PROJECT NATURE NEWSLETTER

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MAY, 2020 ISSUE

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Ecosystem - I

An ecosystem is a community or a group of organisms that live and interact with each other as well as with the non-living environment which they inhabit. *Ecology* is the discipline that studies the roles played by organisms and their interaction with each other and with their environment. For example, flowering plants provide pollen and nectar to insects and other pollinators, such as bats and hummingbirds, who in return, pollinate the plants and help them reproduce. Herbivorous animals feed on plant foliage and grass, and in turn, feed the plants back by fertilizing the soil through their droppings. Carnivorous animals keep the populations of herbivores in check. A natural ecosystem is a “balanced” system. In other words, the interactions between the different elements of the system are in a sustainable fashion, which helps maintain the stability of the system.

An ecosystem has two integral components:

Biocenosis or Biotic These are the living organisms, such as plants, animals, fungi, and microbes.

Biotope or Abiotic These are the non-living elements of the environment, such as soil, which contains minerals and other nutrients, the atmosphere, water, and sun.

These two constituents of the ecosystem are connected to one another through the flow of energy and the cycling of nutrients.

Etymology

The ***Eco*** in ecosystem and ecology is derived from the Greek word ***oikos***, which means “house or place of residence”. The term ecology is credited to the 19th century German zoologist Enrst Haeckel, who used the term *oekologie* to describe the “relation of the animal both to its organic as well as its inorganic environment.” Later, in the 1930s, the British botanist A.G. Tansley introduced the concept of ecosystem in biology. Tansley is considered a pioneer in the science of ecology.

The Biocenosis

Oxeye Daisy

Structure of an Ecosystem

The fundamental source of energy of all life on earth is the sun. This energy sequentially propagates through all the biota of the ecosystem and sustains it. The ***food chain*** is the succession of energy and nutrients from organism to organism, and each level of organism is called the ***trophic level***, based on their feeding behavior. (The word *trophic* refers to 'feeding', and the concept of trophic levels was first introduced by German biologist August Thienemann in 1920.)

The food chain of an ecosystem comprises of the following categories:

Producers These are the green plants and algae that capture energy from the sun and produce complex chemicals, such as carbohydrates and other organic matter that make up the plant, using nutrients from the soil and carbon dioxide from the atmosphere by a process called *photosynthesis*. Some bacteria are also producers. This group of organisms that make their own food, are called ***autotrophs*** or ***photoautotrohps***)

Consumers Consumers are the animals that eat producers. The Primary Consumers are the herbivores, which eat the plants. Secondary Consumers eat the primary consumers. The consumers break down the carbon bonds to release the energy and rearrange the organic compounds.

Decomposers These are a special type of consumers that feed on the waste matter in the ecosystem, such as dead plants and animals. Microbes, such as some species of fungi and bacteria as well as ***detritivores***, such as earthworms and millipedes, are examples of decomposers. These organisms play a critical role in recycling nutrients by decomposing the waste and breaking them down, returning the nutrients back into the soil. This group of organisms are called ***saprotrophs***.

Consumers and decomposers are together referred to as ***heterotrophs*** – organisms that are incapable of making their own food. The term is derived from the Greek word *héteros*, meaning "other". Thus, heterotrophs means "other feeders".

Often there are complex patterns of overlapping and interconnected food chains, referred to as the ***food web***.

Detritivores

Detritivores are organisms that obtain their nutrition by feeding on *detritus*. Detritus is the organic matter of dead plants and animals. Detritivores are decomposers but different from other kinds of decomposers, such as fungi and bacteria. Detritivores can consume discrete lumps of matter, whereas the microbes can only consume through absorption and metabolizing on molecular scale.

