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NPTEL ONLINE COURSE

Ecology

Energy flow, productivity and Biodiversity

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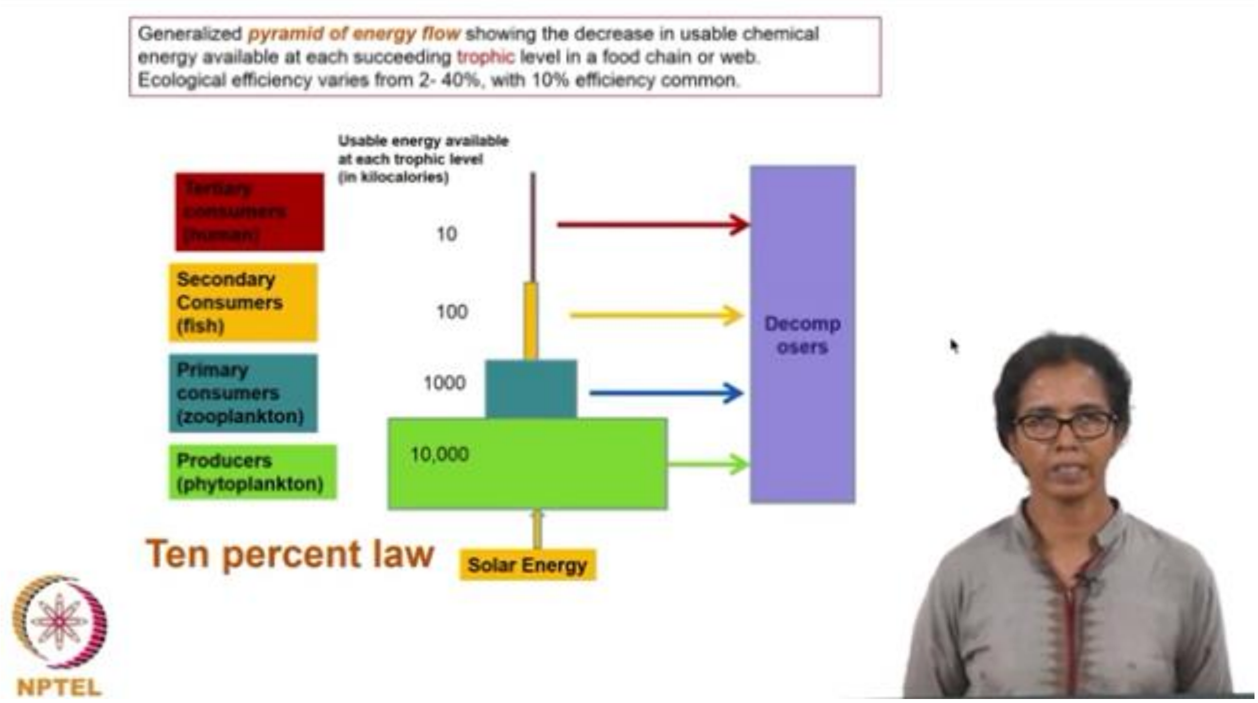
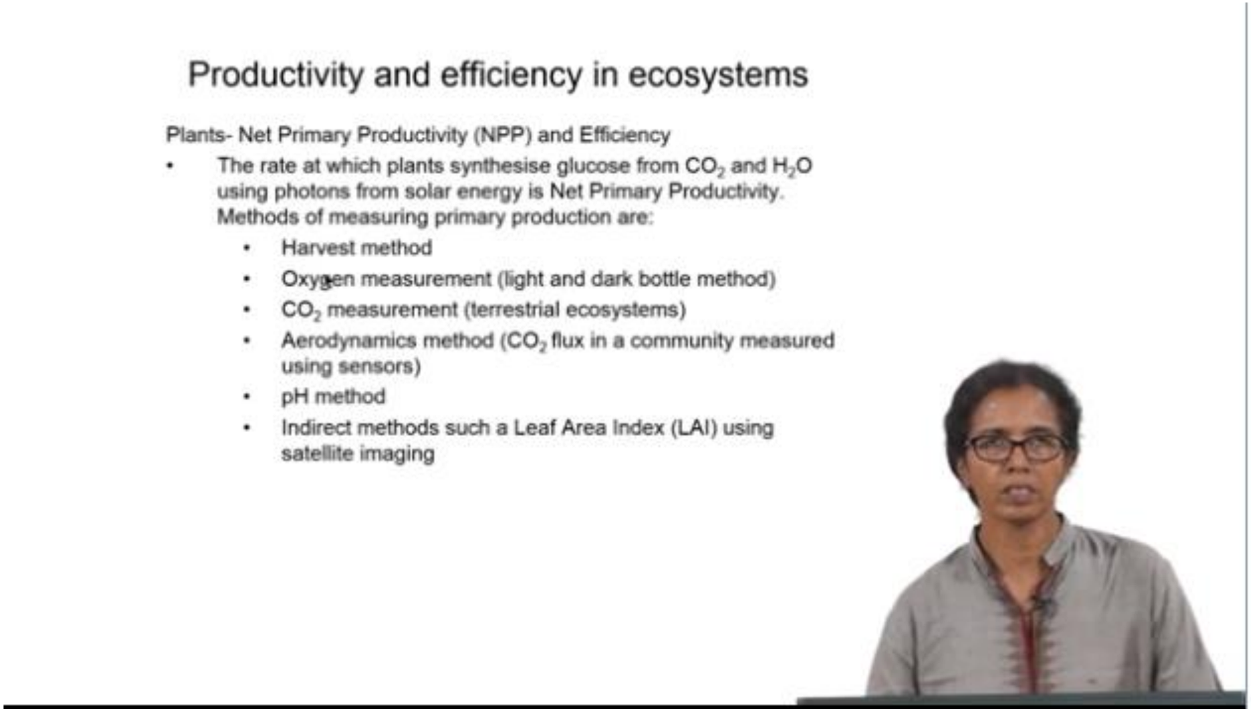


So, till the last class we were looking at the energy flow and the what is known as the efficiency with which energy is flowing through various tropic levels or the food web or what we call as the food web, how the energy is flowing through the system by converting matter that is available to living systems.

So, essentially the solar energy that comes into the the solar energy that is received by the plants or the producers is converted to energy. And that converted from the producers, the primary consumers take up the energy which is about one-tenth of the produced by the plants, and then when it goes to the next level, when it flows to the next level that is the secondary consumer, again the energy reduces by one order of magnitude. And then when it goes to the tertiary consumers, that is, example is given as humans, it again reduces by 10%, by one order of magnitude.

So, in general one can say that the ecological efficiency varies between, though it varies between 2 to 40% in different individuals or different organisms and different species, but 10% efficiency is a common thing that runs through the living systems that we see around. So this is known as the 10% low with the efficiency or the ecological efficiency that is energy is flowing through the systems.

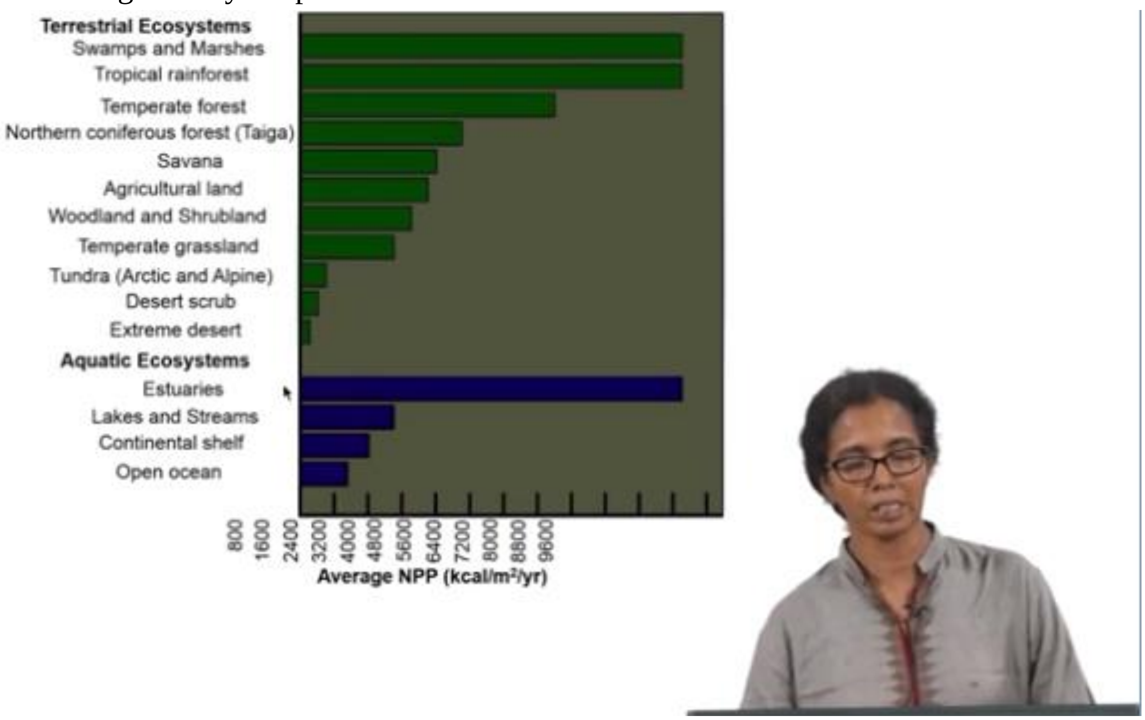


So, the energy flow in the ecosystems is actually estimated as I said in the last class is using productivity and efficiency. In the case of plants, we use the term net primary productivity. And so that can be calculated using various methods, and one of the methods of harvest method was detailed in the last class. So, there are many methods, where direct measurements are possible which are harvest method, oxygen measurement, carbon dioxide measurement, or like aerodynamics methods where aerodynamic method were again carbon-dioxide flux in a community is measured using different sensors, carbon-dioxide sensors. So that you get a concentration of carbon dioxide that is flowing through the system at different times and different periods of the year.

