Conservation Economics
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Module 3
Modern impacts necessitating conservation
Lecture 1
Climate change

Namaste!

Today we begin a new module which is Modern Impacts Necessitating Conservation. In this module we will have a look at certain impacts of human activities because of which conservation has become more important these days. And we will focus our attention on three such impacts climate change, plastics and oil spills and mining.

Let us begin with Climate Change. What is Climate? Climate is defined as: a broad composite of the average conditions of a region measured in terms of such things as temperature amount of rainfall or snowfall snow and ice cover and winds. Climate is a broad composite - which means that, we are not looking at climate in terms of final quantities, we are looking at it as a broad composite of the average conditions of a region - which means that climate is different from weather. Weather changes every day with the changes in a few hours, but climate - because it is a broad composite, it is an average that is taken over several years.

Climate is more or less a constant quantity. It is a broad composite of average conditions of a region measured in terms of such things as temperature amount of rainfall or a snow fall, snow and ice cover and winds. These are different variables through which we describe the climate of a place. When we talk about the average conditions, the classical period for taking these averages is 30 years. It is a pretty long period of time in which we take the averages because of which the climate is fairly representative of the conditions of any region. Even though the conditions might change on an hourly basis or on a daily basis, but on an average the climate will be a very good representation.

How does climate act? There are five components of the climate system. We have the ocean or the hydrosphere, we have land or the lithosphere, we have the winds or the atmosphere, we have the biotic components or the biosphere and we have the ice or the snow cover which is the cryosphere. So, there are these five different components from the climatic system and all five of these interact with each other continuously. For instance if there is a change in the wind condi-

tion, then there might also be certain changes in the biotic composition of the area or when the winds blow over the mountains, then there are changes such as reduction in the debris or snow fall of the area. So, these five components continuously interact with each other.

If climate is an average condition, why do we talk about climate change? When we talk about climate change because even these averages are changing.

How do we define climate change? Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability which is persisting for an extended period of time which is typically decades or even longer. Climate change may be due to natural internal processes or because of external forcings or due to persistent anthropogenic changes in the composition of the atmosphere or in land use.

How can the climate change? The climate change may be due to natural internal processes or because of external forces. What does that mean? Remember that when we said that when we were talking about climate there are these five different components of climate and there are some natural processes that are changing these components. For instance, there might be changes in the tectonic layers of the Earth. The Earth is divided into a number of plates and these plates are in constant movement. When the land surface changes because of the natural processes, then that might change the climate. So, the climate change may occur because of the natural internal processes.

Or it may occur because of external forcings. Now what are external forcings? You have the climate system and there is something that is acting from outside which is resulting in a response to this climate change. We will explore what are these somethings - what are these forcings?

It can be due to natural internal processes or external forcings or also due to persistent anthropogenic changes. Anthropogenic changes means man made changes in the composition of atmosphere or in the land use. Humans are changing the composition of the atmosphere, humans are changing the land use and because of this also we will we can have changes in the climate. So, the next question is, what are these forcings and what are the kinds of responses that we can have?

These are some common forcings: Changes in the plate tectonics. These are changes in the land and sea distribution of the earth because of movements of different plates or changes in the Earth's orbit. Even the orbit of the Earth changes - and these changes occur over thousands of years. Because of changes in the Earth's orbit, if the Earth comes closer to the Sun then the Earth will warm up, if the Earth moves away from the Sun then the Earth will cool down. Or changes in the strength of the Sun. The Sun gives out energy which is regulating the climate on the planet - and this energy is not fixed - it changes. Now, if it so happens that the Sun starts to give out more energy, more amount of heat to the Earth then that would result in a change in the climate -

the Earth will warm up, and there will be changes in the wind patterns. If the Sun starts to give out less amount of energy the Earth will cool down - that will also bring out changes in the wind patterns, changes in the biosphere, changes in the hydrosphere.

So these are also forcings. But the most important forcing these days is the anthropogenic forcing. Anthropos means human and genesis is formation or production. So, anthropogenic forcing is a forcing that has been produced by human beings. What can they be?

The most important anthropogenic forcings or modes of anthropogenic forcings include things such as the release of greenhouse gases such as carbon dioxide. Now greenhouse gases are those gases in the atmosphere that act as a green house by trapping the heat of the Sun in the atmosphere. While they permit the short wavelength radiations of the Sun to enter through the atmosphere and reach to the land surface, once the land surface is heated and it re-radiates the radiation in the form of longer wavelength radiations, then these gases trap them - they do not permit them to move outside to the outer space.