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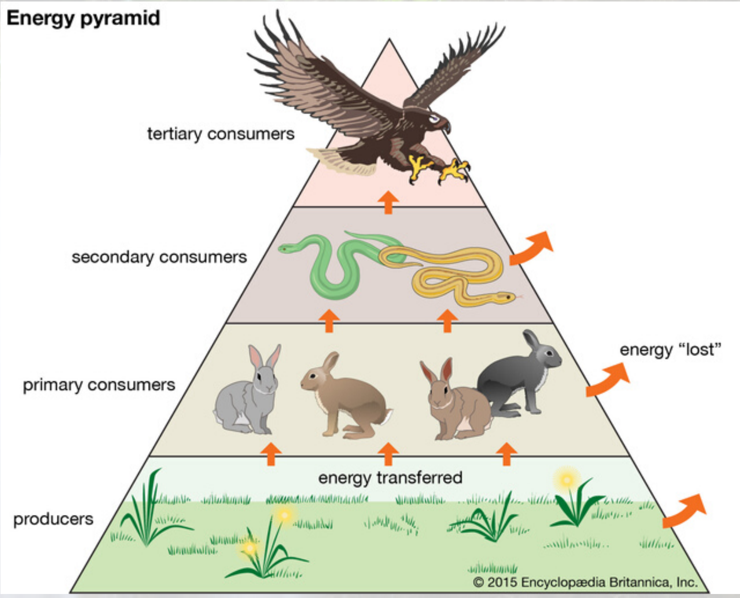
In this transfer of energy, moving from one trophic level to the next, 90% of the energy is lost. In other words, when an animal eats a plant or another animal, only 10% of the total energy available is transferred to the consuming animal (with the exception of the first trophic level, where the energy efficiency of the autotrophs drawing energy from the sun is only about 1%). This is called the **ten percent law**, which was proposed by ecologist Raymond Lindeman. (Although called a 'law', it is only an observational fact!) This is why green plants are the most abundant organisms, followed by herbivores, and carnivores are the fewest as they sit on top of the food chain or the trophic/energy pyramid.



Energy Pyramid
Graphic Source: Encyclopaedia Britannica

Ecosystem Classification

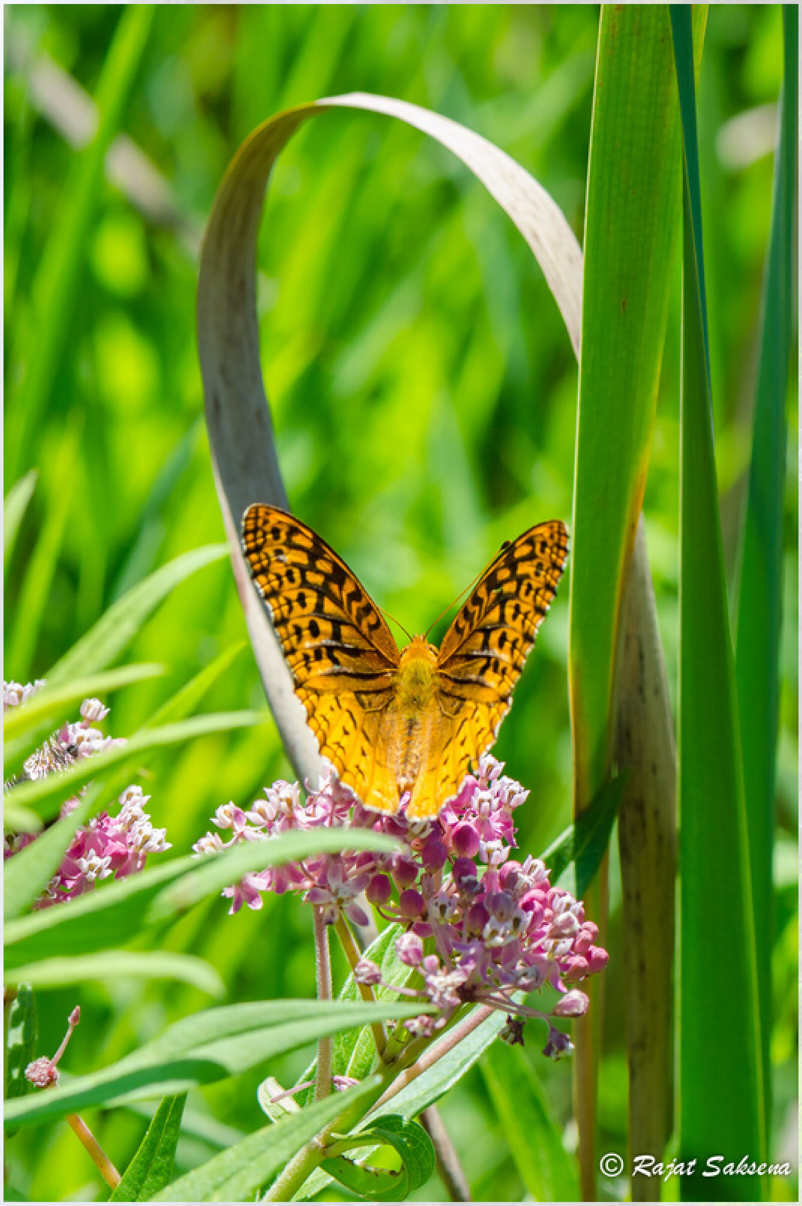
Our planet supports a tremendous biodiversity (or diversity of lifeforms), and as they evolved and adapted to their local environments, they organized themselves into natural groupings and distinct biological communities. Such biological groups are, for the most part, self-sustained and somewhat "isolated" from other groups. From the hot deep-sea hydrothermal vents or near-boiling conditions of hot geysers to the frigid conditions at poles and everything in between, organisms have adapted to the conditions where they not only survive, but thrive in those specific environments. Hence, for ecologists, it is convenient to accordingly divide such groups of organisms and their respective

