Processes of Ecosystem, Biomass. Energy and energy flow, Chemical Element cycles, Succession

Processes of the ecosystem

Ecosystems are controlled both by external and internal factors. External factors, also called state factors, control the overall structure of an ecosystem and the way things work within it, but are not themselves influenced by the ecosystem. The most important of these is climate. Climate determines the biome in which the ecosystem is embedded. Rainfall patterns and seasonal temperatures influence photosynthesis and thereby determine the amount of water and energy available to the ecosystem. Parent material determines the nature of the soil in an ecosystem, and influences the supply of mineral nutrients. Topography also controls ecosystem processes by affecting things like microclimate, soil development and the movement of water through a system. For example, ecosystems can be quite different if situated in a small depression on the landscape, versus one present on an adjacent steep hillside. Other external factors that play an important role in ecosystem functioning include time and potential biota. Similarly, the set of organisms that can potentially be present in an area can also significantly affect ecosystems. Ecosystems in similar environments that are located in different parts of the world can end up doing things very differently simply because they have different pools of species present. The introduction of non-native species can cause substantial shifts in ecosystem function.

Unlike external factors, internal factors in ecosystems not only control ecosystem processes but are also controlled by them. Consequently, they 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, root competition or shading. Other factors like disturbance, succession or the types of species present are also internal factors.

Primary production

Primary production is the production of organic matter from inorganic carbon sources. This mainly occurs through photosynthesis. 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 and fossil fuels. It also drives the carbon cycle, which influences global climate via the greenhouse effect. Through the process of photosynthesis, plants capture energy from light and use it to combine carbon dioxide and water to produce carbohydrates and oxygen. The photosynthesis carried out by all the plants in an ecosystem is called the gross primary production (GPP). About half 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), the 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.

Energy flow (ecology)

Energy flow is the flow of energy through living things within an ecosystem. All living organisms can be organized into producers and consumers, and those producers and consumers can further be organized into a food chain. Each of the levels within the food chain is a trophic level. The unidirectional flow of energy and the successive loss of energy as it travels up the food web are patterns in energy flow that are governed by Thermodynamics, which is the concept of energy exchange between systems. Trophic dynamics relates to Thermodynamics because it deals with the transfer and transformation of energy (originating externally from the sun via solar radiation) to and among organisms. 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. The carbon and energy incorporated into plant tissues (net primary production) is either consumed by animals while the plant is alive, or it remains uneaten when the plant tissue dies and becomes detritus. In terrestrial ecosystems, roughly 90% of the net primary production ends up being broken down by decomposers. The remainder is either consumed by animals while still alive and enters the plant-based trophic system, or it is consumed after it has died, and enters the detritus-based trophic system. In aquatic systems, the proportion of plant biomass that gets consumed by herbivores is much higher. In trophic systems, photosynthetic organisms are the primary producers. The organisms that consume their tissues are called primary consumers or secondary producers—herbivores. Organisms which feed on microbes (bacteria and fungi) are termed microbivores. Animals that feed on primary consumers—carnivores—are secondary consumers. Each of these constitutes a trophic level.

The sequence of consumption—from plant to herbivore, to carnivore—forms a food chain. Real systems are much more complex than this—organisms will generally feed on more than one form of food, and may feed at more than one trophic level. Carnivores may capture some prey that is part of a plant-based trophic system and others that are part of a detritus-based trophic system (a bird that feeds both on herbivorous grasshoppers and earthworms, which consume detritus). Real systems, with all these complexities, form food webs rather than food chains.

Energetics and the carbon cycle

The first step in Energetics is photosynthesis, wherein water and carbon dioxide from the air are taken in with energy from the sun, and are converted into oxygen and glucose. Cellular respiration is the reverse reaction, wherein oxygen and sugar are taken in, and are converted back into carbon dioxide and water. The carbon dioxide and water produced by respiration can be recycled back into plants. Energy loss can be measured either by efficiency (how much energy makes it to the next level), or by biomass (how much living material we have at that those levels at one point in time, measured by standing crop).

