**NPTEL**

**NPTEL ONLINE COURSE**

**Ecology**

# Biodiversity, population and ecological principles

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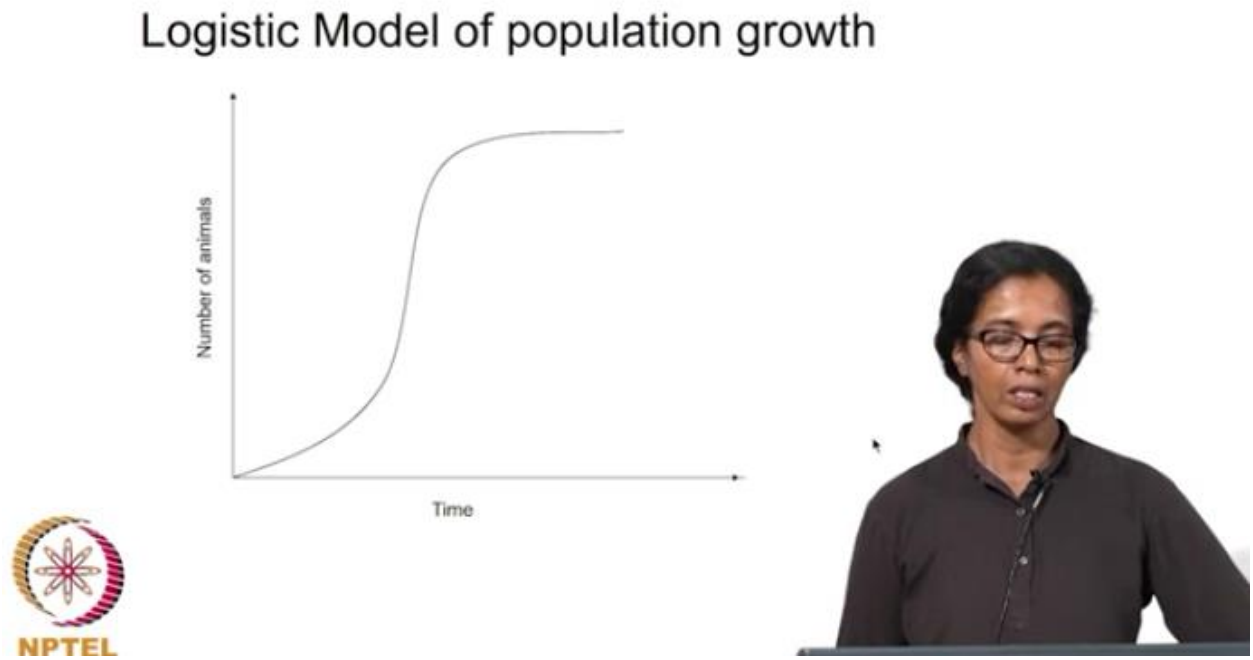
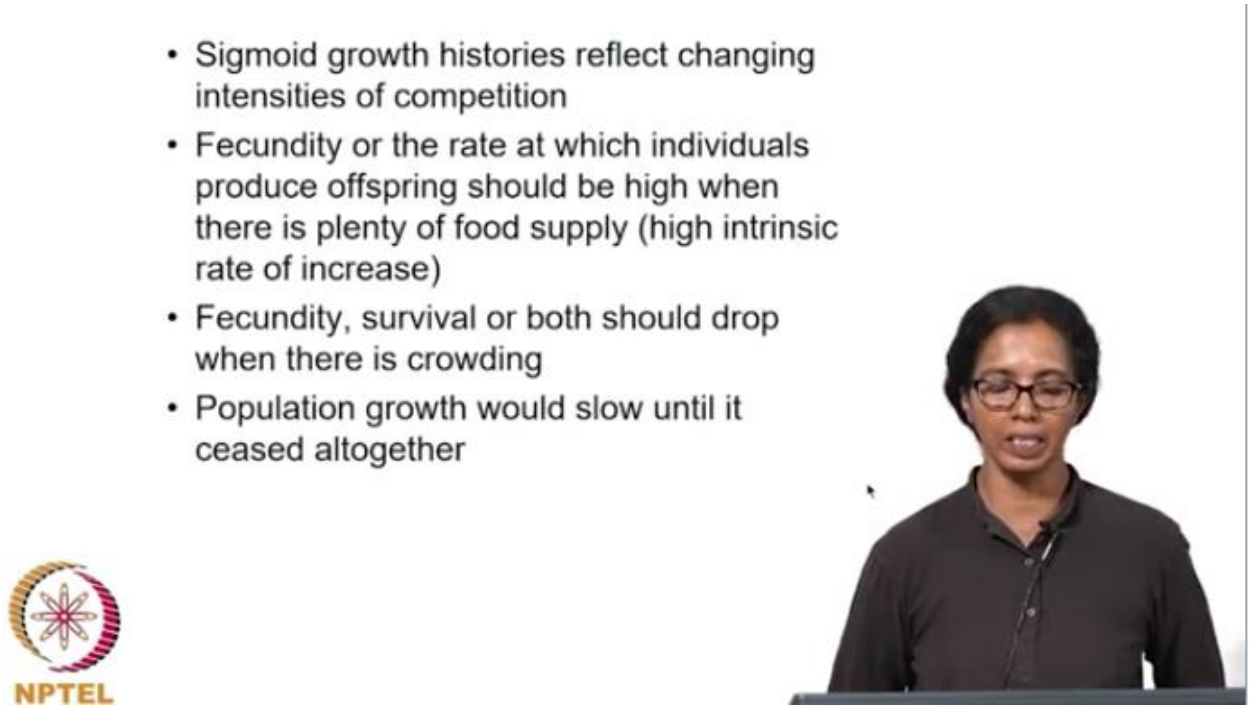
So, in the last class, we looked at the organization of matter in nature at different levels and ecology that is focusing on organism, population, community, ecosystem towards biosphere. And when it comes to organisms and population, we were discussing the population dynamics and how it is controlled in a population or in a community.




So, there are various models which controls, which gives us an idea of the population that is in a community that is growing.

So, the logistic model of population growth essentially defines the growth of population in the absence of competition, so it is a sigmoidal curve which tappers of to an equilibrium level which is limited by the resources or some other external factors.



So, the sigmoidal growth histories reflect changing intensities of competition. Fecundity or the rate at which individuals produce offspring should be high when there is plenty of food supply that is high intrinsic rate of increase. And fecundity, survival or both should drop when there is crowding or when the population increases and population growth would slow until it ceased altogether.

- Logistic hypothesis is also a hypothesis of control by density –dependent factors (the denser the crowd, the more the competition)
- The logistic hypothesis can be manipulated to predict the results of inter-specific competition between species populations with overlapping resource requirements

So, in logistic model also the population cannot go on growing indefinitely it will crash at some point when it is exceeding the carrying capacity of the ecosystem.

## The Lotka-Volterra model of inter-specific competition

- If populations of 2 species compete for a resource it must follow that the carrying capacity of habitat for each is reduced from what it would have been if one species were in sole occupancy.
- This will result in the elimination of one species eventually.

So now when it comes to, when there are two multiple species exist in an ecosystem, the Lotka-Volterra model defines the competition between species. If populations of 2 species compete for a resource, it must follow that the carrying capacity of habitat for each is reduced from what it would have been if one species were in sole occupancy. So, if only one species was there that would have been using all the resources but now into 2 species comes into the population that is competition and the carrying capacity gets reduced because of the competition between the 2 species.

## Lotka-Volterra Model

Lotka-Volterra model is the simplest model of predator-prey interactions. The model was developed independently by Lotka (1925) and Volterra (1926):

It has two variables (P, H) and several parameters:
H = density of prey
P = density of predators
r = intrinsic rate of prey population increase
a = predation rate coefficient
b = reproduction rate of predators per 1 prey eaten
m = predator mortality rate

