Conservation Economics
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Module 4
Threats to wildlife
Lecture 1
Push and pull factors

Namaste!
Today we begin a new module which is Threats to Wildlife. This module will have three lectures: push and pull factors or the localization of species threats through species and ecotoxicology and developmental hazards. So, let us begin with the first one, the push and pull factors that govern the localization of species.
We know that different organisms live in different portions of the earth. So, for instance we find polar bears in the arctic areas, we do not find polar bears in the state of Tamil Nadu. Or we find elephants in the state of Tamil Nadu, but you do not find elephants in Siberia.
Different organisms are found in different locations, the question is why are they found in different locations? What are the factors that govern the abundance and distribution of organisms in different places of the earth? Now, this question falls under the ambit of the field of biogeography.
Biogeography is the study of the geographical distribution of life on earth. It studies the geographical distribution of life, which life is located in which area of the earth and the reasons for the patterns. So, not just a description of which organisms are found there, but also what are the reasons.
Why do we not find polar bears in India? Why do we not find elephants in Siberia? So, the reasons are also studied in this field, the reasons for the patterns one observes on different continents, islands, and oceans. So, this is the field of biogeography. And for different organisms we define the range of the organism.
The range or distribution of a species is the geographical area within which the species can be found. So, for instance India is not a part of the range of polar bears and similarly Siberia is not a part of the range of elephants, but Uttarakhand is a part of the range of elephants, Tamil Nadu is a part of the range of elephants, West Bengal is a part of the range of elephants.
The range of elephants comprises all these locations, but it does not extend to a place like Siberia. So, this is known as the range of a species, the range or distribution of the species is the geographical area within which that species can be found. And when we see that different species are found in different locations, let us first have an overview of the major habitats that we have. Now, habitat as you will remember is the natural home of an organism, it is the natural

abode or home of a species.

Let us before we move forward have a look at what are the different kinds of homes that we have, especially in India. So, we begin with the Alpine Meadows. Now, the term Alpine refers to a very cold mountainous area. Meadow is a grassland. So, Alpine Meadow is a meadow or a grassland that is found in cold mountainous areas, in states such as Jammu and Kashmir or Himachal Pradesh or Uttarakhand. So, this is an image from the Dachigam National Park in Srinagar.

If you look at this Alpine Meadow here we find that there is this hill that is all covered with grasses, there are hardly any trees here because in such locations when you move to a location were which is very high and which is very cold, typically the wind speeds also are very high and in the case of large wind pressures the trees might get uprooted. So, we typically find fewer trees in the Alpine Meadows.

This is another image from Uttarakhand. So, here again we find that this is an Alpine Meadow and it is all full of grasses. Now, the Alpine Meadows would support a large number of species that are dependent on the grasses and these include not just the large sized species such as the tahr, but also includes the smaller size species rats, mice, rabbits and so on.

So, we have Alpine Meadows. Next, we have a look at the Alpine forest, now here again Alpine is a cold mountainous area and this is the forest that is found in a cold mountainous area. Now, typically the Alpine forest will be found in locations where the height is less than that of the Alpine Meadows.

And the most common species that we will find here will be the coniferous trees. Now, these coniferous trees are adapted to a life, which is cold and mountainous. Typically we find that the leaves are very small and the leaves are arranged in such a way that whenever there is snowfall, the snow can fall down on the ground. It does not remain there on top of the trees otherwise; the weight of the snow would lead to the collapse of the tree.

These are the species that are adapted to a life in the alpine forest, we also find a number of animals in these areas. Another habitat that we have in our country is the moist deciduous forest. Now, a deciduous forest is a forest in which the trees shed their leaves in a certain season.

Now, this shedding of leaves can be, say, to prevent the loss of moisture so, in the dry season the leaves will be shed so that the loss of water because of transpiration is reduced. Another option is that we can have shedding of leaves in the winter season to protect the plant from extreme cold.

The forests that are dominated by such trees that shed their leaves in certain seasons are known as deciduous forests. And we have two kinds of deciduous forests in our country. We have the moist deciduous forest which typically has a large amount of moisture that is a larger amount of rainfall and the dry deciduous forest.

This is an image of the moist deciduous forest from Uttarakhand and here we find that this forest is dominated by the Sal trees and Sal associated species. This is an image from a dry deciduous forest in Madhya Pradesh. This dry deciduous forest here again you can find that the floor is completely covered with leaves, and there are very few leaves on these trees.

This is an image that was taken in the season when the trees are shedding their leaves. This forest is dominated by teak and teak associated species, and both these dry deciduous forests and the

moist deciduous forest are very good homes for tigers. Another habitat that we have in our country is the scrub forest.

Now, a scrub forest is found in those locations that have a very great scarcity of water. Typically the climate would be warm or hot and there would be less amount of rainfall. Now, because you have less rainfall, a large variety or a large sized tree cannot be supported in these areas, and so the typical organization would be an open forest.

The canopy is very less, most of the plants that we will have here will be of a short height so, we will find some grasses, we will find some shrubs and we will also find some trees, but typically the trees will also not be very high. Another habitat that we have are the sand dunes.

Now, sand dunes are found in those locations that are even more dry, so here you can see that the sky is completely blue. You do not have a single shade of clouds here. So, this is an image from Jodhpur and this is a sand dune. Now, these trees have been planted in this region. So, that the dunes get stabilized, but the typical vegetation is what you see in this location.

There is hardly any vegetation. We find some grasses, some shrubs, and a few trees, but that is pretty much all. But even in such areas, which have a very much dearth of water here, we also find a large biodiversity and we find some species that are endemic to these regions.

Now, an endemic species is a species that is formed only in one area nowhere else. So, we will find species such as this spiny tail lizard now, this is a species that is adapted to a life of intense sunshine and very less amount of water. So, we find this species in the desert national park for instance.

Another habitat we have in our country are estuaries. Now, estuaries are those areas where a river meets the sea; and typically we will find a gradient of salinity in an estuary from fresh water in the river to a brackish or saline water in the sea and there will be region where the salinity is in between so, we will find a gradient of salinity.

Whenever we find a gradient then typically we also find a large biodiversity, because these areas can support those species that live in freshwater they also support those species that live in salty water and they also support those species that live in salinity conditions that are between fresh water and salty water.

So, these are estuaries. Another habitat we have in our country is the Rann of Kutch. Now, a Rann region is a region which is typically very flat and in the rainy season it gets inundated with water, but then in the other seasons it is parched dry. So, typically you will find very flat regions where you will have certain grasses, there will be a dearth of water and you will find some endemic species such as the Indian wild ass.

This is an image from the Indian wild ass sanctuary. In areas where you do find water, typically the water will be brackish or saline, but these kinds of waters also support organisms such as the flamingos. Another specialized habitat we have in our country are the lagoons. Now, lagoons are those areas where the sea is able to enter into the land; and a lagoon such as the Chilika lake in the state of Odisha, provides a very unique habitat for organisms.

Why, because as in the case of an estuary even in the case of Chilika lake there are certain rivers that are draining into this lake. So, it is getting fresh water from one side, on the other side you have the sea, the Bay of Bengal and you have salty water that is getting in from the other side.

Here as well you will find a gradient of salinity, from very saline water near the sea to fresh water near the river mouth and everything else in between. At the same time Chilika is known for having a less depth of water so, typically the depth of water is less than 60 meters in most of the locations.

Now, that is important because a less depth of water ensures that the sunlight is able to reach from the top of the water column to the bottom. Which means that you have a source of energy everywhere you have light everywhere, which ensures that these sorts of ecosystems like the Chilika lake - they have a very high productivity and because of a good productivity because of all different sorts of variations in salinity we find a large biodiversity in the Chilika lake.

Another habitat we have in our country are the flood plains, such as the Brahmaputra flood plains that we are seeing here in the Kaziranga National Park. Now, flood plains are those areas that are near the river so, when it is the rainy season and the river floods these areas get completely inundated with water.

When that happens, all the plants in these areas or let us say most of the plants that are there in these areas get drowned under water and they die off. Then, in the post monsoon season as the water recedes, you get a ground that is more or less vacant and is also wet. So, in such grounds we get a very heavy growth of grasses.

These flood plains typically support large grasslands and also a large number of herbivorous species. Certain species such as the rhinoceros are endemic to this region. They are only found in these floodplains and they are not found anywhere else.

Another specialized habitat in our country is the shola forest, that you can find in the state of Tamil Nadu or Karnataka. Now, shola forests are a very unique ecosystem, because here we find a dynamic equilibrium between these grasses and these trees. The grasses do not invade into the tree areas and the trees do not invade into the grasses both eat each other in check.

Now, the benefit of such an ecosystem is that you know that an animal can use these grasslands for grazing and whenever it senses danger it can run into these forests to protect itself from the predators. So, these areas support a large diversity of organisms; and we also find a number of endemic organisms in these areas.

Yet another ecosystem or habitat in our country is the equatorial forest. Now, equatorial forest as the name suggests these are the forests that are near the equator. In our country we will find equatorial forests in the islands of Andaman and Nicobar. The equatorial forests are in those areas that are close to the equator and so they are getting a heavy amount of sunshine.

They also get very dense or heavy rainfall. Now, abundance of water and abundance of sunshine means that there is a very profuse growth of vegetation, and the ground gets completely covered so there is a complete canopy closure so, all the the canopies of different trees they touch each other.

Another characteristic of the equatorial forest is that the trees are very tall. So, you can see that this is an elephant for comparison and the size or the height of this tree is much greater than an elephant. Now, because there is a very fast growth of trees, you can also support lumbering or logging operations in these areas and here we are saying that an elephant is being used to pull this log of wood that has just been cut.

Equatorial forests also support a very large amount of biodiversity because there is an abundance of food production in these areas. Another habitat are the mangroves. Now, mangroves are forests that are found at the confluence of land and the sea.

The trees that grow in these forests are adapted to a life that is in between that of a land and the sea. So, typically we will find that they have these very dense roots and these roots are exposed and in certain locations these roots turn up and get exposed to the air they are known as pneumatophores; and they ensure that the roots get aerated.

Similarly, they also have a very unique adaptation that is known as vivipary. Now, in vivipary what happens is that, the the fruits that are formed in these trees they germinate when they are out there in the tree itself. So, the plant forms and once the plant has formed completely and it is a low tide plane, the plant will just drop down and it will get established in the sand that is below.

So, we have very specialized kinds of adaptations that we find in the mangrove trees, and they also support a very large biodiversity because these roots can be used as a shelter. And a number of fishes lay their eggs in the protection of these roots. So, mangroves support a very huge amount of biodiversity.

Yet another habitat that we have in our country is Oceans and Seas, which also have certain specialized organisms. So, our country is blessed with a wide variety of habitats and in each habitat you will find an organism that is found only there and it is not found anywhere else. Now, the question is we have different habitats, but then what governs which organism will be found in which area. So, which brings us to the topic of the distribution of species such as a snow leopard?

We are taking this example of snow leopard, if you plot the locations where snow leopard is found you will get a map such as this. So, the yellow colored region is where the snow leopard is found, and the pink color region is the one where it probably may be found but we do not have very good evidence.

Now, you can observe from this map that snow leopard is found in these mountainous areas, it is not found in our northern plains, it is not found in the Deccan peninsula, it is not found in the desert, it is only found in these areas. Now, the question is why do you find snow leopards only in these areas.

Now of course, the snow leopard has certain adaptations such as when it lives in the snow its color is very much similar to that of this snow so, it is able to camouflage very easily. At the same time it also has a very good amount of fat and the fur coat that it has is able to protect it from the snow.

But then, these are the adaptations that make it possible to live in the snow, the question is why does it live in the snow at all in the first place. Similarly, if we plot the location of coral reefs, now coral reefs are found only in these areas. Now, typically the areas where the coral reefs are found are those oceans, where the ocean temperature is neither very hot nor very cold and you also have clear water; it is not found in muddy waters.