Primary production

A producer is anything that performs photosynthesis. Producers are important because they convert energy from the sun into a store-able and usable chemical form of energy, glucose. Once the sun's energy is converted into glucose, the producers themselves can use it to perform cellular respiration. Or, if the producer is consumed by herbivores in the next trophic level, some of the energy is passed on up the pyramid. The glucose stored within producers serves as food for consumers, and so it is only through producers, that consumers are able to access the sun's energy. Some examples of primary producers are algae, mosses, and other plants such as grasses, trees, and shrubs. Chemosynthetic bacteria perform a similar process to photosynthesis, but instead of energy from the sun they use energy stored in chemicals like hydrogen sulphide. This process is referred to as chemosynthesis, usually this occurs deep in the ocean in hydrothermal vents that produce heat and chemicals such as hydrogen sulphide, and methane. Chemosynthetic bacteria can use the energy in the bonds of the hydrogen sulphide, as well as carbon dioxide, to make glucose, releasing oxygen and sulphur in the process. Organisms that consume the chemosynthetic bacteria can take in the glucose and use oxygen to perform cellular respiration, similar to herbivores consuming producers. One of the factors that controls primary production is the amount of energy that enters the producer(s), this can be measured using productivity. Only one percent of solar energy enters the producer, the rest bounces off of it, or moves through it. Gross primary productivity is the amount of energy the producer actually gets. Generally, 60 % of the energy that enters the producer, goes to the producer's own respiration. The net primary productivity is the amount that the plant gets after the amount that it used for cellular respiration is subtracted. Another factor controlling primary production is organic/ inorganic nutrient levels in the water or soil that the producer is living in.

Secondary production

Secondary production is the use of energy stored in plants converted by consumers to their own biomass. Different ecosystems have different levels of consumers, all end with one top consumer. Most energy is stored in plants, and as the consumers eat these plants they use a small amount of energy. This energy in the herbivores and omnivores is then consumed by carnivores. There is also a large amount of energy that is in primary production that ends up being waste or litter, referred to as detritus. The detrital food chain includes a large number of microbes, macroinvertebrates, meiofauna, fungi, and bacteria. These organisms are consumed by omnivores and carnivores and are a large amount of secondary production. Secondary consumers can vary widely in how efficient they are in consuming. The efficiency of energy being passed onto consumers is estimated to be around 10%. Energy flow through consumers differs in aquatic and terrestrial environments.

Secondary production in aquatic environments

Heterotrophs contribute to secondary production and it is dependent on primary productivity and the net primary products. Secondary production is the energy that herbivores and decomposers use, thus secondary productivity depends on primary productivity. Primarily herbivore's and decomposers consume all the carbon from two main sources in aquatic ecosystems. The two types of important carbon from organic sources are autochthonous and allochthonous. Autochthonous, comes from within the ecosystem. Includes aquatic plants, algae and phytoplankton. Allochthonous, comes from outside the ecosystem it is mostly dead organic matter from the terrestrial ecosystem entering the water. In stream ecosystems annual energy input can be mostly washed downstream, approximately 66%. The remaining amount is consumed and lost through heat.

Secondary Production in Terrestrial environments

Secondary production is often described in terms of trophic Levels, and while this can be useful in explaining relationships it overemphasis the rarer interactions. Consumers often feed at multiple trophic levels. Energy transferred above the third trophic level is relatively unimportant. The assimilation efficiency can be expressed how much food the consumer has eaten how much the consumer assimilates and what is expelled as poop or urine. a portion of the energy is used for respiration, another portion of the energy goes towards biomass in the consumer. There are two major food chains: The primary food chain is the energy that comes from autotrophs is passed onto the consumers; and the second major food chain is when carnivores eat the herbivores or decomposers that consume the autotrophic energy. Consumers are broken down into primary consumers, secondary consumes and tertiary consumers. Carnivores have a much higher assimilation of energy, about 80% and herbivore's have a much lower efficiency have approximately 20 to 50%. Energy in a system can be affected by animal emigration/immigration. The movement of organisms are significant in terrestrial ecosystems. Energetic consumption by herbivores in terrestrial ecosystems have a low range of ~3-7%. The flow of energy is similar in many terrestrial environments, some fluctuation of how much net primary product herbivores consume is generally low. This is a large contrast to aquatic environments the grazers in lakes and ponds have a much higher consumption of around ~33%. Ectotherms and endotherm's have very different assimilation efficiencies

