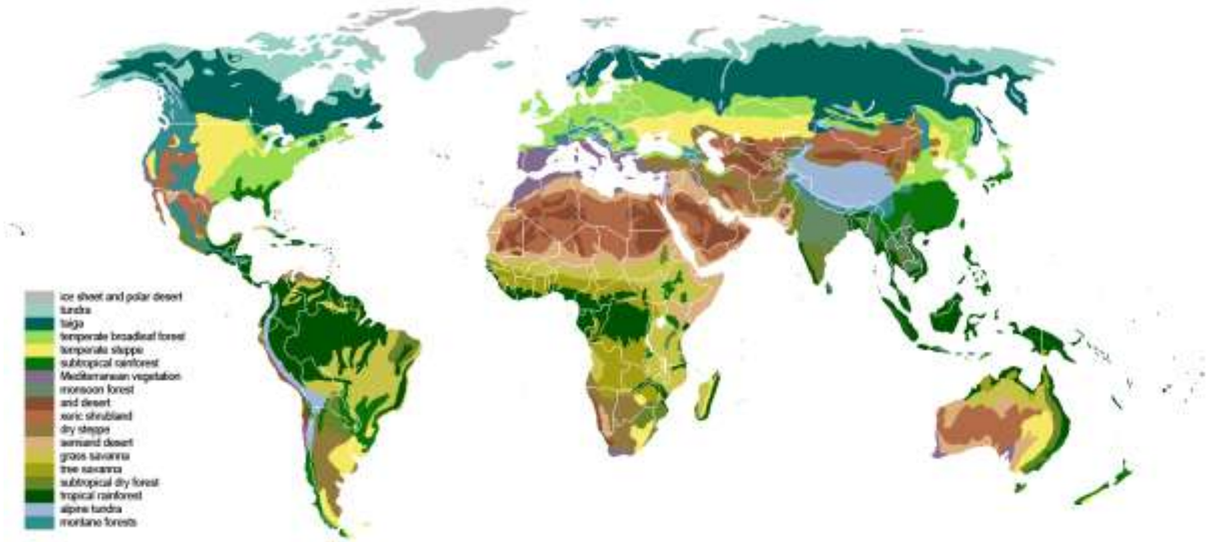
An **ecozone** is the broadest biogeographic division of the Earth's land surface, based on distributional patterns of terrestrial organisms. Ecozones are characterized by the evolutionary history of the organisms they contain. They are distinct from biomes, also known as major habitat types, which are divisions of the Earth's surface based on *life form*, or the adaptation of plants and animals to climatic, soil and other conditions. The patterns of plant and animal distribution in the world's ecozones were shaped by the process of tectonic plates, which has redistributed the world's land masses over geological history.

• Biome

Biomes are climatically and geographically defined as contiguous areas with similar climatic conditions such as communities of plants, animals and soil organisms, and are often referred to as ecosystems. Biomes are larger units of organization that categorize regions of the Earth's ecosystems, mainly according to the structure and composition of vegetation. Biomes are characterized by similar climax vegetation.

Each ecozone may include a number of different biomes. A tropical moist broadleaf forest in Central America, for example, may be similar to one in New Guinea in its vegetation type and structure, climate, soils, etc., but these forests are inhabited by plants and animals with very different evolutionary histories.

There are different methods to define the continental boundaries of biomes dominated by different functional types of vegetative communities that are limited in distribution by climate, precipitation, weather and other environmental variables. Biomes include tropical rainforest, temperate deciduous forest, taiga, tundra, hot desert, polar desert, …



• Ecosystem

• Ecological community

An ecological community is a naturally occurring group of native plants, animals and other organisms that are interacting in a unique habitat (same place). Its structure, composition and distribution are determined by environmental factors such as soil type, position in the landscape, altitude, climate and water availability.

• Population

A population is an aggregation of individuals of the same species that are actively interbreeding, or exchanging genetic information. Evolution refers to changes over time in the aggregate genetic information of a population. Evolution can occur as a result of random "drift," as directional selection in favour of advantageous phenotypes, or as selection against less well-adapted genotypes.

• Habitat/biotope

The habitat of a species describes the environment over which a species is known to occur and the type of community that is formed as a result. Biotope and habitat are sometimes used interchangeably, but biotope applies to a community's environment (a community or biocenosis is an assemblage or associations of two or more different species occupying the same geographical area and in a particular time), whereas habitat applies to a species' environment.

• Ecotone

It is a transition area of vegetation between two ecosystems or biomes), where two communities meet and intermingling integrate such as, forest, grassland, mangroves, littoral zones, reed beds, …. It has some of the characteristics of each bordering biological community and often contains species not found in the overlapping communities. An ecotone may exist along a broad belt or in a small pocket. The influence of the two bordering communities on each other is known as the edge effect. An ecotonal area often has a higher density of organisms of one species, a strong productivity and a greater diversity of species belonging to each of the two communities.

Ecotones are particularly significant for mobile animals, as they can exploit more than one set of habitats within a short distance. The ecotone contains not only species common to the communities on both sides; it may also include a number of highly adaptable species that tend to colonize such transitional areas. The phenomenon of increased variety of plants as well as animals at the community junction is called the edge effect and is essentially due to a locally broader range of suitable environmental conditions or ecological niches.

• Niche

A niche is "a set of biotic and abiotic conditions in which a species is able to persist and maintain stable population sizes." The ecological niche is a central concept in the ecology of organisms.

Biogeographical patterns and range distributions are explained or predicted through knowledge of a species' features (trait) and niche requirements. Species have functional features that are uniquely adapted to the ecological niche.

The habitat plus the niche is called the ecotope, which is defined as the full range of environmental and biological variables affecting an entire species.

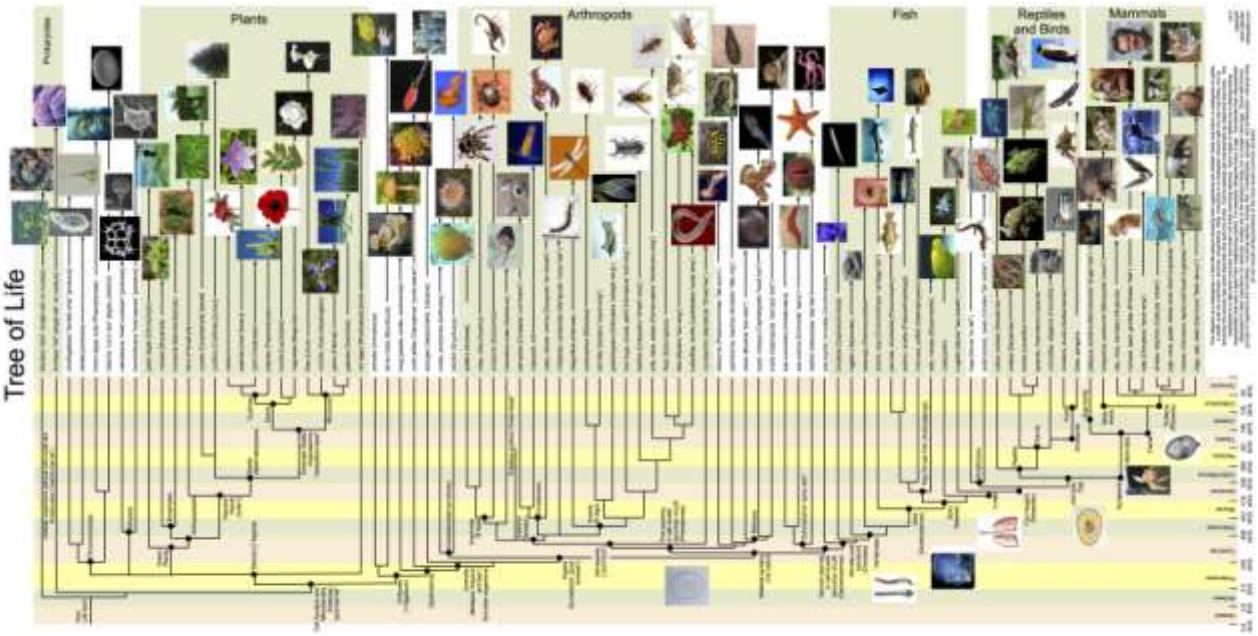
5. Biological classification,

Biological classification is a method of scientific taxonomy used to group and categorize organisms into groups such as genus and species. These groups are known as taxa (singular: **taxon**).

Modern biological classification has its root in the work of Carolus Linnaeus, who grouped species according to shared physical characteristics and introduced binomials composed of generic name (genus) followed by a specific epithet (species). These groupings have since been revised to improve consistency with the Darwinian principle of common descent, a group of organisms having a common ancestor.

With the introduction of the cladistic method in the early 20th century (from ancient Greek κλάδος, *klados*, "branch") Cladistics is a particular method of hypothesizing relationships among organisms based on the idea that members of a group share a common evolutionary ancestor) Cladistics is now accepted as the best method available for phylogenetic analysis, for it provides an explicit and testable hypothesis of relationships between organisms. In phylogenetic taxonomy organisms are grouped purely on inferred evolutionary relatedness (based either on classical evidence of morphology, chemistry, physiology, ecology or molecular evidence or both). Molecular phylogenetics which uses DNA sequences as data, has driven many recent revisions.