$$\frac{dH}{dt} = rH - aHP$$

$$\frac{dP}{dt} = bHP - mP$$

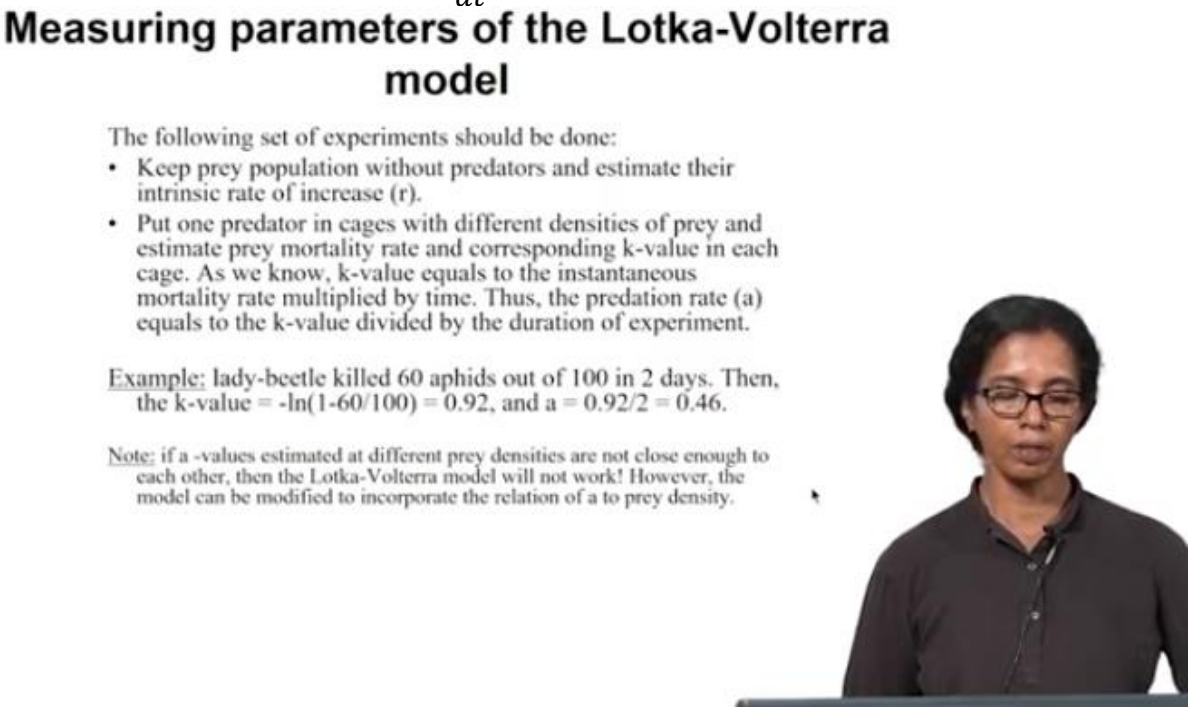
This will result in the elimination of one species eventually if it carries on the competition stuff. So, the Lotka-Volterra model is the simplest model which actually also can be used for prey-

predator relationships or interactions in a particular habitat or an ecosystem. The model was developed independently by Lotka and Volterra in 1925-1926 period, it has 2 variables P and H and several parameters that affect the equation. So it is defined by two independent equations, so the first equation is the variation of the density of the prey that is defined as $^{dH}/_{dt}$ which is given by $rH - aHP$ where H is the density of prey, r is the intrinsic rate of prey population increase, that is in the absence of any predator how much population of that prey can grow with given resources in the ecosystem.

$$\frac{dH}{dt} = rH - aHP$$

Then similarly P is the density of predators, so to determine r the intrinsic rate of prey population growth, we need to consider that predator population is zero. a is the predation rate coefficient that also determines how much in the presence of predator how the prey population is changing. b is the reproduction rate of predators per 1 prey eaten, so that dictates how many predators will be there, so $^{dP}/_{dt}$ is the rate of increase of the predator by eating the prey. So, b gives the reproduction rate of predators per one prey in the eaten.

$$\frac{dP}{dt} = bHP - mP$$




And m is the mortality rate of the predators, so these two equations are used for defining the interspecific competition or the interaction between prey-predator population. So, there are different parameters that are used in this Lotka-Volterra model and how one measures this parameters are the following set of experiments can be done, for example, keep prey population without predators and estimate the intrinsic rate of increase, that we have done in the case of logistic model, you give enough resources to the prey species and then keep counting the number of individuals in the community as with time and that gives the intrinsic rate of increase of the population of the prey.

Then put one predator in cages with different densities of prey and estimate prey mortality rate and corresponding K-value. So, this experiment can be done in lab using small insects like lady-beetle and aphids, so, for example, lady-beetle eats aphids, an example is that lady-beetle kill 60 aphids out of 100 in 2 days. Then, for example, we can determine the K value as equal to minus ln of (1-60/100) which is equal to 0.92, and a, in this case, is equal to 0.92/2, that is the K value equals instantaneous mortality rate multiplied by time.

$$K - value = \ln(1 - 60/100)$$

Thus, the predation rate equals to the, that is the a which is the predation rate equals to the K value divided by the duration of experiment. So now if it is 2 days that is 0.92 by 2 that is given for, so that gives us the value for per day, predation rate. So, if a value is estimated in different prey densities are not close enough to each other then the Lotka-Volterra model will not work.

So, you can change the prey densities and then estimate whether the values that we get, value of a that we get is close to each other. So, then that says that whether the model will work to define the relationship between the prey-predator composition in an ecosystem. However, the model can be modified to incorporate the relation of the prey density in this case.

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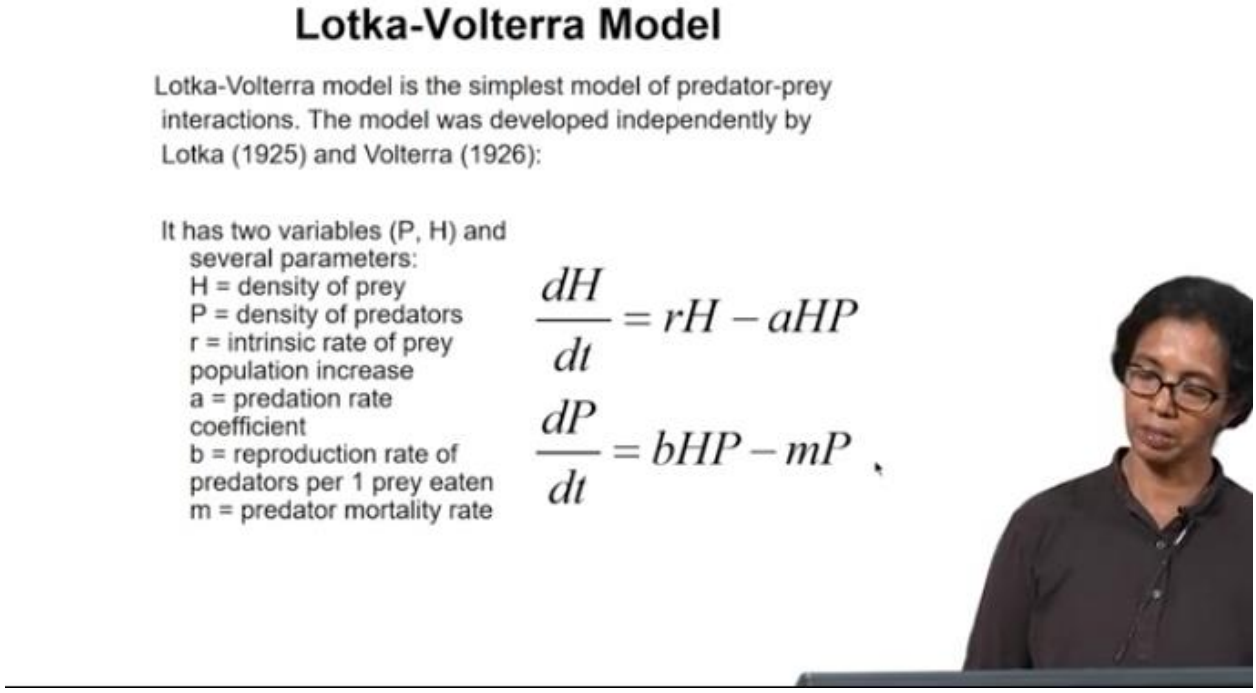
Estimation of parameters ***b*** and ***m***: Keep constant density of prey (e.g., H = 0, 5, 10, 20, 100 prey/cage), and estimate the intrinsic rate of predator population increase (rP) at these densities of prey. Plot the intrinsic rate of predator population increase versus prey density: The linear regression of this line is:

$$r_P = bH - m$$

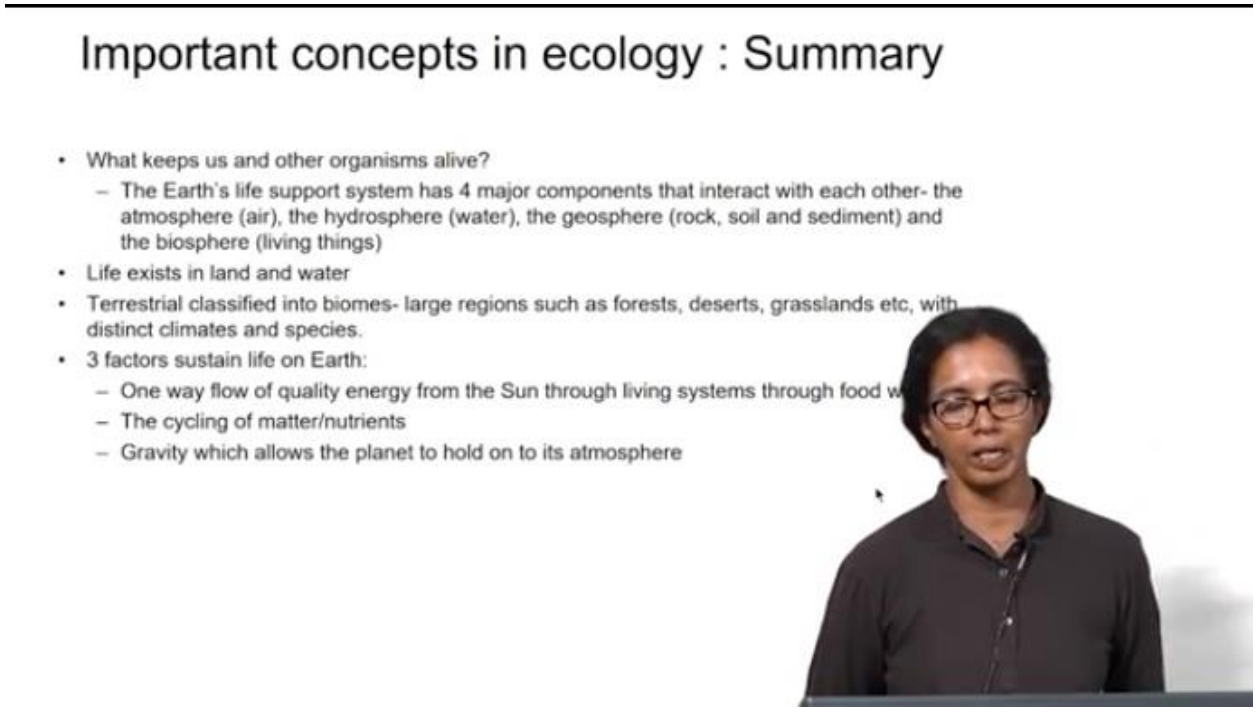
Note: If points do not fit to a straight line (e.g., the intrinsic rate of predator population growth may level off), then the Lotka-Volterra model is not adequate and should be modified.

Similarly, parameter such as b and m, how do we determine that? So, what you do is keep constant density of prey, example H = 0, 5, 10, 20, 100 prey per cage, and estimate the intrinsic rate of predator population increase. So, you just keep, let us say 5 preys or 10 preys in a particular cage and then estimate how many of those the lady-beetles are growing at what rate, and then that will, or the predator is growing at what rate and that at these densities of prey. Plot the intrinsic rate of predator population increase versus prey density, so one can get a linear regression from this, and that gives us the, which is an $r_P = bH - m$ that if you plot this graph we can get the, which is, it

is a straight line, and then from there you can get b and m values and which can be used in the Lotka model for to get these two.



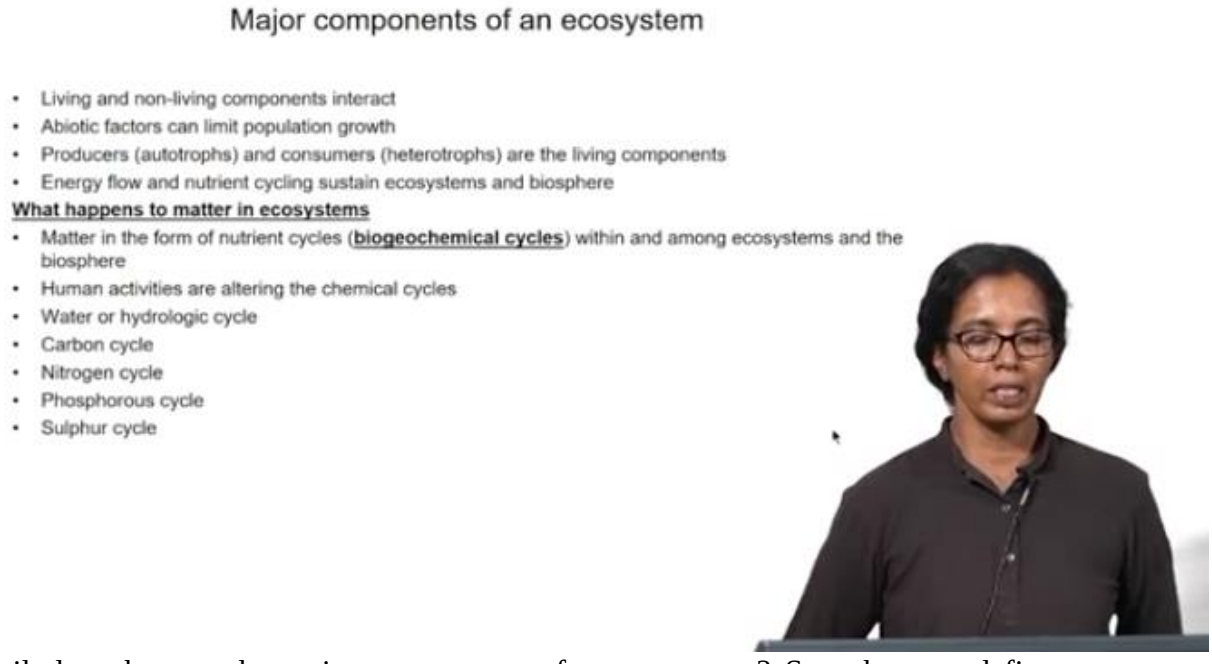

So, the first equation is to get, first experiment was to get r and H, and the second experiment is to get b and m which is, which are parameters affecting the predator population growth, r and a are the values which affect the prey population growth, so these two values will decide how the interaction between these two species happen in the system.



So, now we will summarize what we have looked at so far, and the important concepts that one needs to look in ecology. Ecology is the vast subject which requires as it is the science of the universe or somebody has defined earlier and, but it requires a lot of detailed time and analysis to study that the interactions of different species, different communities and how they coexist or and how life exists on earth itself.

So, we are summarizing some of the important points here, so one of the questions that we ask is what keeps us and other organisms alive on earth. The earth's life support system has four major components that interact with each other that we have to take into account, and we have to remember that is the atmosphere that is air, hydrosphere the water, the geosphere which is consisting of rock, soil, and sediment, and the biosphere which is the, which consisting of the living things. So, we have defined that you know how life and this, and also, we remember that life exists in land and water. Terrestrial, so we classify this life that is existing on terrestrial systems into biomes which are nothing but large region such as forest, so the term biomes is used to classify large region such as forest, deserts, grasslands etcetera with distinct climates and species that particular species that exist in those biomes.

The three major factors that sustain life on earth are one-way flow of quality energy from the sun and through living systems through the process of food web or the second is the cycling of nutrients and matter in the living systems and the nonliving systems. And third is the gravity which allows the planet to hold on to its atmosphere which is very important for us to have the living condition being established here and also the movement of organisms on earth etcetera are also dictated by the gravity.




Similarly, what are the major components of an ecosystem? So, when we define ecosystem, ecosystems we have defined earlier as consisting of living and nonliving components, which

interact and forms the ecosystem and abiotic factors can limit the population growth, because this is the nutrient cycling that is important which has to reach the living systems by nutrient cycling, we will soon see what are the nutrient cycles and so that limit, that can limit the population growth, for example, if nitrogen is in limited supply in an agriculture field we know that the production will reduce.

So, similarly, there are vital nutrients, micronutrients, and macronutrients which are needed for the growth and wellbeing of organisms. For example, vitamins are very important for the wellbeing of humans, it is not the food that we eat alone which gives us energy alone is not sufficient for our biomass growth, we need also some vital supplements of micronutrients, elements like metals and other thing, other elements like calcium, magnesium, and some other trace elements sometimes Zinc, all these are required for the wellbeing and for the living systems. So, abiotic factors can limit population growth due to these aspects.

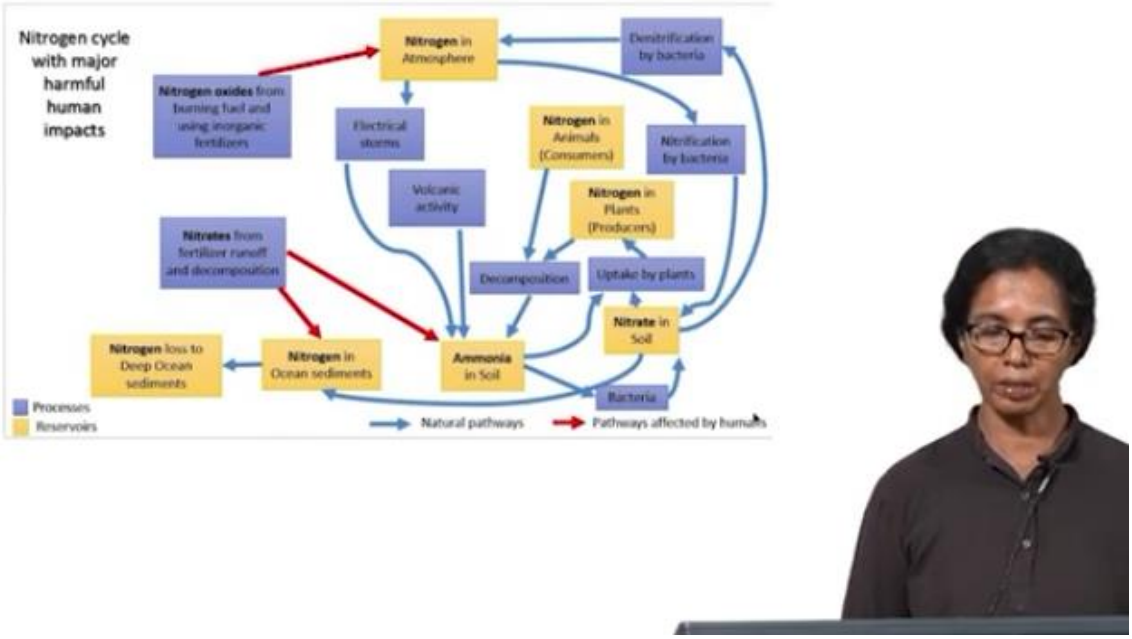
Similarly, producers which are also known as autotrophs, which means they can produce their own energy, and consumers are heterotrophs, which feed upon others, are the living components in this ecosystem.