Decomposition

The carbon and nutrients in dead organic matter are broken down by a group of processes known as decomposition. This releases nutrients that can then be re-used for plant and microbial production and returns carbon dioxide to the atmosphere (or water) where it can be used for photosynthesis. In the absence of decomposition, the dead organic matter would accumulate in an ecosystem, and nutrients and atmospheric carbon dioxide would be depleted. Approximately 90% of terrestrial net primary production goes directly from plant to decomposer. Decomposition processes can be separated into three categories; leaching, fragmentation and chemical alteration of dead material. As water moves through dead organic matter, it dissolves and carries with it the water-soluble components. These are then taken up by organisms in the soil, react with mineral soil, or are transported beyond the confines of the ecosystem (and are considered lost to it). Newly shed leaves and newly dead animals have high concentrations of water-soluble components and include sugars, amino acids and mineral nutrients. Leaching is more important in wet environments and much less important in dry ones. Fragmentation processes break organic material into smaller pieces, exposing new surfaces for colonization by microbes. Freshly shed leaf litter may be inaccessible due to an outer layer of cuticle or bark, and cell contents are protected by a cell wall. Newly dead animals may be covered by an exoskeleton. Fragmentation processes, which break through these protective layers, accelerate the rate of microbial decomposition. Animals fragment detritus as they hunt for food, as does passage through the gut. Freeze-thaw cycles and cycles of wetting and drying also fragment dead material. The chemical alteration of the dead organic matter is primarily achieved through bacterial and fungal action. Fungal hyphae produces enzymes that can break through the tough outer structures surrounding dead plant material. They also produce enzymes that break down lignin, which allows them access to both cell contents and the nitrogen in the lignin. Fungi can transfer carbon and nitrogen through their hyphal networks and thus, unlike bacteria, are not dependent solely on locally available resources.

Decomposition rates vary among ecosystems. The rate of decomposition is governed by three sets of factors

- the physical environment (temperature, moisture, and soil properties),
- the quantity and quality of the dead material available to decomposers, and
- the nature of the microbial community itself.

Temperature controls the rate of microbial respiration; the higher the temperature, the faster the microbial decomposition occurs. It also affects soil moisture, which slows microbial growth and reduces leaching. Freeze-thaw cycles also affect decomposition—freezing temperatures kill soil microorganisms, which allows leaching to play a more important role in moving nutrients around. This can be especially important as the soil thaws in the spring, creating a pulse of nutrients that become available. Decomposition rates are low under very wet or very dry conditions. Decomposition rates are highest in wet, moist conditions with adequate levels of oxygen. Wet soils tend to become deficient in oxygen (this is especially true in wetlands), which slows microbial growth. In dry soils, decomposition slows as well, but bacteria continue to grow (albeit at a slower rate) even after soils become too dry to support plant growth.