	Archaebacteria	Eubacteria	Protista	Fungi	Plantae	Animalia
Cell Type	Prokaryotic	Prokaryotic	Eukaryotic	Eukaryotic	Eukaryotic	Eukaryotic
Cell Structure	Have cell walls	Have cell walls made of peptidoglycan	Have nucleus, mitochondria; some have chloroplasts	Have cell walls made of chitin; have nucleus and mitochondria; no chloroplasts	Have cell walls made of cellulose; have a nucleus	Have a nucleus and mitochondria; no chloroplasts
Body Structure	unicellular	unicellular	Mostly unicellular, some are colonial	Mostly multicellular	multicellular	multicellular
Mode of Nutrition	Autotrophic or heterotrophic	Autotrophic or heterotrophic	Autotrophic or heterotrophic	heterotrophic	Autotrophic	heterotrophic
Examples	Methanogens, halophiles, thermophiles	*Anabaena*, *Rhizobium*, *Streptomyces*	Amoeba, paramecium, seaweeds	Mushroom, yeast, *Penicillium*	Ferns, flowering plants	Corals, fish, duck



6. Ecosystem processes

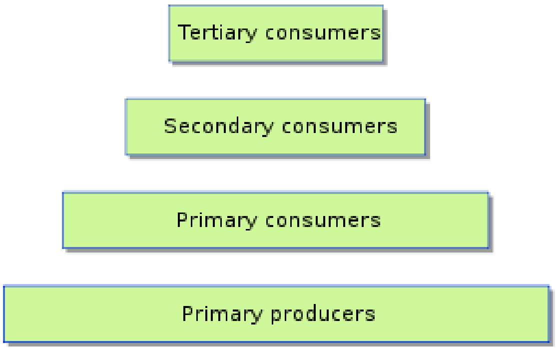
To structure the study of ecology into a conceptually manageable framework, the biological world is organized into a nested hierarchy, ranging in scale from genes, to tissues, to organs, to organisms, to species, to populations, to communities, to ecosystems to biomes and to the level of the biosphere.

This framework exhibits non-linear behaviours; this means that "effect and cause are not directly proportional", so that small changes of critical variables, such as the number of nitrogen fixers (converting nitrogen N2 into ammonium NH4), can lead to disproportionate, perhaps irreversible, changes in the system properties.

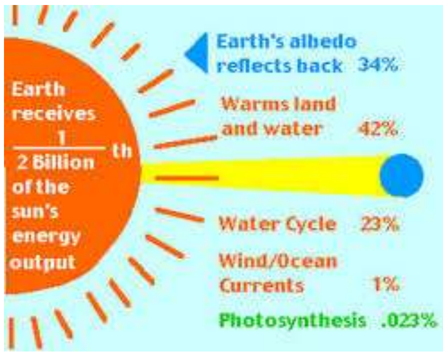
An ecosystem is basically a system that produces organic and mineral matter. The organic production refers to the rate of biological mass or biomass produced by an ecosystem. It is usually expressed in units of mass produced per unit surface (or volume) per unit time, for instance grams per square metre per day ($g\ m^{-2}\ d^{-1}$). The mass unit may relate to dry matter or to the mass of carbon produced. Productivity of autotrophs such as plants is called **primary productivity**, while that of heterotrophs such as animals is called **secondary productivity**.

Energy and Carbon enter ecosystems through photosynthesis, are incorporated into living tissue, transferred to other organisms that feed on the living and dead plant matter, and eventually released through respiration. Most mineral nutrients are recycled within ecosystems.

6.2. Radiation: heat, temperature and light



The biology of life operates within a certain range of temperatures. Heat is a form of energy that regulates temperature. Heat affects growth rates, activity, behaviour and primary production. Temperature is largely dependent on the incidence of solar radiation. The latitudinal and longitudinal spatial variation of temperature greatly affects climates and consequently the distribution of biodiversity and levels of primary production in different ecosystems or biomes across the planet. Heat and temperature relate importantly to metabolic activity. Poikilotherms for example, whose internal temperature varies considerably, have a body temperature that is largely regulated and dependent on the temperature of the external environment. In contrast, homeotherms, regulate their internal body temperature by expending metabolic energy.



There is a relationship between light, primary production, and ecological energy budget. Sunlight is the primary input of energy into the planet's ecosystems. Light is composed of electromagnetic energy of different wavelengths. Radiant energy from the sun generates heat, provides photons of light measured as active energy in the chemical reactions of life.
Less than 1% of the solar energy reaching Earth's surface is absorbed by green plants or **algae** and used in **photosynthesis.** However, this fixed solar energy is the energetic basis of the structure and function of ecosystems.

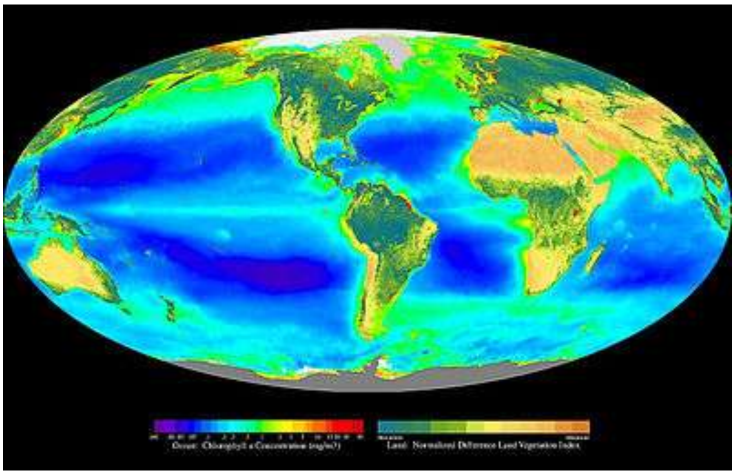
Plants, algae, and some bacteria absorb light and assimilate the energy through photosynthesis. Organisms capable of assimilating energy by photosynthesis or through inorganic fixation of H2S are autotrophs responsible for primary production.

6.1. Primary production

Primary production is the production of new organic matter from inorganic carbon sources such as CO_2 and H_2O. Organisms responsible for primary production include land plants, marine algae and some bacteria (including cyanobacteria)

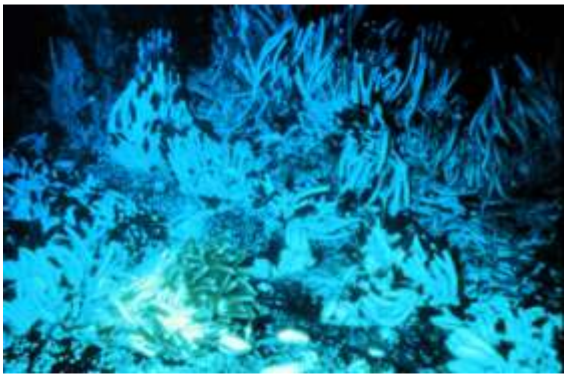
Primary production mainly occurs through the process of photosynthesis when plants capture energy from light by specialized organelles, chloroplasts, and use it to combine carbon dioxide and water to produce carbohydrate and oxygen and synthesise organic molecules:

$$CO_2 + H_2O + \textit{light} \rightarrow CH_2O + O_2$$



A small part of primary production by chemoautotrophs also occurs through chemosynthesis, i.e. the conversion of carbon molecules (usually carbon dioxide or methane) into organic matter using the oxidation of inorganic molecules (hydrogen, hydrogen sulphide, for instance) as a source of energy, rather than sunlight during photosynthesis:

$$CO_2 + O_2 + 4\ H_2S \longrightarrow CH_2O + 4\ S + 3\ H_2O$$



Chemoautotrophs are mainly bacteria and they live in the rare site at which hydrogen molecules are available, for instance in deep hydrothermal springs from oceanic rifts or in continental hot springs.

In both cases, the end point is reduced carbohydrates (CH_2O), typically molecules such as glucose or other sugars.

The energy incorporated through this process supports life on earth, while the carbon makes up much of the organic matter in living and dead biomass, soil carbon, fossil fuels, etc. It also drives the carbon cycle which influences global climate via the greenhouse effect.

The photosynthesis carried out by all the plants in an ecosystem is called the gross primary production (GPP). About 48–60% of the GPP is consumed in plant respiration. The remainder, that portion of GPP that is not used up by respiration, is known as the net primary production (NPP).

Total photosynthesis is limited by a range of environmental factors. These include the amount of light available, the amount of leaf area a plant has to capture light (shading by other plants is a major limitation of photosynthesis), rate at which carbon dioxide can be supplied to the chloroplasts to support photosynthesis, the availability of water, and the availability of suitable temperatures for carrying out photosynthesis

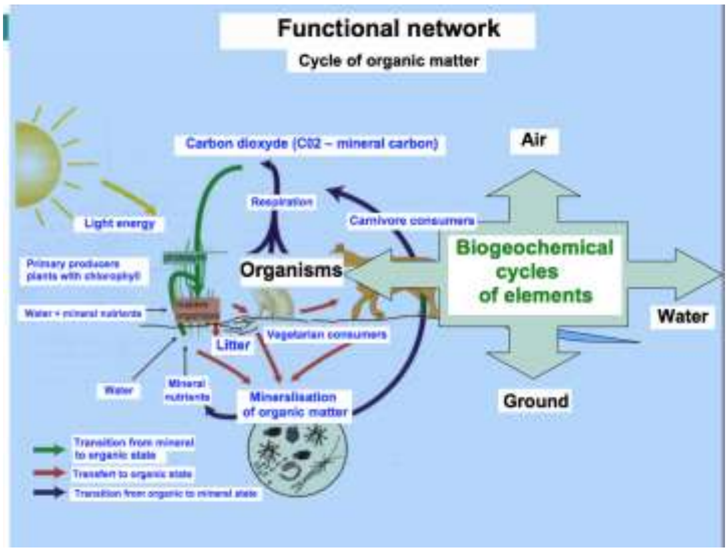
6.3. Secondary production

Secondary production is the production of biomass of heterotrophic organisms (consumers) in an ecosystem. This is driven by the transfer of organic material between trophic levels and represents the quantity of new organic constituents created through the use of assimilated food. Secondary production is sometimes defined to only include consumption of primary producers by herbivorous consumers (with tertiary production referring to carnivorous consumers) but is more commonly defined to include all biomass generation by heterotrophs. Organisms responsible for secondary production include animals, protists, fungi, and many bacteria.