Painted Turtle

environment into distinct ecosystems, in order to provide a better understanding of the biological systems at work in each environment.

Two broad classifications of ecosystem can be defined as **aquatic** (involving water-based environments) and **terrestrial** (involving land-based environments) ecosystems. But within the two, there can be several more classifications of ecosystems. For example, the terrestrial ecosystem can be divided into four major ecosystems — **forest**, **grassland**, **tundra** and **desert**. Within each of these, there are still further classifications. Similarly, the first broad classification for the aquatic ecosystem is **freshwater ecosystem** and **marine ecosystem**. Within freshwater ecosystems, the first classification is ***lentic*** and ***lotic*** ecosystems. Lotic ecosystem refers to fast-flowing waters moving in a single direction, such as rivers and streams. Lentic ecosystem refers to standing water ecosystems, such as ponds and lakes. These ecosystems are further classified into smaller ecosystems. In the marine ecosystem, there are coral reefs, coastal, and other ecosystems. The point where rivers meet the seas, called *estuaries*, is another specific kind of ecosystem.

What defines an ecosystem also depends on what aspects of the system one is observing. For example, from a fisheries management perspective, the ecosystem could comprise everything within the watershed, which could potentially contain forests, prairies, wetlands, grasslands, and other habitats. On the other hand, a forester would see different ecosystems within



Great Spangled Fritillary on Swamp Milkweed

Deep-Sea Ecosystems

In deep-sea ecosystems around the hydrothermal vents, sunlight doesn't reach through the depths of water, and the basis of energy in those ecosystems is chemical, and not solar. Such ecosystems are supported by geothermal energy, and the driving mechanism is not photosynthesis but ***chemosynthesis***. The Sulfur Bacteria that thrive in the hot sulfur-rich waters around these vents, use the sulfur in reduced form, such as hydrogen sulfide (H_2S), and oxidize it into sulfates to derive energy. Hence, such organisms are termed as ***chemoautotrophs*** (rather than photoautotrophs).

the same part of the land, such as oak-hickory forest, beech-maple forest, wetland and open meadow ecosystems. Even smaller habitats could be ***microhabitats***. Microhabitats are small areas that somehow differ from their surrounding habitat, and their unique physical conditions provide home to unique, and often rare, species. Hence, an ecosystem could be as small as a puddle of water in a field or as large as the Amazon rainforest!

The ecosystems are often defined by the dominant vegetation or landscape feature of the region, such as a body of water or a mountain. A boundary of an ecosystem depends on many factors, such as topography of the land (or *gradient*), local climate, soil characteristics, the local plant and animal life and even the geologic history of the area. Usually, there are no hard boundaries where one ecosystem ends and another begins. One ecosystem gradually blends into another, and the overlapping region is referred to as ***ecotone***. Ecosystem boundaries can also change over time — in a short span of time due to a sudden drastic event or gradually through *ecological succession*.

Baltimore Oriole

A group of Pearl Crescent butterflies drawing nutrients from the carcass of a dead mammal

Hierarchical Structure

Organism In ecology, an organism is the basic unit of life.

Population A population is a group of individuals of a given *species* that live in a given region at the same period of time. (A ***species*** comprises the same kind of organisms, which can reproduce among themselves.) Ecologists refer to an organism as an *individual* when discussing in context of members of a population. So, while an organism is the basic unit of life, an individual is the basic unit of a population.