These greenhouse gases such as carbon dioxide or methane are being produced at a at a much larger level by humans and that is an important anthropogenic forcing. Now how do humans produce a heavy amount of carbon dioxide? By burning fossil fuels such as petroleum, natural gas or coal. How do humans aid in the release of methane? By having more and more number of livestock. Not only do humans release these gases, but they also are acting upon in reducing those modes that would have reduced these gases in the atmosphere.

Plants for instance capture this carbon dioxide and convert them into biomass. And when they do that in the process of photosynthesis, they reduce the concentration of carbon dioxide from the atmosphere. But in our quest for having more food, in our quest for having more land for construction, what we are doing is that we are cutting off the trees. When the trees are cut then less and less amount of carbon dioxide is brought back from the atmosphere into the lithosphere. Also things such as burning of the trees - forest fires - a majority of them are anthropogenic - they are manmade. And why would man want to burn forests? For they want to clear off the land.

If somebody wants to encroach upon a forest land and convert it into an agricultural field, it is very easy to burn the forest. And once the land is cleared then the land can be brought up for cultivation. Or the production of things such as concrete. Concrete production releases a huge amount of carbon dioxide when the calcium carbonate is heated. These are all different modes through which humans are ah aiding in changing of climate by providing a forcing.

Now, when there is a forcing on the climate system, it results in a response. And what are those responses? Responses could be changes in the atmosphere, changes in the wind pattern or changes in the ocean, etc. Now this may result in changes in say the flow of the ocean currents or

changes in vegetation or changes in land surface or changes in ice. If the Earth heats up then more and more of ice will melt and the water will get into the ocean. You will have a larger volume of water that is there in the ocean and even this water - when it gets heated up - it will expand. This is a response that we will see because of the forcing of increasing the temperature.

And these responses manifest in the form of heat waves, they manifest in the form of changes in the ice pattern, they manifest in the form of droughts or floods or increased temperatures in a number of areas or in the form of forest fires. So, these are several responses that we are observing because of changes in the climate and these also result in biological responses.

So, the climate change results in changes in the temperature. There is a change in the mean temperature, there is a change in the extreme temperature, there is a change in the amount of variability that we see in temperature, there is a change in the seasonality of temperature, there are changes in rainfall, there are changes in extreme events. We find more and more number of floods, more droughts, more storms, more fires - not only in a greater duration, but also in a greater intensity, or changes in carbon dioxide concentration in the atmosphere or in the oceans.

In the oceans when carbon dioxide gets dissolved it also results in changes in the pH - the water becomes more acidic.

There are changes in the ocean dynamics because of changes in the sea level. Why do we have a a change in the sea level? Because more and more amount of ice is getting melted and this ice is adding to the water in the seas. And when the water is being heated up because of global warming it expands and so, we are seeing changes in the sea level. We are seeing changes in the marine currents.

So, all of these climate change components result in changes in the biological system - at the organismic level, population level, species level, community level, ecosystem level and even at the biome level. For instance we will start seeing changes in the natural selection and we will look at changes in natural selection and allelic diversity in a short while.

There are changes in mutation rates in different organisms because the mechanisms that are there to correct for mutations - they are hindered because of an increased temperature and because the animal is not that fit. There is change in the heterozygosis richness, there are changes in physiology, changes in fecundity. So, organisms will be having less or more number of offsprings. Organisms are changing their activity rates and rhythms - those organisms that earlier used to move in the known period - they are now avoiding the known period because its too hot.

There are changes in the species sex ratios, changes in disease susceptibility - especially because of a changed climate, now the organism is not that fit and when the immune system is down - when the organism is not that fit - it can very easily fall prey to diseases which is resulting in

changes in the survival of organisms. We are also seeing changes in the phenology. Now phenology refers to the timing of different processes. So, we are seeing changes in the arrival and departure times of different migrating species because the summers are coming earlier, they are lasting longer - the winters are coming late, and they end faster. There are changes in migration patterns. Because of changes in temperature we are seeing changes in budding and flowering of different organisms - different plants. If there are changes in the budding or flowering period, there are changes in migration, then it is also possible that there will be certain species that will not be getting sufficient food. Because in a number of cases the migration patterns are correlated with the presence of food in the other location.

Now if there is a species of bird for instance that is dependent on these flowers and if the birds have reached into the area, but the flowers have not bloomed - in that case the birds will not have sufficient food. So, changes in phenology are also leading to a large amount of extinctions.