Secondary production can be estimated through a number of different methods depending of the ecosystem and the nature of the study.

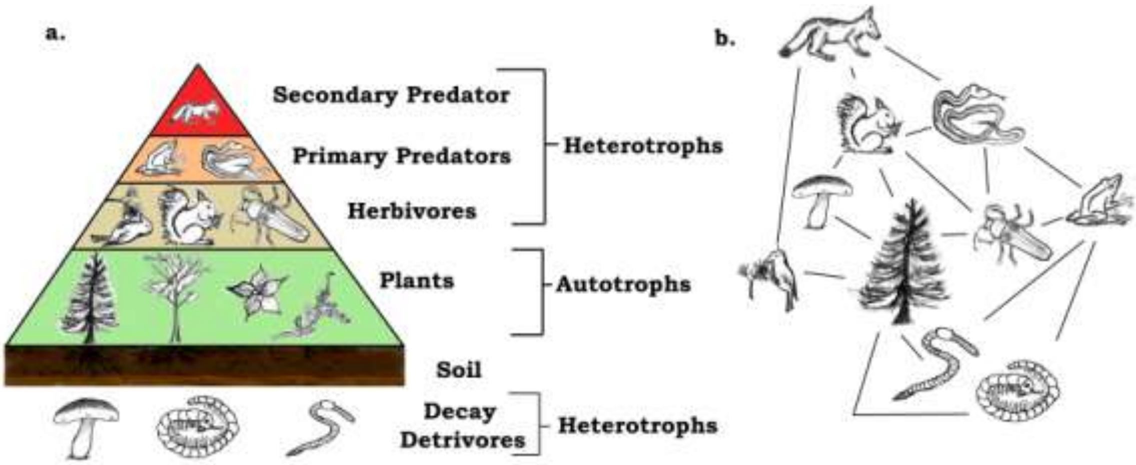
6.4. Food web and trophic levels

A **food web** (food cycle, food chain) is a functional network depicting feeding connections (what-eats-what) in an ecological community and hence is also referred to as a consumer-resource-system. One can broadly put all life forms into one of two categories called trophic levels: the autotrophs, producing organic matter from inorganic substances and the heterotrophs feeding on autotrophs.



A gradient exists between trophic levels running from complete autotrophs that obtain their sole source of carbon from the atmosphere, to heterotrophs that must feed to obtain organic matter, with mixotrophs using a mix of different sources of carbon: they partially obtain organic matter from sources other than the atmosphere (bacteria, unicellular algae, carnivorous plants,).

Food chains start at trophic level 1 with primary producers such as plants, move to herbivores at level 2, predators at level 3 and typically finish with carnivores at level 4 or 5. The path along the chain can form either a one-way flow or a food "web". Ecological communities with higher biodiversity form more complex trophic paths.



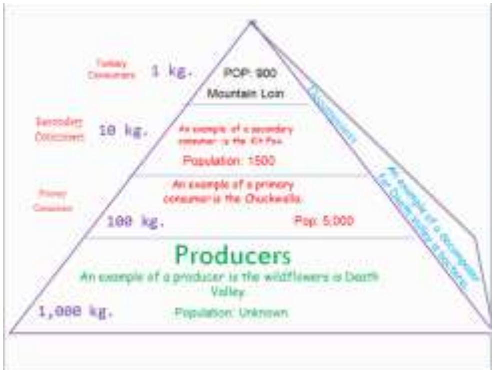
6.5. Trophic cascade and ecology flow

Food webs depict energy flow via trophic linkages. Energy flow is directional, which contrasts against the cyclic flows of material through the food web systems. Energy flow "typically includes production, consumption, assimilation, non-assimilation losses (feces), and respiration (maintenance costs)." In a very general sense, energy flow (E) can be defined as the sum of metabolic production (P) and respiration (R), such that E=P+R.

The biomass of something is equal to its energy content: mass and energy are closely linked. "Organisms usually extract energy in the form of carbohydrates, lipids, and proteins. These polymers have a dual role as supplies of energy as well as building blocks; the part that functions as energy supply results in the production of nutrients (and carbon dioxide, water, and heat). Excretion of nutrients is, therefore, basic to metabolism." The units in energy flow webs are typically a measure mass or energy per m^2 per unit time. Different consumers are going to have different metabolic assimilation efficiencies in their diets. Each trophic level transforms energy into biomass. Energy flow diagrams illustrate the rates and efficiency of transfer from one trophic level into another and up through the hierarchy.

It is the case that the biomass of each trophic level decreases from the base of the chain to the top. This is because energy is lost to the environment with each transfer as entropy. About eighty to ninety per cent of the energy is expended for the organism's life processes or is lost as heat or waste. Only about ten to twenty per cent of the organism's energy is generally passed to the next organism. The amount can be less than one per cent in animals consuming less digestible plants, and it can be as high as forty per cent in zooplankton consuming phytoplankton. Graphic representations of the biomass or productivity at each tropic level are called ecological pyramid or trophic pyramids. The transfer of energy from primary producers to top consumers can also be characterized by energy flow diagrams.

A trophic pyramid at least takes into account three levels, and generally four or five. For instance this one referring to an aquatic ecosystem with seven steps:
- level 3: 10.000 water shrimps feeding on zooplankton;
- level 4: 1.000 bleak (cyprinidae feeding on shrimps)
- level 5: 100 perches
- level 6: 10 pikes
- level 7: 1 osprey (eagle)



7. Population ecology and population dynamics

Population ecology studies the dynamics of species populations and how these populations interact with their environment. A population consists of individuals of the same species that live, interact and migrate through the same niche and habitat.

A primary law of population ecology is the Malthusian growth model which states, "a population will grow (or decline) exponentially as long as the environment experienced by all individuals in the population remains constant." Simplified population models usually start with four variables: death, birth, immigration and emigration.

An example of a basic population model describes a closed population, such as on an island, where immigration and emigration does not take place. In this model three factors have to be considered : the number of births, *t*he number of deaths and natural resource.

At this stage, we have to consider two approaches: a natural ecosystem and another where the action of man is present.

In the first approach, the ecosystem is supposed to be permanent as there are natural mechanisms that regulate the fluctuations of populations and resources (el Nino) ; on the other hand, if man is present and if there is an increase of birth and a depletion of natural resources, the ecosystem may disappear as in Easter Island.

Population ecology builds upon these introductory models to further understand demographic processes in real study populations. Commonly used types of data include life history, fecundity, survivorship, and these are analysed using mathematical techniques for managing wildlife stocks and setting harvest quotas for studying population dynamics.

Population dynamics studies short-term and long-term changes in the size and age composition of populations and the biological and environmental influencing those changes. Population dynamics deals with the way populations are affected birth and death rates, ageing population and population decline, epidemiology (including parasitism), and by immigration and emigration.

One common mathematical model for population dynamics is the exponential growth model. With the exponential model, the rate of change of any given population is proportional to the already existing population.

When a population is overexploited it can reach minimum viable rate that is a lower limit below which it can't survive in the wild. More specifically, MVP is the smallest possible size at which a biological population can exist without facing extinction from natural disasters or demographic, environmental, or genetic stochasticity (partly resulting from randomness). The term "population" usually refers to the population of a species in the wild. For example, the undomesticated dromedary camel is extinct in its natural wild habitat; but there is a domestic population in captivity and an additional "wild" population in Australia.

Minimum viable population is usually estimated as the population size necessary to ensure between 90 and 95 per cent probability of survival in the future. If these conditions are not met, there is a risk of extinction. Causes of extinction may include inbreeding (consanguinity), natural disaster, climate change, epidemic. MVP does not take human intervention into account.

8. Disturbance and resilience

Ecosystems are regularly confronted with natural environmental variations and disturbances over time and geographic space. A disturbance is any process that removes biomass from a community, such as a fire, flood, drought, or predation. Disturbances occur over vastly different ranges in terms of magnitudes as well as distances and time periods, and are both the cause and product of natural fluctuations in death rates, species assemblages, and biomass densities within an ecological community. These disturbances create places of renewal where new directions emerge from the patchwork of natural experimentation and opportunity.

Ecological resilience is a cornerstone theory in ecosystem management. Biodiversity fuels the resilience of ecosystems acting as a kind of regenerative insurance. R**esilience** is the capacity of an ecosystem to respond to a perturbation or disturbance by resisting damage and recovering quickly. Such perturbations and disturbances can include stochastic events such as fires, flooding, windstorms, insect population explosions, and human activities such as deforestation and the introduction of exotic plant or animal species. Disturbances of sufficient magnitude or duration can profoundly affect an ecosystem and may force an ecosystem to reach a threshold beyond which a different regime of processes and structures predominates. Human activities that diminish ecosystem resilience such as reduction of biodiversity, over exploitation of natural resources, pollution, land-use, and anthropogenic climate change are increasingly causing regime shift in ecosystems, often to bad and degraded conditions.

Scientists describe four critical aspects of resilience - *latitude*, *resistance*, *precariousness* - that can apply both to a whole system or the sub-systems that make it up.

- Latitude: the maximum amount a system can be changed before losing its ability to recover (before crossing a threshold which, if breached, makes recovery difficult or impossible).

- Resistance: the ease or difficulty of changing the system; how “resistant” it is to being changed;

- Precariousness: how close the current state of the system is to a limit or “threshold.”