Habitat Habitat is defined as the region that is specific to a population. In other words, wherever the population of a specific species thrives is its habitat.

Community A community is made up of all the species that cohabit in a given region at the same period of time.

Ecosystem An ecosystem comprises the community as well as the physical region where the community thrives, and also includes the interactions and interdependence that exist between the community and their environment. Hence, an ecosystem can contain several different habitats.

Biome A biome encompasses a larger region. Biome refers to the region of the world that is characterized by its climate, resident life, and the environment. A biome can comprise of many different habitats and ecosystems. For example, the tropical rainforests of the planet across different continents can be grouped together to make up one biome. Similarly, deserts can make up another biome. All the ecosystems of the ocean can be grouped into marine biome.

The classification of ecosystems and biomes is fluid, and often depends on the viewpoint of the observer studying the ecology of a given region.

Biosphere A biosphere is the global ecosystem extending from the ocean seabed to the outer extent of the atmosphere of the planet.

The strictly inorganic part of the earth is called the **geosphere**. The geosphere consists of the **lithosphere** (rocks and soil), **hydrosphere** (water) and **atmosphere**. The complete life system that thrives within this geosphere is called the **biosphere**.

American Toad

Eastern Cottontail Rabbit

Ecological Relationships

The interactions between the organisms in an ecosystem take place in many different ways.

Predation It is the process in which a living animal (prey) is consumed by another living animal (predator) that captures and kills it before eating. It is the ecological process of energy transfer through the ecosystem.

Competition When multiple organisms or species compete for the same resource.

Commensalism This is a kind of interaction between two organisms or species in which one benefits from the other, but the other neither derives any benefit nor harm from the interaction. For example, birds, such as the cattle egret, benefit from the grazing of the cattle, who stir up the insects in the process, making it easy for the egret to quickly scoop them up. The cattle reap no apparent benefit from the egrets.

Mutualism In this interaction, both the organisms or species benefit equally from one another. The most common example is that of the relationship between flowering plants and pollinators, or between ants and aphids, where ants feed on the honeydew secreted by the aphids. In return, ants protect the aphids from other predators. Lichens are a special example of mutualism. [To learn about lichens, read the February, 2020 issue of Project Nature newsletter.]

Parasitism In this interaction, one organism or species benefits at the expense of the other. The parasite lives on or inside another organism — the *host* — deriving energy and nutrients, causing harm to the host but usually not killing the host. Examples include ticks and mites that feed on the host's blood but do not cause significant harm to their host.

Commensalism, mutualism and parasitism are together known as ***symbiosis***. Symbiosis is any type of a close and long-term biological interaction between two organisms. Some ecologists would include predation and competition too in symbiosis, because after all, those are also interactions.

Examples of Predation

A robberfly with a leafhopper as its prey

Azure Bluet damsefly feasting on a moth

A Chinese Mantis enjoying a Zabulon skipper

Cooper's Hawk with a captured American Robin

Examples of Parasitism

A gall on the Goldenrod plant, likely caused by the Goldenrod gall fly. *Galls are kind of a swelling growth on the external tissues of plants, animals or fungi. In this case, the parasitic insect lays its eggs on the plant stem. When the egg hatches, the larva burrows into the stem. The larva's saliva is believed to mimic plant's own hormones, and results in the formation of these abnormal growth. The gall provides both food and protection to the insect larva. There's one gall per larva. After the larval stage is complete, the adult fly emerges out of the gall.*

A Blue Dasher dragonfly infested with black water mites. *These mites attach to the dragonfly in their aquatic immature stage. [To learn about life cycle of dragonflies, read the June 2019 issue of Project Nature newsletter.] The free-swimming larval mites attach to the dragonfly larva (or nymph/naiad) in water, but are not parasitic yet. The life cycle of the parasitizing species of mites is somewhat synchronous with that of their host dragonfly, and their emergence is timed with the emergence of the dragonfly, such that the adult mites quickly parasitize the adult dragonfly.*