Energy flow and nutrient cycling sustain ecosystems and biosphere. These are the important points that we have to remember about ecosystems, it is nothing but a mechanism for energy flow which is coming from the solar system or the sun, from the sun to reach organisms and then maintain life on earth.

So, what happens to matter in ecosystems? We have discussed energy flow in ecosystems and the efficiency with which energy flows in living systems, so which can be calculated using in the case of plants it is estimated using net primary productivity and the efficiency. And the efficiency varies according, in different ecosystems that we have looked at and we said, we have also seen that the efficiency of certain ecosystems are much higher than others because of probably the biodiversity that exists there.

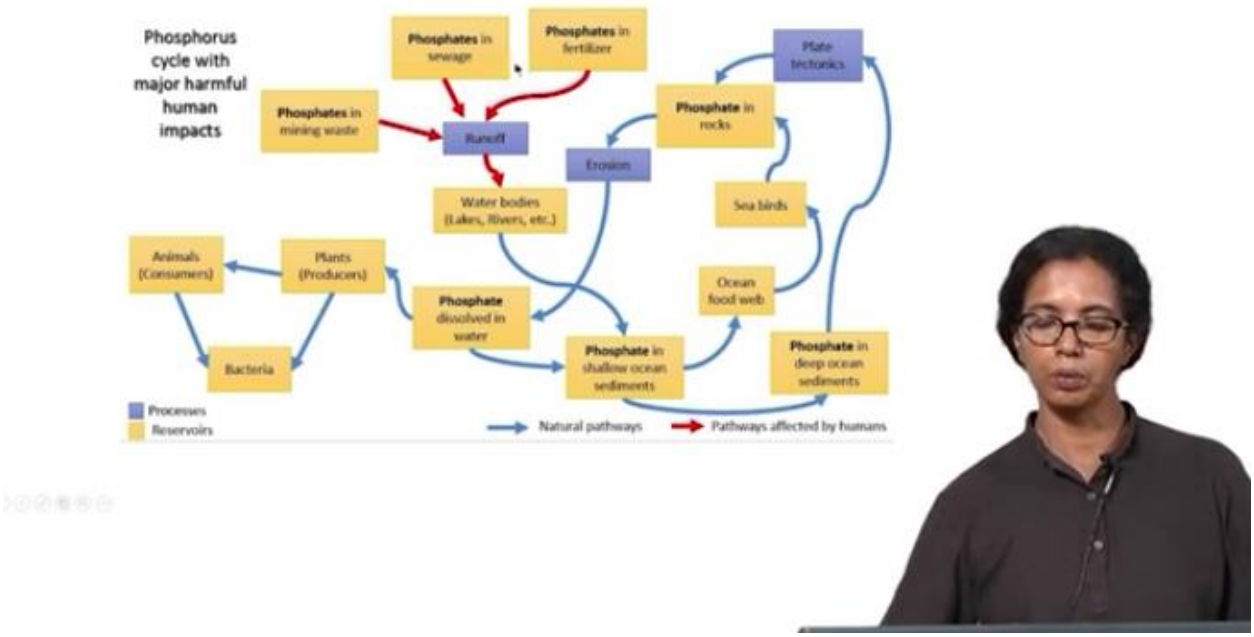
So, similarly matter also flows in the ecosystems, so mostly matter in the form of the nutrient cycle, what we call as biogeochemical cycles within and among ecosystems and the biosphere. So, that is how the matter gets circulated in the ecosystem and between ecosystems and the biosphere, so certain components have, when you look at hydrology cycle or when you look at carbon cycle, or most of the cycles have both atmosphere as well as living systems are involved.

Human activities are majorly altering these biogeochemical cycles, we will soon see those cycles. So, the cycles which we are aware of that controls life on earth are water or hydrologic cycle, the carbon cycle, nitrogen cycle, phosphorous cycle, and sulphur cycle.




Let us take a look at, for example, nitrogen cycle, so in this diagram, there are natural pathways in which nitrogen is, so nitrogen cycle operates on earth, and red arrows indicate the pathways which are affected by human activities. So there are many of this natural biogeochemical cycles are affected today by human activities, example is given in the case of this nitrogen cycle here. So, for example, nitrogen oxides which are from burning fuel and using inorganic fertilizers are released into the atmosphere, and that affects again the other natural flow of nitrogen into the environment.

So, there are processes and reservoirs one can see in different colours, the blue colours indicates processes that go on in regenerating the nitrogen and back into the cycle, and reservoirs are where nitrogen is stored for certain time period. For example, nitrogen lost to deep ocean sediments, nitrogen in ocean sediments, ammonia in soil etcetera are examples of reservoirs. And processes like electrical storms or lightning, for example, volcanic activity, decomposition by microbes, uptake by plants etcetera are processes which go on in converting one form of nitrogen to another form, or it is taken up by plant, so one can see and nitrogen in plants and animals are also considered as reservoirs because they may take time before they can get back into the system.




Similarly, if you look at the phosphorous cycle which is also again affected by human activities, some examples are mining waste, sewage, fertilizers, detergents, all these, for example, can sewages recently because of detergents that we use sometimes have polyphosphates which are used as builders which comes into the water body, and then it runs off and reaches water bodies, so again these are reservoirs of the phosphates, so in the water bodies they get again converted. So, the pathways are affected by human activities by excessively releasing certain phosphates into the water bodies and it affects the biological cycle in the aquatic as well as in the terrestrial ecosystems when water is consumed by organisms and water is also used by aquatic organisms.

Similarly, sulphur also the pathways are again affected by smelting, burning coal and refining fossil fuels or use of fossil fuels also release sulphur dioxide into the atmosphere and so basically you can see, it affects the sulphur cycle as well.

## Biodiversity and evolution

- What is biodiversity and why is it important? Biological diversity is the variety of Earth's species, the genetic diversity, the ecosystem they live in and the ecosystem processes such as the energy and material flow that sustains all life.
- Biodiversity is a vital renewable resource for all life on Earth
- Of the 4-100 million species on earth, 1.8 million have been identified
- Major components of Earth's diversity are:
  - Ecological diversity (variety of terrestrial and aquatic ecosystems)
  - Functional diversity
  - Genetic diversity
  - Species diversity

## Major components of an ecosystem

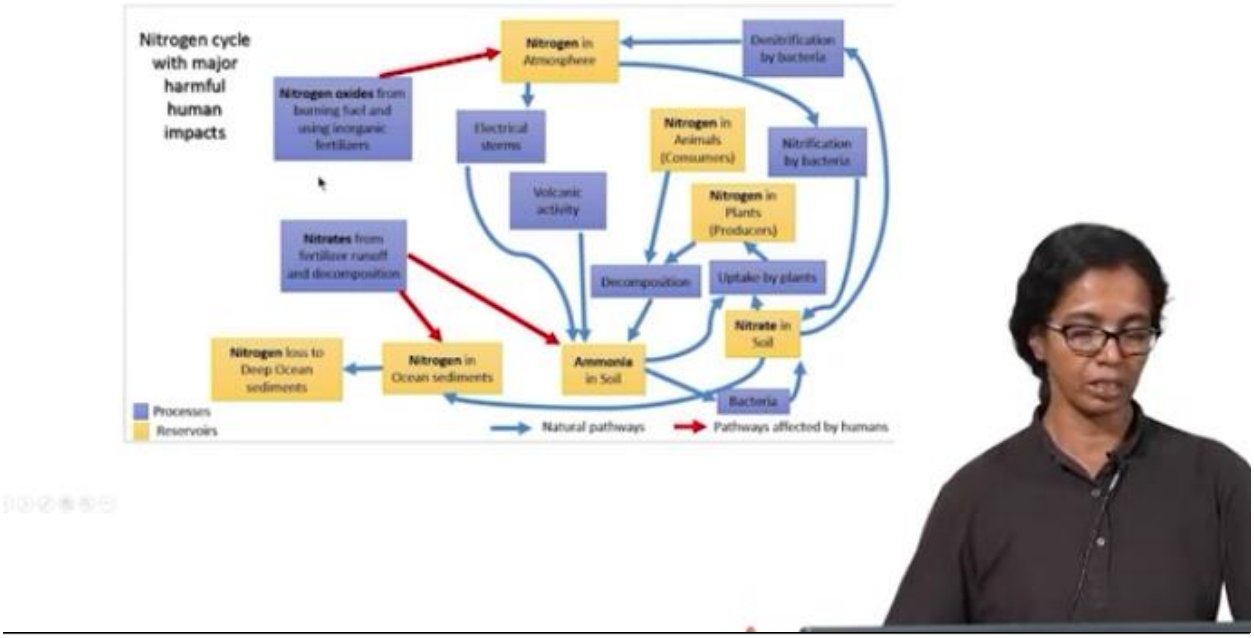
- Living and non-living components interact
- Abiotic factors can limit population growth
- Producers (autotrophs) and consumers (heterotrophs) are the living components
- Energy flow and nutrient cycling sustain ecosystems and biosphere