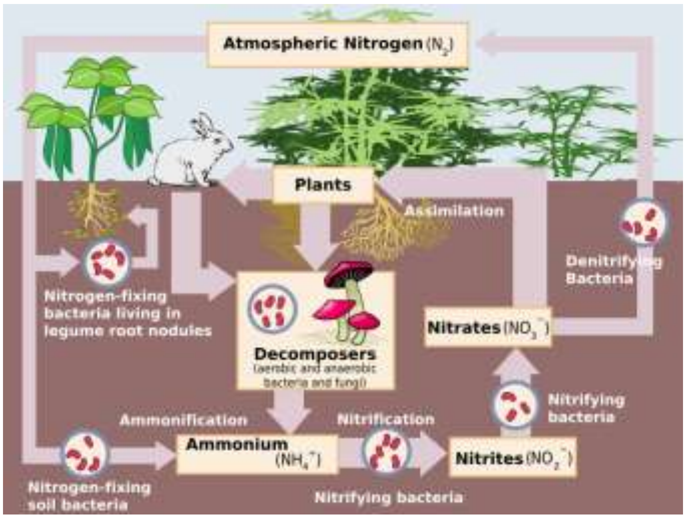
Closely linked to resilience is *adaptive capacity*, which is the property of an ecosystem that describes change in stability landscapes and resilience. Adaptive capacity in socio-ecological systems refers to the ability of humans to deal with change in their environment by observation, learning and altering their interactions.

-> Human impacts on resilience

Resilience refers to ecosystem's stability and capability of tolerating disturbance and restoring itself. If the disturbance is of sufficient magnitude or duration, a threshold may be reached where the ecosystem undergoes a regime shift, possibly permanently. Sustainable use of environmental goods and services requires understanding and consideration of the resilience of the ecosystem and its limits. However, the elements influencing ecosystem resilience are complicated. For example various elements such as the water cycle, fertility, biodiversity, plant diversity and climate, interact fiercely and affect different systems.

There are many areas where human activity impacts upon and is also dependent upon the resilience of terrestrial, aquatic and marine ecosystems. These include agriculture, deforestation, pollution, mining, recreation, overfishing, dumping of waste into the sea and climate change.

9. Nutrient cycle, decomposition and mineralization



A **nutrient cycle** (or **ecological recycling**) is the movement and exchange of organic and inorganic matter back into the production of living matter. The process is regulated by food web pathways that decompose matter into mineral nutrients. Nutrient cycles occur within ecosystems. Ecosystems are interconnected systems where matter and energy flows and is exchanged as organisms feed, digest, and migrate about. Minerals and nutrients accumulate in varied densities and uneven configurations across the planet. Ecosystems recycle locally, converting mineral nutrients into the production of biomass and on a larger scale they participate in a global system of inputs and outputs where matter is exchanged and transported through a larger system of biogeochemical cycles.

Whereas the global biogeochemical cycles describe the natural movement and exchange of every kind of particulate matter through the living and non-living components of the Earth, nutrient cycling refers to the biodiversity within community food web systems that loop organic nutrients or water supplies back into production.

Energy (solar energy) flows through ecosystems along unidirectional and noncyclic pathways, whereas the movement of mineral nutrients is cyclic. Mineral cycles include carbon cycle, sulphur cycle, nitrogen cycle, phosphorus cycle, water cycle an oxygen cycle, among others that continually recycle along with other mineral nutrients into production mechanisms.

Decomposition is the process by which organic substances are broken down into simpler forms of matter. The process is essential for recycling the matter that occupies physical space in the biome. Bodies of living organisms begin to decompose shortly after death. Although no two organisms decompose in the same way, they all undergo the same sequential stages of decomposition.

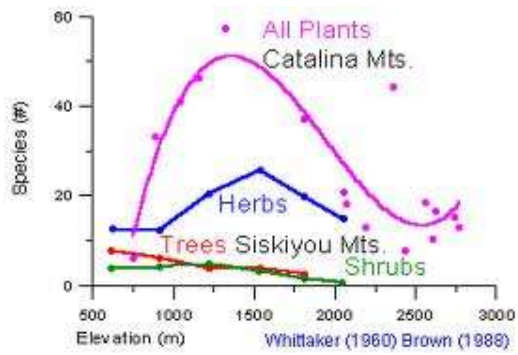
One can differentiate **abiotic degradation,** degradation of a substance by chemical or physical processes (hydrolysis), from **bio degradation,** the metabolic breakdown of materials into simpler components by living organisms, typically by microorganisms and fungi.

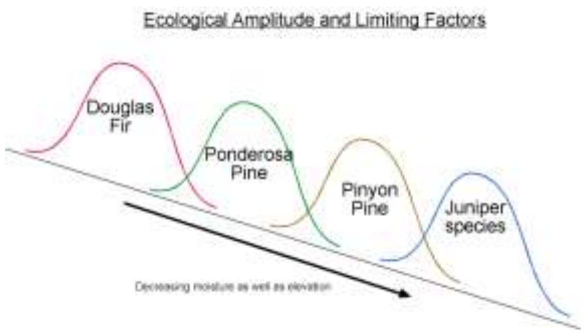
Mineralization is the final stage of decomposition. Mineralization converts organic matter into inorganic substances by soil microorganisms. These substances become available to the production of new organic matter.

10. Ecological Amplitude

The ecological amplitude (Ecological valence) is the degree of adaptation of a living organism to changes in its environment. This ecological amplitude is expressed quantitatively as the range of environmental changes within which a given species is able to carry on its normal vital activities.

The range of tolerance of a species, diagrammatically forms a bell-shaped curve.





Ecological amplitude can be examined as either the reaction of a species to individual environmental factors or to an aggregate of factors. In the first case, species that are able to tolerate a wide range of changes in the strength of an acting factor are designated by a term consisting of the name of the given factor and the prefix "eury," such as eurythermal (referring to the effects of temperature), euryhaline (salinity), and eurybathic (depth). Species that are adapted to only a narrow range of changes in a given factor are designated by the same term with the prefix "steno," for example, stenothermal and stenohaline. Species that exhibit broad ecological amplitude with respect to an aggregate of factors are called eurybionts, while species with low adaptability are called stenobionts.

Comparative studies have shown that stenotopic species have a far greater tendency to become extinct than eurytopic species. This is undoubtedly a result of the fact that eurytopic species are capable, when necessary, of reorienting themselves to a different type of resource, are capable of tolerating quite drastic climatic changes and generally occur over a broader area than stenotopic species. The size of the geographic range tends to be the decisive factor from the viewpoint of survival of the species.

Species with a narrow ecological amplitude often form good indicator species. Stenobionts are very good bio indicators when eurybionts have a too large range of requirements to indicate slight changes in their environment.

11. Ecology, environmental influences, biological interactions

Compared with the potential biological "demand," the environment has a limited ability to "supply" the requirements of life. As a result, the rates of critical ecological processes, such as productivity, are constrained by so-called limiting factors, which are present in the least supply relative to the biological demand. A limiting environmental factor can be physical or chemical in nature, and the factors act singly, but sequentially.

For example, if a typical unproductive lake is fertilized with nitrate, there would be no ecological response. However, if that same lake was fertilized with phosphate, there would be a great increase in the productivity of single-celled algae. If the lake was then fertilized with nitrate, there would be a further increase of productivity, because the ecological requirement for phosphate, the primary limiting factor had previously been satiated.

This example illustrates the strong influence that the environment has on rates of processes such as productivity, and on overall ecological development. The most complex, productive, and highly developed ecosystems occur in relatively benign environments, where climate and the supplies of nutrients and water are least limiting to organisms and their processes. Tropical forests and coral reefs are the best examples of well-developed, natural ecosystems of this sort. In contrast, environmentally stressed ecosystems are severely constrained by one or more of these factors. For example, deserts are limited by the availability of water, and tundra by a cold climate.

In a theoretically benign environment, with an unlimited availability of the requirements of life, organisms can maximize the growth of their individual biomass and of their populations. Conditions of unlimited resources might occur (at least temporarily), perhaps, in situations that are sunny and well supplied with water and nutrients. Population growth in an unlimited environment is exponential, meaning that the number of individuals doubles during a fixed time interval. For example, if a species was biologically capable of doubling the size of its population in one week under unlimited environmental conditions, then after one week of growth an initial population of *N* individuals would grow to *2N*, after two weeks *4N*, after three weeks *8N*, after four weeks *16N*, and after eight weeks it would be *256N*. A financial analogy will help to put this tremendous rate of population increase into perspective: an initial investment of $100 growing at that rate would be worth $25,600 after only 8 weeks.

Clearly, this is an enormous rate of growth, and it would never be sustainable under real-world ecological conditions as environmental conditions would become limiting very fast and organisms would begin to interfere with each other through an ecological process known as competition. In general, the more similar the ecological requirements of individuals or species, the more intense the competition they experience. Therefore, competition among similar-sized individuals of the same species can be very intense, while individuals of different sized species (such as trees and moss) and will compete hardly at all.

Competition is an important ecological process, because it limits the growth rates of individuals and populations, and influences the kinds of species that can occur together in ecological communities. These ecological traits are also profoundly influenced by other interactions among organisms, such as herbivory, predation, and disease.

12. Biodiversity

1- An Introduction to Biodiversity Theory

Biodiversity originates largely from ecology (the study of the relationship between organisms and their environment) and evolution (the study of the origin of diversity). Its purpose is twofold: to understand the way the natural systems works and is structured, and how it got that way.

Biodiversity allow us to better understand which types of species are most likely to decline under different circumstances and also know how to protect those species from extinction. If diversity is reduced in an area, we can also prevent further loss and try to restore the lost diversity if we have a good grasp of what will be the outcome of different actions, such as reintroducing lost species. As human activities continue reduce the biodiversity on the planet, it becomes increasingly important to know what the effect of our actions will be before we lose any more diversity.