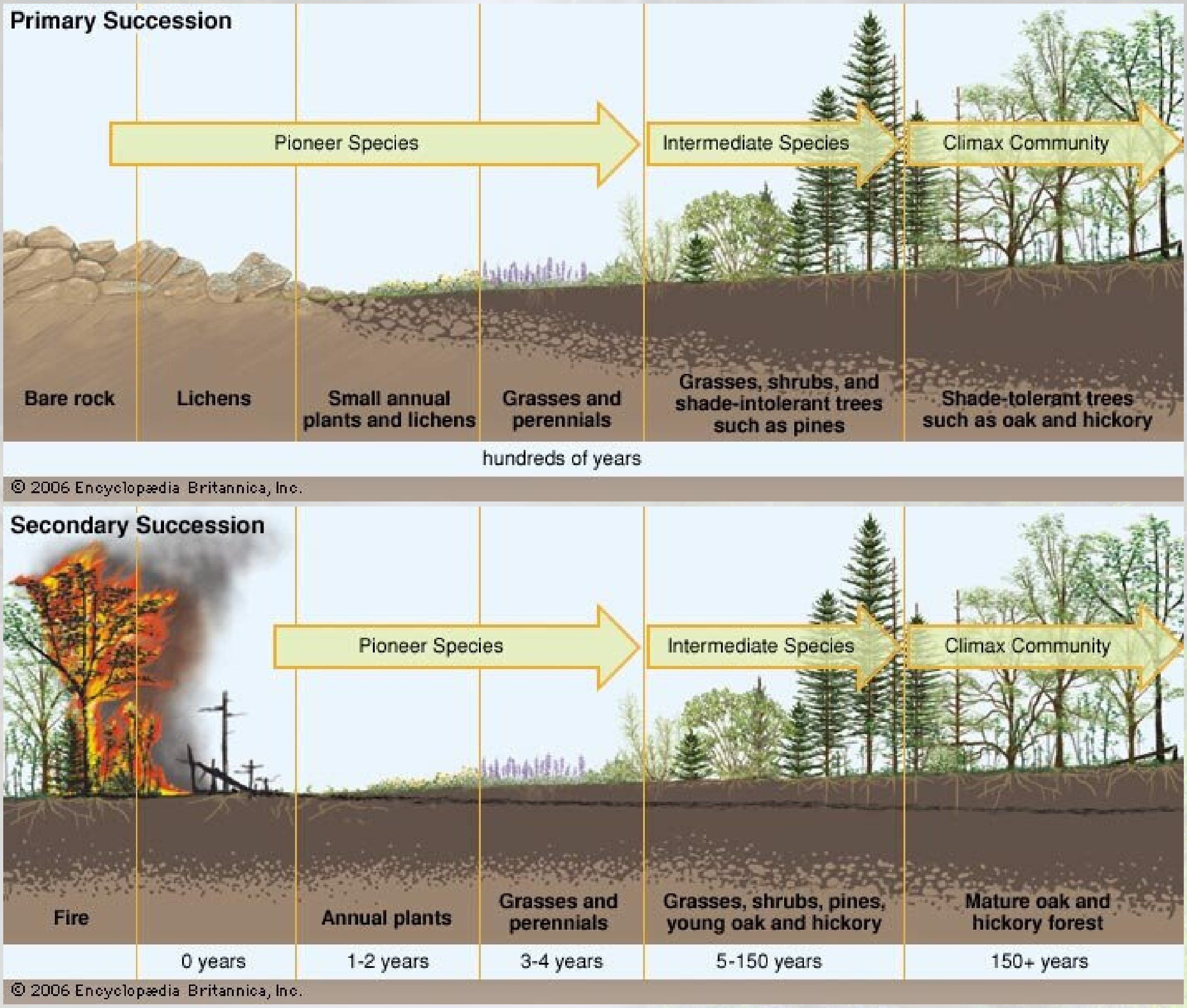
These interactions between the organisms among themselves and with their environment take place through two main forces — **flow of energy**, and **cycling of nutrients and water** through the system. Water is cycled through the ecosystem by means of *evaporation* (transforming to water vapor from the surface of a water body), *transpiration* (water lost by plants through evaporation from its aerial parts, such as leaves, flowers and stems) and *precipitation* (in the form of rain, hail or snow). Nutrients from the soil are drawn by the plants, which are then consumed by animals. After both the plants and animals die, they decay and the nutrients return back to the soil.

Parasitoidism This is a special kind of parasitism, where the parasitoid lays eggs inside another organism and the young develops inside the host and eventually kills it.