Nutrient cycling

Ecosystems continually exchange energy and carbon with the wider environment. Mineral nutrients, on the other hand, are mostly cycled back and forth between plants, animals, microbes and the soil. Most nitrogen enters ecosystems through biological nitrogen fixation, is deposited through precipitation, dust, gases or is applied as fertilizer. Since most terrestrial ecosystems are nitrogen-limited, nitrogen cycling is an important control on ecosystem production. Until modern times, nitrogen fixation was the major source of nitrogen for ecosystems. Nitrogen-fixing bacteria either live symbiotically with plants or live freely in the soil. The energetic cost is high for plants that support nitrogen-fixing symbionts—as much as 25% of gross primary production when measured in controlled conditions. Many members of the legume plant family support nitrogen-fixing symbionts. Some cyanobacteria are also capable of nitrogen fixation. These are phototrophs, which carry out photosynthesis. Like other nitrogen-fixing bacteria, they can either be free-living or have symbiotic relationships with plants. Other sources of nitrogen include acid deposition produced through the combustion of fossil fuels, ammonia gas which evaporates from agricultural fields which have had fertilizers applied to them, and dust. Anthropogenic nitrogen inputs account for about 80% of all nitrogen fluxes in ecosystems. When plant tissues are shed or are eaten, the nitrogen in those tissues becomes available to animals and microbes. Microbial decomposition releases nitrogen compounds from dead organic matter in the soil, where plants, fungi, and bacteria compete for it. Some soil bacteria use organic nitrogen-containing compounds as a source of carbon, and release ammonium ions into the soil. This process is known as nitrogen mineralization. Others convert ammonium to nitrite and nitrate ions, a process known as nitrification. Nitric oxide and nitrous oxide are also produced during nitrification. Under nitrogen-rich and oxygen-poor conditions, nitrates and nitrites are converted to nitrogen gas, a process known as denitrification. Other important nutrients include phosphorus, sulphur, calcium, potassium, magnesium and manganese. Phosphorus enters ecosystems through weathering. As ecosystems age this supply diminishes, making phosphorus-limitation more common in older landscapes (especially in the tropics). Calcium and sulphur are also produced by weathering, but acid deposition is an important source of sulphur in many ecosystems. Although magnesium and manganese are produced by weathering, exchanges between soil organic matter and living cells account for a significant portion of ecosystem fluxes. Potassium is primarily cycled between living cells and soil organic matter.

Function and biodiversity

Biodiversity plays an important role in ecosystem functioning. Ecosystem processes are driven by the species in an ecosystem, the nature of the individual species, and the relative abundance of organisms within these species. Ecosystem processes are broad generalizations that take place through the actions of individual organisms. The nature of the organisms—the species, functional groups and trophic levels to which they belong—dictates the sorts of actions these individuals are capable of carrying out and the relative efficiency with which they do so. Ecological theory suggests that in order to coexist, species must have some level of limiting similarity—they must be different from one another in some fundamental way, otherwise, one species would competitively exclude the other. Despite this, the cumulative effect of additional species in an ecosystem is not linear—additional species may enhance nitrogen retention, for example, but beyond some level of species richness, additional species may have little additive effect. The addition (or loss) of species that are ecologically similar to those already present in an ecosystem tends to only have a small effect on ecosystem function. Ecologically distinct species, on the other hand, have a much larger effect.

Similarly, dominant species have a large effect on ecosystem function, while rare species tend to have a small effect. Keystone species tend to have an effect on ecosystem function that is disproportionate to their abundance in an ecosystem. Similarly, an ecosystem engineer is any organism that creates, significantly modifies, maintains or destroys a habitat.

Dynamics

Ecosystems are dynamic entities. They are subject to periodic disturbances and are in the process of recovering from some past disturbance. When a perturbation occurs, an ecosystem responds by moving away from its initial state. The tendency of an ecosystem to remain close to its equilibrium state, despite that disturbance, is termed its resistance. On the other hand, the speed with which it returns to its initial state after disturbance is called its resilience. Time plays a role in the development of soil from bare rock and the recovery of a community from disturbance. From one year to another, ecosystems experience variation in their biotic and abiotic environments. A drought, a colder than usual winter, and a pest outbreak all are short-term variability in environmental conditions. Animal populations vary from year to year, building up during resource-rich periods and crashing as they overshoot their food supply. These changes play out in changes in net primary production decomposition rates, and other ecosystem processes.