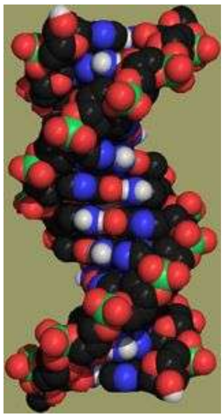
This section consists of four parts:

- introduction to the three levels of biodiversity
- how diversity can be gained or lost
- Composition and abundance of diversity
- How Biodiversity affects the functioning of ecosystems.

2- Three levels of biodiversity

Researchers generally accept three interrelated levels of biodiversity: genetic, species, and ecosystem. These levels are all interrelated, distinct enough as they can be studied as three separate components but most studies focus on the species level.

2.1. Genetic Diversity



Genetic diversity focuses on the level of genes that are the building blocks that determine how an organism will develop and what its traits and abilities will be. Genetic diversity can be measured at many different levels, including population, species, community, and biome.

The amount of diversity at the genetic level is important because it represents the raw material for evolution and adaptation. More genetic diversity in a species or population means a greater ability for individuals to adapt to changes in the environment. Less diversity leads to uniformity, which is a problem in the long term, as it is unlikely that any individual in the population would be able to adapt to changing conditions. As an example, modern agricultural practices use monocultures, which are economically interesting but can be a problem when a disease or parasite attacks the field, as every plant in the field will be susceptible. Monocultures are also unable to deal well with changing conditions.

2.2. Species Diversity

Biodiversity studies typically focus on species because species diversity is easier to work with. Species are relatively easy to identify in the field or under a microscope, whereas genetic diversity requires laboratories, time and resources to identify and ecosystem diversity.

Species are distinct units of diversity. Each species can be considered to have a particular "role" in the ecosystem, so the addition or loss of single species may have consequences for the system as a whole. Conservation efforts often begin with the recognition that a species is endangered in some way, and a change in the number of species in an ecosystem is a readily obtainable and easily comprehensible measure of how healthy the ecosystem is.

2.3. Ecosystem Diversity

Ecosystem diversity deals with species distributions and community patterns, the role and function of key species, and combines species functions and interactions. Trying to understand all the species in an ecosystem and how they affect each other and their surroundings while at the same time they are affected themselves, is extremely complex.

One of the difficulties in examining communities is that the transitions between them are usually not very sharp. A lake may have a very sharp boundary between it and the deciduous forest it is in, but the deciduous forest will shift much more gradually to grasslands or to a coniferous forest. This lack of sharp boundaries is called "open communities" (as opposed to "closed communities," which would have sudden transitions) and makes studying ecosystems difficult, since even defining them can be problematic.

3- Gaining and Losing Biodiversity

Diversity naturally has increased over time, though the great mass extinctions have decreased it for a while. The most famous mass extinction is the dinosaurs extinction, but we are currently in the midst of a human-created mass extinction. Local diversity, on the other hand, is constantly increasing and decreasing at very short time scales and there are many factors that affect diversity. Human-generated impacts on diversity have almost always been negative.

3.1. Island Biogeography

One of the first major theories of biodiversity, the theory of island biogeography, applies to the patterns of diversity found on islands, but this theory shall apply to any isolated ecosystem (oasis, lake, mountain valley). At the beginning, islands start out empty of species, which arrive from a large area (referred to as the mainland) and from neighbouring islands and other partially isolated areas.

The chance that a species will reach the island depends mostly on the distance from the mainland; the greater the distance the less often a species will find the island. Species on smaller islands have smaller populations, making them more vulnerable to extinction. The number of species present on the island is a balance between the rate at which new species arrive and old species go extinct.

This theory considers that all species are considered to be equal. In reality, some species are better at dispersing than others and are thus more likely to be found on islands. The exact species that are actually present has been found to be fairly random.

3.2. Measuring Diversity

To detect changes in biodiversity it is necessary to measure it. Although at first glance biological diversity seems to be an obvious idea, quantifying it is much more difficult. There are several common ways to measure diversity, the easiest way being to measure how many species are found in an area, or how many taxonomic groups higher than species are present. Diversity can be expressed as the number of species found per unit area, per unit mass, or per number of individuals identified. The question is mainly about how to standardize measures taken at different scales.

3.3. Gaining Biodiversity

• Mutation

Mutations increase genetic diversity by altering the genetic material of organisms and this is the only way in which diversity is truly created. Once mutations arise, they are transmitted to the mutated organism's descendants, and in time may either disappear if the line dies out. Depending upon the specific mutation, the result can range from no effect to the creation of an entirely new species.

• Speciation

Speciation is creation of a new species. Species are typically defined as being unable to successfully breed with other species (the so-called Biological Species Concept), although speciation can occur through several different means, including geographical isolation, competition, and polyploidy.

- Geographical Isolation

Geographical isolation, such as new mountain chains or a lake whose level lowers enough that it splits into two separate lakes, can divide a population into two separate populations. The two isolated populations continue to evolve separately from one another. Eventually they can diverge to a great enough degree, either through adaptation to their differing environments or through random mutations, that they are no longer able to interbreed and are considered to be different species.

- Competition

If a new resource, such as a new food source, becomes available to a population, some part of the population may become specialized in obtaining that resource. Being specialized in obtaining either the new resource or the original resource may be better than trying to obtain both. In time, there is a chance that the population will split into two species, each specialized on one of the two resources.

- Polyploidy

Most species are diploid, one copy of chromosomes from each of their parents. A diploid species may become polyploid with more than two copies of these chromosomes through errors at the cellular level (also through genetic manipulation). The additional copies of the chromosomes render them unable to produce functional descendants with normal members of their species. Plants often fertilize themselves to at least some extent, so polyploid species can arise from a single individual. This method of speciation is almost instantaneous, happening in a single generation, and is more common in plants than animals that are more sensitive to large changes in their genetic structure.

• Immigration

Immigration increases diversity as new individuals and perhaps even new species enter an area, increasing its diversity. The rate at which immigration happens depends on the size of the area in question, how many species are there already, and how close the area in question is to the source of immigration. Even if a species is unable to survive in an area, a constant flow of immigrants to the area can keep the species present indefinitely.

Most species that immigrate to a new ecosystem have only minor effects on their new system, though some drastically change it. Zebra mussels, native to the Caspian Sea and Ural river, were first recognized in the Great Lakes in 1988. It is most likely that they were brought over in ballast water. Since then they have spread throughout the Great Lakes and beyond, killing native mussel populations and fouling all manner of pipes and intakes. The same with the Florida turtle in Europe competing with the European turtle Cistude and the American crayfish with the European one.

• Succession

Succession is the process through which an area gains species as successive communities of organisms replace one another until an equilibrium is reached, the climax.

Different regions have varying climax communities - the tundra of the north is extremely different from the grasslands of the prairies or the US west coast rainforests, though they are all the local endpoints of succession. One usually refers to the different stages of succession in terms of the plants rather than the animals because the plants precede the animals and provide the structure and environment that the animals live in. One exception to this is aquatic communities, where sponges, corals, bivalves and other animals are responsible for much of the three-dimensional structure of the community.

3.4. Losing Diversity

• Extinction

Extinction is more an outcome than a process. Once a species goes extinct, all the diversity that it represented is lost forever. The vast majority of species that have ever existed are now extinct through natural processes. Genes also go extinct if they fail to get passed on to the next generation. Ecosystems may be destroyed by severe disturbances, but they don't really go extinct unless the species that make them up are lost.

Species can also go locally extinct. Although the local loss of diversity is the same, the species still exists elsewhere and may be able to return in the future through immigration.

• Competition

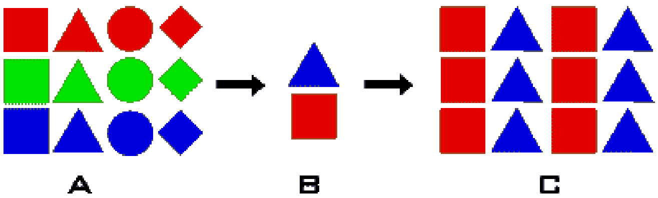
If one species outcompetes others to a dramatic extent, it may lead to the extinction of the other species and a reduction of diversity. Diversity will also be lowered if other species have their populations greatly reduced by a competitor or predator.

• Disturbances

Disturbances can maintain diversity to a certain point, but extremes can reduce diversity. Constant large-scale disturbance can eliminate many populations and keeps an area at the early levels of succession, which have lower diversity.

• Bottlenecks

Genetic bottlenecks happen when many individuals in a population die. In the example, the population initially has many different types of shapes and colours, representing genetic diversity (A).



The few individuals that are left after most die (B) have a small amount of the genetic diversity that originally existed, as much of the genetic diversity was lost with the rest of the population. Although the population's numbers quickly recover (C), the genetic diversity is much slower to respond, which can cause problems if conditions change in the future, as there will be a lack of reserves of diversity.

4- Abundance and Composition

In addition to diversity increasing and decreasing, it can also change by alterations in the relative numbers of individuals in species or by the particular species that are present.

One question that comes up is why there are so many species in the first place. Why doesn't a single species outcompete and eliminate the rest? The answer is that no species can be perfect at everything; it must instead make trade-offs between different abilities, and the species that we see around us are the results of these different trade-offs. So many species exist because they all have different niches

4.3. Niches

A niche is the "role" of a species in a community, and can be defined as the conditions in which the species can survive or the way of life that it follows as species tend to find niches in which they can avoid competition rather than engaging in direct competition with other species for resources. When two species share the same niche, one will eliminate the other by outcompeting it.

Any ecosystem has a limited amount of resources, and it is assumed that there are rules about how the resources can be used. The rules deciding how the resources are allocated to species and the species fit into their niches determines how many species can exist in the system and how abundant each species is. Each species is added to the system one by one, with each species following the same rules. One common rule in these models says that the niches of new species added to the community should be as different as possible from those of the species already present.