Now the question is why is it found there. Now, one thing that we can note here is that most of the organisms are found in those locations that have a particular sort of climate. So, a coral reef

will be found in those areas that are not very hot nor very cold so, essentially you can mark the oceans where you have a temperature that is a moderate temperature.
In that you can also mark those areas that have muddy waters and those areas that have clear waters, and then you can say yes, this is the location where coral reefs should be found, which brings us to the topic of climate. So, it has been found out that climate plays the largest chunk of goal in deciding or determining where an organism will be found.
And a good way of understanding that climate has the largest impact is by looking at altitudinal zonation. So, what this curve is showing us, is that if you move from the equator towards the poles you find that earlier you will have the tropical forest or the equatorial forest, after that you will find subtropical forest, after that you will find warm temperate forests followed by cool temperate subarctic and arctic regions.
Now, this is occurring when you are moving from the equator towards the poles. However, if you take a location such as this location which is at 10 degrees latitude and if you go and if you start going up a mountain then, what do you find? You find that up to around 1,000 meters, you will find the typical tropical forest in these areas.
But then, from an altitude of 1,000 to 2500 meters we will start observing subtropical forest. Now, remember that this is a location that is very close to the equator, but still you are observing a subtropical forest area. Then, if you move even higher in altitude, you will start finding the warm temperate forest or the warm temperate vegetation.
Now, this brings us to the point that there is something that is common between say this region between 30 and 35 degrees latitude and this region which is at 10 degrees latitude, but is at a greater height. So, what is that common thing, now it turns out that the common thing is the climate.
As we move up a mountain the temperature goes on reducing and so, after a level we will start observing the subtropical forest and the warm temperate forest and so on. So, the trees that are found here, near the equator but, at a greater altitude they will be very similar to the trees that are found here near the sea level, but at a greater latitude.
This is an example that tells us that because of the similarity in climatic conditions we find similar sorts of vegetation, but here again the question is why does this vegetation occur in these areas. So, we are observing that in areas with similar climates we are finding similar vegetation, but the question is why is this vegetation found here.
This brings us to the enfold factors. The question is why are things where they are? And we can say that there are certain factors that pull the species towards them and there are certain other factors that push species away from them. So, these are the pull and push factors.
Pull factors are conditions that attract organisms to any area, such as good amount of food availability and an amiable climate that suits the species. So, if there is a region with an abundant amount of food and with a good climate then, species will come to that area.
On the other hand, there are certain push factors that drive the organisms away from an area, such as the scarcity of food or an inhospitable climate. So, if there is a scarcity of food, if there is a climate that does not suit the organism, probably the organism will not be found there.
For instance we can say that the polar bear is finding a pull factor in the arctic's because it is get-

ting food in sufficient quantity it is not having any predictors of itself. Whereas, our location such as Madhya Pradesh offers a push factor to the polar bears because their temperatures here are too high and these temperatures are not amiable to the polar bear.

So, we have different push and pull factors and whenever we observe that a certain species is found in certain areas, we can start thinking about the push and pull factors. If we consider this image from the Shivalik hills here we find that these slopes are completely devoid of vegetation.

Whereas these areas are thickly vegetated now, the question is why are these areas bare and why are these areas thickly vegetated? Now, if you start thinking on the lines of push and pull factors, you will start to think that there is something in these areas that is not permitting this vegetation to thrive.

There are certain push factors. What are those push factors? You can observe that these areas are very steep and in these steep areas whenever any soil gets formed with the next rains it falls down. And so these areas are typically devoid of soil now, plants require soil to grow and so, if you do not have a soil here then probably you will not find plants here.

The absence of soil is probably acting as a push factor for the plants in these areas. Another push factor could be the lack of moisture now; these areas are the south facing slopes. Now, Uttarakhand is in the northern hemisphere and so the south-facing slopes will have a greater amount of sunshine as compared to the northern freezing slopes.

And because of an abundance of sunshine the moisture gets evaporated. So, these areas not only have an absence of soil they also have less amount of moisture. So, these could be two push factors that are not permitting the plants to thrive in this area. On the other hand, if you consider this region then the slope is much lesser as compared to this region and because of that the soil is able to remain in this location.

And when you have soil and also you have more moisture because this is not the south facing aspect of this hill. So, you have more soil, you have sufficient amount of moisture and these are acting as pull factors for these plants to thrive in this region.

So, there are push and pull factors that can help us understand why certain organisms are found in certain areas and not in other areas. Now, in this context we can also look at Liebig's law of the minimum. Liebig's law of the minimum states that, the rate of any biological process is limited by that factor in the least amount related to requirement, so that there is a simple limiting factor.

The rate of any biological process including say the growth of plants is limited by that factor that is there in the least amount relative to requirement, so that there is a single limiting factor. Now, what does that mean? Let us consider that in a location where the plants are going plants require several nutrients.

And three most common most important nutrients are nitrogen, phosphorus, and potassium that we call as N P and K. Now, suppose the plants require 1,000 units of nitrogen, but only say 800 units are available, which is 80 percent. Now, in this location for phosphorus a plant requires 200 units of phosphorus, but only 100 units are available; which is only 50 percent of the requirement can be met at this particular site.

For potassium probably the plants need only 100 units, but only 99 units are available. Which

means that it is present in 90 times it is able to meet 99 percent of the requirements of plants. Now, Liebig's law of the minimum states that the rate of growth of plants will be limited by a single factor, they will not have the growth of plants that is limited by all these three factors. There will probably be only a single factor and that single factor is the one that is available in least quantity related to the requirement.

In this case the phosphorus is available in the least quantity related to requirement, because it is able to meet only 50% of the requirements of the plants, others are able to meet 80 percent and 99 percent. So, Liebig's law of the minimum will say that the rate of plant growth will be dependent on the amount of phosphorus in this area.

The rate of any biological process is limited by that factor and least amount related to requirement, so that there is a single limiting factor. Now, why is Liebig's law of the minimum important? Because it is giving us an indication of what could be a push factor in this region.

We can note that the phosphorus - because it is available in a very less quantity related to the requirement - so this lack of phosphorus in this case is acting as a push factor. Another similar concept is the Shelford's law of tolerance, which states that the geographical distribution of a species will be controlled by that environmental factor for which the organism has the narrowest range of tolerance.

There is a certain range of tolerance, for different environmental factors and these ranges of tolerance govern where this species will be found or not. Now, of late what we have observed is that the environmental conditions are changing and so even for those environmental factors for which the organism earlier used to have a narrow range of tolerance it is now possible for organisms to extend their reach; and a good example is of global warming.

Now, it is known that a number of insects are regulated in their distribution because of the temperature. So, a number of species of mosquitoes for instance cannot tolerate a very low temperature, and so because of altitudinal variation of temperatures we will find that in a mountainous area, the mosquitoes or the flies will be found in the lower areas and as we go up we will not find any of these mosquitoes or flies.

Because these species are adapted to a life at higher temperatures, but because of global warming what we are observing is that the temperatures are rising and so even in these higher up locations now, we are having a higher temperature, which is now within the range of tolerance of these flies or mosquitoes. And because of that we are observing that now the flies and mosquitoes are able to invade even higher reaches of the mountains.

Even if the range of tolerance remains the same, if there is an environmental variation that brings more areas into the range of tolerance then the organisms will extend their range. This is the field observation as the mean temperatures are rising the median altitude where mosquitoes are found or where malaria is found is also increasing.

We are seeing this thing practically. Now, another factor that acts as a push factor is Allelopathy now, Allelopathy is the phenomenon in which certain organisms secrete certain chemicals that inhibit the growth of other organisms or that kill away other organisms, and a very good example is antibiotics.

This is a photograph from the Nobel lecture of Alexandra Fleming and here we are seeing that

there is this petri dish on which there is this colony of penicillium which is a moon. Now, this penicillium colony is secreting something and now we know that that something is penicillin the antibiotic, and because of this antibiotic and here we are seeing bacterial colonies which belong to staphylococci.

Here we have staphylococci colonies and in this zone where you have the penicillin, we are seeing that these staphylococci are undergoing lysis. So, the penicillium colony is secreting something that is killing off or inhibiting the growth of these bacteria.

A phenomenon such as this is known as Allelopathy and we find Allelopathy not just in these microorganisms but also in the case of plants. So, if you consider a dry deciduous forest floor and especially one that is dominated by peaks you will find very less vegetation in the ground cover.

Now, why is that so, because the leaves of teak when they fall down, they carry with them a chemical that inhibits the growth of a number of species of plants. So, we find Allelopathy because of these leaves in a dry deciduous forest as well, and in a number of cases we can demonstrate this impact experimentally.

Similar to the impact of teak it is known that in areas that have grasses it is difficult to raise apple trees. So, how do you demonstrate that the grass is doing something through Allelopathy to reduce or to inhibit the growth of the apple trees? Now, remember that in the case of Allelopathy something is being secreted and if there is something that is being secreted if you take that chemical out then, it should still be able to inhibit the growth of the apple saplings.

This is how the experiment is done. So, you take soil in which you have grass, you add water and you take off the runoff. So, here we are adding water and the water is percolating through the soil and the runoff and the water that has been populated down it is collected, and here you have another piece of soil in which you are growing apple tree seedlings and here also you do the same thing.

And you find that, because you are adding water from outside, the grass is able to grow and the apple tree seedlings are also able to grow. There is no difference or there is no mortality or more innovation. Next, what you do is you add water to this grass and you remove this water that has percolated through this grass and soil or has flown over this grass and you add this water to the apple saplings.

Now, you will start to observe that these apple saplings or the seedlings will be showing a very reduced growth as compared to this control. So, in this control we were adding water from outside, in this experiment we are adding that water that has passed through grass and the grass roots; and we are observing that it is now inhibiting the growth of the apple seedlings.

Probably there is something that is coming out of this grass or the soil that is inhibiting the growth of the apple seedlings. Now, how do we prove that it is not something that is coming from the soil? Well we repeat the same experiment, but without the grass.

Now we add water to the soil. We take all the water that has run off or that has populated through this soil and we add that water to the apple seedlings, and here we find that there is no inhibition of growth. So, such an experiment would help us prove that there is something that is being secreted out by the grass, not by the soil and this something is hampering the growth of the

apple seedlings.
This is the classic Allelopathy. Allelopathy can very easily be demonstrated in experimental settings in certain cases we grow two organisms together and we observe, if this organism is able to inhibit the growth of this organism, but at a distance or we can do experiments such as these to demonstrate if something is being secreted out which is inhibiting the growth of the other species.
Allelopathy is a very important push factor for a number of species. Another push factor is predation. Now, predation is the phenomenon in which one species kills or hunts or eats other species for food. So, for instance if there is an area which has a very big population of say wolves.
In those areas we will not find a very big population of deer. So, the deer will try to avoid those areas where you have the wolf population, whereas the wolves will be attracted to those areas that have the deer. So, predation works in these two ways.
A very classic example of predation is how sea urchin regulates the distribution of algae. So, this is a field observation so, here you have the abundance of sea urchin. Now, here sea urchin is the predator that eats up the algae and here we find that in so, this is the abundance of sea urchin and this is the abundance of algae.
And here we find that wherever you have a heavy growth or heavy abundance of sea urchin you do not find the algae, but in those locations where you do not have the sea urchins you have a very good amount of algae. Now, how do we prove that this distribution is because of sea urchin and not because of any other organism.
We show this by experiments. So, the scientists took an area where they were not finding the algae and they experimentally removed the sea urchins in those locations. Experimentally all the sea urchins were picked and moved to other locations. What happens in the absence of the sea urchins, is that the algae start to grow and occupy this area and within a year - so, this experiment ran from July 1959 to July 1960 - within a year the whole area got covered with algae.
If you just remove the sea urchins you find that the algae have come back to this area, which tells us that the sea urchins were doing something to the algae because of which they were not able to thrive in this location. But then, not only does predator govern the abundance of the prey in certain cases the prey also governs the distribution and abundance of the predator.
A good example is those locations where you find deer or sambars and you find tigers in those locations. So, if you have the prey you will find the predators nearby, but in certain situations this goes to the other extreme as well. For example, in the case of Drosophila pachea now Drosophila pachea is a predator species which preys upon a species of cactus.
Now, this species of cactus not only provides food for this Drosophila, but also it secretes or it manufactures a particular sterol that is required for the development of Drosophila. So, if you do not provide this sterol, if you try to grow Drosophila on some other species the Drosophila colony will not be able to establish.
So, in this case this Drosophila pachea or this predator will only be found in those locations on earth where you have this particular cactus. So in this case, the prey is governing the distribution and abundance of the predator; in this case the prey is acting as a full factor for the predator.

Another factor that governs the distribution is competition, especially interspecific competition. Now, interspecific competition is a phenomenon in which there are two species that are competing against each other. And during this competition it could be say for food or it could be for space, during this competition one of the species is able to to have so much amount of aggression that it drives away the the species from that area.

And a good example is these birds the red wings and the tri colored black birds. Now, this is a field observation. In 1959 on 15th of March it was found that this whole area was covered with redwing territories, but later on on 20th of March it was found that the central region had the blackbird territories and the red wings were displaced out.

So, they could only remain in the periphery, but the central region is now a space where these red wings are no longer found. So, this is an example of interspecific competition that governs the distribution and here the black birds are acting as push factors for the red wings.

They are pushing them away from their original territories. There is nothing else in this area that is unsuitable for the red wings, the red wings could have easily formed their colonies and as they had done previously, but then because these black birds are acting in a push factor so they are pushing them out of this region.