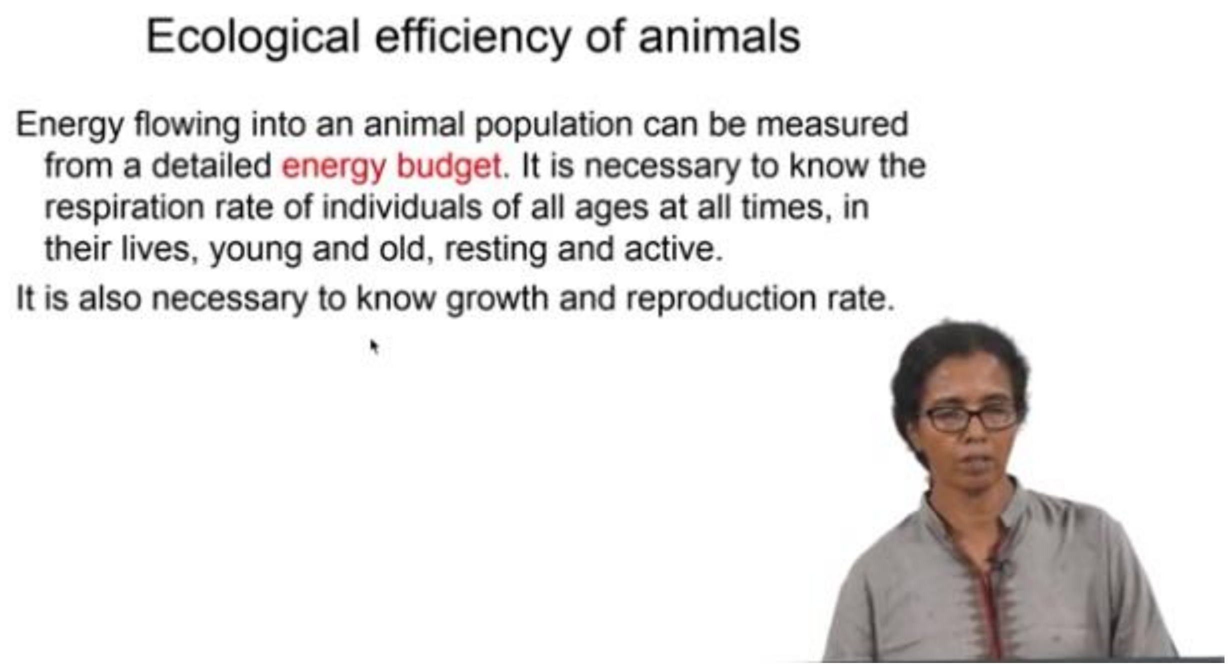
Then in aquatic systems, we have to use pH method which is again a measurement of the amount of carbon dioxide that is dissolved in the water systems. So that you can find out how much carbon dioxide is released by the producers, the primary producers that which are there in the water or so the concentration of, how the concentration of carbon-dioxide is varying in the aquatic systems. Because carbon dioxide is used by the plants for producing biomass and oxygen is released to, while while photosynthesis is going on.

Similarly, when these direct measurement methods are not possible, there are indirect methods, for example, a large forest area if one wants to find out the productivity, there are indirect methods such as leaf area index that is the area of leaf that is exposed on one side to the sunlight, which can be measured by measuring the green index, or the green reflected light from the leaf surfaces. Can be measured using satellite imaginary. So that is also possible for large areas where you want to find out the amount of sunlight that is received, that could be effectively used by plants.

But then this measurement has some disadvantages like if it is a dense canopy of forest it may not be possible to find out a different layers of the leaf how much energy is being harvested or how much light is being used by the plant.

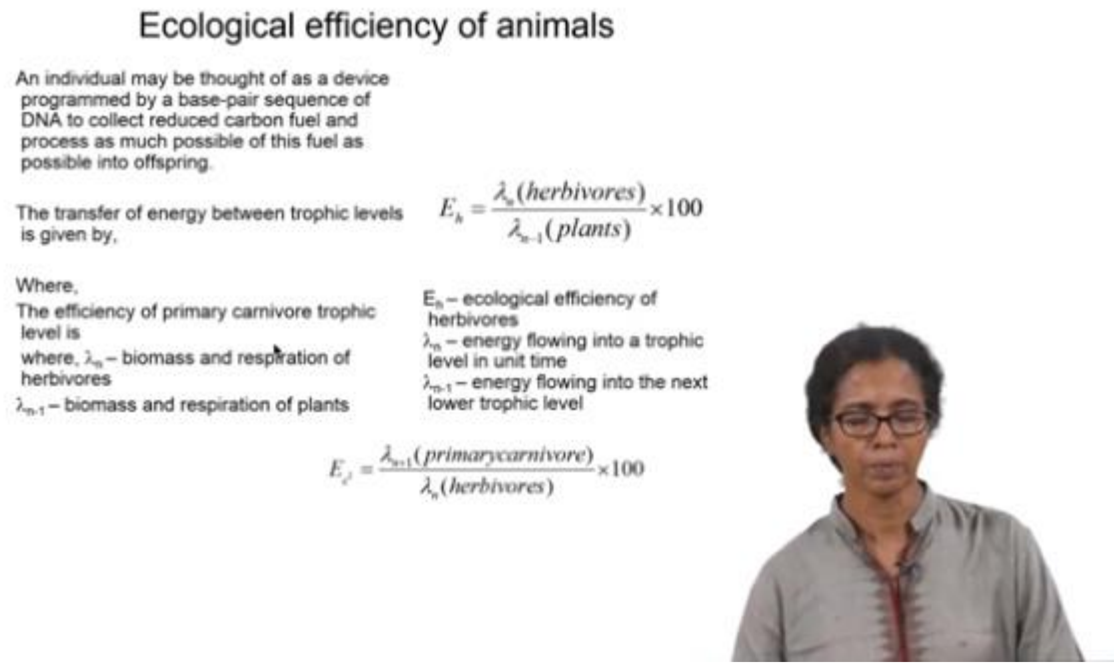


So, based on this terrestrial ecosystems and aquatic ecosystems are classified based on the average in net primary productivity that is based on the plants that occupy these spaces or these systems, so we find that you know swamps and marshes and tropical rainforest have the highest productivity in terrestrial ecosystem among terrestrial ecosystems, and among aquatic ecosystems, estuaries are equivalent to the swamps and marshes and tropical rainforest that you find on the terrestrial ecosystem, among the terrestrial ecosystems.



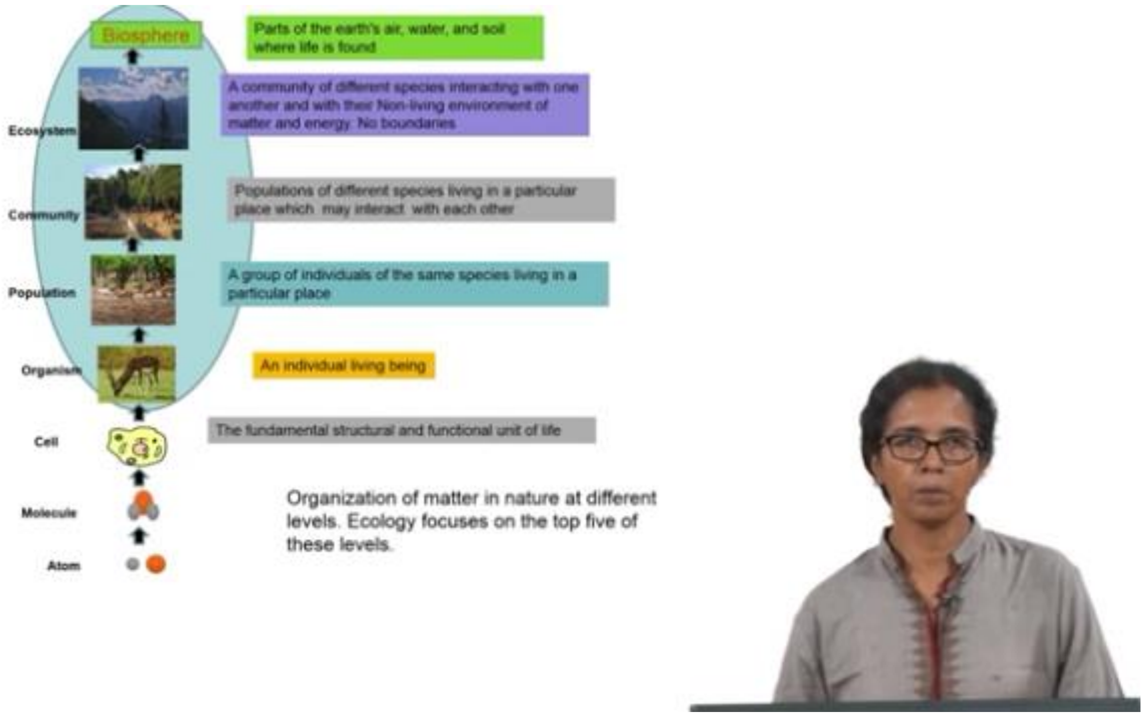
Now, when it comes to the next level that is when the energy is transferred to the primary consumers or the secondary consumers, the efficiency with which energy is transferred is known as ecological efficiency of animals. So for that one needs to, how the energy is flowing through an animal population, if one needs to figure out, it needs what is known as detailed energy budget which will be done using the laws of thermodynamics and the heat flow that is taking place in the animal populations.

So, there are some modeling that is required to find out the efficiency with which animals are using up the energy that is flowing into that system in the form of food. So the food that is taken up by the animals for the growth and reproduction and the energy that is flowing in these systems will be, has to be determined for all individuals of all ages at all times in their lives. Whether they are young or old, and whether they are resting or active then only we get approximation of the efficiency with which energy is flowing into that system.



So, the efficiency of that energy flow is again determined by the output by the input into 100. So the output is basically how much is the that is stored in that particular level of tropic level as biomass divided by that of the energy that is flowing into the system that is a food taken by the animals that is taken. So, some amount of energy is wasted from the animals in the form of excretion or respiration, or activities which are again respiration will be indirect measure of the activity, and also you can figure out the amount of the undigested food that comes out of the system.

So, the effective amount will be that what is used for growth and reproduction will be the amount of energy that is assimilated by the animal. So, when it comes to, so now we have talked about the energy flow and the material flow in ecosystems and the energy that is flowing is converted to materials with some loss at different levels, so the loss is quite high, so the efficiency with which energy is flowing is only about 10% in different levels.



So, how this, now when we look at this the matter that is circulated in the biosphere, there is some amount of organization that one can see in this. So now, if you take a look at this picture here, it is an upside-down picture which is showing from atom to biosphere, how we are related to each other. So, if you look at this picture one can see that, you can see atoms form molecules, molecules are the constituents of what is the living, the first from primary structure that we are interested, the fundamental structure and functional unit of life is a cell.