There are changes in the growing season length. Those plants that grow in the summer season - they are now getting more time to grow; those plants that use the winter season - they now have a shorter growing period. There are changes in dispersals of hatchlings and fledglings; there are changes in hibernation. Now because of these we are also seeing changes in the population dynamics, the number of individuals that are recruited which means the number of offsprings that have been born and that are able to survive. Because of that if less number of individuals are getting recruited, less number of young ones are getting recruited - that changes the age structure, because now the population will be older population because you have less number of young ones. There are changes in sex ratio - especially in the case of reptiles because in a number of reptiles such as crocodiles - or in the case of tortoises, the sex selection is temperature dependent. So, if the temperature changes you will have a changed ratio of the number of males and females that are born.

We are seeing changes in abundance, we are seeing changes in distribution. Why changes in distribution? Because the habitat is changing. And why is the habitat changing? Because of changes in the growing season, changes in budding and flowering time, changes in hibernation. That is changing different habitats.

We are seeing changes in the range size, range localization, and we are seeing changes in the interspecific relationships. There is an uncoupling of a number of relationships such as those between the flowers and the insects. So, in the case of a number of flowers the pollination is done by, say, insects. Now if the flowers are blooming at a period when the insects have not yet arrived on the scene - because probably the insects have not come out of their eggs - in such a scenario there will be a decoupling because earlier the insects were getting food from the flowers and the flowers were getting pollinated by the insects. Now because there is a change in the timing the insects will not get sufficient food, the flowers will not be pollinated and so, this will result in a decimation of both of these species.

We are seeing new interactions that are coming - because whenever you have a change in timing then those species that are already present - there they will start to form a new relationship. Now that may have a positive consequence, but that can also have a negative consequence. So, for instance the invasive species are able to come up into newer areas much more easily because they are forming newer relationships and these invasive species are then decimating the local indigenous flora and fauna and they are establishing themselves - the local biodiversity is gone and it gets replaced by the invasive species. This is another change that we are observing.

There are changes in the community productivity - the amount of biomass that is being produced. We are seeing changes in the ecosystem services because the ecosystem composition is changing, the production is changing, the function is changing. And we are seeing changes in biodiversity.

Because we are seeing catastrophes at a much greater frequency, at a much greater intensity, there are changes in the resilience of different communities - there are changes in the eco types, we are seeing shifts in the distribution patterns, we are seeing more and more amount of desertification. So, there are a number of biological responses that we are also observing because of climate change.

And we have a pretty solid evidence that these anomalies are occurring because of changes in the climate or changes in the temperature. In the case of a number of species we have observed that the more is the temperature anomaly, the more is the phenological anomaly. And this is also manifesting in terms of say the amount of phytoplanktons that are there in water. With increased temperature the amount of phytoplankton in water is going down which will have an impact on the amount of productivity, that is there in this aquatic ecosystem.

We are seeing that the total biomass is going down as temperature increases. Certain species of zooplanktons - they increase in number or increase in concentration when the temperatures go up. Certain microorganisms increase in number. Now some of these microorganisms may even be pathogenic. So, we will start observing more and more number of diseases.

We are observing bleaching of corals. Corals are very important species in a number of ecosystems because they provide shelter to a number of other species. They are the keystone species - their importance is much greater than the numerical abundance. Now because of changing climate, because of acidification of water, because of increased temperatures and because of certain pathogens the corals are dying out. And this dying of corals is manifested in the form of lack of color. So, we are observing more and more amounts of coral bleaching.

We are observing that the ice cover near the poles is going down which is putting species like the polar bear in a much perilous state. Species of mangroves are dying out, species of kelps are dy-

ing out. All of these - the corals, the kelps, the mangroves and the ice - they are habitats that provide a living space to a number of organisms and when we are seeing these habitat level destructions, it means that a number of species are now under threat because of climate change.

We are seeing an increase in the invasion - and rise - of exotic species. In this curve you can see that over the years the number of frost days has gone down which means that the temperatures are rising up, at the same time the number of exotic species is going up. So, there could be a correlation between both of these.

We are observing rigorous responses in plants in the forest - we are seeing changes in the stand volume, changes in the annual increment that the forest is putting down, changes in the gross primary productivity, changes in carbon sequestration that has been done by the forest, and we are also seeing changes in a number of animals in terms of their health. Things such as climate change result in extremes of temperature which increases the chance of an animal getting the heat stroke. Climate change is leading to weather disasters. An increased frequency and an increased intensity of extreme weather events such as floods and fires increases the chances of animals drowning or animals suffering from dehydration or from gastrointestinal illnesses. Because in the case of a flood-like situation, the animals are forced to have dirty water which is resulting in a lot of trouble to animals. Climate change is also leading to ecological changes because of changes in the phenology, because of decoupling of pollination relationships between plants and animals - which is leading to changes in food availability.