**What happens to matter in ecosystems**

- Matter in the form of nutrient cycles (**biogeochemical cycles**) within and among ecosystems and the biosphere
- Human activities are altering the chemical cycles
- Water or hydrologic cycle
- Carbon cycle
- Nitrogen cycle
- Phosphorous cycle
- Sulphur cycle

Carbon is a major cycle which is affected by human activities, and one knows that the carbon dioxide in the atmosphere is one of the reason for the maintaining the temperature, maintaining the temperature and it forms only 0.03% by volume in the atmosphere. However, it affects, or it dictates the temperature control of our planet, so we all know that the climate changes one of the factors which are affected by the carbon cycle in a major way, and also the hydrologic cycle. So, all these biogeochemical cycles can affect climate as well as the existence of life on earth, so it is

important for us to take into account how this nonliving part or the abiotic part of ecosystem affects life cycle on, life itself on earth and how it affects ecosystems and their maintenance.

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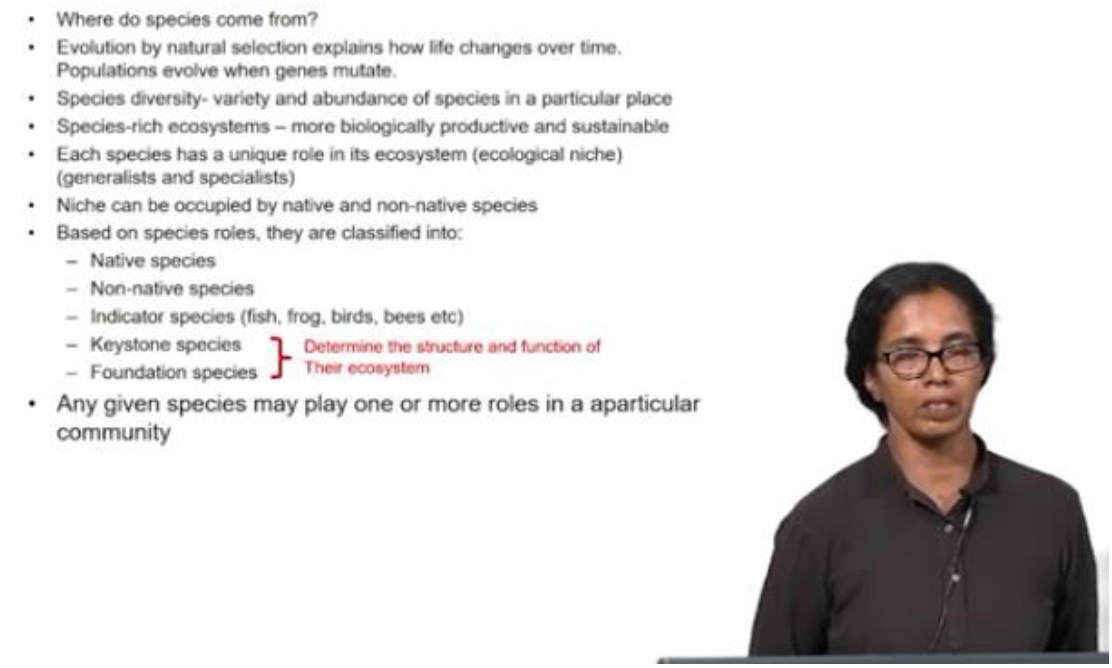
Similarly, another point that we need to summarize this about biodiversity and evolution, so these are two points we touched upon, what is biodiversity and why is it important? So biological diversity is the variety of earth species, the genetic diversity, the ecosystem they live in, and ecosystem processes such as the energy and material flow that sustains all life. So, this is essentially not just the diversity of the living beings that we see around are is not the only way to

explain biodiversity, it is given here there are four major components for earth's diversity which can be called as ecological diversity that is the variety of terrestrial and aquatic ecosystems that we see around.

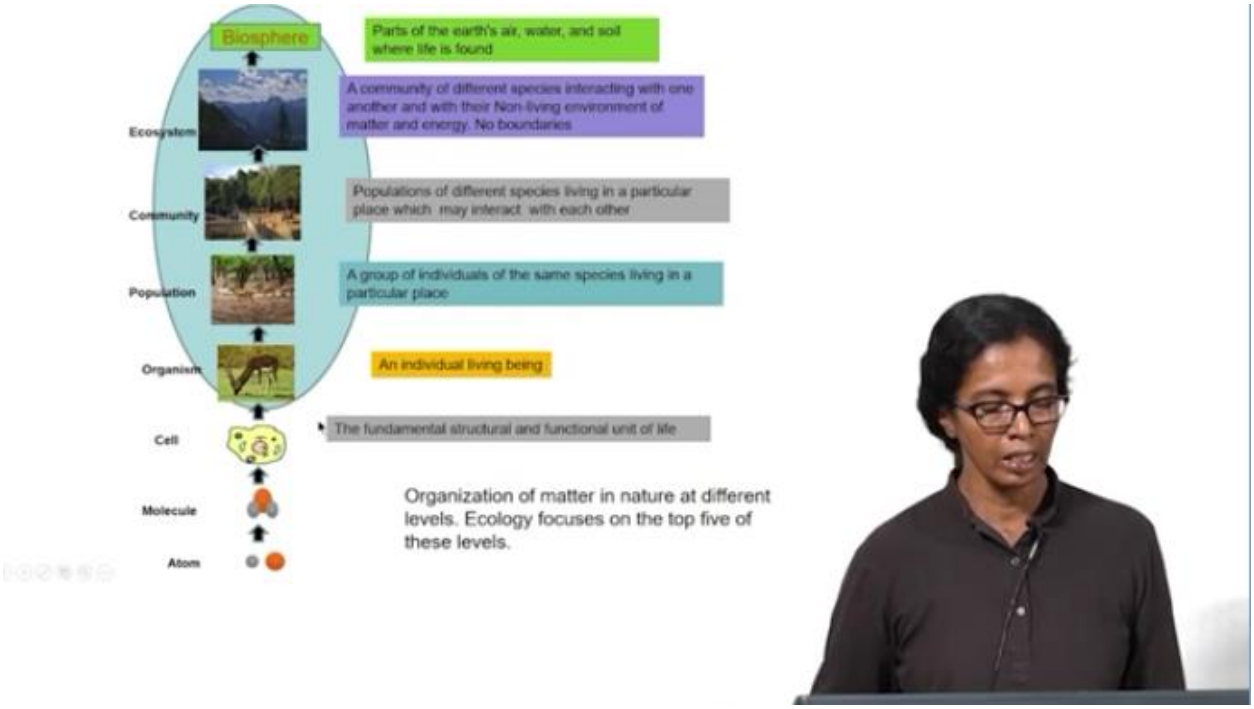
Second is functional diversity because there are many functions by the ecosystems. Genetic diversity, so the genetic pool of different organisms, for example, if you take, if you consider fish there are different species of fish which are genetically different in a particular pond or a lake that we take as a example ecosystem. Species diversity, so these are the four major components that we see on earth as we go from one region to another or when we consider biomes, so you can see different forms of life exist, and this diversity is that is contributing to biodiversity. So, the biodiversity is the vital renewable resource for all life on earth, so that is the most important message that we have to keep in mind and to make life sustainable on earth, biodiversity is very necessary.

And as far as our human understanding is concerned of all the research that we have done so far with the scientist finding out how many species are there, out of the 4 to 100 million species on earth, we have only identified 1.8 million species, and there are 1000s of species discovered every year or identified every year which we do not know what their functions are, what exactly their contributions are etcetera, but is it important for us to know it?




No, each of them have a unique function to serve on the planet, and that is why it is important to have each and every species.

So, and where do species come from? So, the definition or the understanding of species, where do species originate or the everyone is aware of the book origin of species, so which tells us that evolution by natural selection explains how life changes over time or different species come into existence.




So, populations evolve when genes mutate, and that is the slight changes in the genetic makeup is what or when we have seen in the first slide that is essentially telling us. So, this slide for example, tells us that at the cell level, whatever changes that happens affects the organism and runs through the population, community, and the ecosystem, and that is essentially what we mean by the mutation that can happen at the molecular level which changes the cell and the organism and then how the community get affected.