So a cell, multiple cells organize themselves and form what is known as an organism. So that is with an organism which is organizing different cells to, but at the same time serving a purpose of different functions in their body with different functions. But at the same time function as a single individual which can move about, which can gather its food, which can think for return, or move, or organize itself, do various things, for activities like whether it can jump or walk or whatever.

So, an individual living being is something that is formed from different cells and then forms from individuals of a group, so in this case, a blackbuck is shown as an organism here which is grazing in grassland. And the next picture shows a population of blackbuck, it could be a population of, a population of cows or a population of elephants or a population of lions or jackals or tigers that we talk about, so it forms a population, a group of individuals of the same species living in a particular place, so that they are known as a population.

And when different populations of different species living in a particular place that is known as a community that is a next level, so if you go to any particular place or grassland or if you go to forest you will see different species, population of different species coexisting together in that particular community. So that forms a next level of organization, so but they have again at that level also if you look around there is some organization and each community is living within its means, and it knows how to use the energy and the material that is flowing into the system.

And the next level is ecosystem, that is basically the community of different species that interacting with one another and with their nonliving environment of matter and energy. So when we are talking about population and community, we were not talking about the nonliving environment of matter and energy though they are also interacting. But when you have to say a system level, ecosystem-level you have to understand that a community of different species which interact with one another, and among themselves and interact with each other and also they interact with the nonliving environment of matter and energy.

And one has to remember that ecosystems do not have solid boundaries, they have what is known as ecotones. So they merge with the surrounding system which may be another ecosystem, for example, if you take a pond or a lake or a river, you see that though the boundaries are what we think are the water body but that is not strictly a boundary, they softly merge with the surrounding other ecosystems or other communities, through what is known as ecotones or buffer areas or buffer sounds of those systems. So, for example, a lake water boundary, strictly we cannot say where it will be in summer or where it will be during a flooding season, so that dictates that the boundaries of the lake, for example, can be moving back and forth.

And the surrounding areas of the lake, if you take it, will be more moist and wet, and the plants and the other species that you see will be very different from little far away from the lake surroundings. So there is this gradual change in the living systems that you find around an ecosystem due to this soft toning of the living systems that you find there.

And in different ecosystems combine together we find the biosphere, so biosphere is nothing but the parts of the earth, it is air, water and soil where life is bound is known as the biosphere. So there is a blue envelop that connect this 5, top 5 levels of this that is what mostly ecology is dealing with, so ecology deals with organism, population, community, ecosystem, and biosphere.

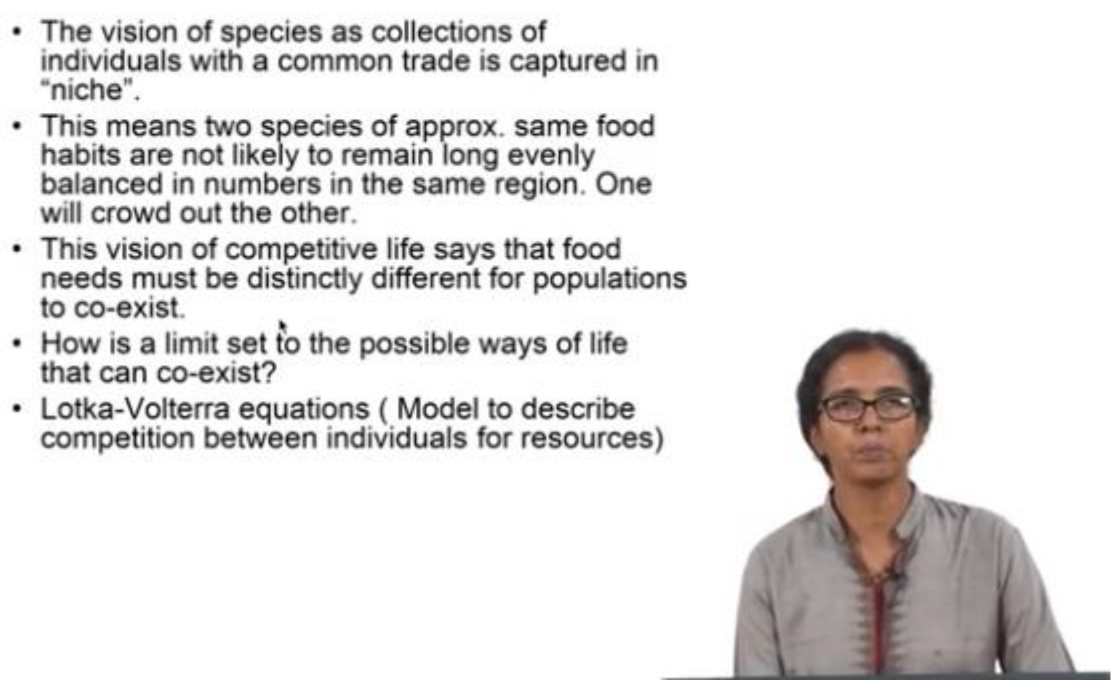
The cell studies mostly are dealing with biotechnology and other areas or genetics, they look at cells or molecules and then see how to manipulate them and which might affect organisms or population or community or even ecosystems at different levels. So because they are all linked through this particular connection that we can see here and the order that you can see in the, at the different levels.

Now, when it comes to ecosystems, why, the questions that we ask are, what do we call as diversity? So, one of the first questions that comes in terms of, the question is like why so many kinds of plants and animals? So, why did not it be like you know all organized in a uniform way and you can have one species, one level, even if it is energy flow you would have had only one species of plants, you could have had then the next stage level of energy level flow if you required you just one species of animal, it could have been you know uniformly spread. So why we see so many different kinds of plants and animals.

And then the next question is why should individual animals and plants be organized into regimented populations of look-alikes and behave-alikes. Look into different regions, for example, those who know a different birds, let us say, we commonly see crows around us. How many of us look and see that there are different types of crows that we see around, so there are at least two types that you see around when you look. One is a completely black colored one, the other one which has a little ash head and it is smaller in size with a smaller bill, and the black one will have you know large bill. So these two are look-alikes, and they also behave alike, but at the same time they are not the same species, they are two different species, so this is what is meant by, why should individual animals and plants be organized into regimented populations, why do we have this look-alikes and behave-alikes? So, this actually is, we have all heard about the origin of species by Charles Darwin, and this is the ecological part of the origin of species, how different species are originated on earth.

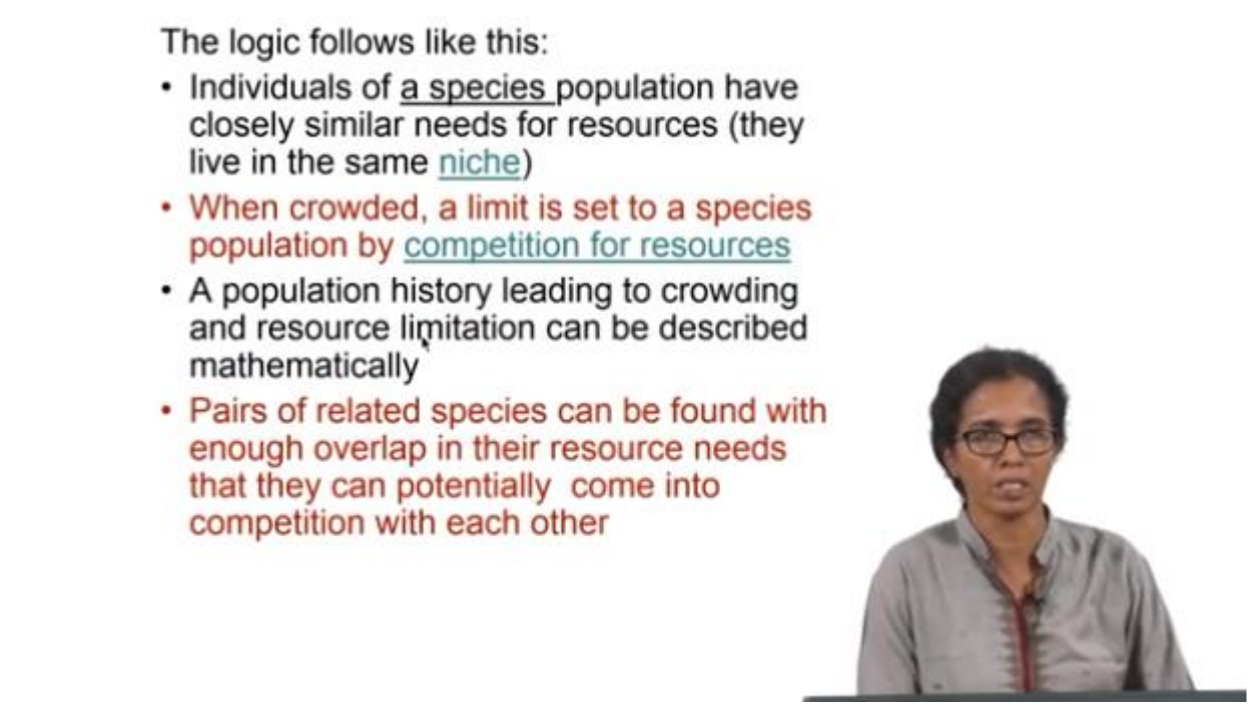
So, the answer to the first question that why so many kinds of plants and animals that we see around. Answer is a successful way of life brooks no variance, or in another words to be deviant from the characteristic job that this species is doing, it exacts a penalty in fitness, so traits inherited from parents or successful traits and they are changed only at peril. So each species is characterized by what is known as the trade, okay, it is like saying that somebody is practicing carpentry or somebody is practicing teaching, or somebody is practicing particular trade or somebody is an electrician who is practicing it. So, when you transfer this knowledge to the next person, and that person does not impart the same knowledge, then there is a problem in executing the job with perfection, so it is almost similar to that.

So if a species is something that practices particular trade or particular way of life that it can, it can leave in the in its surroundings and in its environment. So this requires certain types of skills or certain types of adaptations we call, let us say a long beak or a long neck, long feet or a webbed feet. So different kinds of adaptations that we see in different animals, so animals it is easy to see or different plants for example, long leaf, short leaf, broad leaf, colored leaf, non-colored leaf, there are so many differences that we see around, these are known as the trades that are inherited through genetic source or genetic diversity from parents and then it is successfully transferred to the next generation by through reproduction.