This is another factor that governs the distribution and abundance of species. Another factor is the behavioral factors, such as habitat selection "Habitat selection refers to a hierarchical process of behavioral responses that may result in the disproportionate use of habitats to influence survival and fitness of individuals".

In the case of habitat selection what we are saying is that there are two habitats that are equally suited for an organism, but it so happens that the organism does not prefer one it only prefers the other one; and because of this behavioral response it is possible that the organism will be found only in one habit and will not be found in the other habitat.

And a good example is the chipping sparrow. Now, this experiment was done to demonstrate that habitat selection has both innate and learnt responses; innate means a response that is present from birth and learnt is something that the organism learns after it has been born.

In the case of natural chipping sparrows the wild caught adults if you take this if you take the birds if you catch the birds that have grown in the wild conditions, and if you put them into a situation where they can spend time on pine trees or they can spend time on the oak trees, you will observe that as much as 71 percent of the time is spent of the pine trees so, the majority of time is spent on the pine tree and only 29 of time is spent on the oak trees. Now, in this case what is happening is that the oak can also serve as a habitat for these birds.

It also provides them with shelter, it also provides them with a place where they can boost or nest, but they have a behavioral preference for pine. So, this is an example of a habitat selection. Now, it has an innate component which is present from birth because if you have laboratory reared, birds which have not been exposed to any outside foliage then also we observe a very similar pattern, they spend as much as 67 percent of time on pine when they are released and only 33 percent of time in the oak.

Which means that, this habitat selection or this preference for pine is present from birth, but then if you have laboratory reared chipping sparrow chicks and you raise them in oak foliage so,

when you are raising these chicks you put the oak leaves together with these chicks.
What happens is if this slowly and slowly they develop a preference for oak as well. And when you release them out in the forest you will find that now they are spending 54 percent of their time on oak and 46 percent of their time on pine. Which means that, earlier we were seeing a dramatic preference for pine, but now we are not seeing a preference for pine?
Now the birds have become ambivalent; they spend time in oak roughly as much or a bit more than the time that they spend on pine. So, habitat selection has a learned component as well and habitat selection can be changed. Other factors that govern the distribution of species are things like dispersal. Dispersal is the movement of individuals away from their place of birth or hatching or seed production into a new habitat or area to survive and reproduce.
What we are seeing here is that, if you consider a tree and this tree is giving now a number of fruits and seeds, if all the seeds grow into plants in this same area the area will very soon become overcrowded and there will be a very heavy amount of competition.
So, typically what happens is that there are mechanisms through which these seeds are able to move to other locations. Such as in certain plants you will find that the trees are surrounded by a cotton like ball and then together with the wind they are able to move to other areas, or in certain cases we have movement because of water.
In certain cases we have fruits that are edible so, birds and animals eat these fruits and when they go out to other locations and when they defecate the seeds are also able to reach these other locations. So, this is a phenomenon that is known as dispersal. The movement of individuals away from their place of birth or a hatching or seed production into a new habitat or area to survive and reproduce.
Now, dispersal is different from migration, because in the case of dispersion the organisms are moving not along fixed booths and not in a regular or seasonal manner, but they are moving in search for a better habitat. Now, dispersal is of three different kinds, you can have diffusion which is a gradual movement over several generations across hospitable terrain.
In diffusion you have the organisms that are moving over several generations and the terrain is a good terrain and so slowly and steadily they are moving, such as the movement of lions across the Gir landscape that is diffusion. In certain cases we have the jump dispersal which is a quick movement over large distances often along unsuitable terrain.
There is a quick movement over large distances often across unsuitable terrain; a good example is the dispersal of zebra mussels through ballast water or say the movement of rats on ships. Now, if there are two islands and the first island has rats, the second island does not have rats and between these islands the area is covered with water.
Now, water is an inhospitable terrain for the rats because they cannot swim and they will die if they try to swim over these long distances. But, if a ship is moving from island one to island two, and if the rats are able to get into this ship they will be able to cross this inhospitable terrain very quickly probably in a single generation. So, this is an example of a jump dispersal quick movement over large distances and often across unsuitable terrain.
Another example is the invasion of zebra mussels through ballast water. So, when ships move from one place to another place to maintain the stability there is a structure called ballast and

whenever there is loading of goods then, water is pushed is pumped out of the ballast; and whenever there is unloading of goods water is pumped into the ballast.
And when that happens, whenever there is pumping of water into the ballast, then the organisms that are out there in the lake or in the sea where the ship is located they can also enter into the ballast. And when the ship moves to another location then these organisms are also able to hitchhike, because they are there in the ballast water.
So, the surrounding waters may have become salty and in the salty water these zebra mussels would have died, but because they are inside the ship inside the ballast where there is fresh water, they are able to survive. Now, when they reach another location and when again there is pumping in and out of water then, these zebra mussels can come out and this is an example of a jump dispersal.
Because, there was an inhospitable terrain in terms of high salinated water, which the zebra mussel was able to cross very quickly in one generation or in the span of a few generations. Another mode of dispersal is the secular dispersal, which happens so slowly that the organisms have finally diverged from the original populations, such as the dispersal of humans out of Africa.
So, we have these three different modes of dispersal, and whether a species is found in a location or not also depends on whether it has been able to disperse to that location or not. So, in the example of our two islands, island two did not have a rat population, but if you have a dispersal from island one to island two we will start observing rats in island two as well.
Because island two was able to meet all the other requirements of rats, it was having space it was having food but, till the point that the rats are able to reach that island we will not find rats in that island. Other factors are anthropogenic factors or manmade factors, this clearing of forest or pollution.
In this image we can see that this area is clear-felled now, if humans had not acted here this area would have had the same trees that are found in this area. And human factors are playing a major role in the case of the abundance or distribution of different organisms.
Now, we can understand the reasons why an organism is found in a certain region or not through transplantation experiments. Now, in the case of transplantation experiments what is done is that and the is that a group of organisms is transplanted from a site where they are found, that is this green site to another to other sites where they are not found, such as this yellow site and the red side and there is also control experiment.
Now, if you take organisms from this green zone into the yellow zone and the organisms are able to survive. It would tell us that there is nothing wrong with this area everything is fine it is just that the organisms have not reached to this area, probably because they have not been able to disperse to that area so, it will take a bit more of time, which is our example of rats moving between the two islands.
But, if we do any transplantation experiment from this green to the red zone and the organisms die, then we will see that there is something in this red zone that is not allowing these organisms to thrive. A good example is when algae are shifted to areas that have sea urchins.
So, transplantation experiments are used to determine whether the range is limited or the distribution is limited because the area is inaccessible due to a physical barrier or it is a factor of dis-

persal that it will take a bit more time, or whether there is a habitat preference.
Or whether the distribution is limited by other species such as because of predation parasitism competition and so on, or whether its distribution is limited by physical and chemical factors. So, transplantation experiments help us decide what is the reason for a particular abundance and distribution or localization of the species.
So, to sum up we can analyze why a particular distribution is there by looking by performing different experiments and by having different observations. If an area is inaccessible such as our second island in the case of rats moving from island one to island two, if there is if everything else is fine but the area is inaccessible we will say that the localization is because of dispersal or absence of dispersal.
But, if the area is inaccessible then if we observe that there is a preference for a particular habit and if there is a habitat selection, then we will say that the localization is because of behavioral aspects. If behavioral aspects are also not there the species has equal preference then, it is possible that the distribution is limited because of predation parasitism competition or disease which are biotic factors.
So, we can perform transplantation experiments and see if it is because of say predation or because of parasitism. But, if that too is not there, if this is there then we will say that other species or biotic components are regulating the distribution, if even that is not there then we will say that it is because of certain physical and chemical factors.
And if we change these physical and chemical factors, say by use of greenhouses or by adding water or by providing fertilizers; we will be able to show whether it is because of a particular physical or chemical factor or because of something else. By doing such experiments by doing such analysis, we can discern what are the push and pull factors that are governing the localization of any particular species.
That is all for today. Thank you for your attention. Jai Hind!

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Module 4
Threats to wildlife
Lecture 2
Threats to species

Namaste!
In today's lecture, we will have a look at the Threats to Species. The threat factors can be discerned from ecology and in the last lecture, we had seen that there are a number of push and pull factors that decide whether an organism will be found in a particular place or not.
Pull factors as you will remember are those factors that attract organisms to them. So, they could include things like a good climate, a good soil, ample amount of food and so on.
Whereas push factors are those factors that push the organisms away from them and they include things like a climate that is very hot or very cold or very dry, so areas that do not have good amounts of food available for them or areas that have predators or diseases.
These are the areas where these factors would be pushing the species away from these areas. So, any organism that is found in these areas, there is a very good chance that either this organism will be killed or this organism will shift to some other place.
There are certain push factors and certain pull factors. Now, when we talk about the threat factors, then if an organism is a threat, what does it mean? It means that the organism is facing push factors everywhere and it does not have a pull factor anymore, which means that from all the areas, this organism is being pushed out and there is no place where this organism is finding a habitat that is suitable for itself.
The threat factors discened from ecology are that you have push factors everywhere and pull factors nowhere and that would be a major threat to any wildlife species. And if you look at these push factors, we can divide them into certain categories. So, the first one has no suitable habitat.
You have an area which does not provide a suitable habitat for the species. It is either too hot or too cold or there are no trees. So, there is no shelter that is available for the organism, there is no food, there are no nutrients in this area or an area that is completely burnt out. So, probably there was a forest fire and this forest fire burnt away all the habitats of a particular species.
In that case, this organism will not be having any other suitable habitat in which to live - areas are rich in noxious factors or are too polluted. For instance, there is a species that is found in a particular lake and this lake is now being used as a dump site for industrial accruals.
When that happens, the organisms will lose out their habitat or areas that are not suited behaviorally because of habitat selection. Probably an organism could have thrived in an area, but then,

this place is all full of such trees that its habitat selection does not permit to use or to prefer as a habitat.

These are push factors that are related to the habitat. Then, there are certain other push factors that are related to competition. Probably, the habitat of the organism is now full of invasive species.

Invasive species are those species that when they come into a habitat, they grow so profusely and they out-compete the native species to such an extent that in a very short period of time, you will only find these invasive species that are predominating these areas.

If an area has invasive species, then probably the habitat will go back or areas that have too many predators or diseases. So, the organism could have lived there, but now there are so many predators in that area that any organism that remains in this area might get killed off or there are a number of diseases in those areas.

There could be competition because of invasive species, because of predators and so on. So, these are other push factors or you could have the push factors of being killed out, specially to by human beings; say due to heavy poaching.

So, for organisms such as tigers, this is a major threat. Then, we also have other push factors in the form of small population dynamics. Now, small population dynamics act when the population has already become very small and these include things such as Allee effect or stochastic difference.

Allee effect is an effect that occurs when the population size has gone down. Now, in the case of a number of species, the size of the population plays a very important role in how efficient this population and the individuals of the population are.

For instance, if we consider a pack of wolves. If there is a single wolf, it might not be able to kill the prey. So, it requires a certain small number of wolves that should be there so that the prey is killed effectively and all the individuals in the pack are able to get their food.

Now, if the pack size reduces to such an extent, that you only have a few wolves. So, these wolves will not be able to hunt in an efficient manner and in that case this would start acting as a push factor for this small pack of wolves. So, this is known as the Allee effect or you could have stochastic deaths.

Stochastic deaths means that you have a random death that is occurring in this area and it is just possible that you already have a very small population, say around 4 individuals and these 4 individuals die off or 3 out of these 4 individuals die off.

Now, this would not have had a big impact if the population size was large. In a pack of say 40 wolves, if 3 individuals died, it could not have mattered much. But in a pack of 4 wolves, if 3 individuals die off, the lone individual will not be able to breed any further and this pack will be as good as gone.

These are the impacts that occur when the population sizes vary and these are known as small population dynamics. So, these are all different threat factors that we can discern from the ecology of different species.

There could be the push factor of an unsuitable habitat everywhere or there could be a biological factor that these individuals are getting completed out because of a invasive species, because of

predators or humans could be involved in killing out the individuals of the population or there could be the small population dynamics because of which there is a big threat to the small populations.

When we talk about these push factors, these push factors can be divided into two categories. There are factors that push a population towards smaller numbers. So, here the population is currently large in size and these are the factors that are pushing the population towards a smaller number.

And these are known as Declining population paradigm. So, the declining population paradigm is the study of those factors that push a large size population towards the smaller numbers and this occurs through population dynamics.

On the other hand, we also have the Small population paradigm which occurs due to factors that push a small population towards extinction. So, in the case of the declining population paradigm, you have a large population and the declining population paradigm is converting a large population to a smaller population.

Whereas, in the case of a small population paradigm, we are talking about a small population that is now being eliminated. So, the small population paradigm comprises factors that push a small population towards extinction.