Ecological Succession

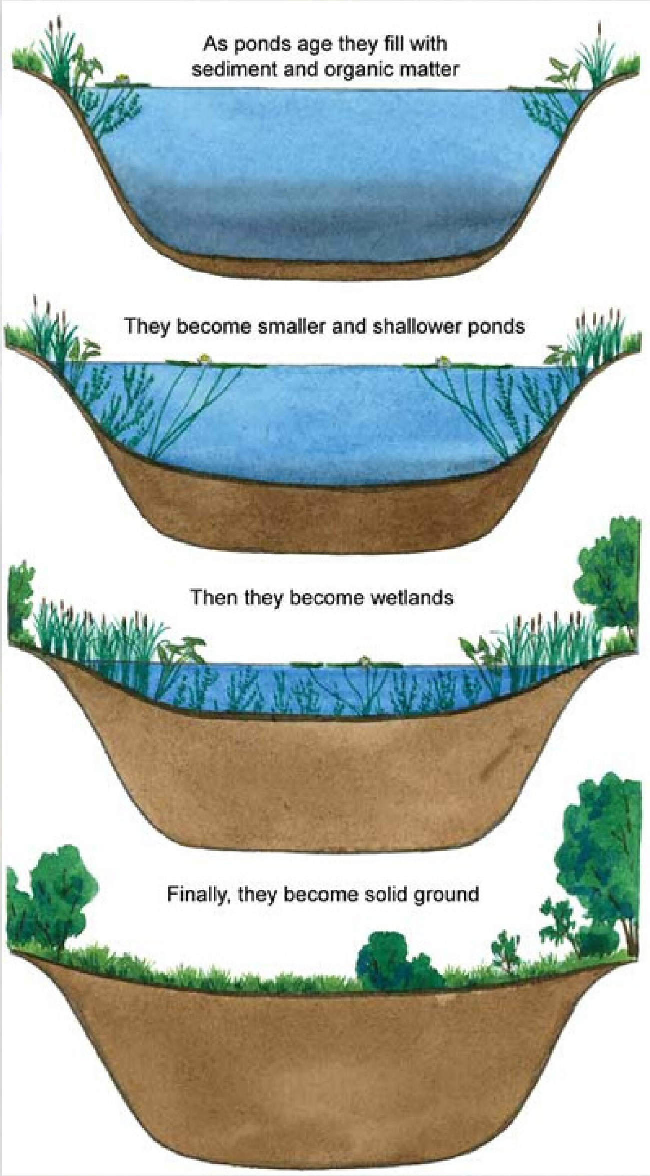
The ecosystem is a dynamic system. Earth's landscapes undergo periodic disturbances. Just like every living organism, the ecosystem is also always evolving. There are climatic and other natural phenomena that can lead to a transformation in the environment. Even though the ecosystem is a stable system, there are always natural imbalances, which tend to shift the system to a new stable condition or state of equilibrium, causing the organisms to adapt. This results in the communities responding to the constant changes in their environment. As the organisms adapt and evolve to the new conditions, so does their interactions, which results in the transformation of the whole ecosystem. The disturbances range from very small and localized, such as a small opening in the forest canopy, to catastrophic and much larger in scale, such as wildfires or big storms. Each disturbance — big or small — impacts some of the existing communities of the ecosystem and makes way for new species, which are better adapted to the new environment, to establish. This process is known as ecological succession, through which the structure of the ecosystem evolves.

There are two types of succession – **primary succession** and **secondary succession**. Primary succession occurs in an entirely new and lifeless habitat, which has not been colonized before. Examples of such habitats include recently formed sand dunes, or newly deposited surface by a recent lava flow or a fresh exposed rock face due to a landslide or created as a result of mining in a quarry. Secondary succession occurs in a region with a previously established community, which has been disturbed. Disturbances in a secondary succession do not eliminate all the life and nutrients from the habitat. For example, events such as forest fires or storms that uproot and destroy hardwood trees, create patches of habitat for smaller non-woody herbaceous plants to grow. This is known as ***early successional habitat*** and the new species that colonize the region referred to as ***early successional species*** or ***pioneer species***. The newly changed habitat not only replaces the flora, but with it, a succession of a new community of fauna also occurs, and the new interactions between the plants, animals and the environment influence the ecosystem.