So, basically the natural selection is the process which happens at the molecular level of the DNA and that or the genetic the gene of the organism and that gets transferred to the, in the flow of the organization of life on earth. So that is one can see how species evolve in this process itself. So, the species diversity is nothing but the variety and abundance of species in a particular place that we see, what is meant by varieties, the number of species that you see abundances nothing but the number of members of a particular species that you see. So, the species diversity or biodiversities expressed using a quantity that has both the components that is the number of species as well as the number of members in each species that have to be taken into account to estimate the biodiversity.

Species-rich ecosystems, why are they important? They are important because they are more biologically productive and also sustainable in under circumstances such as disturbance happens, or some chemical pollution happens or let us say storm or a flood or drought happens, in all this cases species-rich ecosystems are more stable when it comes to stability of ecosystems, when it comes to stability of ecosystems.

And the important thing that we have to remember is that that is nothing unwanted on earth. So, each species has a unique role in its ecosystem which is known as ecological niche. And there are generalist and specialist species in an ecosystem, but at the same time each species has a unique role to play in that ecosystem and which cannot be underestimated or under, we cannot disregard

the role played by that particular organism or particular species in an ecosystem. So, the niche can be occupied by that particular place in the ecosystem can be occupied by native and non-native species. So, when it comes to what is meant by native and non-native is that based on species roles, we can classify species into different types, so that is why we call them native species, native species means species which are native to that region or that native to that habitat.

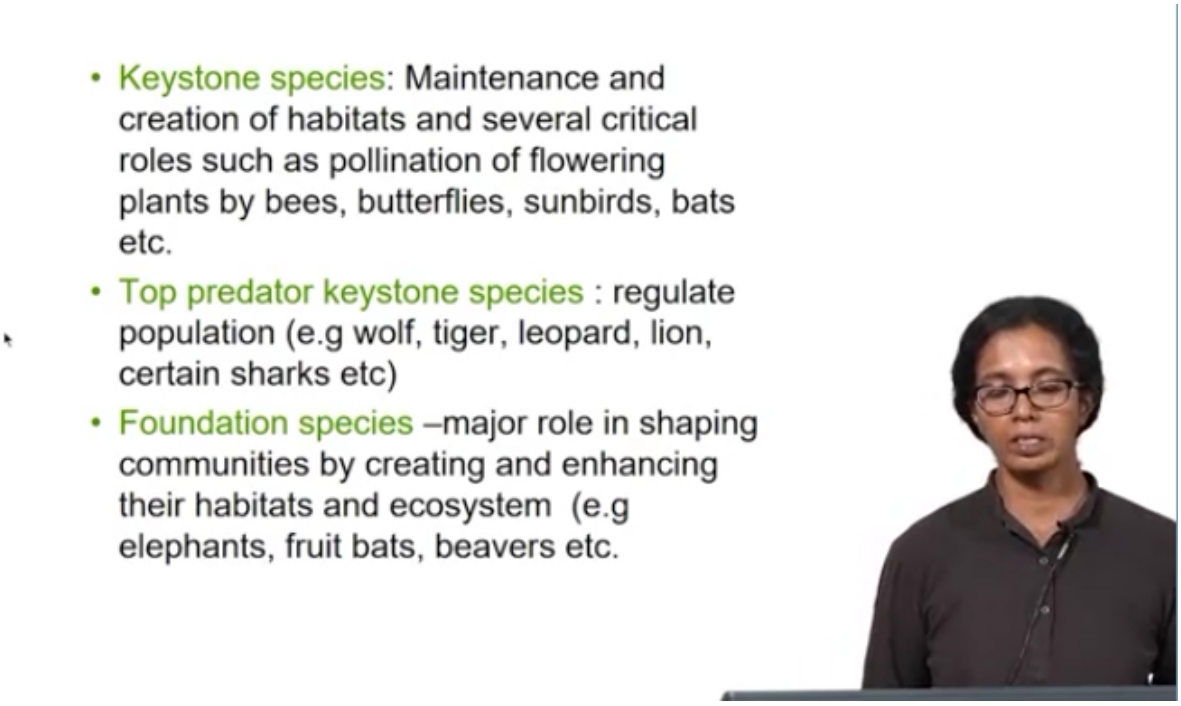
And non-native species which maybe migratory or brought by humans or brought in by some other means, mostly humans have introduced many species as non-native species which may not belong to that particular area. Sometimes food, for example, potato which could have come from a different continent because it was you know considered as a good food item, or it could be any other plant or organism that were brought to various parts of the planet by human beings. So, they are all non-native species, but they form major part of food today for human beings, so that is one of the reasons why many non-native species can be found in many different places.

Then there are indicator species, so they indicate the healthiness of a particular ecosystem, examples are fish or frog, birds, bees, they all tell us how, what is the health of an ecosystem. Let us take the case of a frog or a pond for example, how do we know that the pond is in a healthy state or is it in a, for example, the water in the pond can be, can we drink the water, is it healthy system? So many indicator species can be found for example, in a pond or a lake in a freshwater system which can point the fact that the water quality is very good, so for example, frog, frog is an amphibian, and it has life in the water as well as on the land. So, frog lays eggs in the edge of water and the land, so for example, it is very sensitive to the quality, the nature of water, for example, the surface extension of water can be altered by let us say adding surface active agents or surfactants into water, we all know that the surface tension will decrease. So, if the water quality is different, surface tension can be different, pH can be different, the oxygen in dissolved oxygen water can be different, all these affects. For example, the existence of let us say fish, frog etcetera in water, and that actually indicates whether the water for example is or that ecosystem where they are living is healthy or not. So, it is good to see the species like frogs around us and to tell us that you know the ecosystem is healthy, so frogs egg as I said is actually made of a membrane which is semipermeable in nature and any change, any certain changes in its environment can affect the integrity of that membrane and the frog can be either, it can die in the egg state itself or it can be born with some defects and which can be observed in the case of any disturbances in its, in the environment or in the ecosystem. So, it gives us a kind of indication for the quality of the ecosystem that it lives.

Similarly, birds, world over it is seen that the population of birds in many species are declining drastically due to various factors such as atmospheric pollution, climate change, global increase in temperature, various other human contributed factors, habitat loss, and lack of food all this are contributing to the decline of birds, bees, etcetera all over the world. So, these are indicator species which tells us that all is not well with the earth and its biomes, and it is time for us to wake up and then act on these issues.

Then there are two more classes which is keystone species and foundation species, so these determine the structure and function of their ecosystem, that is why they are called keystone species and foundation species. Keystones we all know that when buildings are constructed there is a keystone that starts, that is laid where you start the construction of the building, so that is

considered as the first stone that determines the rest of the alignment of every other stone that is used in the construction.



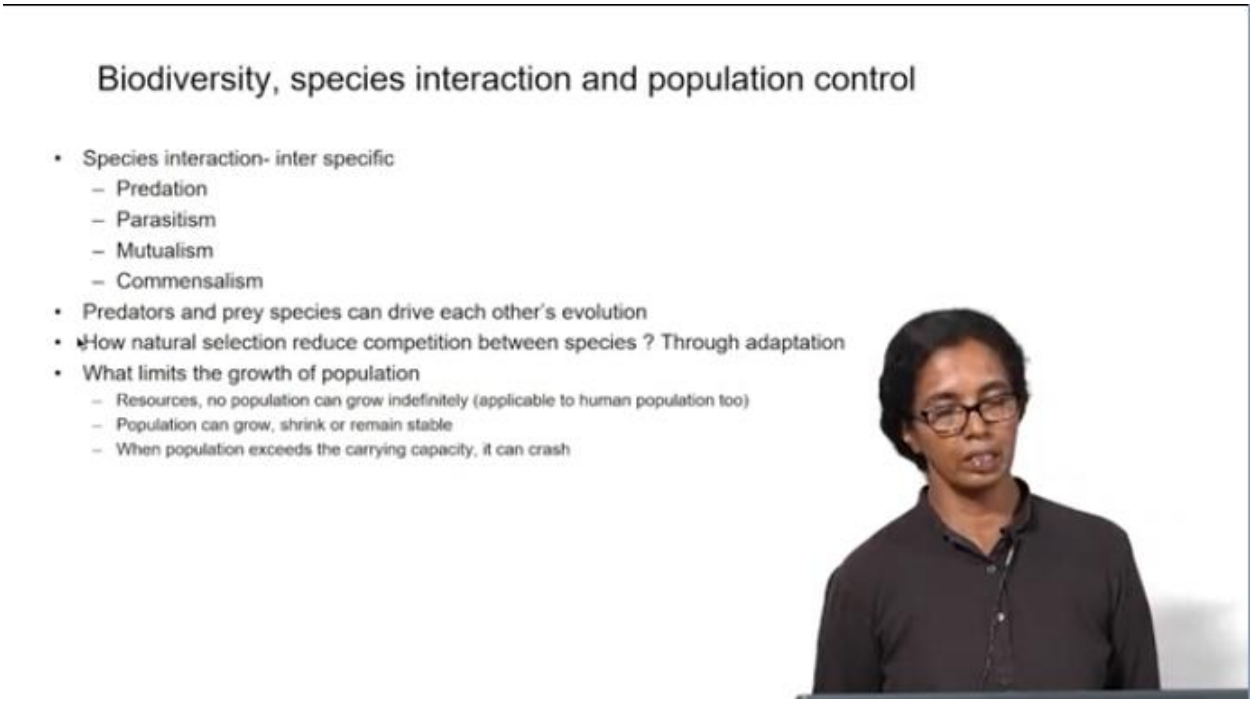

Similarly, the species determines the structure and function of their ecosystem, so they have a major role to play. So, any given species may play one or more roles in a particular community, we will take a little-detailed look at keystone and foundation species. Keystone species are they maintain and create habitats, and several critical roles they can play such as pollination of flowering plants, example keystone species are bees, butterflies, sunbirds, bats, these are all examples of keystone species. For example, without the contribution of bees or many insects which can pollinate a plants, the food availability to major part of the planet will, especially to humans will be constrained to a large extent and human species can face a large humungous problem if bees, butterflies and all these birds disappear from the planet.