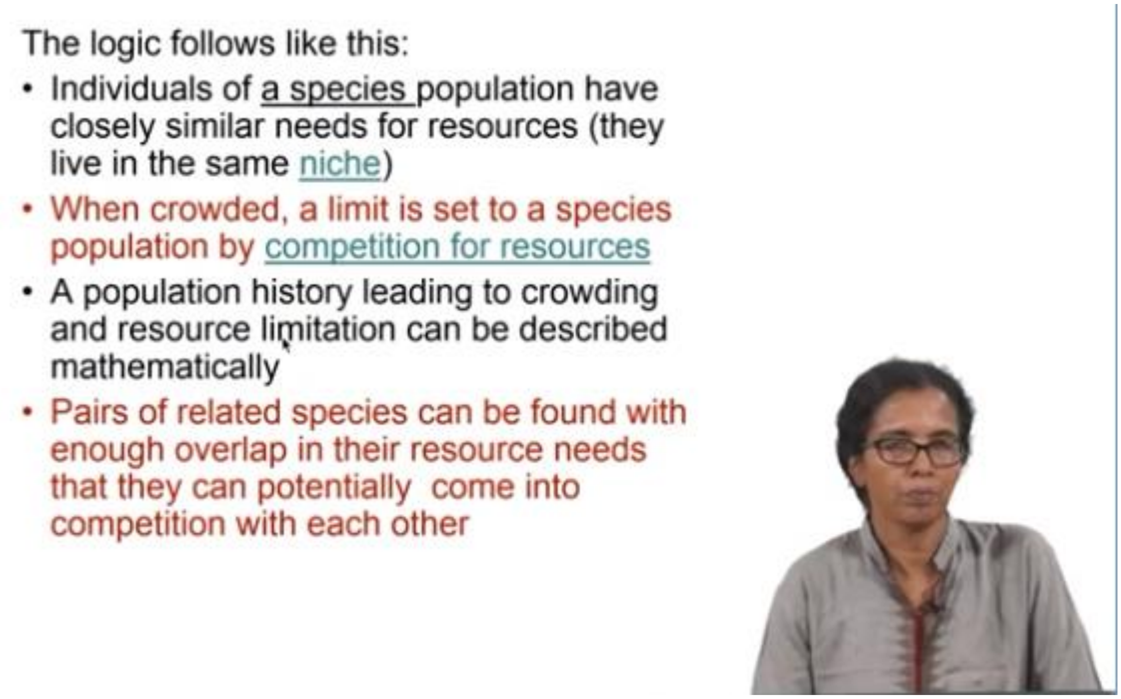
So, now when it comes the vision of a species, so what is a species? It is a collection of individuals with a common trade, so which is why they are called, which is captured in what is a term called niche, a niche. So a species is a collection of individuals with a common trade that is captured in niche. So this means two species of approximately same food habits are not likely to remain long evenly balanced in numbers in the same region. So one will crowd out the other so which means some kind of competition that will set up the vision of competitive life says that food needs must be distinctly different for populations to coexist, otherwise both the populations will start to compete for the same food source and then they will, one of them will outnumber the other one.

So how is the limit set to this possible way of life that can coexist. So there are various ways in which this can be modeled so that we will be discussing later. So the logic of for different species is that individual of a species population have closely similar needs of resources that is they live in the same niche.



And when crowded limit is set to species population by a competition for resources, a population history leading to crowding and resource limitation can be described mathematically, so that is where we come into describing what is known as a population dynamics and how population is varying in a community, so if you take a species or a community or different levels that we have seen in the earlier chart, so ecosystem is formed from communities and communities are formed from population and population is formed from organism.

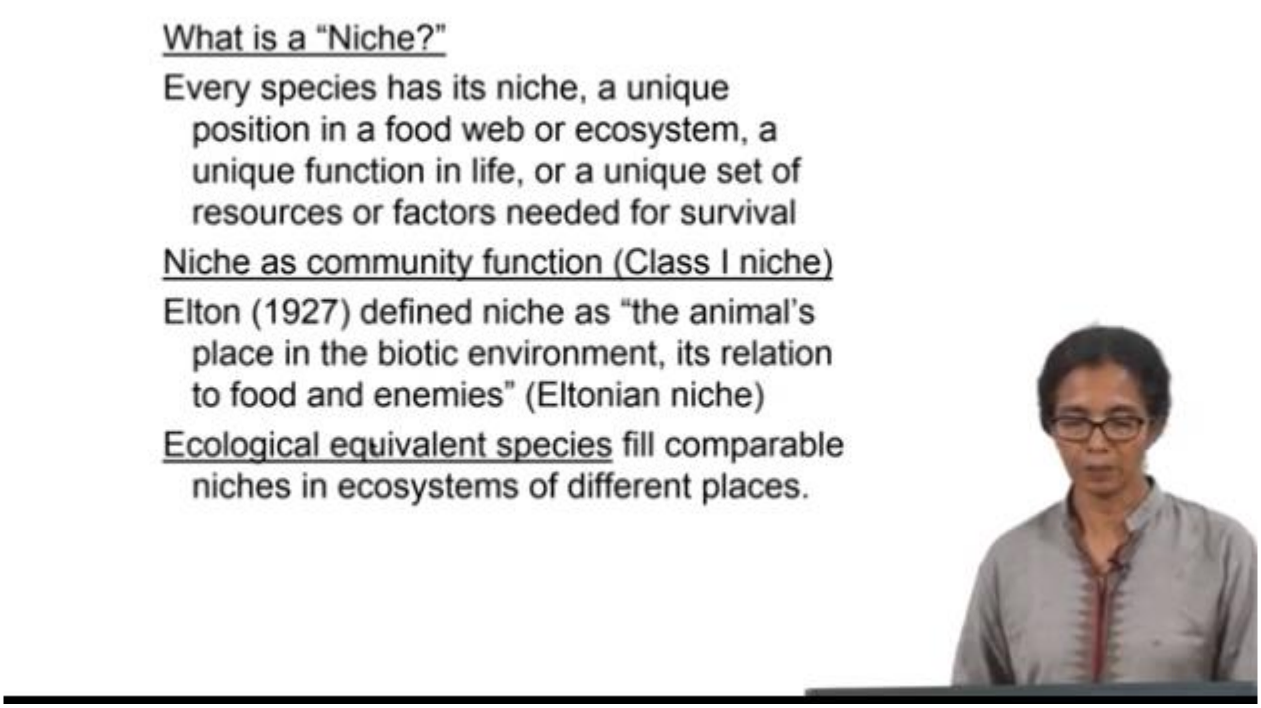
So, at the levels of population and community and then ecosystems we have to look up for the population dynamics or how different species are interacting for example when it comes to community you can see population of different species living together, how can they live together? If their food needs are same, can they live together? Or how many numbers can be there is each species? These are the questions that one needs to address at this levels when it is coming to population and communities, so that is why the question of population, how do we determine the population? So, what determines a population? So, population number or the dynamics is determined is to leading to crowding and resource limitation can be described mathematically. So, pairs of related species can be found with enough overlap in the resource needs that they can potentially come into competition with each other.



So, as I said earlier when we look around in our own surroundings we can see two species of crow, so do they have the same food needs or do they specialize with something which is slightly different from each other.

So, these are possible ways in which ecologist go around and look and study the behavior of those organisms and that can be related to its niche and how they find out their special resource requirements and how they vary from one another in their specializations. So, there will be some adaptation may be possible for one of the species, one may be a generalist, the other maybe little more specialist and which may be eating only certain food, okay. Or one may be seen only in certain environments, for example, if the black crow which we see around are not very commonly seen, whereas the crow with a grey head or the little less color and the small one which is known as the house crow which is very very common everywhere, and which is probably generalist and can feed on many common food that we see around or food waste that we see around. Whereas the other crow may not be that common because it may not be feeding on every kind of food that is available, maybe it is specializing or has a niche that requirement that is different, slightly different from the other species though they can overlap in their food needs, but they may not be exactly crossing their paths.

But at the same time, one can also observe that their population numbers, if you look at they are different in numbers, one of them is not so common, the other one is little more common. So, this also could be saying that the same that, what is shown here the pairs of related species can be found with enough overlapping the resource needs that they can potentially come into competition with each other, and so one is crowding out the other, so one will be more in number, the other one will be less in number, and so that is how it goes.



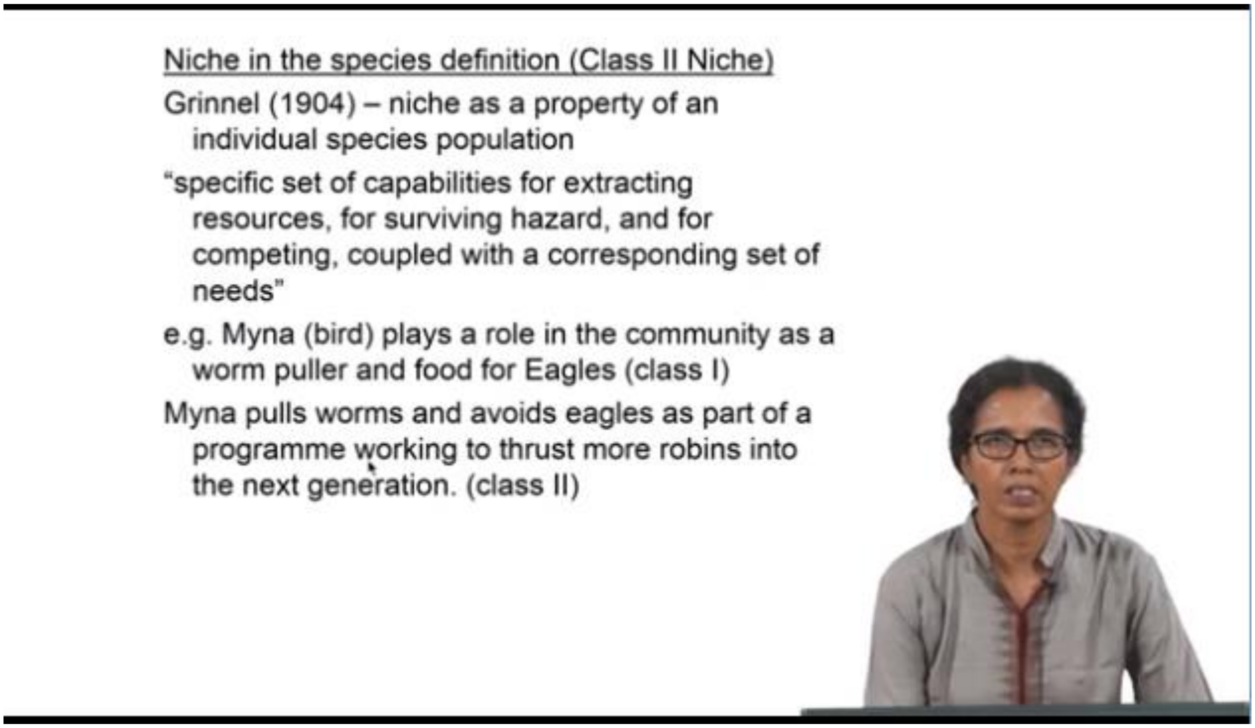
So, what is a niche? So there are very different definitions for niche, and so every species has its niche or a unique position in a food web or ecosystem, unique function in life or a unique set of resources or factors needed for survival. For example, if you take a sunbird which is an equivalent of a hummingbird which you see in the temperate climates, what we see in India are sunbirds. So, if you look at them what is a unique set of resources that they require is nectars from plants or you know from flowers, so they collect, for example, there you know in the process they also serve certain function in the ecosystem. So, during the process of nectar collection, they also help in or aid in pollinating the plants through going from one plant to another.