If an animal gets less amount of food it will suffer from malnutrition - we will have cases of growth retardation, developmental delays. Similarly, because of changes in the phenology and because of changes in the range of different plants, we are seeing changes in allergen and mycotoxin exposure that the animals are suffering from. We are seeing more cases of allergies, cancers and birth defects - these ecological changes also increase the chances of exposure to infectious diseases - and a number of infectious diseases are also emerging anew.

We are also observing other changes. Every organism has a particular level of temperature that it can tolerate. There is a best temperature that the animal prefers - there is a tolerable temperature and if we go beyond the tolerable temperatures, the animals suffer from discomfort and may even perish.

Now, because of changing temperatures what is happening is that, we are observing a large number of local extinctions. If the temperature increases beyond the tolerable limit, then we will start seeing animals that are dying. So, there are local extinctions in the warm edge. And these extinctions have been predicted to increase with more and more amount of global warming. We are also observing changes in the spatial distribution of organisms - because suppose this is the equator and this is the north direction. As temperatures go up, more and more of these colder areas are now becoming warmer. These organisms that were living here, they will be able to occupy

these areas that were so far not being occupied because they were beyond the tolerable limits of these organisms. So, on the one hand the organisms will be dying in the warm end, on the other hand there will be an expansion in the cold edge. So, we are seeing changes in the spatial distributions, changes in the ranges of different organisms. A good example is the spread of insects in the mountains as the temperatures are going up.

As we move up the temperature goes down. There are a number of species of insects that are only able to tolerate the warmer conditions; they cannot tolerate the colder conditions. Because of that a number of species of insects are only localized in the lower height of the boundaries. Now as the temperatures are rising what is happening is that these cooler areas are also now becoming warmer. As temperatures rise, these insects - which were earlier only in the lower altitudes - they are now able to reach into the higher altitudes. So, we are observing changes in the spatial distribution of insects.

Also with increased amounts of climatic extremes, increased amounts of rains in certain areas, increased amount of flooding, we are also observing that insects are making use of these pools of water to increase their numbers - because they lay eggs in these waters. We are seeing changes in the vectorial capacity of mosquitoes or the ability of mosquitoes to transfer diseases - and we are seeing changes in the allele frequencies at the genetic level. A very good example here is the story of the Tawny owl.

The Tawny owl is a species of bird - its an owl that is found in Europe. This bird is available in two colors - there is a lighter version which is grayish in color and there is a darker version which is brownish in color. In the areas where this bird lives the trees are generally covered with snow. When the trees are covered with snow - and snow is white in color, so the gray colored birds are able to hide in the snow. If there is say a rat here that one of these birds wants to catch and eat. In that case if it is a brown colored bird, then it will be very easily seen by the rat and this rat may try to hide whereas, if it is a gray colored bird then it camouflages so well that the prey is unable to observe this bird and it increases the the chance of the bird getting a prey.

Because of this reason a majority of the birds are gray in color. Now the color of the bird is determined by the genes that the bird has - the allele frequencies that are there in the bird population. A majority of the birds are light in color and there are very few birds that are dark in color. Now, because of global warming what has happened is that, the snow is melting. So now, if we look at these birds that were gray in color now they are very easily seen in the backdrop of these trees and so, the advantage that they had in terms of color is now gone. Now if it is a light colored bird then the prey will very easily spot the bird, if it is a dark colored bird then it will be difficult for the prey to spot the bird. And so, how has nature responded? Or how has this species responded? Because these light colored birds are now less able to get to the food so, they have lost their fitness or they have greatly reduced their fitness whereas, the fitness of these birds has gone up and slowly we are seeing that more and more number of these birds are now in darker

shades - there are changes in the allele frequencies. So, we are seeing changes at the genetic level because of climate change. So, this is another thing that we are observing.

When we have such a huge amount of climate change what can we do about it? The kinds of responses that we can put up for conservation and to tackle climate change are divided into two categories: we can have mitigation or we can have adaptation.