So, for example, these species are getting drastically affected by some of our activities, for example, when we see a mosquito or when we see some adverse insects we use insecticides, and you know herbicides and other weed killers and other plants, other chemicals which can harm these organisms which are playing a vital role in our existence on earth. So, we are compromising the quality of existence and compromising the quality of ecosystem services provided by these organisms towards or to the species towards life on earth, and especially to human beings life as well, and the quality of life that we have.

Then we also have top predator keystone species, examples are wolf, tiger, leopard, that we hear always or like certain sharks, etcetera, they are predator species which are on the top of the food chain and also they are keystone species, how do they affect the ecosystem is by regulating the population. So, their important role is in controlling the population of the different species which they feed upon, so that is very important role in so that for example a health of a forest ecosystem

will be dictated by the tiger or let us say leopard or a lion in that ecosystem. And which is important for let us say introducing the number of herbivores species there, and the herbivores otherwise could increase in number and could feed upon all the plants which are, which they can eat up, so which can result in the collapse of a system for you know certain time before it recovers back. So, their top predator keystone species are required for controlling the population of herbivore species and other plant and other links in the food web below.

Similarly, foundation species is as plays a major role in shaping communities by creating and enhancing their habitats in the ecosystem, an example is elephants, elephants when they move around they uproot trees and plants and then trample the soil, they also turn around the grass many times, so the changes that they inflict into the habitat helps in, for example, when trees are uprooted, grasses, when sunlight can reach the lower bottom of the forest canopy, and this helps in grass to come back and or start growing in an area where there was no grass before and herbivores will get benefited greatly by this activity, or for example, fruit bats, so these for example fruit bats can, for example, help create forest back, rejuvenate forest back in a place where there is degraded forest land because they spread, they are very good dispersal agents for seeds and that is how they can bring back forest in places which are degraded in nature. So, their role is very important, so we should not be like considering them as pests or disturbance just because some angle of it is not acceptable to us is not what the role in on earth in ecosystems, so it is very important for us to consider these facts before we act upon certain things with humans and relook at the living systems.




So, the biodiversity is also species interaction and population control are interconnected, so the species interaction can be of various kinds which you have studied in school itself, which are interspecific and can be classified into based on predation or that could be parasitic relationship which means one is exploiting the other one. Mutualism means both are benefited from each other which you would have seen, many species have this helping each other by, for example, controlling

the say certain insects let us say which you know troubles certain animals. So, in the process, for example, you would have seen when buffalos and cows are moving in a field you can see certain birds like herons or other birds may go along with them, so this could be an example where both animals are benefited by the process. When animals are moving some flies are flying around, or insects are flying which helps the bird feed upon, and also the animal also gets help from the birds in turn by removal of the nuisance of the insect which are biting them.

So, similarly commensalism, where an example is crow, which is commensal bird which lives along with us and sometimes lives on the leftover food and other things and so there are species which are living based on human beings, which is an example of commensalism or many other species also could be just living on the scrap which is left by one species could be used by another one.

And one more important thing when it comes to species interaction is that predators and prey species can drive each other's evolution, how is this done? So, when predators hunt a prey, the prey's instinct for escaping from the predator will help it evolve better strategies, for example, a prey species may evolve to become a faster runner by evolving to escape from the predator.

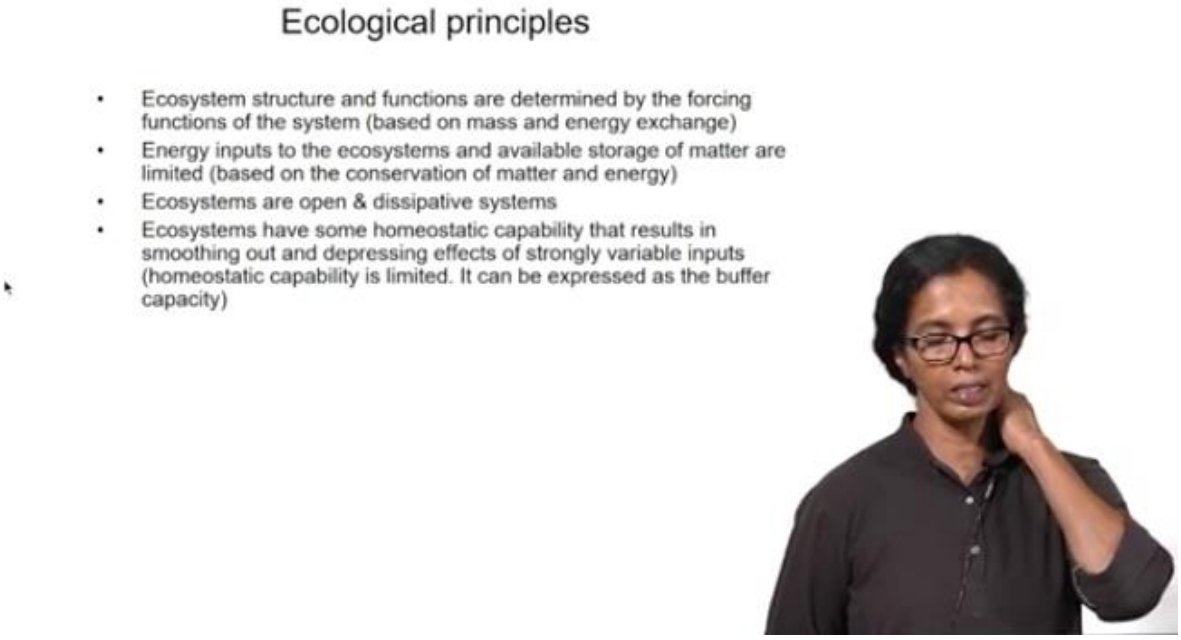
Similarly, the predator will also evolve because it is constantly strategizing to you know inventing strategies to get the prey which it can feed upon. So, both are evolving in the process over a long time period, and that is how evolution happens in such circumstances when there is prey-predator relationships.

Similarly, natural selection how it reduces competition between species. So that is another question that comes to us, so adaptation is the answer to this, so adaptation means how, if you look at many different water birds, so if you go and look at marsh or a swamp area there will be so many different species of birds which are feeding there in the marsh. So, what are the adaptations for these birds if you look at, they will have, different birds will have different length of stock of, the height of their legs will be different, the length of the beak will be different, the kind of food they may be eating will be very different so you can see that a variety of food habits they will evolve as well as different strategies to get the food will also be evolved in the same place to see, so these are known as adaptations. Or for example in a canopy if there are birds which are feeding in the canopy itself, they may also restrict themselves to certain regions of let us say top, very tall trees if they are predating so, if they are finding food from let us say insect-eating birds, they are finding food let us say in a canopy of particular tree, so they will evolve eventually to specialize maybe in different heights of the same tree itself, so there may be difference species locating and looking at food, looking for food at different heights of the tree itself.

So, this is an example of how adaptation, would adaptation to a particular stress that is evolved in the environment could lead to some form of survival strategy. So, that helps them survive in a situation where there is interspecific interest, or intraspecific competition between species is happening

And in the absence of any competition what limits the growth of population that we have seen is that resources especially the food availability is one of the important things, food availability as well as for example if it is birds or other species, where do they nest or where do they home? That

is also an important parameter, so nesting facilities, resources, when we say resources, it could be food, home, everything that comes into the picture. So, with the constraints given no population can grow indefinitely, this is applicable to human population also because the resources will be shrinking as our population keep on increasing.