We can categorize our push factors into the declining population paradigm because of smallness such as things like no suitable habitat. So, if the habitat is becoming unsuitable it is, say, because of climate change. If climate change is occurring in an area, then it is possible that the habitats become too hot or they become too dry or too wet and when such a scenario occurs, then it is possible that the large size populations will now be pushed towards smallness.

Because they are now not getting sufficient food, they are not getting sufficient suitable habitats in which to thrive or we can have this competition. So, competition also pushes a large population towards small size populations.

Or poaching. Now, poaching or heavy poaching, generally reduces a large population into a smaller one. And in the case of the small factor paradigm, we can consider these small population dynamics such as the Allee effect and the stochastic deaths.

Now, when we talk about any population, a population is composed of individuals of the same species that are living in the same area and can potentially interbreed amongst each other. So, basically, we are talking about the small cohesive group of individuals.

Now, if you consider any population, there are two factors that are occurring at all times. Now, these factors are the deterministic factors and they are the stochastic factors. Now, deterministic factors act at large population sizes and stochastic factors are more important when the population sizes are smaller.

What are these factors? The deterministic factors are the factors that act at large population sizes. So, these include things like birth rate, death rate, population structure and so on. So, basically if you have a population, a large size population and the birth rate has gone down or say the death rate has gone up.

Now, why could such a thing happen? Probably, there is some pathogen that is affecting the the breeding females because of which a spontaneous abortion occurs. So, that would reduce the

birth rate in this population or probably, there is an infection that is killing off the individuals because of which the death rate has increased.

Now, these sorts of factors, the changes in birth rate and the changes in death rate, are important even when your population is large in size and so, these are deterministic factors. So, things like birth rate, death rate, population structure; suppose, your population is now composed of individuals that are very old.

It is just a matter of time that the population will collapse because these very old individuals will not be able to breed. So, at all points of time, you need to have a population structure that comprises certain young individuals, a number of mature individuals and some old individuals.

And the population structure should also be such that you have roughly equal numbers of males and females. Now, if you do not have a suitable population structure, then even if you have a small a large size population, it is possible that the population might be pushed towards smallness and so, this is a deterministic factor.

On the other hand, the stochastic factors which are more important when the population sizes are small comprise things like demographic stochasticity. Now, demography's demographic stochasticity includes occurrence of probabilistic events such as reproduction, litter size, sex determination, and death.

What do we mean by demographic stochasticity? Suppose, you have a large population; suppose, you have 1000 individuals and, in this population, you have 500 new young ones that have been born in this particular year.

Generally, the sex ratio is close to 1 is to 1. So, out of these 500 500 young ones, you have 250 males and 250 females. Now, what happens if by chance it happens that more males are born?

In place of having 250 males, suppose you have 300 males and you only have 200 females, will that make a very big difference to this population? Probably not. What about if you had say 400 males and 100 females?

Well, it might have a certain influence; but again, this is just a chance factor. It is possible that in the next letter, you will have more females. So, it does not matter much when we consider a large population.

But now consider a small population. So, you have a small population that is composed of only 3 individuals and these and you have 1 breeding pair and these 3 individuals which have given rise to a litter and it so turns out that the litter comprises say 2 males.

In the parent generation, you had 2 males and 1 female and in the next generation, you again came up with 2 males. Now, this is a random phenomenon. It can occur in any population. But in the case of larger size populations, some deviation would have been quite acceptable.

But in this small population, it so happens that the females have gone down in numbers so fast that now you do not have sufficient females for this population to continue. So, demographic stochasticity plays a very important role in the case of small populations and so, this is a stochastic fact.

Another stochastic factor is environmental variation and fluctuations. Now, the environment and the weather of any place is variable and it might so happen that in a particular year, it turns out to be a droughts like situation. Now, in a drought like situation, if you have a large population, a

number of individuals would die off.
Probably you started with say 1000 individuals and out of those 1000 individuals, 500 individuals perished in the drought. So, this could happen. But the 500 individuals that remain will be quite sufficient to take this population back to its original state.
Probably in the next year, when it rains better, then the population will be able to jump back to its original state. But now, consider a very small size population, suppose you only started with a population that comprised say 5 individuals. Now, in these 5 individuals. suppose 3 or 4 individuals perished in the drought.
The 1 or 2 that remain might not be sufficient to take this population back to the normal state, which is why the environmental variation and fluctuations are also stochastic factors that are very important when the population sizes are smaller. Then, we have catastrophic factors such as forest fires and diseases.
These are also much more important when we talk about smaller populations because we are talking about the perishing of a large number of individuals from the smaller populations. So, this would push these small populations to such small states that probably the population will not be able to come back to its original state.
Other stochastic factors include genetic processes such as loss of heterogeneity and inbreeding depression. Now, what we mean here is that in the case of a small population, it is possible that all the individuals that are there in the population are related to each other and in that case, when a breeding happens between these individuals.
It is possible that you have breeding between brothers and sisters or you have breeding between parents and children. When that happens, the recessive alleles that are there in the individuals, they get a chance to express themselves and in such scenarios, we will find a number of recessive disorders that come up into these populations.
You will start seeing diseases, which are recessive diseases, which would not have expressed themselves had this population size being larger and had these breeding's occurred between individuals that were not related to each other.
But now because the population size is small, there is a much greater chance that inbreeding depression occurs and that would be a genetic process that is leading to extinction because of the stochasticity.
Or we have things like deterministic processes such as density dependent mortality on exceeding the carrying capacity of the habitat. Now these processes, what we are talking about here is the density dependent mortality.
Now, in a number of indi in a number of species it has been observed that as the population density increases, the rate of mortality increases. Because you have a large number of individuals that are there in a very small area and there are very continuous contacts between individuals.
There is much greater aggression, much greater competition and diseases can also spread in a much quicker manner. Now, if we talk about a small population which comprises a small area.
Then, even though your population size is small, the population density is very large. Because of which, we will start seeing density dependent mortality. And this is again a stochastic factor that becomes much more important when the population sizes are smaller.

When the population sizes are larger, then the density dependent mortality is a mechanism by which the population size is getting controlled. So, when the population increases very much, then a number of individuals die off and the population comes back to the level of carrying capacity of the habitat.

That is ok when the population sizes are large. But when the population sizes are small, then it becomes a very important factor that can push the population towards extremes. Then, we also have the factor of migration among the populations.

Now, we have seen in an earlier lecture what migration is. So, migration is the movement of individuals from one place to another. Typically, it is a seasonal movement and typically, it occurs along fixed groups.

Now, if it so happens that in a population you have say 4 individuals and out of these 4 individuals, there is 1 female and this female migrates out. So, the 3 males that remain in this area will not find a partner to breed and in that case, this small population will turn towards extinction.

It is a very similar manner, if you have 3 females and 1 male and the male goes off. So, such factors become very important, when the population sizes are small. If the population sizes were large, say in a group of 1000 individuals, say 10 or 20 or 100 individuals move out during a migration period, it's fine. It does not make much of a difference.

But in the case of smaller populations, if it so happens that members of a particular sex move out, then it is possible that the remaining members may not find partners and the population will be pushed towards extinction.

Now, the factors that drive a species towards extinction can very easily be remembered using this acronym HIPPO. Now, the first H refers to habitat loss. The habitat is getting lost and if a particular species does not have suitable habitat.

It will not have a place to live and this factor will lead or push the species towards extinction. I refers to invasive species; so, invasive species if they come to the habitat of your species of interest and they can lead to the degradation or loss of the habitat.

Next is pollution; so, pollution reduces the quality of the habitat because of which it is unable to support a large number of individuals. The next P is human overpopulation. Now, these days' humans are the most important factor when we consider the extinction of species.

More the number of humans in an area, more is the impact of these humans. Because more number of humans, more amount of affluence it would mean that more amount of pollutants are being released into the environment, more and more amount of resources are being taken from the environment.

In a number of cases, we have seen that in a forest if there is a small pond and this pond would have met the requirements of the wild animals. Now, if a village comes up in the vicinity, then these humans start competing with these wild animals for water and in most of the cases, the wild animals will be out-competed by the humans and slowly, their population sizes will go down.

The next O is over harvesting; over harvesting is harvesting beyond the capacity of a system. So, in a number of cases, we have seen that in a forest if you have a species that is commercially important, say you have a shrub or a herb that has medicinal properties.

If humans were to extract this herb or shrub in a sustainable manner, what they would have done is that they would take out some individuals and let others remain so that the next generation comes up.

But then in the case of over harvesting, what happens is there would be a few greedy people, who would get inside, remove all the individuals of this herb or shrub species and then, not a single individual is left in that area and the population declines or collapses.

The factors that drive a species towards extinction are these five factors; the loss of habitat, invasive species that have come into the habitat, pollution, human over-population and over-harvesting. Now, the impact of humans on different species is different. So, the sensitivity of a species to human impacts is dependent upon a number of factors such as the adaptability and resilience of the species.

There are certain species that produce a large number of offspring. So, even if humans are taking out individuals from this species, the individuals that remain, they breed so profusely that it hardly matters. Good examples are things like mosquitoes or things like rats and mice.

Now, humans have been trying to exterminate mosquitoes for quite a long period of time. But what happens is that every female mosquito lays hundreds of eggs. And so, even if a few individuals survive, they are sufficient to bring the mosquito population back to its original state.

This is an example of a resilient species. On the other hand, there are certain species such as elephants. Now, elephants have a very long gestation period. Elephants do not produce a large number of offspring; typically, in a birth you will only have a single calf that is produced and they also have a very long period of sexual maturity.

Now if humans remove a few elephants from the population, the population will not be able to come back. So, the impact of humans on a species would depend on how resilient the species is. Rats and mosquitoes that are very resilient; earlier the species like elephants that are not resilient. Adaptability and resilience of the species has a very important bearing on the impact of humans on that species. Next, we have human attention. So, there are certain charismatic species such as tigers which are more sensitive. Because humans have a high demand for their skin, for their bones and their other body parts.

If humans pay a lot of attention, if humans find that a certain species is beautiful or charismatic or it is majestic, then that species will have a much greater impact of human beings.

So, there is a much greater danger, if the species is beautiful like peacocks, if it is majestic like tigers and humans are giving attention to that species. So, that is a big problem. Next, we have ecological overlap between humans and the species. The greater the overlap, the greater the impact.

Now, a good example is those species that live in the plain areas. Now and especially, the grasslands. Now, humans have converted a large number of grasslands into agricultural fields.

Those species that lived in those grasslands were much more affected than those species that lived in, say the deserts, because there is a very less ecological overlap between the activities of humans in the desert and the activities of those wild animals in the desert.

Because humans typically avoid going to the desert. That is not a very good place for humans; whereas, in the case of grasslands humans find so many uses because it is a flat land, it has soil

and the land is also rich in nutrients.
It is very easy to convert these grasslands into agricultural crops. So, the impact of humans because of this ecological overlap on the species that live in the grasslands will be very high.
Next, we have the home range requirements of the species. The species that have larger home ranges are more sensitive to human impacts right. To take an example, let us consider elephants. Now elephants require hundreds of square kilometers of area for a small population.
If humans say dissect this area into two small parcels; parcel a will not be able to hold an elephant population and parcel b will also not be able to hold the elephant population. And the elephant population will slowly get wiped off; whereas, if you had a species that requires a very small area.
Again, to take an example let us consider rats. Now, rats require a few square meters of area or say a few hundreds of square meters of area. Now, even in these two patches, this patch can support a rat population, this patch can support a rat population.
So, the rat population will be able to thrive; but the elephant population will go into a decline because elephants have the larger home range requirements, they cannot live in smaller areas. But then is this threat real or is this threat imaginary and what is the rate at which we are losing out this species?
We can make an estimate by using the principles of biogeography and especially, the Island biogeography model. Now, the island biogeography model says that the species richness is dependent on the area.
If you consider an island and if you have a small sized island, it will have a smaller number of species; if you have a larger sized island, it will probably support a larger number of species. Now, the richness of the species in this island will be dependent on the area of the island.
But it is not directly proportional, it is proportional to some power of the area and we call that as z. So, we can write it as S is equal to C into A to the power of z; where, C and z are constants.
Now, it has been found that z varies between 0.15 and 0.35. Now, taking a middle value 0.3 for an area A 1, you will have S 1 is equal to C into A 1 to the power of z which is 0.3, which is telling us that the species richness in this area of size A 1 is this much.
Now, even if the area decreases by as much as 90 percent. So, you only have one-tenth of the area left. Let us say that 90 percent of this island has been cleared off by human beings and only 10 percent of the area remains.
Now, how many individuals or how many species will be able to survive on this island with 90 percent of the area gone? So, if we write A 2 as 0.1 into A 1, we will have the species richness now is C into A 2 which is 0.1 into A 1 to the power of 0.3.
Which means that if we take a ratio, we will find that S 2 by S 1 is approximately 50 percent which is telling us that even when the area has been reduced by 90 percent, the species richness has only become half, which means that out of the complete area of the island, you have removed 10 percent only 10 percent remains.
But even in this 10 percent, 50 percent of the species that were earlier there in the island, they will find a representation; only some species that have larger home range requirements would be extinct. But now, this is just an example. If we consider what is the amount at which or what is

the rate at which the areas are actually going down.