Mitigation is defined as a human intervention to reduce the sources or enhance the sinks of greenhouse gases. The other way out is adaptation. Adaptation in a natural organic system is response to actual or expected climate stimuli or their effects which moderates harms or exploits the beneficial opportunities. It is an adjustment in the system - you are trying to adjust your lifestyle, you are trying to adjust your profession, you are trying to adjust the industry you are working in or you are trying to make adjustments in the ecosystems. So, it can be an adjustment in either the natural systems or in the human systems. And why are you doing these adjustments? In response to actual or expected climate stimuli or their effects.

You are making these adjustments so that you can respond to the climate change that is either actually happening or which is predicted. Adaptation is in response to actual climatic stimuli or expected climatic stimuli or their effects. The aim of adaptation is to moderate the harm. So, you are trying to reduce the harm or you are trying to exploit the beneficial opportunities that climate change may offer.

So, for instance, if you are living in an area that is extremely cold and you think that because of climate change - because of some amount of warming, now the climate will become a bit more pleasant in your area. That might result in the development of a new opportunity - probably tourists will now start coming to your area. And if you are making changes - if you are say developing infrastructure or if you are doing advertisement so that you can attract these tourists to make use of the beneficial opportunities - then you are doing adaptation.

So, the two responses to climate change that you normally make are either mitigation or adaptation. In the case of mitigation what happens is that, we ask what can we do to avoid climate change or to reduce the climate change. If the earth was going to raise its temperature by say 1.5 degrees can we bring it down to 1 degree, then we bring it down to 0.5 degrees? If we are doing that by either reducing the amount of greenhouse gases that will be emitted into the atmosphere or by trying to bring down the gases that have already been emitted, then we are doing mitigation. The other response is adaptation where you say that ok climate change is going to happen, and I cannot do anything about it, but is there anything that I can do to reduce my harm or to make use of the beneficial opportunities? If you have such a response then what you are doing is adaptation.

Often both of these strategies are needed together and they are used together. So, how do you de-

cide? What needs to be done? So, there is climate change - if you foresee that the impact is minimum or if you find that the impact is minimal then probably you do not need need to do anything in that area.

But if the climate change is too much and you find or you predict that the limits are going to be exceeded then you have two options - you can either figure out if there is a way to mitigate the emissions or you can figure out that there is no way that mitigation is possible. If there is an option of mitigation that is available and you deploy it, then you may have a success or you may have a failure. If you are expecting that climate change will exceed the limits, will bring you too much of a harm, you try to mitigate the emissions and you get a success because of which the impact is now minimal. When that happens you do not need to do any other thing - you can sit back and relax, but if you get a failure - so you tried to mitigate the emissions, you tried to bring the levels of greenhouse gases down, but they resulted in a failure - you could not do anything - then you will decide that mitigation is now not possible which means that the only option that you have now is adaptation.

In the case of adaptation, we can adapt to a particular capacity. There is always an adaptive capacity of any system whether we talk about a natural system or whether we talk about manmade system, whether we talk about an industry or whether we talk about a profession, we can only adapt to a particular extent - adaptation is not infinite.

So, when you cannot mitigate the only option that is left is adaptation. Now, if you have an adaptive capacity that is sufficient to adapt - which means that suppose there is a society that has ample amount of resources and say can come up with an air conditioner in every home. Now air conditioner in this case will be an adaptation because it is not doing anything to reduce global warming, but it is helping people to live in this area which has heated up too much. So there could be certain societies that can do adaptation - there will be certain other societies that are probably the poor societies and they will not be able to bring about adaptation. If the adaptive capacity is sufficient then adaptation is possible. If the adaptive capacity is not sufficient then adaptation is not possible.

If the adaptation is not possible here again you have two options, you can either build up the capacity - so you build your adaptive capacity, you find out ways in which you can have more sources of energy, you can have more number of air conditioners, you try to increase your capacity of adaptation as a society and if you are able to do that then adaptation becomes possible.

So we reached to this point where mitigation was not possible. So, the first step is that if we can mitigate we will try to mitigate, but if we are not able to mitigate - if mitigation is not possible, then we will try to adapt, but then it is also possible that the adaptation is not possible - and it is not possible to build the capacity. Now that becomes an issue because you are neither able to mitigate , nor are you able to adapt.

In that case the only options are either to perish as a society or to look for some other ways of mitigation. So, what we find from this flowchart is that at all points of time we as a society need to think. If we can mitigate the emissions, we should try to act in that line; if mitigation is not possible or if we as a society fail to mitigate climate change then we could adapt, but it is also possible that if adaptation is not possible because we have a limited adaptive capacity as a society, then it is also possible that we will perish. So, these are the options that are there. Mitigation and adaptation both need to be tried. The first option is of course, mitigation. You try to ameliorate the climate change, but if that is not possible then as a society adaptation might be our only option.