Ecological succession in a forest. Graphic Source: Encyclopaedia Britannica

Succession can be gradual, happening over a long time-scale or sudden and more drastic. For example, the ecological succession of a lake into a shallow wetland and then to a prairie, takes place over hundreds or thousands of years. Examples of sudden disturbances include forest fires, storms or human-caused changes. Succession can also be caused by animals, such as beavers, in a relatively short span of time. The dams and lodges that beavers build, can alter or create new habitats by modulating the availability of both biotic as well as abiotic resources, causing an ecological succession. For this reason, beavers are often called nature's "ecosystem engineers".



Ecological succession of a pond
Graphic Source: texasaquaticscience.org

In certain habitats, continual small-scale disturbances keep the ecosystem constantly changing through corresponding successions. In others, such as forests, succession reaches an ultimate stage, referred to as the *climax community*, beyond which there is no further stage of succession. This is the state of equilibrium, such that no other biotic community can be admitted anymore. Only events, such as large forest fires or storms that destroy the climax community, would cause succession to restart from the beginning with the early successional community. [To learn about forests, read the August 2019 issue of Project Nature newsletter.]

The natural disturbances, such as wildfires, certainly appear destructive and damaging, but they play a crucial role in the ecological cycle, and such destructions could be beneficial to certain ecological communities. For example, certain species of trees in fire-prone forests have adapted to this force of nature in such a way that they depend on fire to reproduce. Some species of pine trees, such as the southern yellow pine, keep their buds dormant underground, and sprout only after they have been burned in a forest fire. Others, such as lodgepole pines, have hard cones that are glued with a strong resin. A forest fire melts the resin, which opens the cone and releases the seeds. Wildfires are also particularly important for the early successional species.

Ecological succession is a constant and necessary process of the planet and part of nature's cycle, allowing different communities to have their chance to thrive, and maintain a healthy and balanced ecosystem.

Trophic Cascade

A trophic cascade is an ecological effect that starts at the top of the food chain and propagates all the way down to the bottom. A great example of trophic cascade is the impact on the ecology of Yellowstone Park when wolves were reintroduced in 1995. Wolves stood at the top of the food chain, who hunted deer and other mammals. Before the arrival of European settlers, wolves roamed the forests of Yellowstone National Park, but by the 1920s the last pack was hunted and killed off. Without the wolves at Yellowstone, elks didn't have any natural predators. Consequently, the elk population in the park exploded. The disproportionately large elk population grazed away almost all the vegetation in the forest. With only a few wolves reintroduced in the park in 1995 (31 wolves were relocated to Yellowstone from Jasper National Park in Alberta, Canada), they started to hunt some of the elks, but the greater impact they had was in changing elks' behavior and the elks started avoiding areas where they could be easily spotted by the wolves, particularly in the valleys and the gorges. As a result, vegetation started to regenerate in those areas. With forests rejuvenated, there were more birds. The number of beavers started to increase as there was more food for them. Beavers, in turn, further aided the biodiversity because of their building activities, which creates niche habitats for other species, such as otters, muskrats, ducks, fishes, reptiles and amphibians. Wolves also preyed on coyotes, and with their numbers reduced, the number of mice and rabbits increased. With more rabbits and mice, there were more hawks, weasels, badgers and foxes. Birds that feed on carrion, such as Bald Eagles and crows, increased as they would come to feed on the leftovers from the wolves' kill. Bear populations started to rise as well. With more vegetation on river banks, there was less erosion and the rivers held their course and did not meander as much. This resulted in more riffles and pools forming in the rivers. These features created habitat for the macroinvertebrate community to thrive, resulting in improved water quality. [To learn about macroinvertebrates and water quality, read the July 2019 issue of Project Nature newsletter.]

Wolves

Wolves were almost seen as a species that needed to be removed so the West could be settled. Wolves were pursued and hunted with more determination than any other animal in US history! Their populations declined alarmingly, and the Gray Wolf was added to the list of Endangered Species Act in 1974. However, the positive impact of wolves on the ecosystem is not seen in the same light by everyone. Protection of wolves has been controversial ever since they were included in the Endangered Species Act. Wolves do occasionally prey on livestock, but that number remains a small fraction of the overall livestock losses. Wolves have been delisted from the endangered species list in Idaho and Montana. In 2019, the US Fish and Wildlife Service, Department of the Interior, proposed that the gray wolf be removed from all federal protections under the endangered species list in the lower 48 states.