Let us consider the tropical forest. Now, tropical forests are actually decreasing at the rate of 1.8 percent per annum. So, the rate is very small. We are not putting the area down by 90 percent, we are only reducing it by 1.8 percent every year and let us consider the lowest value of z which is 0.15.

Now, if you put both of these values into the equation, you will find that there is an annual loss of 0.27 percent. Now, an annual loss of 0.27 percent would look like a very small figure. But then the estimated number of species in the tropical forest is as high as 10 million.

So, we are having an annual loss of 0.27 percent of 10 million which is 27,000 species in a year. So, taking a very conservative estimate of the lowest value of z, we are finding that we are losing as many as 27,000 species from the tropical forest every year and this is only talking about the tropical forest.

Because the impact of human beings is there on all different kinds of habitats. We are also seeing loss of habitats, when we talk about temperate forest, when we talk about subarctic forest, when we talk about grasslands, when we talk about the wetlands, when we talk about lake strain areas,. When we talk about even the oceans because the oceans are also being dumped with so much of chemicals and waste materials, then they are also degrading in their habitat quality. So, just from the tropical forest, we are getting a figure of 27,000 species every year.

Just consider how many species we are losing when we consider all the habitats together and this figure is every year. So, we are losing 27000 species every year and the sad part here is that we will not even know what species we are losing because we have not yet documented all the species that are found in the tropical forest.

We do not know how many species of frogs are there, we do not know how many species of snakes are there, we do not know how many species of lizards are there, we do not know how many species of plants are there and this estimate is telling us that even before documentation they are losing out a number of these species.

So, the threat to these individuals is actually very large and the susceptibility of species to extinction varies. As we saw that when we are reducing the area of an island by 90 percent, 50 percent of the species remain.

What are the 50 percent that get exterminated in priority and what are those 50 percent that remain in that area? So, some species have a much greater chance of extinction, primarily because they are rare. Rarity is a function of the ecology and the and the evolutionary characteristics of the species.

And the rarer a species is, it means that you already have a very small population. Probably, it is localized in a very small area and this rarity would mean that the small population paradigm would act very fast and those small habitats, where these organisms are found, if those habitats are lost, we will lose out these species.

Now, why are certain species rare? There are three reasons. One, there is a habitat selection and evolutionary characteristics because of which a species is restricted to an uncommon habitat. Example is species that are found in desert springs. Now, in the deserts, we already have a very small number of springs.

So, a species that is localized to a spring that is found in the desert will automatically be a very rare species or species with limited geographical range such as those species that are found in a single lake. Now, it is possible that the individuals that or the species that are found in that lake, are unable to move to some other lake.

Because maybe these species cannot fly. So, they have no means of moving to another lake or those species that have low population densities, especially species such as elephants. Because larger animals require more space.

And so, because the individuals are large in size, they require large areas and a mechanism to deal with it is that these species have low population densities. Now, because this species has a low population density, it is a rare species.

Now, the impacts on the habitat or the push factors on the habitat can be accentuated by these four processes. We have the processes of habitat degradation, habitat fragmentation, habitat displacement and habitat loss.

And all four of these are different, but they have a very similar impact in reducing the habitat that is available for the species. So, let us look at these one by one. Habitat degradation is the process by which the habitat quality for a given species is diminished.

So, in the case of degradation, the habitat quality goes down. Now, what do we mean by habitat quality? Suppose, consider a lake and earlier this lake was able to support say 1000 individuals. Now, in this lake, we are dumping municipal waste and because of which the habitat quality has gone down. Now, in place of supporting 1000 individuals, it can only support 800 individuals.

Now, when such a thing happens, we will say that the habitat has become degraded; the quality has gone down, because of which this habitat is unable to support the large number of individuals and the large number of species that it was able to support beforehand.

So, it is the process by which habitat quality for a given species gets diminished. Some causal agents for habitat degradation include things like contamination; air pollution, water pollution, eutrophication, pesticides and accumulative toxins can all degrade the habitat.

Now, eutrophication is the phenomenon in which fertilizers are able to reach into water bodies. Primarily, because these days we are using a large amount of fertilizers in our agricultural fields and when it rains, these fertilizers also get washed down together with the rain and they reach into the water bodies.

Now, what happens when you artificially increase the amount of nutrients that are made available in the water bodies? So, earlier, consider there was a lake and this lake was a very good ecosystem. It was supporting a large number of fishes. Now, fertilizers have entered into this lake together with the rain water; now what happens?

These fertilizers will result in a very profuse and a very rapid growth of plants in this lake and these plants will in turn strangle the fishes and when these plants die off, then when their bodies get get decomposed, then that would also result in lowering of the oxygen levels that are there in the water.

At the same time, when these plants are growing, then they are also taking up space in that water and so, the amount of space that is available to the fishes also goes down. All these processes eutrophication; eu is good, trophication is the presence of nutrients.

In the process of eutrophication, you are putting a good amount of nutrients into the system which is having a negative impact on the habitat quality. Pesticides and accumulative toxins ah; so, pesticides can also reach into the water bodies together with the rain water and these pesticides can get accumulated in the bodies.

Now, this is an example of a Eutrophied state of a water body. So, this is the Potomac river and here, we can see that there is such profuse algal growth because the amount of nutrients in this water body has gone up.

Now, when we say bioaccumulation, what it means is that suppose we had sprayed an insecticide into the agricultural fields and together with the wind, it has also reached into other areas. It has reached into grasslands; it has reached into the forest areas.

Now, what happens? These grasses now also have a certain amount of pesticide. The insects that live on these grasses or that feed on these grasses will also eat up pesticides when they are eating of the grasses and these pesticides will in turn get accumulated or stored in the bodies of these insects, primarily in the fat tissues.

A number of pesticides are very easily stored in the fat tissues and in the bodies of these organisms, they will get accumulated and this is known as bioaccumulation. Now, what happens? The level of pesticides that was there in these grasses was very low; but now because these insects have fat bodies in their bodies, so now, the pesticide is getting accumulated in the bodies.

Now, when the next organism like frog, when it eats these insects, what happens is that the fat that was there in the bodies of these insects is now entering into the body of this frog. Now, one frog will be eating a large number of insects and all of these pesticides that were there in the bodies of so many insects, a large proportion of it will get stored in the body of the frog.

The concentration of pesticides in the grass was very less. It was higher in the case of the insects because one single insect was feeding on a large number of grasses; it is even more in the case of frogs because one frog is eating up so many insects. Then, a snake eats a large number of frogs.

And so, the pesticides from the bodies of a large number of frogs will get accumulated in the body of the snake and as we move up the food chain, we will find that the concentration of pesticides goes up and up and this is known as biomagnification. So, there is a bioaccumulation in the bodies and this accumulation goes on increasing as we move up the food chain and this is known as magnification.

A good example is the concentration of DDD in a Lake ecosystem. When it was measured, it was found that water had 0.01 parts per million of DDD. The Planktons, which are small plants, had 5 ppm.

So, there is a large increase around 500 times in the concentration of DDD that was present in water to what was present in the planktons. Then, the fishes that eat these planktons had a concentration of 40 to 300 ppm and the fish-eating birds had a concentration of 1600 to 2500 ppm.

Now, this is a very high concentration and it would have a very drastic impact on these birds and it was also found that a number of these birds, their population was declining very fast because of the presence of these pesticides, they were not able to lay eggs with strong shells.

This is an impact that occurs as we move up the food chain, the concentration of the pesticides increases and it may increase to such an extent that it starts showing up a negative influence.

Other causal agents of habitat degradation are trash. So, trash includes things like ghost nets.
Now, a ghost net is a net that was earlier used for fishing; but then probably because of a storm, it just drifted out into the sea or probably it had completed its utility and so, it was dumped into the sea and you have a number of animals that get trapped in these nets.
These ghost nets keep on reducing animal numbers by trapping these animals and killing these animals or we have things like entanglement. So, here you have a seal and this seal is surrounded by this piece of plastic and this plastic is cutting into its body.
Another example is this Tahr. So, we have Mukurthi National Park, where we have Nilgiri Tahrs and if you go to this area, you will also find certain trash that is there alongside the roads. So, this is having an impact of habitat degradation for the Nilgiri Tahr. We also find that plastics have entered into the areas often of a number of other wild animals such as Hyenas.
Other factors of habitat degradation include things like soil erosion. Now, when soil erosion occurs the top layers of the soil get washed away or they get blown away and when that happens the amount of soil that remains in the habitat goes down. When that happens, a number of plants may not be able to thrive in that area. So, this is also an example of habitat degradation. Another is fire regimes.
If you have a forest and there is a fire. Now because of this fire, a large number of plants can die off, a large number of animals will die off, the amount of nutrients that are available in this ecosystem will go down. So, this is another example of habitat degradation.
Another causal factor is over-exploitation of water which makes water less available for the species and deforestation. Now, we have seen this example before. If there is deforestation, then that is also degrading the habitat. And we are seeing deforestation on a large scale. So, this is an area in Balaghat, district of Madhya Pradesh in 2006.
And this is the same area in 2018 and here, we are seeing deforestation for mining operations. This is a region in Umaria district and I would like you to concentrate on this area. So, here we have a road and I I would like you to concentrate on this area.
This is how it looks in 2018. So, all of these forests are now gone and this is deforestation to expand agriculture. Here, we have a region in Bhopal district in 2003. And here is the same region in 2018 to make this dam.
So, deforestation is occurring in a big way. Another causal agent of habitat degradation is desertification, which is conversion of good areas into deserts. Primarily by overgrazing and through cultural practices.
This is an image from Gujarat and when all these goats eat up this vegetation, then this area will slowly and steadily be converted into a desert. Other causal agents include draining, dredging and damming operations; in water bodies, over-exploitation of biota in which case humans go into the forest areas and extract these biotic resources out of these areas and introduction of exotic species.
When habitat degradation occurs to such a large extent that the habitat quality goes down to an extreme, then we call it a habitat loss. Habitat loss occurs when the quality of the habitat is so low that the habitat is no longer usable by a given species. So, this is the extreme form of habitat degradation.

Then, we also have habitat fragmentation. Fragmentation occurs when a natural habitat landscape is broken up into small parcels of natural ecosystems, isolated from one another in a matrix of lands dominated by human activities. It involves both loss and isolation of ecosystems.

What we are saying here is that in place of a continuous large sized area, we are dividing the area into very small parcels or pockets of land, pockets of habitat and this is known as habitat fragmentation. So, a large sized habitat is fragmented into smaller parcels.

Now, habitat fragmentation is important because larger fragments typically support more species because larger fragments have more diverse environments, more habitats, they are more likely to have both common species and uncommon species.

And also, because these smaller fragments have smaller populations, the chances of them getting extinct are greater. Because if you have smaller populations, then the small population dynamics also start acting on those small populations. So, it is always beneficial that we should have habitats as big contiguous areas and not as small parcels.

Now, how does habitat fragmentation occur? The causal agents include things like roads, railways, dams and other structures and structures such as these linear infrastructures of roads and railways, they not only cause mortality, they act as a physical barrier because of which the animals are not able to cross them, they act as psychological values.

If you consider a road in which there is heavy traffic, the animal, if it wants to cross to the other part of the habitat, will not be able to do that. Because of the fear of getting hit by one of these vehicles. So, either this animal gets hit or in certain cases it is so afraid that it does not cross this area because it acts as a psychological barrier.

Then, these structures such as roads and railways also increase the access to human influence and they increase access to invasive species and exotic species. Other causal agents for habitat fragmentation include diversion of land for agriculture. So, here we are seeing linear infrastructure in the form of pipelines.

If you have such pipelines, animals find it very difficult to cross from this area to this area. If you have a dam an animal will not be able to cross just like this. It will have to either cross a very long stretch or it will just not cross this area. So, dams cause habitat fragmentation.

Now, the process of habitat fragmentation and loss occurs in a series of steps. So, we will understand these steps through these illustrations. Let us consider that this is an original forest and you have a line number of trees here.

Now, the first step that occurs is Dissection. In dissection one or more linear infrastructures, primarily roads are set up and these roads dissect this complete forest into two or more smaller parcels. Now, once this dissection has occurred, it is now easier for humans to come to these areas and so, we will start seeing small settlements.