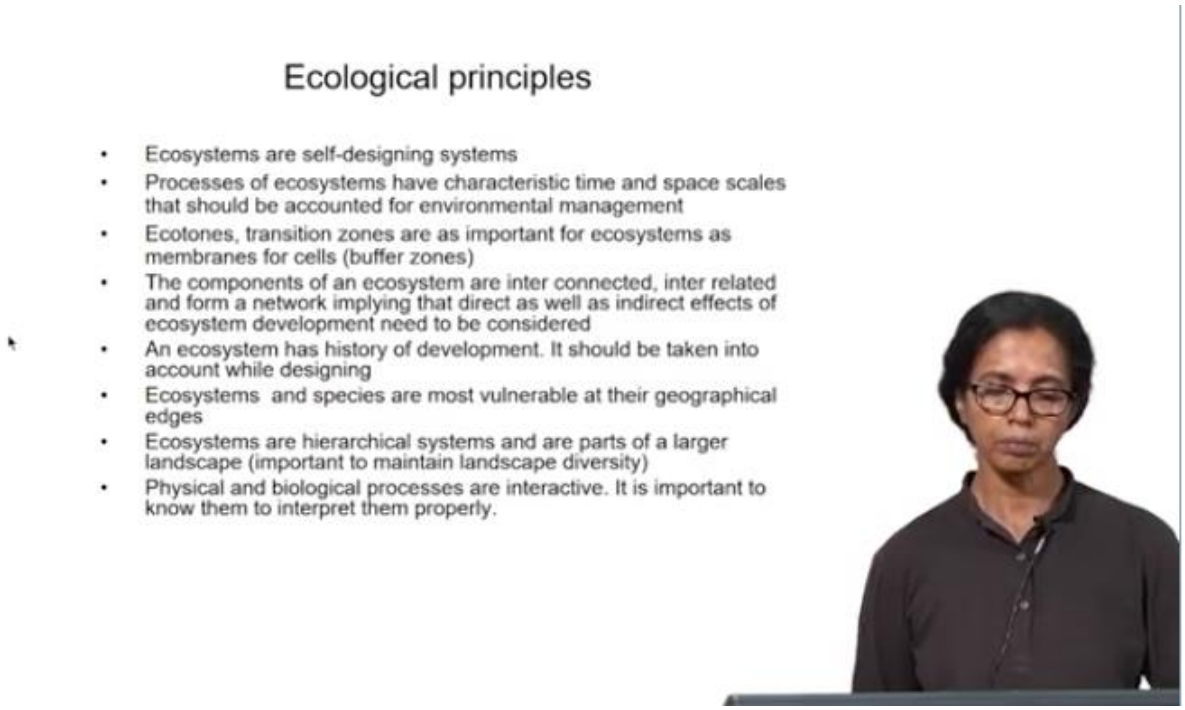

And population can grow shrink or remain stable depending upon the availability of resources, and when population exceeds a carrying capacity it can crash, so this is the summary of what we have land in this course. So, there are certain principles in ecology that we can carry home that is ecosystem structure and functions are determined by the forcing functions of the system, that is based on mass and energy flow into the system. So, this how in ecosystem evolves and what is its structure, how it functions etcetera are determined by the energy flow and the material flow into the ecosystem.

And the energy inputs to the ecosystems and available storage of matter are limited, so based on the conservation of matter and energy. So, all ecosystems function based on the first and second law of thermodynamics, so the energy inputs and how the energy is getting transformed into material or storing, how it can be stored as matter are limited, based only in which can be stored.

And similarly, we have to remember that ecosystems are, when we consider them as thermodynamics systems, they are open systems and dissipative systems that means there is loss always from the system to the environment, it is not something that is, it is not a closed system, so all ecosystems, if you look, are open systems thermodynamically.

Similarly, ecosystems also have a property called homeostatic capability, that results in smoothing out and depressing effects of strongly variable inputs. Which means, for example, if a flood or a drought or a fire happens, forest fire happens, eventually through ecological succession of the disturbed land they can come back to normal, some normalcy, though the homeostatic capability

is limited, and it is not necessary that none of the ecosystems will go back to a particular state in or you know a particular stable state that we call, it is continuously influx and continuously evolving, so it is a dynamic state that it is achieving.




And one more thing that we have to remember is these are ecosystems are self-designing systems. So, the processes of so of ecosystems have characteristic time and space scales that should be accounted for environmental management, so there is something that we have to remember always. That the ecosystem, so it is unlike or many human device processes whether a mechanical system like a watch or a clock or a helicopter or a ship works unlike that, an ecosystem is something has, it has its own characteristic time. So, an ecosystem will evolve over a long period of time, it is not something that happens which with short time scales which we can observe and analyze, and their space scales are also different. So, they can be as small as my few micron scales to, it could run into kilometer scales.

The space scales are can be very, very large or it could be very, very small under which it can operate, the ecosystems can operate, so it has to be accounted for when we are considering management of ecosystems.

Similarly, when we are considering ecosystems as they said they are open systems and not only that they do not have clear boundaries, so basically, we need to consider the ecotones or the transition zone, these are important areas of an ecosystem, they work as membranes for cells. So, if you take biological cells, there is a membrane which is surrounding the cell. Similarly, each ecosystem has what is known as an ecotone area or a transition zone, for example, if you take a pond, the immediate surroundings of the pond, for example, can get flooded during you know excess rains or it could withdraw it a smaller area pond when there is no rain or a drought happens.

So, there is no clear line that you can draw it to say what is the area of that pond or a lake or a river or an ecosystem that we are considering or a forest for example also.

So, what is the exact you know boundary for it? There is no boundary, so there is a, so we need to take into account that transition zones, for example, seashore, it is a transition zone or river banks they are transition zones. So that is why it is very important to consider coastal regulations and regulations in constructing away from ecologically sensitive zones and also ecotones and transition zones because animals and birds and other living creatures do not see these boundaries as we see as walls and roads are such constraints that we put in place. Other creatures require to crossover to this different places, and that has to be kept in mind anytime when we are considering ecosystems. And so for example, considering construction of roads through forest patches, so which will result in fragmentation of ecosystems or habitats and animals will be in distress. And many different species can become you know suffer because their water bodies or water access points could be elsewhere, so these are all problems that could happen also because of this lack of this considerations.

The components of an ecosystem are interconnected, interrelated and form a network implying that direct as well as indirect effects of ecosystem development need to be considered. So, every component in an ecosystem are interconnected, and interrelated and forms a network. So, it is like if you are looking at a spider's web, so if you go and disentangle one of the legs of those, one of the strings of the web it becomes less functional, and it can actually damage the web itself.

So, similar implications can be thought about in ecosystems also where we may not visualize, or we may not always see all the connections which are existing there which can have catastrophic effects.

An ecosystem has history of development, it should be taken into account while doing anything with ecosystems. So this is also other important factor that ecosystem is something, not that has not come about overnight. It has happened over millions of years and including its nutrients cycling, the soil formation, the different species that has come about there, all this has happened over millions of years of time, so that has to be taken into account while we are doing any projects or any activities in this on earth.

Ecosystems and species are most vulnerable at their geographical edges, this is also another important factor or principle that we need to think about or consider, an example as I said is the coastal zones or banks of rivers or for example so, water channels, all this are or for example even when we are considering a pond or a well where we have fresh water, and then, for example, it has a boundary, a geographical edge or a boundary, so how do we treat those boundaries, I mean you can go and impact those boundaries by let us say you know put concrete and then concretize the boundary, which may not be a good idea at all because there are so many living organisms like frogs which actually have life which is between the water and the land. So, by concreting you may be affecting their life cycle and also affecting the wellbeing of that ecosystem itself, so there are many other species which are also making use of such areas which are very, very vulnerable and ecosystems are more vulnerable at that geographical edge, so that needs to be taken into account and though we consider them as we do not take into account this facts many times when we look at ecosystems.

Similarly, ecosystems are hierarchical systems and are parts of a larger landscape. So it is not that they are isolated systems which are sitting somewhere, and we can tamper with it, or we can do what we would like to, they are just part of a larger landscape, and this is just a small part of the system itself. So it is important to maintain landscape diversity rather than looking at in a smaller and smaller unit such as ecosystems or individual species and their protection and you know the aspects of protecting those habitats, so it is important to consider maintenance of the larger landscape itself which it forms a part of.

Similarly, physical and biological processes are interactive, it is important to know them to interpret them properly. It is not that we can isolate physical processes, for example, there is a climate change it will affect the biological processes as well, or if there is a temperature change in the atmosphere, it affects our wellbeing or the biological systems which are dependent on them. Or, so there are different physical processes that we have discussed especially the nutrients cycles and the biogeochemical cycles, all these are affecting the biological processes.

So with this certain guidelines about ecology and how we protect ecosystems, so there are various measures which are put in place for protecting ecosystems and biodiversity on earth, and the different countries have different protocols. India also has different protocols to protect the biodiversity, so and the ecosystems which are very, very important for the wellbeing of not only human beings but also other organisms which serve us lot of ecosystems functions and ecosystem services as we have described in this class. And that is one of the major reasons why we need to have an understanding of ecology, and I would suggest reading of good books on ecology that is available, many books are available on web also, and many resources are available on the web to understand more about ecology and concepts in ecology. And so, I would stop at this point, in that recommending, reading more about ecology and understanding ecosystems and their importance in our lives. Whether we are doing in different profession of engineering or science, it is important for us to understand the living system or the living biomes where we are located ourselves and how our activities are disturbing the different ecosystems and our own existence on earth.

Thank you