There is, however, some debate among scientists on the magnitude of the impact wolves had on the elk population at Yellowstone. There are arguments on both sides. Perhaps it is not easy to assess the impact based on only 25-years worth of data, as it is too short of a time-frame to study such a complex ecology. Scientists studying Yellowstone ecology continue to learn new things about how the forest ecosystem is adapting itself to wolves and what changes are caused by wolves and which ones are not. But it’s an undeniable fact that wolves did have a positive impact on the ecosystem of Yellowstone National Park!

Dogbane Beetle

Gray Tree Frog

Climate Change and Ecosystem

The warming of the planet caused by the anthropogenic greenhouse gases is causing a serious impact on the ecosystem. With global warming, the distribution of both terrestrial and marine ecosystems is changing as species of plants and animals are forced to gradually move to higher latitudes or higher elevations, where conditions are more conducive to their survival. For many species, the climate of their habitat is tied to their life cycle, such as emergence, migration, blooming, and reproduction. As winters are getting shorter and milder, the timing of these events is changing. Some species are able to adjust, while others are vulnerable to these changes. Coastal ecosystems are being lost to sea-level rise. Rise in sea-levels is also causing saltwater intrusion into freshwater systems, causing certain key species to relocate or perish.

In addition to the warming of the planet, the ecosystem is being put under further stress due to habitat loss and habitat degradation, caused by human activity. With reduced habitat, there is more competition, resulting in local extinctions of some species. Over-harvesting of species and other ecosystem resources for human-needs is creating unsustainable conditions, threatening the stability of the ecosystem.

The ecosystem has forever been evolving and it always adapts itself to new conditions. However, that adaptation happens at large time-scales. Cataclysmic events result in mass extinctions. There have been several such natural events in our planet's 4.5 billion-year history that have caused mass extinctions. For example, the mass extinction that happened at the end of the *Permian* period, about 250 million years ago, has been the worst mass extinction in earth's history, when almost 90% of aquatic and 75% of terrestrial vertebrate species went extinct. It took 150 million years from that point for the planet to regain the biodiversity it had at the peak of Permian period.

The impact that humans are having on the planet is much like the cataclysmic events of the past, where the conditions of the environment are changing at such rapid rates that the system is unable to adapt in that short period of time. The rich biodiversity of the ecosystem has evolved over millions of years and is irreplaceable!

In the late 20th century, biologist and ecologist Edward O. Wilson (credited for coining the term *biodiversity*) estimated that at least 27,000 species of flora and fauna were going extinct each year!

A 2016 study estimated the global biodiversity of earth, with a total of about 1 trillion (1,000,000,000,000) species on the planet. Of that number, only a tiny fraction of species has been scientifically documented and described (by one estimate, about 1.7 million species have been scientifically described so far). Other estimates of the total global biodiversity range from 3 to 30 million. The least estimate is still more than twice than what we have documented. This must give us a pause for a moment to think about the many organisms that we don't even know about, but are constantly working in the functioning of the ecosystem. We haven't been able to even document all those species that currently exist, let alone understand their role in the ecosystem. Another unfortunate thing to think about this fact is that we are losing so many species that we never even knew existed!

It has been found in many studies that the seemingly insignificant species are crucial to the stability of the ecosystem. But the ecosystem doesn't function based on whether or not we understand how it works, and regardless of our understanding of the role an organism plays in the system, it is an important element in the smooth functioning of the system.

We have changed our planet so drastically, impacting its atmospheric, geologic, hydrologic and biological systems, that scientists have proposed a new geologic epoch marked by human dominance of the planet and another mass extinction, called the ***Anthropocene***!

But if *anthropocene* means a time defined by us humans, it also means we can choose how it is defined. We must understand that we are an inseparable part of the ecosystem, and if the global biodiversity of the system is in peril, we are not spared from it either. If it was our actions that caused the degradation of the environment, then we also hold the ability to reverse it. We need the ecosystem for our own survival. The decision rests entirely with us — whether this epoch is defined by a global mass extinction, or a time of harmonious coexistence between the most dominant species of the planet and all other organisms — an epoch of mutual respect when every resident of the planet thrived and flourished!

A mating pair of Eastern Tailed-Blue

Cover Photo: *Red Milkweed Beetle*

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