Now, in these small settlements, people will start farming these areas or raising some certain livestock and to make space for farming and for livestock, they will clear up certain portions of the forest and this is the stage known as Perforation. So, now, they are perforating into the forest. So, this is how it will look like. These are livestock in the forest near the Mudumalai Tiger Reserve.

Now, after perforation, once you have certain human beings that are living there in the settle-

ments, these settlements slowly grow and why do they grow? Because they are right next to the door and any produce that these farmers or these early settlers produce in the form of milk or say agricultural produce, it finds a ready market because people who are going through these roads will buy their stuff.

Slowly and steadily, the number of livestock will increase, the area under cultivation will increase, more and more buildings will come up and in this process, it is now converting this whole forest into smaller parcels. So, this is one parcel; this is one parcel; this is one parcel and this is one parcel. So, we now have four small parcels. So, this is habitat fragmentation that is happening.

This is an example of habitat fragmentation. So, these early settlers have now converted all of these areas into their agricultural or plantation areas and so, the animals that were there in these forests are now unable to cross these areas and so, this has become a small fragment.

After fragmentation, we will have the process of Attrition. Now, in the process of attrition, these settlements grow to such a large extent that these pockets have now become very small areas and during this process of attrition.

We will also start seeing electricity coming into this area or small industries coming into this area or certain facilities such as schools and hospitals that are being built up. Because now, these settlements are so large that the government is bound to provide them with certain facilities.

And so, with this process of attrition, we have very small parcels that are left. This is an example. So, this was a beautiful hill that was covered with forest, but now through the process of attrition, we only have this small patch of forest that is left in this area.

Now, we can see an example through the deforestation of the Amazon rainforest. So, these are satellite images from 1975 and I would like you to pay attention to this road. So, this is how the dissection occurred in this area. So, this road was constructed in this pristine forest.

Now, this is 1975; this is 1984. So, by 1984, people have started to enter these areas and they have constructed a new road. So, we did not have a road here, but now you see very clearly that this stream has also been converted into a passageway and now, deforestation is occurring in the form of this fish bone pattern.

So, this is 1984, 1985, 1986, 1987 and we see that slowly and steadily the forests are being converted. And the wood is being extracted out. 1996-98, 2002, 2007, 13, 15, 16 and so, what was there in the form of a pristine forest is now completely deforested.

What started with a small amount of habitat degradation and habitat fragmentation, ultimately resulted in the loss of the forest. So, before we have a situation like this a pristine forest. Afterwards, we hardly have any forests that are left in this area.

And this is an example of an extremely fragmented habitat from Mudumalai. So, this area is a part of the elephant corridor. So, elephants traditionally use this area to move from one place to another place. But now, with the settlements, we can see that these hills still have some forest left.

But the rest of the place is now completely converted into a human dominated landscape and in such landscapes, people set up fencing and because of that animals are unable to cross into these landscapes and the hills that are left are so high that the elephant will not be able to cross through

this landscape by going through the hills.
Because it is a very massive animal, it has a weight of like 4000 or 5000 kgs and it takes a tremendous amount of energy to lift that huge weight through gravity on top of these hills.
So, animals do not prefer going like that and so, this has resulted in a fragmentation in this area.
Now, apart from habitat fragmentation, we also find another phenomenon which is known as habitat displacement. Now, habitat displacement is the shifting of wildlife to non-prime or sub-prime habitats such as hills or rocky patches.
Now, what is habitat displacement? Now, typically if you go to any grassland area that is near a forested area and if you find that people are taking their cattle into these grasslands and if you ask these people that- 'oh, your cattle are out competing the wildlife', they would normally say- 'oh, no, this is not the case because our cattle graze in these grasslands; whereas, the wild animals live on top of the hills.
Now, if you think about it logically, the wild animals do not live on top of the hills because the wild animals also require the same resources, they also require access to the same grasses, the same fodder, the same water that is being used by the cattle. But then, because of a tremendous competition with the cattle.
Because together with the cattle, there will be humans who will be going into these areas with their and probably, they will also be taking a few dogs and so, the animals have been displaced out of these grasslands.
These animals do not have any other place to live than the top of the hills. So, the animals have been shifted from their prime habitats to a non-prime or subprime habitat. Now, why are these hill areas non-prime or subprime habitats?
Because they do not have a sufficient amount of fodder, they do not have a sufficient amount of water and so, they are subprime habitats and in this process of habitat displacement.
The the wildlife has been shifted from a prime habitat to a sub-prime habitat such as hilly or rocky patches and because these sub-prime habitats do not have sufficient amount of food and water and other resources for the animals, so slowly and steadily there the the population of the wildlife will go on decreasing because the habitat does not have sufficient canal capacity.
These are all different threats to the species. So, we looked at the large population dynamics, we looked at the small population dynamics and we looked at processes of habitat degradation, habitat loss, habitat fragmentation, habitat displacement and so on. These are all the threats that our wildlife are facing these days.
That is all for today. Thank you for your attention. Jai Hind!

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Module 4
Threats to wildlife
Lecture 3
Ecotoxicology and Developmental Hazards

Namaste!
We carry forward our discussion on the Threats to WildLife and in this lecture we will have a look at Developmental Hazards and Ecotoxicology. Now you must have heard in a number of circumstances that we are aiming for economic growth and are aiming for economic development. The question is are both of these the same or is there a difference between economic growth and economic development.
Let us look at what growth and development mean, growth is an increase in size of something or increase in the level of output of something. For instance if you see that there is a child and the child over the years is increasing in height it is increasing in its weight, then we would say that the child is growing because there is an increase in size of something.
Similarly when the economy grows it means that the economy is increasing in size, the total amount of income that we are having or the total resources that we are having are increasing with time. When that happens we will say that an economic growth is occurring or an increase in the level of output of something. So, for instance there is an industry that is producing say 100 cars in a day and because of some technological changes or because of certain managerial decisions this output increases to 250 cars a day.
In this case the level of output of the industry has increased and so we will say that the industry is showing a growth and if a number of such industries show a growth we will say that the automobile sector is showing a growth. So, growth is an increase in the size of something or increasing the level of output of something.
This is different from development. Development is the process by which the economic wellbeing and quality of life of a nation, region or local community are improved according to targeted goals and objectives. Now when we are talking about development we are not talking about an increase in size of something, we are talking about things which are wellbeing, we are talking about things which are quality of life.
Similar to our child example when the child is increasing in size or increasing in height we see that the child is growing. But, then when the child learns something new when the child has started to learn the alphabets. When the child has started to walk or has started to talk then we say that the child is developing. So, there is a difference between growth and development.

Growth is an increase in size, whereas development is an increase in wellbeing or an increase in the capabilities.

In the case of economic development we are talking about the economic wellbeing of a nation, region or local community. We can look at development at different scales. We look at development at the scale of a nation or region or a local community. But when the economic well being increases and also the quality of life increases, then we say that there is an economic development.

We generally consider 3 dimensions of economic development or human development, these are the life expectancy index which is how many years can a person or a child that has just been born can expect to learn. So, if for instance there is a society in which sanitation is good everybody gets adequate nutrition and health care is good, then we will see that the life expectancy increases.

And when life expectancy increases we will say that the development has occurred, because there is an increase in the quality of something. Similarly, education index: how much a person can expect to receive in terms of education. If people are literate then they are said to be more developed, if people go to colleges, if they go for a post graduation course we will say that they are more developed than say a person who is illiterate.

Because, education gives you the capability of doing something, so it increases the wellbeing and it increases the quality of life. So, the Education index is also another component of development. Income index: how much income do people receive and what is the level of equality or inequality in the society, when we talk about income index we look at how much can a person expect to earn.

And also what is the level of income inequality in the society, because for instance there is one person who is earning a lot and a majority of people are not earning anything. So, in that case the average income will be high, but because of income inequality we will say that this society is less developed, than perhaps another society where everybody has a similar level of income on an average.

These are the 3 dimensions of the human development index. Essentially what we are saying is that when we talk about economic growth we are talking about an increased output and an increased concentration of resources. But when we are talking about economic development then we are talking about how much is the wellbeing of people, how much is the capability of people to have a control over their lives, so that is economic development.

Now both of these are related, but there is also a trade off. For instance if you want to empower people, this empowerment can be taken as an indicator of development because, when people are healthy, when people are educated and when people are financially capable of doing things, then they are more empowered than when people are unhealthy or they are illiterate.

So, empowerment is a proxy that we are using here for economic development. Production is another proxy that we are using for economic growth, what is the amount of production that an economy is doing? Now this curve is telling us about a trade off between production and empowerment. Suppose society decides that we are going to invest our resources into producing more and more stocks.

In that case the empowerment might take a hit, because the people who were necessary for doing empowerment such as doctors or nurses or teachers that would have helped people to have a much better control over their lives are now being diverted into say production.
In that case we will or this society will have a much greater production, but at the cost of empowerment. The society might even take another decision that empowerment is more important for us and so we are going to divert certain resources from the production sector and we are going to put them into the empowering sector. So, for instance we will take out the best managers that are there in the industries and we are going to put them into academics.
When such a thing happens then we will say that the society is focusing on empowerment. Now a curve such as this represents the production possibility frontier. Now it shows us that there is a trade off that needs to be made between production and empowerment and different societies face choosing different things and in a number of cases it might be difficult to have in excess of both of these at the same time. It is possible it is what we are aiming at, but at times there has to be a choice that needs to be made.
When we talk about economic growth we say that the production is increasing. So, this is how the production possibility frontier will look like when the production increases. Now when the society shifts from the black curve to the red curve then the the amount of production in the economy has gone up, but the level of empowerment has not changed.
Probably people are still illiterate, people are still unhealthy, but there are some people in this society that have become richer. So, this is an example of economic growth without any amount of empowerment to the society. Another example is this one where the amount of production remains the same, but the society is only focusing on empowerment. So, in this case everybody has become more capable of having control over their lives, the empowerment has increased without the economic growth.
But in a number of cases what we are aiming at is an increase in production as well as an increase in empowerment. So, there is economic growth, but there is also economic development. Now, why do we require both of these together because we are as a society we are aiming at economic development which is increasing the wellbeing of people.
Now the well-being of people will not increase if they do not have access to stuff. So, to increase their well-being you have to provide them with more resources. So, if there is a society where everybody just has one board of transportation which is walking, then probably they are less empowered than say a society where everybody has a bicycle or say everybody has a car.
To empower people to move from one place to another in a faster manner we will have to provide them with bicycles or cars and this is only possible if there is a production of bicycles and cars. So, for development we want to increase production, but at the same time we also want to increase the level of empowerment that is there with everybody.
So, you need to devote resources to ensure that people are educated and people are healthy. For instance if this if our society just wanted to produce more and more cars and it led to such a huge amount of pollution that everybody in the society became ill. In that case we will say that there has been an economic growth, but at the cost of empowerment and so we will not say that the society has developed economically. So, there is no economic development even though there is

growth. So, this is a distinction that we need to keep in mind.
However in a number of cases what we have observed is that if there is an increase in production people say that the economy has developed. Whereas, in reality we are only having economic growth without having any development, now this distinction needs to be kept in mind before we move further.
What happens when we only focus on growth we do not focus on development or in other words what are the hazards of focusing just on an unsustainable growth. Now remember that when we talked about development we were talking about the wellbeing of people, now the wellbeing of people increases when they have access to nature. The wellbeing of people increases when they live in an area or in a society that has less levels of pollution.
The wellbeing of people increases when they have the joy of watching wild animals such as tigers. So, if we remove all these well beings, if we just provide economic growth and to provide the economic growth we put people into a condition where they have or where they are forced to live in very polluted areas where they are forced to live in a society, where the biodiversity is all gone where the children have never observed a butterfly or birds then probably there is something that is going wrong.
When we focus only on unsustainable economic growth there are a number of hazards that are proper. Now remember here that these are the hazards of going for an economic development which technically should be called only as an economic growth, because these are reducing the wellbeing of different people.
What are these hazards? These results include the loss of biodiversity. So, in this image what we are observing is that there is this net that was used for fishing and to increase the production of fishing we have increased the production of these nets or probably we have subsidized these nets. So, there is an excess of these nets.
Now, if there was not an excess of these nets if they were scarcer, then what people would have done is that if the nets went bad if there was say a cut in the net people would have tried to mend it. But if you can get these nets very cheaply because of the economic growth, what people do is that they do not or they are not incentivized to mend the net, but they go for a disposable culture.
In this case what people would do is that if there is even a small cut in the net they will throw this net off and buy a new one, because the economic growth has made it possible for them to get another net very quickly. So, what happens to the previous net? It will be thrown into the rubbish dump and suppose it goes to a landfill and because most of our landfills are already filled up.
It is washed away and when it gets washed away it reaches into a water body. Now the net was designed to capture animals and in this case even though there are a few cuts in this net this net is still capable of catching animals. So, this is an example of the hazard of having economic growth without development.
Because if there was development, if people were made more aware of what are the negative impacts of doing this fashion then probably they would have refrained from throwing this net out they would have disposed of it more properly. But if there is no development if there is a lack of awareness or education then this is what happens. So, one hazard is the loss of biodiversity.
We are observing all over the world that a number of animals are dying, they are getting entan-

gled in these pieces of plastic and they are dying off. And when there is a loss of biodiversity this also reduces the wellbeing of quite a number of people, because biodiversity has its own advantages.