So, what are the mitigation options that we have in the society? To reduce emissions we can come up with laws. For instance, the government might say that any vehicle that has a fuel efficiency less than a prescribed limit will no longer be permitted to be manufactured. In this case we are using a law to mitigate climate change by not allowing the production of those vehicles that are fuel inefficient or we may come up with a law that says that any person who is using electricity above a a certain threshold will have to pay a a a penal rent. Here again we are talking about a law to incentivize people to cut down on their electricity consumption.

You will remember that incentives are what induce people to act in a certain way and law is a very powerful tool to induce activities that need to be promoted or to dis-induce those activities that need to be suppressed. So, the government may use laws to promote those mechanisms that reduce the emissions or the government may make use of laws to penalize those mechanisms that are leading to a large amount of emissions other options with us are use of green energy. Green energy - such as solar cells - they take off our dependence on the fossil fuels. If in place of using a thermal based power plant we have shifted to say solar power plants - in that case the emissions because of the burning of coal they will be gone.

So, we will be acting in a way to reduce the emission or REDD. REDD stands for Reducing Emissions from Deforestation and Forest Degradation which means that whenever there is deforestation that is a forest is getting cut and is getting destroyed or there is a degradation of forest which means that we are shifting from a dense forest to a moderately dense forest to an open forest probably to a no forest or a scrub forest. Now, when such a thing happens we say that there is a forest degradation. Now whenever there is deforestation or forest degradation there is emission of greenhouse gases because the carbon that was stored in the plant biomass that has now been released because when people cut these trees they will either burn them or they will convert them into furniture which will slowly and steadily again emit out the carbon.

Now when we have deforestation or forest degradation all of this carbon is getting released out. There is also another chunk of carbon which is there in the soil. So, the soil carbon gets released when you remove the tree cover and the carbon that is released is of a very significant quantity.

So, whenever there is deforestation or forest degradation there is an addition of greenhouse gases. If you prohibit or if you can prevent deforestation and forest degradation then you are reducing the amount of emissions that would have happened if there was a deforestation or forest degradation. So, REDD is another mitigation option - you are trying to reduce emissions from deforestation and forest degradation.

Other option that we have is to create sinks which are the mechanisms that are going to take greenhouse gases away from the atmosphere - things such as having more amount of afforestation. Planting more trees or going for artificial trees - artificial tree is nothing but a device that can mimic photosynthesis and try to capture carbon from the atmosphere. Now it is still in an experimental phase, but yes if the technology gets developed that can also be used as a mechanism. To create a space for carbon - we can try to do carbon sequestration in geological sites. Now, what is that? You make use of machines to capture the carbon from the atmosphere; we compress this carbon dioxide - probably react it with certain chemicals so that it gets fixed and then we store it in a geological site - probably you make use of an old mine and you put these chemicals or these this carbon dioxide in that area and we shut it off, so that the carbon dioxide that was there in the atmosphere is now no longer in the atmosphere - it has been kept closed in a geological facility. So, this is another way of creating a sink - carbon sequestration in a geological site. Or we can look at REDD plus. So, here REDD is reducing emissions from deforestation and forest degradation. When we say REDD plus what we do is we do conservation, sustainable management of forest, and enhancement of forest carbon stocks.

In the case of REDD plus what we are saying is that we are going to conserve the forest that we already have and at the same time we are going to perform a sustainable management of forest. In a sustainable management of forest the wood is removed from the forest, but it is removed in such a fashion that you always have trees that are absorbing carbon from the atmosphere. What it means is that if you have a forest and the forest only has those trees that have become very old - so they are no longer putting up any further growth in them. In that case they are not collecting or fixing the carbon dioxide that is there in the atmosphere - because if they were fixing the carbon dioxide then there would have been certain growth in their bodies, but they are so old that they are no longer putting up any increment.

So, in the case of REDD plus what we do is that we do a sustainable management of forest in which case we remove those trees - that is we cut down those trees - that are very old and plant a new tree in its place or plant several new trees in its place and the wood that has been removed from this old tree is processed in such a manner that the carbon will not be released back into the atmosphere for a very long period of time. So you process it and you use it to make certain goods that are long lasting that is you are not going to use this wood say for fuel wood or for the manufacturing of paper that has a short life, but you will probably use it to make certain furnitures that will last for several decades and in the place of this tree that was removed you plant several new trees so that you always have a young generation that is fixing the carbon dioxide that is there in

the atmosphere.