Which type of species is added next depends upon what type of species are already present and which rules are being followed. Similar areas will not necessarily have the same species, as the order that they appear in will affect which other species may successfully invade.

Rules include the phenomenon of new species invading already occupied niches or unused niches, or whether the size of the niche makes a difference to its chance of being invaded. A good example is the herbaria of Posidonia in the Mediterranean littoral.

4.4. Keystone Species

Keystone species are species that are important to an ecosystem. This importance comes from their niches and interactions affecting the system as a whole, rather than only affecting the species that they directly interact with. Removing or adding keystone species to a community can result in enormous changes to the rest of the community through the effects they have on other species. The resulting cascade of interactions can have drastic effects on the ecosystem.

The sea otter, *Enhydra lutris* is a well-known keystone species. They are found in the waters off the US west coast, where one of their main prey species are sea urchins. Sea urchins, in turn, eat algae such as kelp. By keeping the population of sea urchins low, the otters indirectly let kelp flourish. An increase in kelp coincides with a decrease in barnacles, mussels, and chitons. Fish species that can use the kelp for cover increase also take advantage of the structured environment. When sea otters are removed from some areas, the sea urchins and other herbivores quickly managed to severely reduce the kelp, allowing barnacles and mussels to flourish at the cost of other species.

An example of a keystone species in Canada is the beaver which modify large amounts of land through the flooding caused by their dams that generate ponds and lakes, allowing many aquatic species to thrive. If beavers were removed from an area, many species that live in the ponds caused by beavers would drop in numbers or go locally extinct.

4.5. Catastrophes

Disturbances and catastrophes change which species are found in an ecosystem and their relative abundance. By disturbing the system, the catastrophe mostly affects the current stage of succession and effectively sets the disturbed section into an earlier successional stage. When species from earlier stages are present, diversity increases. They also allow succession to occur at a faster rate, as the species that are needed for a given stage are relatively nearby in other recently disturbed areas (tsunami, eutrophication).

5- Ecosystem functioning and stability

Ecological functions involves ecological and evolutionary processes, including gene flow, disturbance, and nutrient cycling. This is the study of how components such as energy and types of species in the ecosystem change over time. It differs from the study of structure, which investigates how the components of ecosystems change over space. Ecologists have long examined the ecological function (or role) for individual species, but the study of the ecological function of biodiversity itself is very recent. It is an extremely complex field, and is rapidly growing.

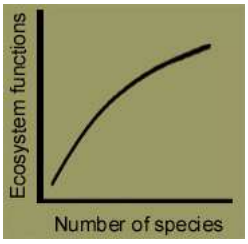
5.1. Functional Types and Functionally Equivalent

Species in an ecosystem can be functionally equivalent, meaning that they do much the same thing (*i.e.*have similar niches). Functionally equivalent species can be grouped together as functional types (f.i. guilds) depending on exactly how they are put together. Functionally equivalent species are considered to compete with one another, for instance all herbivores may compete with each other for the plants they eat. A more realistic and finely detailed model will be less likely to have species compete with one another, as herbivorous species tend to specialize on different plant species or even different parts of the same plant.

Species of different functional types don't compete against one another for resources. Carnivores and herbivores, f.i., don't compete with one another. Instead, the carnivores eat the herbivores.

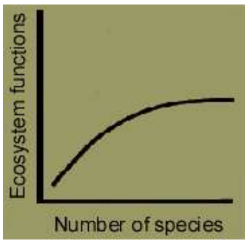
5.2. Functional Diversity

Both the different functional types and number of functionally equivalent species in an ecosystem contributes to its functional diversity that is the variety of responses by species in the ecosystem to environmental change, or how many ways the ecosystem can respond to change. A larger functional diversity can mean the ecosystem is more stable, as some species will react well to environmental stress, while low functional diversity means the community as a whole can react poorly to change.



5.3. Diversity and Ecosystem Functions

There are many theories about how the number of species affects ecosystem functions. One of these is the redundancy hypothesis which assumes that the rate of ecosystem functions increases as more species are present, but only up to a point. After this point, more species are redundant and do not have any additional effect on ecosystem functions. In this theory the loss of species has no initial effect, but after a certain point functions begin to suffer.



Another theory, the rivet hypothesis claims that each species added to an ecosystem increases ecosystem functions, although the increase in function may increase more slowly as more species are included. In this model any loss of diversity should be noticeable.

Opposed to theories assuming a definite relationship between diversity and ecosystem functions is the idea that there is no fixed relationship, and that the functions of an ecosystem are the result of the interactions between species. In this case what is important is not how many species are present but which species are present together and what environment they are in.

Which of these theories is most accurate is not certain, given the problems of scale and the complexity of the measurements.

5.4. Does Diversity lead to Stability?

As with many topics in biodiversity, there are different ways of expressing stability. One way is to define it as the ability of a system to return to its original state after being disturbed, so how quickly it can return and how large a disturbance it can return from are key variables. Another definition is how resistant to change the system is in the first place. No matter what the definition used, however, there are definite trends that appear.

If either the redundancy or rivet theories are correct, then more species means more stability. Current consensus is that greater diversity does lead to greater stability, for three general reasons:

• **Insurance Effect**: Different species do better under different conditions. As the number of species increases, the range of conditions that at least some species do well in also increases. When perturbations do occur, it's more likely that some of the species present will be able to do well, and these species will protect the community as a whole.

• **Averaging Effect**: Stability is measured as variability relative to community abundance. As diversity increases, the value of the variability will naturally decrease. One problem with this is that the impact of additional species can be confused with the effect of larger numbers of individuals

• **Negative Covariance Effect**: species are competing for resources (space, food,…) and any gains that one species makes will be to some extent at the expense of the other. This means that as a species does more poorly its competitors will do better. The result is that disturbances aren't as detrimental to the entire system as they could be, as the losses in one species are offset by the gains of another.

The structure of a food web also affects the stability of the system. Food webs describe the flow of energy through the system, basically who eats whom and how often. Different levels exist, such as producers, primary consumers (herbivores), secondary consumers, aso. The food web (food chain) has an amount of cross-links making it nearer from a web rather than a simple linear chain.

Most of the links in the food web are weak, meaning that the consumer doesn't depend excessively on what it consumes. As long as the links are weak, no species will be greatly affected by a predator or prey whose population changes. Strong links means that species are greatly affected by changes in the populations of species they're linked to; if there are many strong links in the system, drastic changes in one species spread through the system along the strong links, destabilizing it.

13- Environmental degradation

Environmental degradation is the deterioration of the environment through depletion of resources suchas air, water and soil, the destruction of ecosystems and the extinction of wildlife. It is defined as any change or disturbance to the environment perceived to be deleterious or undesirable. Environmental impact degradation is caused by the combination of an already very large and increasing human population, continually increasing economic growth and the application of resource depleting and polluting technology.

The United Nations International Strategy for Disaster Reduction defines environmental degradation as “*The reduction of the capacity of the environment to meet social and ecological objectives, and needs*”. Environmental degradation is of many types. When natural habitats are destroyed or natural resources are depleted, the environment is degraded. Efforts to counteract this problem include environmental protection and environmental resources management.

The primary cause of environmental degradation is human disturbance. The degree of the environmental impact varies with the cause, the habitat, and the plants and animals that inhabit it.

Nevertheless, even if environmental degradation is most commonly associated with the activities of humans, the fact is that environments are also constantly changing over time. With or without the impact of human activities, some ecosystems degrade over time to the point where they die. Things like landslides, earthquakes, tsunamis, hurricanes, and wildfires can completely decimate local plant and animal communities to the point where they can no longer function. This can either come about through physical destruction via natural disaster, or by the long-term degradation of resources by the introduction of an invasive alien species to a new habitat. The latter often occurs after hurricanes, when lizards and insects are washed across small stretches of water to foreign environments. Sometimes, the environment cannot keep up with the new species, and degradation can occur.

13.1.Water resources deterioration

One major component of environmental degradation is the depletion of the resource of fresh water on Earth. Approximately only 2.5% of all of the water on Earth is fresh water 70% of which is frozen in ice caps, so only 30% of the 2.5% of fresh water is available for consumption. Fresh water is an exceptionally important resource, since life on Earth is ultimately dependent on it. Water transports nutrients and chemicals within the biosphere to all forms of life, sustains both plants and animals, and moulds the surface of the Earth with transportation and deposition of materials.

The current uses of fresh water account for 95% of its consumption; approximately 85% is used for irrigation, 6% is used for domestic purposes and 4% is used for industrial purposes. It is estimated that one in three people over the planet is already facing water shortages, almost one-fifth of the world's population live in areas of physical water scarcity, and almost one quarter of the world's population live in a developing country that lacks the necessary infrastructure to use water from available rivers and aquifers. Water scarcity is an increasing problem due to many foreseen issues in the future, including population growth, increased urbanization, higher standards of living, tourism and climate change.

A rise in global temperatures is also predicted to correlate with an increase in global precipitation, but because increased runoff, floods, increased rates of soil erosion and mass movement of land should lead to a decline in water quality, a decline in water quality is probable, while water will carry more nutrients, it will also carry more contaminants.

Furthermore, water use will rise with population while the lack of water will be aggravated by decreases in stream flow and groundwater caused by climate change. An increased population means increased withdrawals from the water supply for domestic, agricultural, and industrial uses, the largest of these being agriculture believed to be the major non-climate driver of environmental change and water deterioration. The next 50 years will likely be the last period of rapid agricultural expansion, but the larger and wealthier population over this time will demand more agriculture. Urbanization causes overcrowding and increasingly unsanitary living conditions, especially in developing countries, which in turn exposes an increasingly number of people to disease. About 79% of the world's population is in developing countries, which lack access to sanitary water and sewer systems, giving rises to disease and deaths from contaminated water and increased numbers of disease-carrying insects.