So, similarly there are so many insects that we see around, they also have unique resources so each insect maybe approaching a different kind of flower or a plant and it is not that all the plants will be visited by the same insect, or different species of plants will be visited by different kinds of insects. So there is a unique niche that we are talking about for a particular species. So, that determines what, where they can survive or where they cannot survive. Let us say if a particular bird is feeding only on a particular plant and that plant disappears due to some disease, or let us say some catastrophe, or a drought, or something like that, so it is possible that the bird will also disappear because of this connectivity between, or the specialization of that bird for that particular species of plant.

Similarly, niche also can be defined as a community function, so there are various definitions for niche, so one is the definition of niche has a community function that what function does it serve in the community. This was defined by Elton in 1927, so he defined niche as the animals place in the biotic environment, it is relation to food and enemies, okay, so it is known as a Eltonian niche, so what is meant by, each animal has a place in its biotic environment, and it also has a relationship to its food and its enemies. So, for example, certain birds if you take, they may be food, they make take some food from their environment, and at the same time, they may be food to something else. For example, if you take frog, a frog will be taking food from the, from its surroundings it may be capturing some of the insects around, but at the same time a frog is also food to snake.

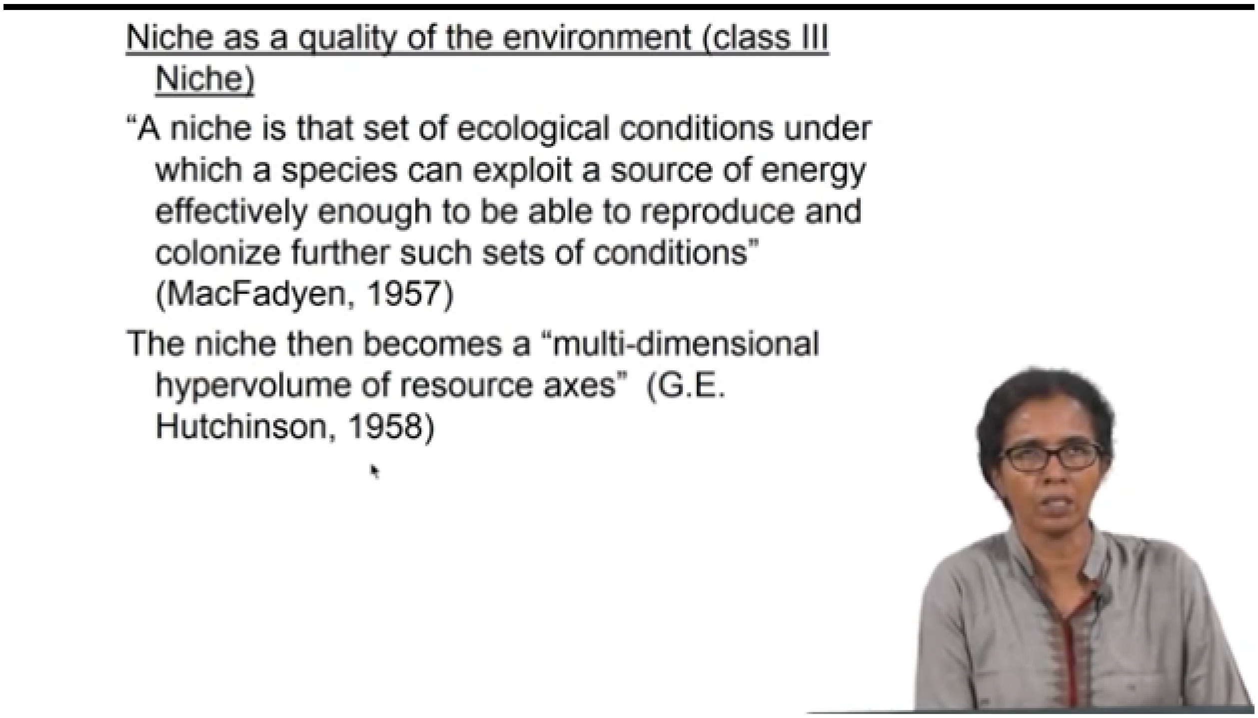
So similarly, so it is a community function, it is serving a community function, so it has a function that it is serving here. Ecological equivalence species will comparable niches in ecosystems of different places, so that is a consequence of this community function. So, equivalent species that what we see in different for example if you take the latitude or longitude of earth and then go around finding what species we find, for example, if you take equator and then walk from one end to other. So, if you walk around on the equator let us say from one end to the other, and you will find that so many varieties or different kinds of plants and animals that they can see. Which will places on niches and ecosystems of different places, so this could be due to various reasons like the rainfall that is received in different places will be different, so the plants and different species which may come up there will be different.

The temperature that will be, that is existing in a local area will be different, this also can result in, so mostly what dictates is the rainfall pattern that dictates a vegetation in a particular area or in ecosystem and this further dictates, what kind of species which are dependent on those plants come up in that particular area.



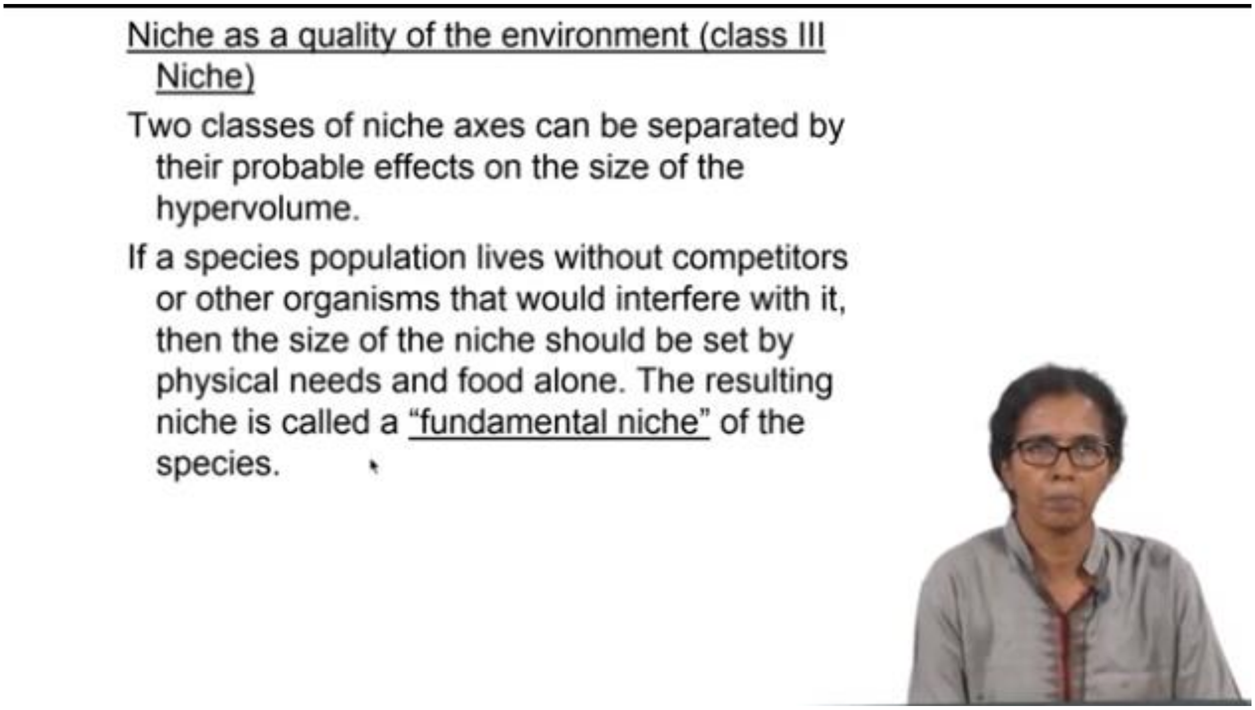
Second definition of niche is, niche in the species definitions, so, for example, Grinnel in 1904, niche has a property of an individual species population, so which means a specific set of capabilities for extracting resources for surviving hazard and for competing coupled with a corresponding set of needs. It is elaborated here below myna is a bird that we see around everywhere, it plays a role in the community as a you know worm puller or food, worm puller or it eats also certain insects, it is not exactly worm puller it eat insects, mostly grasshoppers and other insects like that. But at the same time, it is also let us say food for eagles, an eagle can you know hunt and feed on a myna which is its definition of as a class one niche.

And similarly, myna not only eats grasshoppers and it also avoids eagles as part of the program working to thrust more mynas into the next generation. So, what we see is that myna is serving two functions one is that it is taking insects from the environment like grasshoppers or other insects and then it is also being food for, being served as a food for some other species that is the eagle.