Now, the people who live in the cities might be less aware of the advantages of biodiversity, but then if you talk to anybody who works in say an apple orchard he or she will tell you the importance of honeybees. If the honey bees are gone there is nothing that can pollinate the apple orchards and probably the production would go down. So, the loss of biodiversity is a hazard of unsustainable growth.

Another hazard is trashing the planet: you go to even a national park and you will find that there is trash all around. There is plastic that has released into a majority of areas our wildlife are now living with the trash and we are trashing everywhere we are trashing the water bodies, this trash is coming to the beaches we are even trashing the seafloor. So, trash or trashing of this planet is a hazard of a development or an economic growth that is unsustainable.

Another is Clearing a forest because for economic growth you require resources, resources such as land resources such as wood resources such as pores and minerals that are there in the land. Now to have access to all of these there has been a rampant cutting of trees and rampant deforestation which is another hazard of unsustainable economic growth.

This is an example of deforestation for mining. So, this is Balaghat in 2006 this is the same area in 2018 the forests are gone this is an example of going for an economic growth because of which people are diverting the forest into agriculture. So, this was Umaria in 2002 and if you concentrate on this area it is gone. All of these forests are now gone, so this is the Umaria in 2018.

This is a portion of the Brazilian rainforest in or the Amazon rainforest in Brazil Rondonia in 1975 and this is the same place in 2016 the forests are all but gone. Now, why are we seeing this rampant deforestation, this is because we are focusing only on economic growth and the cost of wellbeing of people.

If you talk to the local communities in Brazil a number of these communities are up against this rampant deforestation because it is encroaching upon their lands, it is encroaching upon their culture, it is encroaching upon their way of living. But for an unsustainable economic growth the governments are permitting these things to happen or they are unable to stop people from doing this.

This is another example of deforestation for mining. This is the Ok Tedi Mine and if you concentrate on this area or if you concentrate in the river where the dumps are, there is now a massive amount of deforestation. So, this river has become so toxic that the trees around it are dying off.

Another hazard of unsustainable economic growth is desertification and overgrazing. Now, in the case of economic growth we wanted to increase production. So, every farmer wants to have more and more milk. Now if the farmer wants to have more milk he or she will want to have more goats, but then this environment cannot sustain such a huge number of goats.

What do these goats do? They eat off all the grass they eat off a majority of the herbs and shrubs that are there in this area which leads to an expansion of the desserts. So, this is overgrazing, overgrazing why because the people are going for unsustainable economic growth.

We are also observing a large amount of fragmentation of the habitats. So, there is this road where you have forest on both sides, if the animals want to cross from here to there they are unable to do that because there is a road in between and if the animal tries to cross it may get hit.
And this extreme fragmentation of the habitats is also another hazard of unsustainable economic growth. Another hazard is what we are observing in terms of climate change. So, these are bleached corals because of climate change. So, all of these corals, these beautiful organisms, are now dead.
Because of unsustainable economic growth we are spewing out. So much greenhouse gases such as carbon dioxide that the earth's temperature is rising. It is impacting the coral reefs it is impacting the coral bears whose habitats are now going down. There are a number of instances in which the eye sheet has become so less, that now these polar bears do not have a place to rest.
Climate change is impacting the mangrove forest climate change is impacting the kelp forest in our oceans. We are seeing a large amount of habitat level destruction because of climate change and what is causing this climate change. Economic growth is unsustainable economic growth, so this is also another hazard that we are observing.
We are observing changes in the spatial distribution of organisms. The organisms that were living in colder areas now because of an increase in temperature are dying off, because they cannot tolerate that amount of heat or those areas that were. So far inaccessible by certain organisms they are now getting colonized. So, there is a change in the special distributions of different organisms. This is also because of global warming which is occurring because of an unsustainable economic growth.
Another hazard is wars. Why would 2 countries go for a war? Because each country wants to increase its resources for economic growth and because there is a limit to the amount of natural resources that are present within any country. There is a limit to the amount of land that each country has. They try to attack someone else to capture their land to capture their resources and that leads to war that leads to a heavy destruction of the environment. This is another hazard of unsustainable economic growth.
The trash that we are putting into the environment, even if it gets degraded it is still trash. So, we have smaller fragments of plastics that we are finding everywhere. And there are a number of organisms that mistake plastic for their food, these plastic bags look like jellyfishes.
So, an animal that eats jellyfishes might attack these plastics might try to eat these plastic, we have we have seen instances of birds where the parents bring in plastics to feed their chicks mistaking these plastics to be fish and because of that the full of the alimentary canal of this bird gets choked and this bird dies out of starvation. Loss of biodiversity in this way is also a hazard of unsustainable economic growth.
We are seeing it everywhere, even deep in our oceans. We are finding that the plastics have reached, there they are impacting all organisms whether big or small even in the case of microscopic organisms we are finding that their bodies are now filling up with plastics.
The behaviours of organisms are changing. So, this is another hazard of unsustainable economic growth. We have trashed the planet to such an extent that now the organisms are getting more and more accustomed to these plastics, they are now using these plastics and showing the behav-

iour that is not a natural behaviour. So, this loss of natural behaviour is also another hazard that we are observing

This image of a seahorse that is sticking to an ear bud or these animals, these hyenas that are living in trash or these rhinoceros that we are finding full of plastic. Now a Rhinoceros in a natural environment does not eat plastics, but we are changing the behaviours of animals by trashing our planet. So, this is another hazard of unsustainable economic growth.

Now, in the quest for having more growth in the quest of having more production we have produced such a huge quantity of plastics that now it has turned into a menace. Changing behaviours of different animals here we are observing that now everybody has access to roads everybody has uh is having big cars and this interaction with wild animals is changing their behaviours.

Now there is a greater interaction of people and animals we are finding that we have developed or we have constructed. So, many roads that now they are acting as big barriers to the movement of wildlife wild life is. Now finding it more and more difficult to cross the road. So, earlier this whole habitat was this, but now we have divided it into fragments.

If they try to cross they might get hit, they get killed or even otherwise there is a huge structure in their habitats. So, these are all different hazards of unsustainable economic growth pollution because of the heavy amount of vehicles that we are flying on the roads.

Now having more vehicles we will obviously say that yes that is economic growth, but is pollution leading to the welfare of people of course not. We cannot say that we are developing economically if these negative impacts are not checked. So, pollution is another hazard of unsustainable economic growth.

There is also a huge number of deaths of birds, because they are getting collided with a number of our infrastructures and the birds are dying. So, that is not leading to the welfare of people that is not development. So, we are just aiming at economic growth at the cost of welfare and that is a big hazard.

We are changing the distribution of species because of our trashing the planet, more and more invariant species are now able to reach more and more areas. And this is an issue not just for animals, but this is an issue for humans because ultimately the wellbeing of humans is getting impacted because of these conflicts because of the trashing of the planet.

What we can say is that if you go for an unsustainable economic growth there will be a huge number of hazards, hazards of pollution, hazards of fragmentation, hazards of loss of biodiversity, hazards of increasing conflicts with wild animals and that is not leading to a welfare for the society. That is not development, that is just economic growth at the cost of development. So, this distinction - this fine point needs to be kept in mind whenever we are doing any economic analysis.

Next we will have a look at Ecotoxicology which is the study of the effects of toxic chemicals on biological organisms especially at the population, community, ecosystem and biosphere levels. Now the point is why do we need to study Ecotoxicology. So, this is important because we are releasing a huge quantity of toxic substances into the environment and they are having an impact on different organisms at the individual level. Sometimes at the population level and sometimes at the even greater higher levels.

Now, the common toxic chemicals that are present in the environment include pesticides and their residues. These days, because of the need for more and more quantities of food grains we are using a heavy dose of pesticides. Now these pesticides kill the pests such as insects or rodents, but whenever these pesticides are used and they are toxic chemicals some portion of them is always leaked out into the environment and it remains in the environment.

Even though there might be certain processes, certain chemical reactions that will change these pesticides, some of the residues will remain in the environment and that will create a condition that will have an impact on certain organisms. So, Ecotoxicology studies the impacts of pesticides and their residues and we will have a look at what these impacts are in a short while. Heavy metals: heavy metals especially those that we are releasing because of our mining activities such as in the case of tailings dam.

This is an image from Balaghat. So, we have a mine there and this is a tailing dam. Now in the tailings dam the residues that are released from the mine are stored and we can observe that in this satellite image from 2006 we can observe so many trees that are there in between this fake tailing dam.

This is another image from 2018, so we can see that if you concentrate in this area we had trees here in 2006 and in 2018 these trees are gone. Now uh similarly if you consider this section, so we have trees till this line in 2006 and by 2018 that these trees are gone.

Now, nobody is going into a tailings dam to cut these trees, but what is happening is that because you have a heavy concentration of heavy metals. So, that is creating a toxic impact on these trees and these trees are dying off. So, heavy metals and their release and their impact is also something that we study in Ecotoxicology

Plasticizers, so whenever we talk about plastics plasticizers are the chemicals that are added to plastics to modulate their properties to make them more elastic or to make them a little transparent or to improve their properties these are the chemicals that are added to plastics. Now a number of these chemicals have toxic impacts such as this chemical bisphenol-A.

Bisphenol-A is a plasticizer that is added to plastics to make it more supple to make it more transparent, but it acts like hormones in the bodies of different organisms. It disrupts the functioning of the endocrine system in different organisms and Ecotoxicology will try to study what is the impact of this chemical on different organisms at different scales or volatile organic compounds such as formaldehyde.

The formaldehyde is released as part of a number of chemical reactions and it is a toxic chemical or mycotoxins. Now mycotoxins are toxins that are released by different fungi. Myco refers to a fungus and mycotoxin is a toxin that is being created by a fungus. But what is happening is that because we are changing the environment to such a large extent. So, we are increasing the amount of mycotoxins that are present in the environment.

What is the impact of these mycotoxins on different organisms is also something that Ecotoxicology will try to decipher. Or the impacts of things such as Brominated flame retardants. Now these Brominated flame retardants are added to a number of plastic products to reduce the probability that they will burn up in case a fire occurs.

Now, these Brominated flame retardants are bioaccumulative toxins they accumulate in the bod-

ies of different organisms and in this manner they are able to concentrate themselves and then have a larger impact on different organisms at different levels.

Now talking about toxicity, all of these chemicals will be having different levels of toxicity. Those chemicals that have an oral lethal dose which means what is the amount of any chemical that when given to an organism in the oral route - which is through food or water - will result in a lethality that will kill the organism.

This is the oral lethal dose it is generally expressed in terms of milligram per kg body weight of the organism. Now if there are chemicals which are lethal or which kill the organism at as low as 1 to 50 milligram per kg, then we say that these are the most poisonous chemicals and whenever they are being transported this is the symbol that is used.

If the oral lethal dose is between 51 and 500 milligrams per kg we still call it a poison but it gets a yellow layer. If the oral lethal dose is between 501 to 5000 milligrams per kg it gets a blue label and to be call it a dangerous chemical and in case the overall lethal dose is greater than 5000 milligrams per kg we put the label which is green in in color and we say that this is a chemical that we need to be cautious about. So, different chemicals have different levels of toxicity and of course those chemicals that have a higher toxicity will have a much greater impact which will be an acute impact.

Now, an acute impact means that the impact of this chemical on the organism or on its population or community will be quick. That is known as an acute toxicity, an acute impact or a quick impact. It generally occurs in a very short period of time because of a very sudden exposure.

In the case of those chemicals that have less amount of toxicity in a number of places they will observe a chronic toxicity, which means that if these chemicals are released into the environment they will slowly act and produce their side effects. So, it will act over say many months or many years and in that case we will say that it is a chronic toxicity which occurs over a large period of time.

Now, what are the impacts of these chemicals? In very high doses these chemicals will have lethal effects which means that they will kill certain individuals or a large number of individuals in any population or community. So, this is known as a lethal effect in certain cases we can have sub lethal effects in which case the organisms do not die, but they have a reduced amount of functioning.