13.2. Climate change

Climate dictates much of the way the world is. All over the planet climate differs and human activities, such as agriculture, have developed according to local climatic conditions. Just as humans are influenced by the climate, they have also influenced our global climate. The increasing number of people and economic development continue to cause adverse affects for the global environment.

• Climate change and temperature
Climate change affects the Earth's water supply in several ways. It is predicted that the mean global temperature will rise in the coming years due to a number of forces affecting the climate, the

amount of atmospheric CO_2 will rise, and both of these will influence water resources (evaporation, plants transpiration, soil moisture, groundwater supplies, decrease in snowpack and glaciers, melt of snow and glaciers, thermal expansion of water and rise in sea level, disease with bacterial development, …).

• Climate change and precipitation

Climate models show that while some regions should expect an increase in precipitation, such as in the tropics and higher latitudes, other areas are expected to see a decrease, such as in the subtropics; this will ultimately cause a latitudinal variation in water distribution. The areas receiving more precipitation are also expected to receive this increase during their winter and actually become drier during their summer.

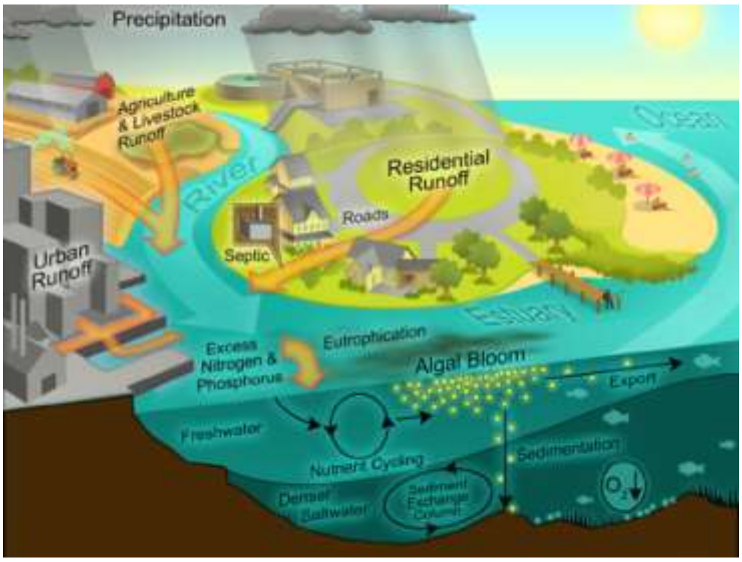
Vegetation patterns and growth rates will be directly affected by shifts in precipitation amount and distribution, which will in turn affect agriculture as well as natural ecosystems. Decreased precipitation will deprive areas of water, causing water tables to fall and reservoirs and wetlands, rivers, and lakes to empty. Groundwater reserves will be depleted, and the remaining water has a greater chance of being of poor quality from saline or contaminants on the land surface.

• Agriculture

Agriculture is dependent on available soil moisture and changes in climate, especially in precipitation and evapotranspiration, will directly affect soil moisture, surface runoff, and groundwater recharge. In areas with decreasing precipitation, soil moisture may be substantially reduced driving to an increase of irrigation. Irrigation damages streams and rivers from damming and removal of water, and increases salt and nutrient content in the environment leading to a strong eutrophication of aquatic ecosystems.

The transfer of water from agricultural to urban and suburban use raises concerns about agricultural sustainability, rural socioeconomic decline, food security, an increased carbon footprint from imported food

13.3. Nutrient pollution



Nutrient pollution released to freshwater and coastal areas comes from many diverse sources including agriculture, aquaculture, septic tanks, urban wastewater, urban stormwater runoff, industry, and fossil fuel combustion. Nutrients enter aquatic ecosystems via the air, surface water, or groundwater.

From region to region, there are significant variations in the relative importance of nutrient sources. For example, in the United States and the European Union, agricultural sources—commercial fertilizers and animal manure—are typically the primary sources of nutrient pollution in waterways, while urban wastewater is often a primary source of nutrients in coastal waterways of South America, Asia and Africa.

Diagram of the different pathways of nutrient deposition into coastal waters and ensuing processes leading to eutrophication (algal blooms) and hypoxia.

• Agricultural Sources

Agricultural nutrient sources include fertilizer leaching and runoff from agricultural fields, manure (excrements) and aquaculture operations.

-> Chemical fertilizers

Between 1960 and 1990, global use of synthetic nitrogen fertilizer increased more than sevenfold, while phosphorus use more than tripled. On average, about 20% of nitrogen fertilizer is lost through surface runoff or leaching into groundwater Under some conditions, 40 to 60% of the nitrogen applied to crops can be lost to the atmosphere by volatilization. A portion of the volatilized ammonia is redeposited in waterways through atmospheric deposition. Phosphorus, which binds to the soil, is generally lost through soil erosion from agricultural lands.

Nutrients and sediments entering the Mississipi River in the form of surface runoff. The latter is considered to be the main source of nitrogen into the Gulf of Mexico (Rabalais 2002).

-> Manure

Livestock over the last century has also contributed to a sharp increase in nutrient levels. Animal production is intensifying, and as a result, more production is occurring further away from feedstock supplies, making it harder to spread the manure. The large quantity of manure produced by these operations is applied to land as fertilizer, stacked in the feedlot, or stored in lagoons. Frequently, an oversupply of manure means that it is applied to crops more than is necessary, further exacerbating nutrient runoff and leaching.

In China, meat production rose by 127 percent between 1990 and 2002 (FAO 2009a), but fewer than 10 percent of an estimated 14,000 intensive livestock operations have installed pollution controls (Ellis 2007). In the Black Sea region, one swine operation—which subsequently closed—had over 1 million pigs and generated sewage equivalent to a town of 5 million people (Mee 2006).

-> Aquaculture

Aquaculture is another growing source of nutrient pollution. Annual aquaculture production worldwide increased by 600% in twenty years, from 8 million tons in 1985 to 48.2 million tons in 2005. Today nearly 43% of all aquaculture production is within marine or brackish environments, with the remainder in freshwater lakes, streams, and man-made ponds (FAO 2007). Marine fish and shrimp farming often occur in net pens or cages situated in enclosed bays. These farms generate concentrated amounts of nitrogen and phosphorus from excrement, uneaten food, and other organic waste. If improperly managed, aquaculture operations can have severe impacts on aquatic ecosystems as nutrient wastes are discharged directly into the surrounding waters. For every ton of fish, aquaculture operations produce between 42 and 66 kilograms of nitrogen waste and between 7.2 and 10.5 kilograms of phosphorus waste

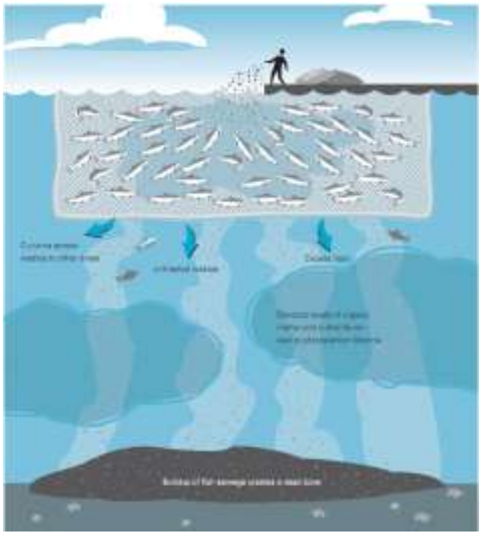


Diagram illustrating the mechanisms by which aquaculture can contribute to eutrophication and hypoxia

• Urban and Industrial Sources

Municipal wastewater treatment plants and industrial wastewater discharges, nitrogen leaching from underground septic tanks, and storm water runoff are some of the urban and industrial sources of nutrient pollution. Municipal and industrial sources are considered "point sources" of nutrient pollution because they discharge nutrients directly to surface waters or groundwater via a pipe or other discrete conveyance. They are typically the most controllable sources of nutrients and are often regulated in developed countries.

Percentage of sewage treated in different regions worldwide

Percent of Sewage Treated by Region

Region	Percent of Sewage Treated
North America	90
Europe	66
Asia	35
Latin America & Caribbean	14
Africa	<1

The most prevalent urban source of nutrient pollution is human sewage, though its importance varies by region and country. Sewage is estimated to contribute 12% of riverine nitrogen input in the United States, 25% in Western Europe, 33% in China, and 68% in the Republic of Korea. This variation is due, in large part, to differences in sewage treatment levels among countries (Table 1). In developing countries, fewer than 35% of cities have any form of sewage treatment, and when sewage is treated, it is typically aimed at removing solids, not nutrients.

Households in developed countries often use septic systems when they are not connected to municipal wastewater treatment plants. Septic systems are designed to purify waste by leaching it through soils. They leach, on average, 14 kilograms of nitrogen per system per year—much of which reaches groundwater or nearby surface waters. Storm water runoff is another significant source of nutrients from urban areas. Rainfall events flush nutrients from residential lawns and impervious surfaces into nearby rivers and streams. In some cities, combined sewer overflow systems worsen storm water runoff problems. During heavy rain or snowmelt, wastewater volume can exceed the capacity of the CSO system with the result that the excess wastewater, including raw sewage, is discharged directly into nearby streams and rivers. Pulp and paper mills, food and meat processing, agro-industries, and direct discharge of sewage from maritime vessels are some of the larger sources of industrial nutrient pollution.