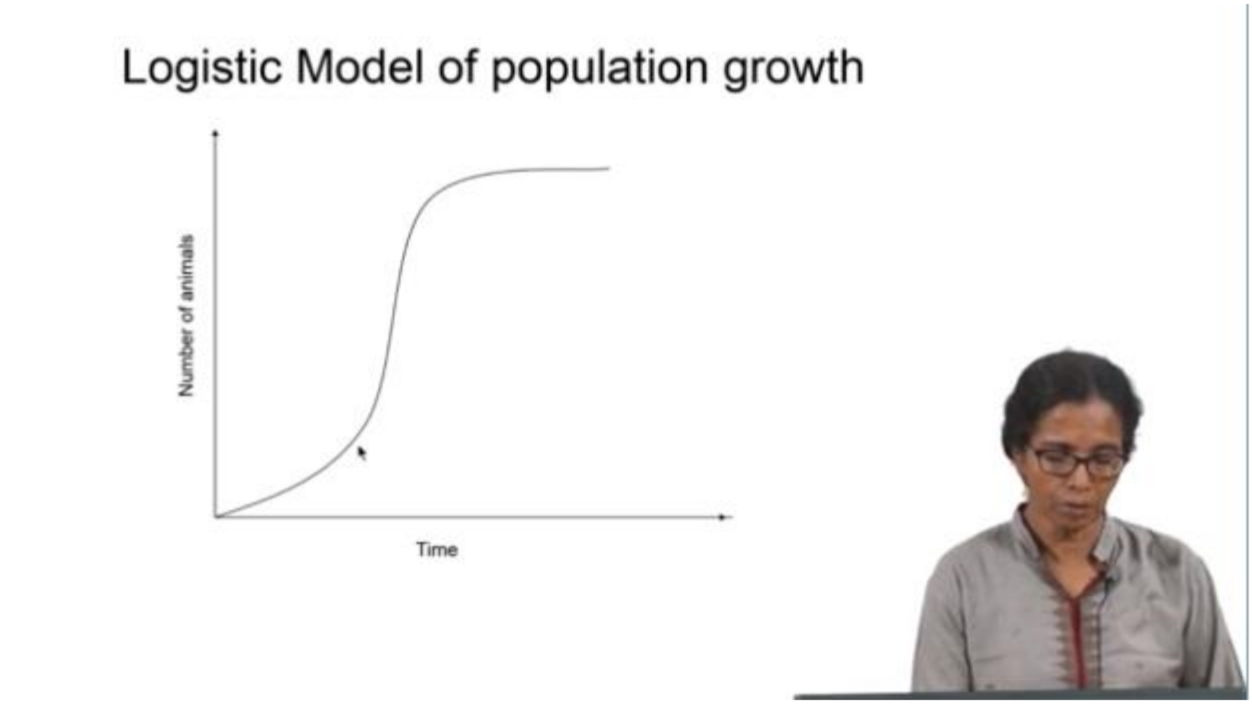
Third definition of niche is as a quality of the environment which is known as a class three niche. A niche is that set of ecological conditions under which a species can exploit a source of energy effectively enough to be able to reproduce and colonize further such sets of conditions. So, this is the further definition given for a niche which is in the ecological context, it has to be defined as a niche is a set of ecological conditions that you know a species can exploit a source of energy effectively, its effectiveness is dictated by how much, whether it is able to reproduce and colonize furthering the using of this ecological conditions available to the particular species.

Then this case the niche will become a multidimensional hypervolume of resource axes because there maybe multiple resource axes that are possible to which a species can extend itself and make use of those axes.



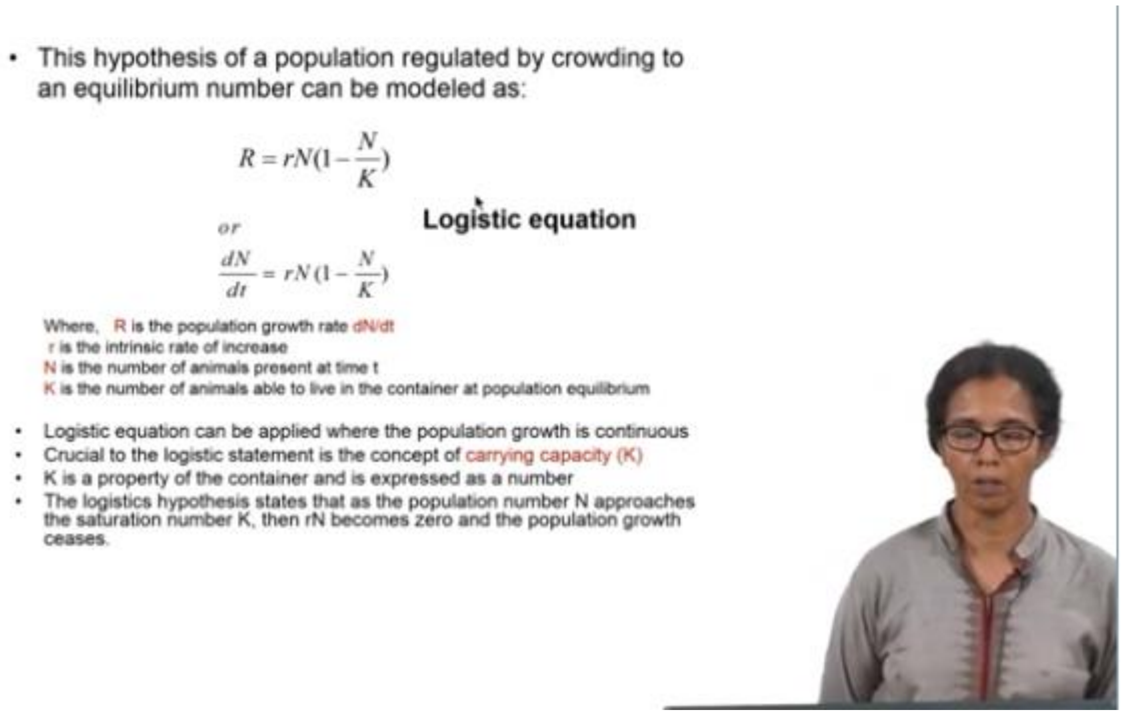
So, when it is the, so it is also is like that when niche is a quality of the environment or the class three niche what we define, two classes of niche axes can be separated by their probable effects on the size of the hypervolume. So for example, if a species population lives without competitors or other organisms that would interfere with it, then the size of the niche should be set by physical needs and food alone. So, this is known as the results and what is known as a fundamental niche of the species if there is no competition the species will make use of the available food, and it grows in its number, or the population grows.

So, in such cases when the fundamental niche is growing, so now when it comes to this species and population, the important concept that comes in is how the population dynamics or the population number of in members in individual species, how they are controlled? Let us say in this case when niche as a classic quality of the environment when it is the class three niche we are defining, a species population lives without competitors or other organisms that would interfere with it let us say, then the size of the niche should be set by physical needs and food alone. How is the number of the or the number or the population of a particular species is controlled? Let us see if there is no competitors or if there is nothing interfering with the lives of that particular species, in that case, what we define something called a fundamental niche. There is no competitors, and there is nothing else, there is only food and physical needs that are met by the individual species, so this is described using what is known as a logistic model of population growth.



So, one can see that in on the X axis you have time, and on the Y axis you have the number of individuals or animals in the particular species how it will grow in the absence of any competition.

So, this is known as logistic model, and it has a sigmoidal growth curve which as you can see, it is a growth which is slow initially then it picks up with the very high rate and then it terminates of to a levels of to a steady number. So, what dictate this growth curve and what dictate its steady state that it reaches after certain time.



So, as we said already it is dictated by the container in which it is growing or the resources available to that population. This is in the absence of any competition. So the logistic model can be expressed using the equation logistic equation. So population regulated by crowding to an equilibrium number can be modeled using the equation that is R is equal to small r into N into 1 minus N by K.

$$R = rN\left(1 - \frac{N}{K}\right)$$
$$\frac{dN}{dt} = rN\left(1 - \frac{N}{K}\right)$$

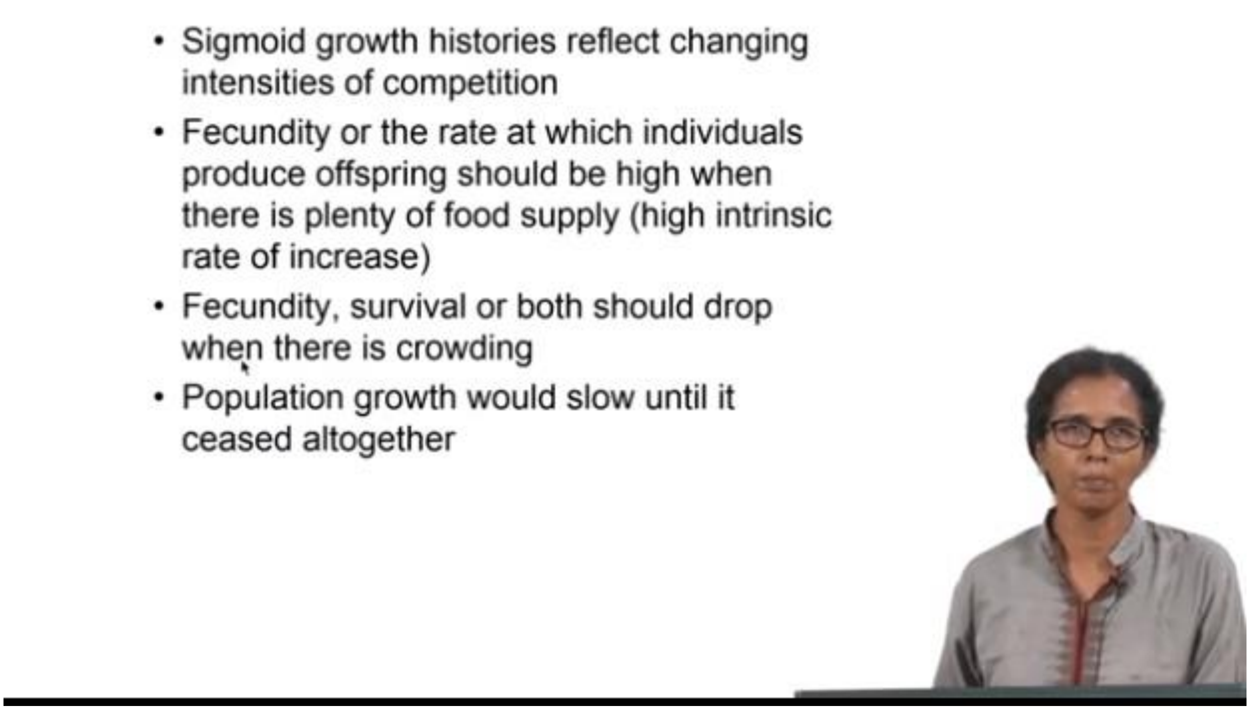
Where this capital R stands for the population growth rate that is given by ${dN}/_{dt}$, so that is N is the number of animals present at time t.