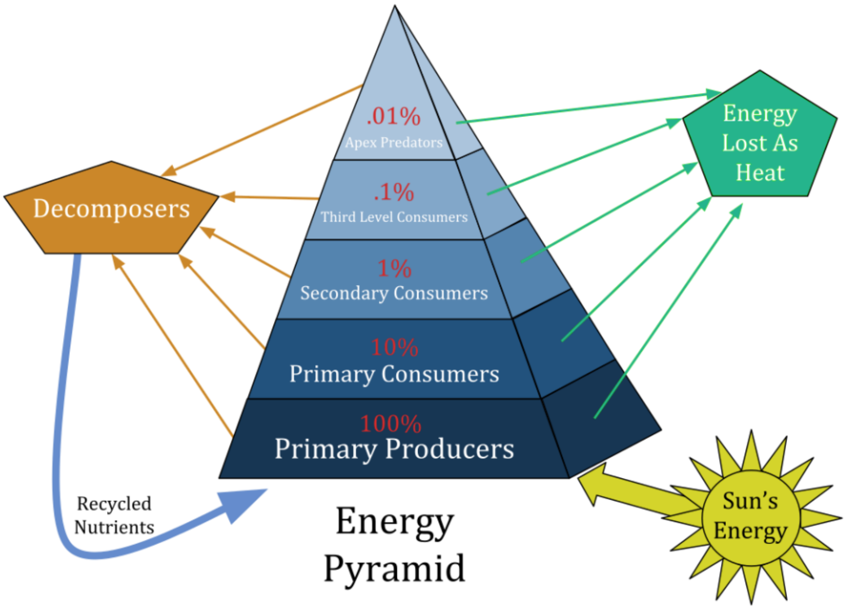
Disturbance also plays an important role in ecological processes. This can range from tree falls and insect outbreaks to hurricanes and wildfires to volcanic eruptions. Such disturbances can cause large changes in plant, animal and microbe populations, as well as soil organic matter content. Disturbance is followed by succession, a directional change in ecosystem structure and functioning resulting from biotically driven changes in resources supply. The frequency and severity of disturbance determine the way it affects ecosystem function. A major disturbance like a volcanic eruption or glacial advance and retreat leave behind soils that lack plants, animals or organic matter. Ecosystems that experience such disturbances undergo primary succession. A less severe disturbance like forest fires, hurricanes or cultivation result in secondary succession and a faster recovery. More severe disturbance and more frequent disturbance result in longer recovery times.

Ecosystem ecology

Ecosystem ecology studies the processes and dynamics of ecosystems, and the way the flow of matter and energy through them structures natural systems. The study of ecosystems can cover 10 orders of magnitude, from the surface layers of rocks to the surface of the planet. There is no single definition of what constitutes an ecosystem. An ecosystem can encompass a much larger area, even the whole planet. Ecosystems can be studied through a variety of approaches; theoretical studies, studies monitoring specific ecosystems over long periods of time, those that look at differences between ecosystems to elucidate how they work and direct manipulative experimentation. Studies can be carried out at a variety of scales, ranging from whole-ecosystem studies to studying microcosms or mesocosms (simplified representations of ecosystems).

Biomass transfer efficiency

An energy pyramid illustrates how much energy is needed as it flows upward to support the next trophic level. Only about 10% of the energy transferred between each trophic level is converted to biomass. In general, each trophic level relates to the one below it by absorbing some of the energy it consumes, and in this way can be regarded as resting on, or supported by, the next lower trophic level. Food chains can be diagrammed to illustrate the amount of energy that moves from one feeding level to the next in a food chain. This is called an energy pyramid.



The energy transferred between levels can also be thought of as approximating to a transfer in biomass, so energy pyramids can also be viewed as biomass pyramids, picturing the amount of biomass that results at higher levels from biomass consumed at lower levels. However, when primary producers grow rapidly and are consumed rapidly, the biomass at any one moment may be low; for example, phytoplankton (producer) biomass can be low compared to the zooplankton (consumer) biomass in the same area of ocean. The efficiency with which energy or biomass is transferred from one trophic level to the next is called the ecological efficiency. Consumers at each level convert on average only about 10% of the chemical energy in their food to their own organic tissue (the ten-percent law). For this reason, food chains rarely extend for more than 5 or 6 levels. At the lowest trophic level (the bottom of the food chain), plants convert about 1% of the sunlight they receive into chemical energy.

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