That is the sustainable management of forest. Through sustainable management of forest we are converting an old forest that was no longer putting up an increment, that was no longer doing carbon sequestration and perhaps was even emitting carbon - because the old trees were dying naturally and they were being acted upon by other organisms that were eating up those wood and were releasing the carbon back into the atmosphere. Here we are avoiding that and we are converting it into a sustainably managed forest where wood is extracted for a long term use and the old trees are replaced by younger crop that can do the carbon sequestration. So, that is sustainable management of forest.

Or we can look at opportunities where we can enhance the forest carbon stocks which means that if you already have a forest is there a way to increase the density of plants, so that you can have more amount of carbon that gets sequestered? Is there a possibility that apart from having trees you can also have certain undergrowth or say certain climbers - climbers and undergrowths are also plants - they will also been be fixing carbon dioxide that is there in the atmosphere and and storing them as biomass. So, is there a way in which we can enhance the amount of carbon that is there in the forest? Can we do something about the amount of carbon that is stored in the soils - it gets increased? When we look at these opportunities - conservation, sustainable management and enhancement of forest carbon stocks - we are talking about creation of sinks through REDD plus. So, this is also another mitigation option that we have.

In the case of adaptation, these are the elements of adaptation: You begin by observing the climatic variables such as temperature or the amount of rainfall that you have in your area - you look start to look at non climatic variables such as if there is an invasive alien species of plant or animal that is coming into your area and through these observations you make an assessment. What will be the impact of climate in your area? How vulnerable is your country or your society or your community to the impacts of these climate changes? And once you make this assessment that yes the community is vulnerable you make a plan. You could make a plan such that you are trying to remove the invasive alien species of plants that are coming into your area and will have an impact on agriculture. So, you say that we are going to cut out all of these plants that are coming into our area then we implement the plan, you actually take help of people and you actually cut the plants and then you do a checking - did you achieve the objectives? Were you able to control these plants?

Now it is possible that you were able to control the invasive alien species or it is also possible that the roots that got left behind - they sprang up new shoots in the rainy season. In that case you will have to make certain adjustment, which means that we are going to uproot the roots - you are going to uproot the plant completely and for that you make the new plan and you do the cycle again and again. This is the Deming cycle: plan do check act, and in between you make use of observations; you make a continuous assessment.

Now adaptation is of three different kinds. It can be anticipatory that is proactive or it can be reactive. Anticipatory adaptation is an adaptation that is done before the negative consequences are being felt by your community. A reactive adaptation is done once the negative impacts are already being seen. For instance, if you anticipate that you are going to have droughts in your area and you start to come up with new irrigation mechanisms - you are doing an anticipatory adaptation. On the other hand, once you are already seeing a drought and you install more pumps you are doing the reactive adaptation.

Adaptations can be spontaneous or they can be planned. A spontaneous adaptation is say increasing the speed of your fan because you are feeling warmer. A planned adaptation could be a plan - to say remove the invasive alien species or to set up new hospitals because you are seeing a rise in the number of diseases.

Or the adaptation can be private or public that is done at the individual or community level or at the government level.

And in adaptation we generally do three things: we try to create a resistance to change. So, if we expect that there will be more number of forest fires, we try to reduce the effect of fires. In the case of insects and diseases you try to have a better protection against them - you remove the invasives, you do a resistance breeding so that the plants or animals in your area are more capable of tolerating the drought or flood situations or increase temperatures. So, that is creating a resistance to change.

Another option is promoting a resilience to change. The resilience means that if there is a climate change and there is a negative influence if later on you are able to bring back the effects of the climate change you should have a capacity to bring your system back to normal - things such as surplus seed banking. So, in this case what we are doing is that we are creating a seed bank so that we have the seeds ready whenever the temperatures come back to normal - whenever the climate comes back to normal, we can make use of these seeds and recreate the whole ecosystem. Or intensive management during establishment - here establishment means establishment of trees or promotion of biodiversity rich ecosystems because biodiversity rich ecosystems are more capable to come back to normal whenever the situations are brought back or the third adaptation option is to enable a response to change. Now, how do you enable response to change? You assist natural adaptations and transitions - assisted migration to newer areas. So, what we are saying here is that because of changing climate we expected that this that we will have a range expansion in this area and we will have an extinction in this area. So, in the case of assisted migration what you do is that, it is possible that the dispersion in this area will be very slow - so you actually take a few individuals and you bring them to this area. So, that is an assisted migration in which case you are trying to enable the forest or the ecosystem to respond to change. We try to increase redundancy; you manage for asynchrony. So, when you are expecting that your flowers