And so now, if you say that K is the number of the number of animals able to live in the container. So if you imagine that we are growing some algae in the container, and we are providing some food to the algae, and it is growing in, or some let us say paramecium or a single cell organism or some bacteria is growing inside a particular container, but it is not allowed to go out. So how much number, how many numbers can grow inside that container? Or let us imagine that you know a boundary wall which encompasses let us say a population of deer, how many can they grow? Will they outnumber or can they keep on growing without any limit or will they be controlled? The population will be stabilizing, or will it be reaching some kind of equilibrium? So that is a question addressed in this logistic model in the absence of let us say, Predator.

So, in this case, the number R is the population growth rate that is the $dN/_{dt}$, N is the number of animals present at time t, and K is the number of animals that are able to live in the container at population equilibrium. That is the value that you can get on this logistic curve when it reaches the equilibrium that is, this value is K. So, at any given point of time the population is growing with different rates. So and small r is the intrinsic rate of increase that is how much a number is increasing that is dependent on the growth, the birth rate and the death rate of the animals that is what give you the small r value.

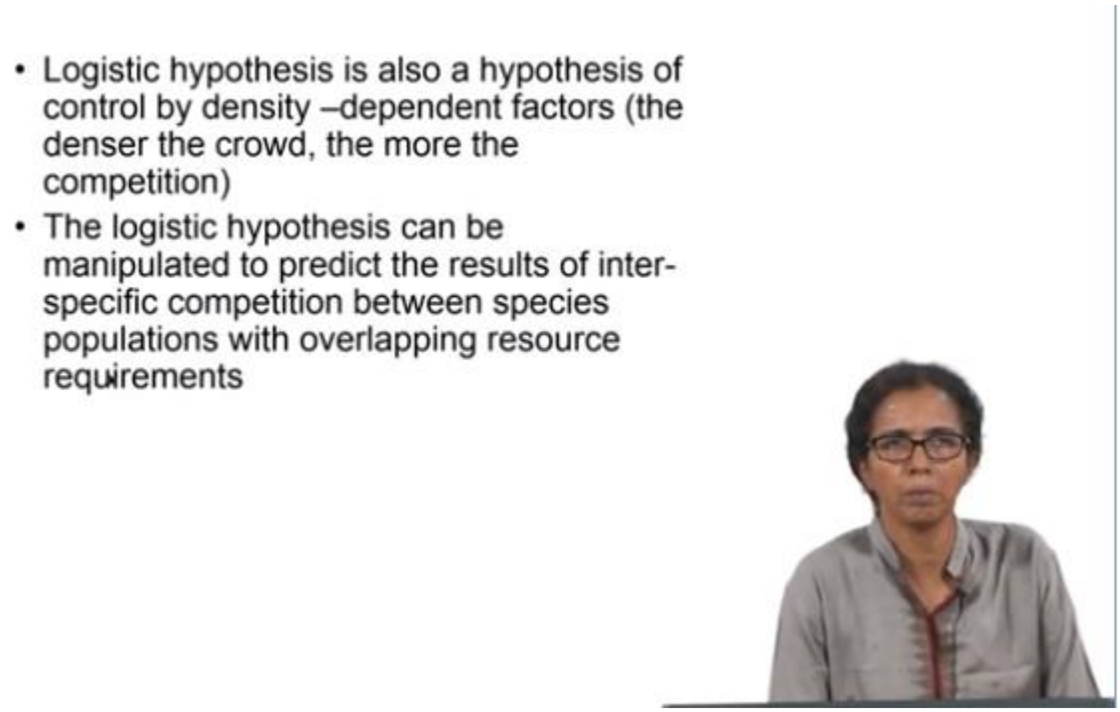
The logistic equation can be applied where the population growth is continuous, okay, so basically there is no interference in terms of any predators or anything else, so the population is growing continuously. So, continuously how long can they grow is the question, so as long as food is available to the system, available to the individual members the growth will continue and then they will reproduce and multiply and the population will grow. So then once it reaches the capacity of the container that is the limit to which it can grow, that is the number it can hold, this is known as the carrying capacity, K is known as the carrying capacity of the system which is crucial to the logistic statement. And once it reaches the value K so then, N becomes equal to K, so you can see that the value, that $dN/_{dt}$will become equal to 0 because one minus one it will become zero and so you can see the growth rate will become zero.

So, the logistic hypothesis states that as the population number N approaches the saturation number K, then rN becomes zero and the population growth ceases. So, no organism can, so the sigmoid growth histories reflect changing intensities of competition, and fecundity or the rate of which individuals produce offspring should be high when there is plenty of food supply, that is high intrinsic rate of increase. And that is what you see in the sigmoidal curve in the middle region when there is plenty of food there will be lot of growth.

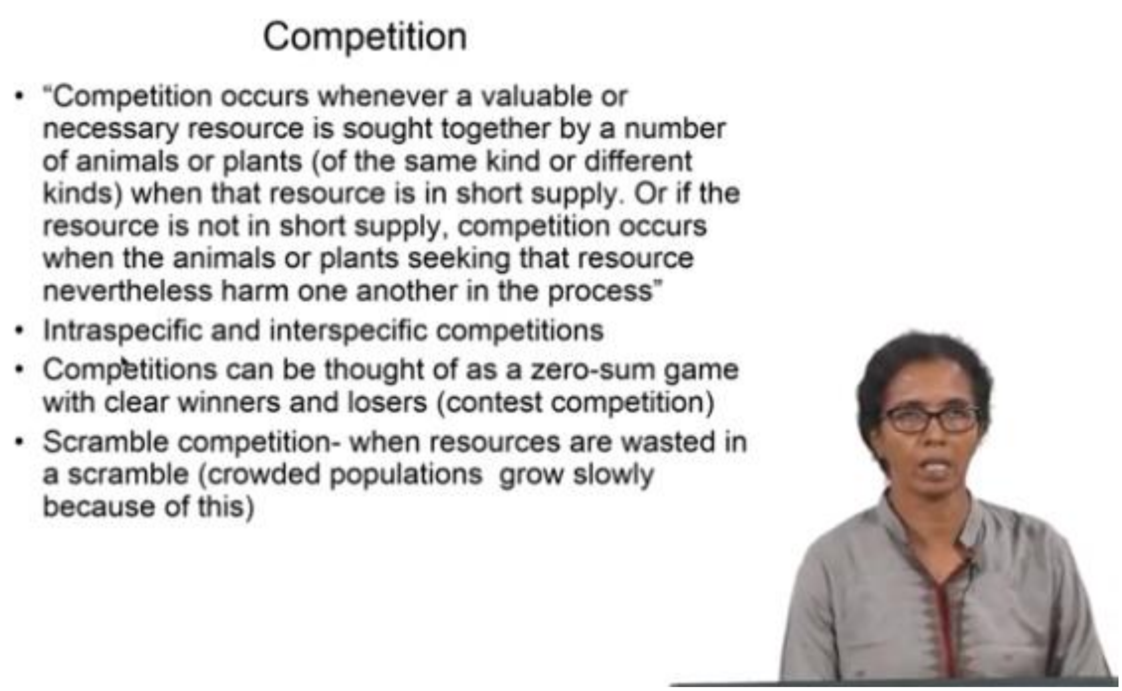


And when the number of individuals increase, the food available to individuals will decrease, and then they will reach the carrying capacity of the system. So, the fecundity or survival or both should drop when there is crowding, so once the growth reaches the K value or N becomes equal to K, the container is almost full with the animals, so basically it cannot grow further, so it starts dropping.

So, you can multiple ways, so if you continue to supply external food source then the growth curve can keep growing, increasing, or it will decline because the individuals, the intraspecies competition or the competition among individuals of the species will come into the picture, and then they will compete for the resource of the food and the population growth will slow down and or cease altogether.



The logistic hypothesis is also a hypothesis of control by density, density-dependent factors that is the denser the crowd, the more the competition. So that is what would happen there and then the growth will again be self-controlled. The logistic hypothesis can be manipulated to predict the results of in this specific competition between species populations with overlapping resource requirement.

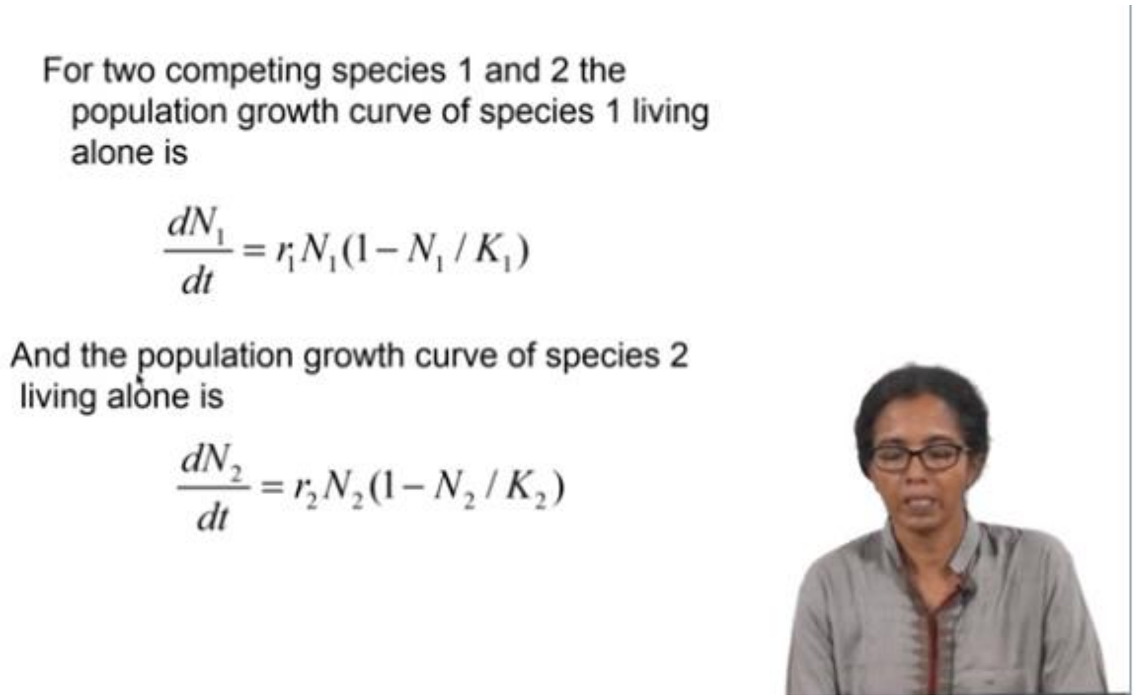


Now, let us say if you have two different species competing for the same resource, so how will it be described? So, this is what we call as competition, so the competition occurs whenever a valuable or necessary resource is sought together by a number of animals or plants, it could be nutrient by different plants, or it could be a resource food resource by different species of animals let us say.