That is a sub-lethal effect certain chemicals are mutagens which means that they produce mutations in the genetic code. So, we have chemicals that produce mutations, so they have a genetic effect on organisms. Certain others have Teratogenic and developmental effects, now teratose means a monster and genesis means production.

Teratogenic chemicals are those chemicals that are monster producing which means that if the organisms are exposed to these chemicals and especially those organisms that are pregnant. So, these chemicals will act on the fetus and will produce developmental abnormalities which means that you might observe that there is a frog which in place of having 4 limbs is having say 5 limbs or 6 limbs or there is a tortoise that is born without limbs.

Now, these kinds of organisms can be produced because of Teratogenic chemicals or developmental inhibitors. In certain other cases we observe a reduced fecundity which means that the or-

ganisms will be having less number of children or less number of offspring. So, this is a reduced fecundity that you observe in a case of a number of toxic chemicals and especially the chronic toxins.

They manifest their impact in terms of reduced fecundity. This is possible because in certain cases the offspring when they are there in the fetal state they will die off or there will be spontaneous abortions, because of these chemicals and so the fecundity will go down and in any case these toxic chemicals add to the existing stressors. Which means that if the organisms are weakened because of a disease or because of malnutrition and if they also are exposed to these toxic chemicals in the environment the impacts add up. So, they act to the existing stressors that are already there in the environment.

What is the impact of a chemical such as DDT, now DDT is a pesticide which was traditionally heavily used for agriculture and it was also used in the control of malaria. Now when DDT is used as a pesticide a portion of it remains in the environment. So, when DDT is used in an agricultural field to kill off insects that were destroying the crops with the next screens a portion of it may get washed off and beat into a water body. Now DDT may be acted upon by oxygenation or because of certain organisms and it gets converted into another residue which is known as DDT or DDE so dichlorodiphenyldichloroethane or ethylene.

Now, these chemicals are very persistent chemicals that remain in the environment for a very long period of time and they can show their impacts on different organisms. Another characteristic of these chemicals or these residues is that they accumulate in the bodies of different organisms and as we move up the food chain their concentration goes on increasing because of a process that is known as bio magnification.

If you look at the DDT or DDE concentration in the water it will be very less because it is only a small fraction of the residue that came to the water body and the concentration in plants or say the phytoplanktons again will be very less, but the zooplanktons they eat these phytoplanktons will have a greater concentration of these residues in their bodies.

The fishes that eat up these zooplanktons will have an even greater concentration of these chemicals in the in their bodies, because what is happening here is that all the the the zooplanktons that the fish was eating they were having certain concentration of these residues in their bodies and the residues from all of these zooplanktons will now get accumulated into the body of the fish. So, the concentration increases.

Those fishes that eat up these smaller fishes will have an even greater concentration, the birds that feed on these fishes will have an even greater concentration. Now what happens is that when the concentrations increase the impact of the chemicals or the toxicity of the chemicals also starts playing a role, because as we have seen there is a lethal dose for different and in between it will start doing certain sub lethal effects.

So, in that case the organisms will not die, but will show impact in terms of reduced fitness or reduced fecundity and this is what was observed in the case of Bald Eagles. Now, Bald eagle is the natural bird of the United States and it was found that when the researchers looked at the concentration of DDE in the egg shells.

This curve is showing the DDE concentration on the x axis and the average 5 year productivity

that is the number of eggs or the or the number of chicks that were that were that were born in every generation on the y axis. Now, this is the average of the curve, this is the regression curve, the sigmoidal regression curve and here we can observe that if the concentration of DDE is less than or equal to 2 microgram per gram then there is hardly any change in the average fiber productivity of these birds.

If the concentration of DDE is greater than 20 microgram per gram in the egg, then we observe that the average 5 year productivity is very less. It is close to 0.1 that is roughly one tenth of what we see in the national conditions. And in between we see that this curve slowly goes down which is telling us that as the concentration of these residues increases the average 5 year productivity or the fecundity of these birds decreases

Now, it was later found out that because of these residues the egg shells that are formed are very thin and they are so thin that when the bird sits on these eggs the eggs break, which reduces the productivity of these birds. So, this is the curve that is telling us that as the concentration of these residues increase they start showing a more drastic impact as was shown or was shown when the concentrations were lesser. And because these chemicals are very persistent chemicals and so these impacts can be shown for a very long period of time.

But then we still have hope because a number of these populations are also resilient. If you look at this curve on the x axis we have the years and DDT was banned in the year 1972 in the United States and when before this ban the this this line is showing us the DDE concentration in terms of ppm of dry weight and the average concentration was close to say around 100 ppm.

After the ban it took a few years but then the concentration came down to around 30 ppm. Now remember that here the concentration has not gone down to zero because it is a persistent chemical, but the concentration has come down. Now before the bank the mean number of young for breeding area was 1.3 and then because of the impact of DDT it was coming down. So, from a natural level of 1.3 it had come down to around 0.5.

But then when this ban was enclosed, so slowly and steadily the concentration of DDT went down and the residues such as DDE also went down and after a while we see that this curve is now increasing. So, the mean number of young per breeding area they are now increasing from 0.5 they have reached to around 1.1 they have not yet reached to 1.3 but they have reached to 1.1.

Now, this is showing us that even in the case of a number of these persistent chemicals, if we enforce a ban then there is still a possibility for a number of species to come back. Now this coming back is known as resilience and this curve is also telling us why it is important to study the impacts of these different chemicals, because only when we know their impacts will we be able to act upon them.

Now, such a recovery can also be aided through certain activities that are known as restoration and this comes under the domain of restoration ecology. So, restoration ecology is the scientific study supporting the practice of ecological restoration which is the practice of renewing and restoring degraded damage or or destroyed ecosystems and habitats in the environment by active human intervention and action.

It is telling us that even when we have damaged the ecosystems and habitats. So, they are now

degraded, damaged or destroyed. In the field of restoration ecology we try to put in active human intervention and action and we try to bring them back to their original state. We are aiding in the restoration of these damaged habitats. There is damage that has already been done, but through restoration ecology we are trying to bring the system back to that.

How do we do that we have already released a heavy amount of toxins, we have already released a large quantity of plastic. Is there anything that we can do and if yes what are the steps that we can do? What kinds of actions are done? So, there are certain actions that degrade the environment and there are certain actions that restore the environment.

Degrading actions include things such as precision of prescribed burning. If you do not perform prescribed burning, your grass will be taken over by trees which will be a change in the local system, which will be having a degrading impact.

Cultivation and cropping in a number of cases degrade the habitat, disturbance, excavation or burial or substrate things it is mining. Eutrophication - Eutrophication is excessive nutrients being made available to the system, especially the water bodies because in a number of cases the fertilizers get run off from the fields into the water bodies.

Disruption of hydrology by say construction of a dam invasion by non-native species, especially the invasive species, logging of trees that is cutting off of trees overgrazing, removal of animals by poaching and contamination of soil, so these are all different examples of degrading actions.

Restoration actions could include things such as cessation of the degrading action. So, in case you were doing say poaching in an area, then a restoration action would be to give up poaching. But this is a passive restoration in the case of active restoration you will also reintroduce the animals into this area to make up for the population loss.

Another action is extirpation of the damaging species. So, if there is a non native invasive species you will remove that species. So, that will be a restoring action that will help the system come back to normal more quickly. Nutrient removal in cases where you already have eutrophication, you may try to remove certain nutrients to remove the negative impact planting of grasses and grass like other herbs or pops.

Especially in those areas where you have done an excavation if you plant grasses then the soil will get stabilized or planting of trees or reinstatement of burning if you were not doing the prescribed burning that is the restoration action. The remodelling of topography especially in cases where you have already dug a huge exclamation pit or where you have already created huge amounts of waste.

In that place remodelling of the topography to ensure that these waste do not get washed away, that is restoration action or soil amendments to bind or to dilute the contaminants how to restore the fertility. These amendments can be done in space where there has been heavy erosion. We may try to increase fertility. In cases where there are contaminations we may try to wash away the contaminants to reduce their concentrations. These are all different examples of restoration activities.

Now, it is important to keep in mind that the restoration has certain constraints, as we have seen before there are always tradeoffs and in the case of restoration we need to keep in mind the regional constraints and the local constraints. For instance in certain cases it may not be possible to

bring the system back to its original state. We may try to bring it to a state which is a bit better or maybe a bit different from what was there originally, because there are certain constraints at the local level and at the regional level.

Probably the carnivore that was removed or was made locally extinct because of poaching that is no longer available. So, in that case you may try to reintroduce some other carnivore to stabilize the system. So, the constraints have to be kept in mind.

Now we will look at a few examples in the case of mining. If mining was done then a lot of degradation activity had already taken place. Deforestation because to access the earth we remove the trees that are there, because these trees have been removed there will be soil erosion. In the case of mining there will be a certain amount of heavy metals that will be released that will lead to water pollution.

So, anyway metal releases water pollution. Soil erosion and deforestation are all different kinds of degrading activities or degradations that have already occurred in a mine. The restoring actions could be things such as flattening of waste dumps and landfills to prevent erosion, filling up of the duct pits covering with a layer of clay to prevent access to rain and oxygen, covering with a layer of topsoil because there because of the heavy erosion the topsoil is gone.

We cover it with a layer of topsoil and plant trees or evaporate tailings dams, so that the water is removed, the waste gets concentrated and then it can be removed from the area, so these are examples of restoration activities. Similarly, in the case of river systems we can have degrading actions such as construction of dams.

A dam completely changes the hydrology of the area. From a running water system you have converted the area into a stagnant water system. So, that causes a change in the hydrology, it changes the movement of different organisms such as fishes.

Other examples include diversion of land. So, land that was there in a flood plain has now been diverted and made into, say a building area. Overuse of groundwater, channelization of streams - these are all different things that lead to changes in hydrology.

Then we have changes in the habitat clearing of land grazing especially over grazing, mining in the area introduction of the invasive species. These are all different kinds of degrading actions. Restoration actions would include things like restoring the hydrological processes and the geomorphic features. If the floodplains have been diverted into construction areas then probably some of these have to be brought back into the flat plains.

Restoration of the riparian vegetation, so in case certain invasive species have invaded into the area then they will have to be removed and the natural indigenous riparian vegetation will have to be brought back. That will be a restoring action, restoring of animal life that was affected because of the degradation.

And when we are doing restoration activities these days bioremediation has come in a big way to aid the restoration activities. Bioremediation is the process that is used to treat contaminated media including water, soil and subsurface material by altering environmental conditions to stimulate the growth of microorganisms and degrade the target pollutants.

What we are saying here is that this is a process used to treat contaminated media. For instance there was an oil spill and the oil has been leaked into a water body. Now this oil is bringing up

certain toxic impacts. Now to treat this oil we can either make use of dispersants such as detergents or you can make use of bioremediation.

In the case of bioremediation what will be done is that the microorganisms that can eat up these oil spills will be introduced into the area and probably certain nutrients will be added to the area to promote the growth of these microorganisms. And when you have these microorganisms they will act upon the oil and they will eat up the oil, so this is an example of bioremediation.

It is a process used to treat contaminated media including water, soil and subsurface material by altering environmental conditions. Now in this case an altering environmental condition is introduction of the nutrients, so that the microorganisms are able to grow. So, you alter environmental conditions to stimulate the growth of microorganisms and degrade the target pollutants.

Another example is phytoremediation, in which case we make use of those plants that can treat the pollutants. So, a good example is the treatment of municipal waste. So, the municipal waste is very high in organic compounds and that may lead to changes in the body of or the biological oxygen demand of the water bodies. Which means that so much organic material is put into the water body, that it reduces the amount of oxygen that is there in the water body when it gets degraded.

Now, to act upon these organic compounds we can make use of phytoremediation such as root zone treatment. Now in this case the wastewater that is coming from the municipal facility is put into a sedimentation tag, so that a majority gets sedimented and the water that comes out is passed through a bed of wetland plants. And after this water has passed through the root zone of these plants it is then put out into an output.

Now, what happens in this root zone if you look at the root zone there is an oxidized zone and there is an anoxic zone around these roots. Now this reduced zone will be reducing the organic compounds and the oxidized zone will be oxidizing the organic compounds.

Now because of this, oxidation and reduction reactions, what will happen is that a majority of the organic compounds that are there in the wastewater will be acted upon and they will be treated. And once they are treated now the water is safe to be removed and released into the environment otherwise all of these chemicals would have had a toxic impact or a negative impact on the ecology and these methods are pretty efficient.

If you look at the biological oxygen demand reduction you load these plants with the wastewater and they are able to remove the bod. Or if you look at the total suspended solids you load the water and the water that comes out is clean. So, this is acting to purify the water it is clearing off the water, the water becomes transparent and the organic compounds are treated in a manner that it does not cause any further harm to the environment.

That is all for today. Thank you for your attention. Jai Hind!