• **Fossil Fuel Sources**

When fossil fuels are burned, they release nitrogen oxides (NOx) into the atmosphere. NOx contributes to the formation of smog and acid rain. NOx is redeposited to land and water through rain and snow (wet deposition), or can settle out of the air in a process called dry deposition. Coal-fired power plants and exhaust from cars, buses, and trucks are the primary sources of NOx. Fossil Fuel combustion contributes approximately 22 millions Tons of nitrogen pollution globally every year.

Smog from industry and vehicles originates in China and is blown over Yellow Sea towards Korea. Atmospheric deposition of NOx is a significant source of nitrogen to the Yellow Sea which suffers from severe symptoms of eutrophication.

In the Baltic Sea, atmospheric deposition, primarily from burning fossil fuels, accounts for 25% of nitrogen inputs Similarly, in the Chesapeake Bay, atmospheric deposition accounts for 30% of all nitrogen inputs. In some areas, such as in the U.S. North Atlantic, atmospheric deposition of nitrogen can exceed riverine nitrogen inputs to coastal areas

13.4. Eutrophication

• Mechanism of eutrophication

http://www.wri.org/our-work/project/eutrophication-and-hypoxia/about-eutrophication

The rise in eutrophic and hypoxic events has been attributed to the rapid increase in intensive agricultural practices, industrial activities, and population growth that together have increased nitrogen and phosphorus flows in the environment. The Millenium Ecosystem Assessment (MA) found that human activities have resulted in the near doubling of nitrogen and tripling of phosphorus flows to the environment when compared to natural values.

Before nutrients—nitrogen in particular—are delivered to coastal ecosystems, they pass through a variety of terrestrial and freshwater ecosystems, causing other environmental problems such as freshwater quality impairments, acid rain, the formation of greenhouse gases, shifts in community food webs, and a loss of biodiversity.

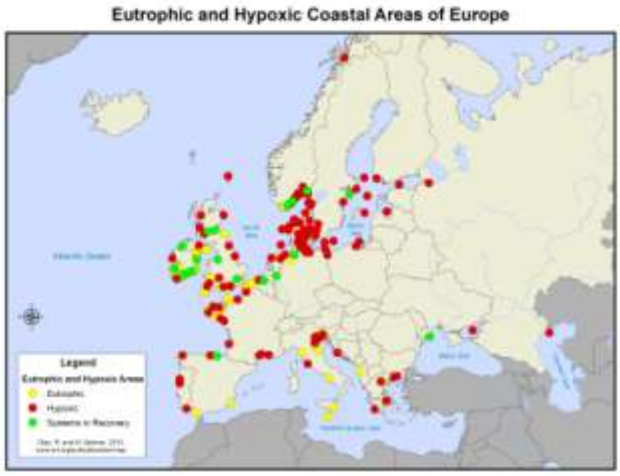
Once nutrients reach coastal systems, they can trigger a number of responses within the ecosystem. The initial impacts of nutrient increases are the excessive growth of phytoplankton, microalgae (epiphytes, microphytes), and macroalgae (seaweed). These, in turn, can lead to other impacts such as: loss of subaquatic vegetation, change in species composition, coral reef damage, low dissolved oxygen, and the formation of dead zones (oxygen-depleted waters) that can lead to ecosystem collapse.

• Lakes and rivers

http://www.wri.org/applications/maps/aqueduct-country-river-basin-rankings/#x=-69.96&y=18.76&l=4&v=home&d=bws&f=1&o=97

Farming creates agriculture runoff which is a deadly source of pollutants which can degrade environments, so much so that the EPA identifies agriculture as the primary source of water pollution. Fertilizers containing large amounts of phosphorus can cause explosions of algae in water. Eutrophication generally promotes excessive plant growth and decay, favouring simple algae and plankton over other more complicated plants, and causes a severe reduction in water quality. The addition of phosphorus increases algal growth. When algae die they sink to the bottom where they are decomposed and the nutrients contained in organic matter are converted into inorganic form by bacteria. The decomposition process uses oxygen and deprives the deeper waters of oxygen which can kill fish and other organisms. Enhanced growth of aquatic vegetation or phytoplankton and algal blooms disrupt normal functioning of the ecosystem, causing a variety of problems such as a lack of oxygen needed for fish and molluscs to survive. The water becomes cloudy, typically coloured a shade of green, yellow, brown, or red. Eutrophication also decreases the value of rivers, lakes and aesthetic enjoyment. Health problems can occur where eutrophic conditions interfere with drinking water treatment. As the algae die, bacteria start to breakdown the organic material. It soon develops into a situation where bacteria are using up the available dissolved oxygen in the water. Plants, fish, and other organisms begin to die off. The water becomes acidic. Like acid rain, lakes become dead zones with conditions so toxic that neither plants nor animals can live in these environments.

• Ocean waters



Eutrophication is a common phenomenon in coastal waters. In contrast to freshwater systems, nitrogen is more commonly the key limiting nutrient of marine waters; thus, nitrogen levels have greater importance to understanding eutrophication problems in salt water. Estuaries tend to be naturally eutrophic because land-derived nutrients are concentrated where run-off enters a confined channel. Upwelling in coastal systems also promotes increased productivity by conveying deep, nutrient-rich waters to the surface, where nutrients can be assimilated by algae.

About 400 hypoxic coastal zones have been identified in the world, concentrated in coastal areas in Western Europe, the Eastern and Southern coasts of the US, and East Asia, particularly Japan.

In addition to runoff from land, atmospheric fixed nitrogen can enter the open ocean. A study in 2008 found that this could account for around one third of the ocean's external (non-recycled) nitrogen supply, and up to 3% of the annual new marine biological production. It has been suggested that accumulating reactive nitrogen in the environment may prove as serious as putting carbon dioxide in the atmosphere.

The eutrophication process and subsequent formation of sea-bottom hypoxia in coastal waters Urban Development.

13.5. Other examples of Environmental degradation

• Habitat Fragmentation

Habitat fragmentation carries long term environmental impacts, some of which can destroy entire ecosystems. An ecosystem is a distinct unit and includes living and non-living elements. Plants and animals are obvious members, but it will also include other components on which they rely on such as streams, lakes, and soils.

Habitats become fragmented when development breaks up solid stretches of land. Examples include roads which may cut through forests. The largest of these consequences are initially felt by specific plant and animal communities, most of which are specialized for their bioregion or require large areas of land to retain a healthy genetic heritage.

• Area Sensitive Animals

Some wildlife species require large stretches of land in order to meet all of their needs for food, habitat, and other resources. These animals are called area sensitive. When the environment is fragmented, the large patches of habitat no longer exist. It becomes more difficult for the wildlife to get the resources they to survive, possibly becoming threatened or endangered. The environment suffers without the animals that play their role in the food web.

• Aggressive Plant Life

A more critical result of habitat fragmentation is land disturbance. Many weedy plant species are both opportunistic and invasive. A breach in the habitat gives them an opportunity to take hold. These aggressive plants can take over an environment, displacing the native flora. The result is habitat with a single dominant plant which doesn't provide adequate food resources for all the wildlife. The same phenomen may occur with invasive species

• Acid Rain
Acid rain occurs when sulfur dioxide from coal plant emissions combines with moisture present in the air. A chemical reaction creates this acid precipitation. Acid rain can acidify and pollute lakes and streams. It causes similar effects to the soil. According to the U.S. Environmental Protection Agency (EPA), if enough acid rain falls in a given environment, it can acidify the water or soil to a point where no life can be sustained. Plants die off. The animals that depend upon them disappear. The condition of the environment deteriorates.

• Agriculture
The provisioning services afforded by ecosystems refer to the physical products that ecosystems provide for us. Essentially, they include food, fibres, useful molecules, energy resources like firewood and biofuels, softwood lumber and timber, and genetic resources.

The conversion of traditional agricultural ecosystems causes the break-up and destruction of habitats that are linked to agro-biodiversity. This goes hand in hand with the impoverishment of genetic diversity. In the case of forests, thousands of years of human activity have reduced their original area by about 30%.

Because of various pressures and their combined effect, caused by population growth and the need for farming to be economically viable, itself part of a much bigger picture of a market economy with its sights on the international market, many producers have abandoned polyculture and traditional farming methods, in favour of the intensive production of a single species, in the hope of a quick profit.

Basically, the food provided for nearly half of the world's population comes from a small number of varieties of three mega-crops: rice, wheat and maize; a considerable number of plant varieties, on the other hand, that could be grown are being neglected, sometimes abandoned altogether and threatened with extinction.

We see the same pattern in livestock farming, where it is estimated that a third of the 6,500 breeds of domestic animals are currently in danger of extinction.

The FAO has estimated that about a million farmers in Latin America and the Caribbean are now dependent on rice and on a single species in particular (XX), which is therefore their main source of energy, and also their main source of employment and income. Given this scenario, it is not difficult to imagine what the dramatic consequences of a poor harvest would be.

→ Urbanisation and land use
Increasing urbanisation exacerbates the consequences of these agricultural practices. By 2030, 70% of the world's population will live in cities. This rural-to-urban migration will increase the human pressure on urban environment plagued by problems like water shortages and polluted water, insufficient sanitation, and increasing need for expansion into farmland and other areas. In the rural areas fertile soil is lost to land degradation and desertification, which strip away the crucial topsoil needed for food production. The degradation of soil, due to pollution, deforestation, overuse of fertilizers, and urban expansion, leads to serious threats to global food security.

Topsoil is, after water, maybe the most valuable resource on the planet. Everything grows out of it – and yet we are throwing it away recklessly: 40 thousand million tonnes of topsoil has been wasted in the last 20 years - equivalent to all the topsoil in India! It is a real waste, and without the fertile topsoil (resulting from the rock degradation) we cannot have food.

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