So, when that resource is in short supply, so let us say there is a resource is in short supply then there is competitions setting up, or if the resource is not in short supply competition occurs when the animal or plant seeking that resource nevertheless harm one another in the process, then also competition can result, there is no need for you know the resource to be in short supply. So even if let us say plenty of food is available sometimes animals and plants seeking that resource can harm one another then also it is also known as a competition.

So, intraspecific and interspecific competitions are possible, that is intraspecific is the competition within the species and members of the same species, and intraspecific competition is between different species, let us say for the same food resource two species are competing. Let us say grazing land, where different species of animals are coming, and then they compete for the same food source, how do they survive? Competitions can be thought of as a zero-sum game with clear winners and losers, that is the contest to competition. So in the sense that there will be clear losers or winners at the end of this competition because one of them have definite advantages over the other in gathering the resource or eating the food, so basically they will overcrowd the other species.

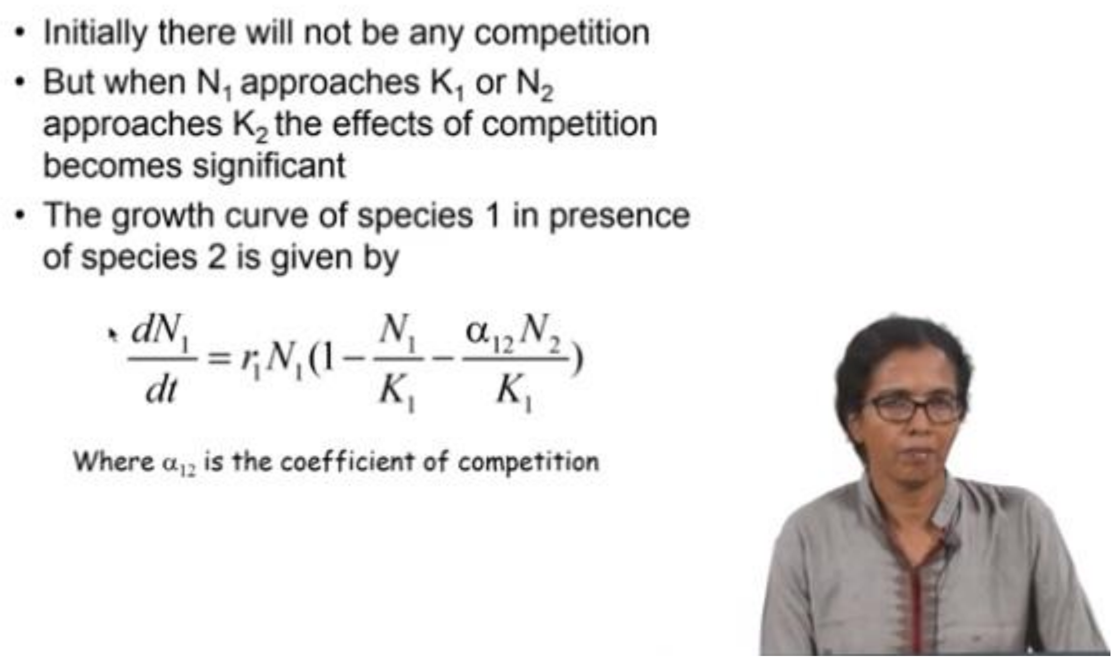
Then another definition need to be looked into is scramble competition, that is when resources are wasted in a scramble, crowded population grow slowly because of this, because of the scrambling they waste the resources.



$$\frac{dN_1}{dt} = r_1 N_1 \left(1 - {}^{N_1}/_{K_1}\right)$$
$$\frac{dN_2}{dt} = r_2 N_2 \left(1 - {}^{N_2}/_{K_2}\right)$$

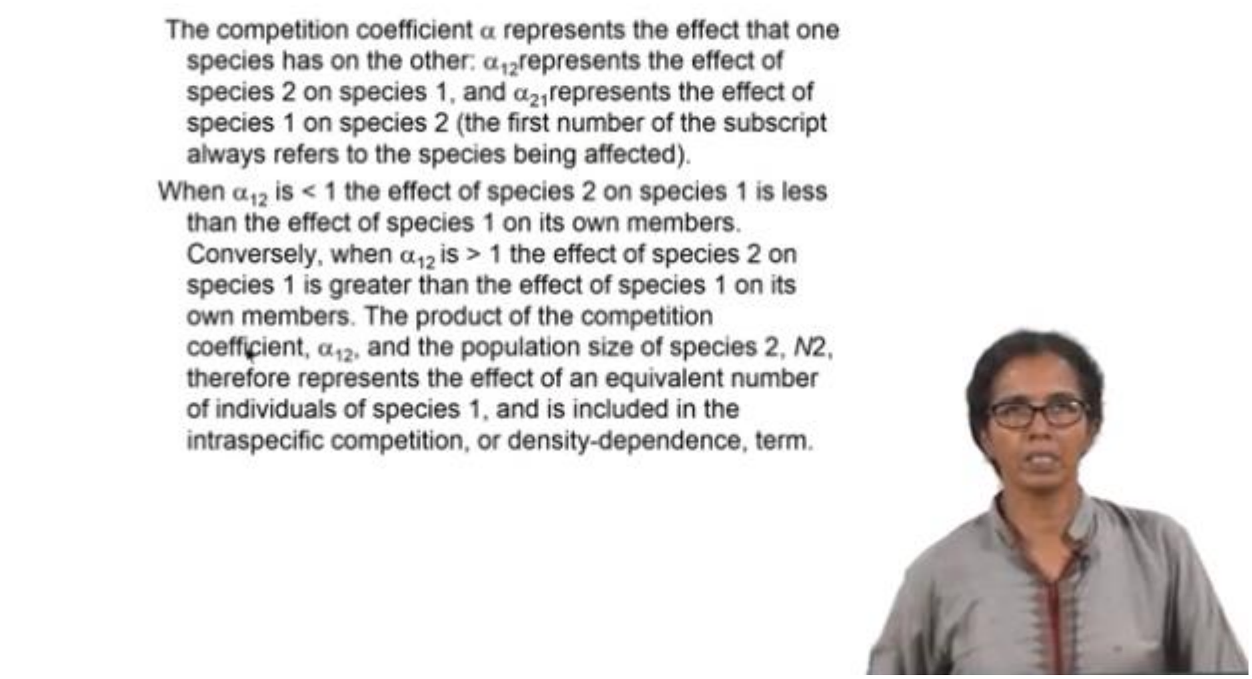
So, the same logistic model can be modified when there is a competition between two species for the same resource, for to competing species one and two the population growth curve of species one living alone can be written as $dN_1 \,/\, dt$, which has an intrinsic growth rate of r_1, and the N_1 is the population of that particular species at given point of time, and K_1 is the carrying capacity of the species 1, if species 1 was only occupying that space.

Similarly, you can also write another expression for let us say species 2, if it was living alone in that habitat we can say that you know the growth rate of species 2 will be written as $dN_2 \,/\, dt$, which is equal to the intrinsic growth rate of r_2 multiplied by number of individuals of species to at that given time, and K_2 is defined by the carrying capacity if only that is species 2 was living in that area.



$$\frac{dN_1}{dt} = r_1 N_1 (1 - \frac{N_1}{K_1} - \frac{\alpha_{12} N_2}{K_1})$$

Now, let us say that this 2 species are coming together, so initially, there will not be any competition because there is enough food supply and resources available, but when N_1 approaches K_1 or N_2 approaches K_2 the effects of competition becomes significant. So the equation will become a coupled equation here, the growth curve for of species 1 in the presence of species 2 we can write as let us say we want to write for species, how is species 1 growing? It can be expressed using the equation dN_1 / dt, which is the growth rate of species 1 in the presence of species 2. So that equation will get modified as r_1N_1 which into 1-N_1 by K_1, N_1 and K_1 are relevant to species 1, minus α_{12} into N_2 by K_1, so N_2 is again relevant to species 2, and α_{12} is a coefficient which is known as the coefficient of competition.



So, we will see what is this coefficient of competition? The coefficient of competition is alpha which represents the effect that one species has on the other, so α_{12} means the effect of species 2 on species 1, so how it is positively or negatively impacting the species, the other species. And α_{21} means the digits below alpha or subscripts indicates which species is affecting the other one, so α_{21} represents the effect of species 1 on species 2, α_{12} means the effect of species 2 on 1, α_{21} means the effect of species 1 on species 2. The first number of the subscript always refers to the species being affected.

So, when α_{12} let us say is lesser than, this coefficient can be having a value which is less than 1, the effect of species 2 on species 1 is less than the effect of species 1 on its own members, so that is the meaning of α_{12} being less than 1. Or on other words, if α_{12} let us say is greater than 1, the effect of species 2 on species 1 is greater than the effect of species 1 on its own members. So, the product of the competition coefficient α_{12} and the population size of species 2 that is N_2, therefore represents the effect of an equivalent number of individuals of species 1 and this included in the intraspecific competition or density-dependent term.

So, when it comes to competition, so when there is no competition among the species, the logistic model of growth is happening, and the competition happens only within the species and the population tappers as you could see in the logistic model. And when two species are competing for the same resource, we introduce what is known as a competition coefficient, α to capture the effect of one species on the other, how it will improve, increase or decrease the population of both the species.

So, in the next session, we will be looking at how if there is, in the absence of any prey-predator relationship we could use this logistic model. Now let us say we have a predator coming into the picture, so there are herbivores and then if there are predators, how this logistic model gets modified or are there different ways in which you can capture the population of both the prey and the predator existing in a particular place. So, this will become very complex if you have multiple species of, let us say preys and multiple species of predators coexisting in a same ecosystem, and the population will be having different dynamics because of this different parameters of competition coefficient that is, that will be affecting each species due to the presence of the other species in the same area, same ecosystem.

Thank you