will not be pollinated because there is a change in the timing of flowers and the insects. Can you manage for that? And you bring in say an insect species from some other area that will be able to pollinate your plants in this particular point of time or you can try to look at the past spread of different forest. And you can try to establish them now. Or you can try to promote connected landscapes so that the animals are able to move to the other areas. In this case we are enabling the forest or the ecosystem to respond to changes. So, these are the the three main adaptation options: you create a resistance to change, you promote resilience to change and you enable the forest to respond to changes.

Now whenever we are doing adaptation it is important to note that there is an adaptive capacity: the ability of a system to adjust to climate change including variability and extremes to moderate potential damages, to take advantage of opportunities or to talk to the consequences. There is a capacity whether we talk about the forest, whether we talk about the nation, whether we talk about the community - there is a capacity to adapt. If you try to do an adaptation that is greater than the capacity, then probably you will bring harm to the system and in that case we will say that we have gone through a maladaptation - any change in the natural or human systems that inadvertently increases the vulnerability to climatic stimuli, an adaptation that does not succeed in reducing vulnerability, but increases it instead.

So, for instance, a good example is that you tried to do an adaptation by installing an air conditioner into every home in your country and in running of those air conditioners you you release so, much amount of carbon dioxide - because of burning coal or say natural gas - that the climate change increased even further and because of which there is a catastrophic collapse of the community - everybody perishes out then we will say that this is a maladaptation. So maladaptation is any changes in natural or human systems that inadvertently increase the vulnerability to climatic stimuli or an adaptation that does not succeed in reducing the vulnerability, but increases the vulnerability - that is maladaptation.

Now, as before we can relate climate change and the responses to the ten principles of economics. People and society face tradeoffs. Here the tradeoff is whether you want to have more and more resources now or whether you want to survive in the future, whether you want to have more and more electricity now by burning fossil fuels or do you want to forgo the impacts of climate change. So, there are always tradeoffs - these tradeoffs lead to cost - what you give up to get something. So, if you want your children and your grandchildren to live in a on a planet that is still safe to live - that is not seeing very extreme climatic events, then probably you will have to give up on certain amounts of comforts.

So, tradeoffs lead to cost. People respond to incentives which means that if we can incentivize the use of green technology or if we can disincentivize, the generation or emission of greenhouse gases, then probably people will respond to them and these incentives could mean things as simple as taxes and subsidies. So, if the airline tickets cost more because of an added tax say because

of of greenhouse gas emissions, then probably less people will be interested to use the airline and more people will, say, shift to other modes of transportation. And when we talk about incentives, the governments can sometimes improve market outcomes because the government has a legitimized power to make changes.

So climate change is something that is happening today, climate change is something that is because of the misguided actions of humans. We have the option to mitigate, we have the options of adaptation, but then if we want to actually perform significant and successful mitigation and adaptation, we will have to make use of the principles of economics to incentivize people towards the right path. So, that is all for today.

Thank you for your attention. Jai Hind!

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Module 3
Modern impacts necessitating conservation
Lecture 2
Plastics

Namaste! We carry forward our discussion on the modern impacts necessitating conservation and in this lecture we will have a look at plastics. Now plastics need no introduction - they are synthetic materials made from a wide range of organic polymers such as polyethylene, polyvinyl fluoride, nylon etc., that can be moulded into shape when soft and then set into a rigid or slightly elastic form.

So, what are the characteristics of plastics? They are synthetic materials. Synthetic material means that it is a manmade material. It is made from a wide range of organic polymers. So, it is not a homogeneous substance, but quite a large variety of chemicals can be formulated into plastics. Good examples are polyethylene, polyvinyl chloride, nylon and so on.

Now, the important characteristic of plastics is that they can be moulded into a shape when they are soft, which permits us to manufacture different kinds of substances using plastic materials. So, you can mould plastic into say a bottle, you can mould it into a pen, you can mould it into a chair and so on.

So, they have this important property that they can be moulded into a shape when they are soft and then set into a rigid or slightly elastic. So, it is no wonder that plastics surround us. In any room where you are sitting, if you look around you will find a number of particles that are made out of plastics and plastics surround us because they have some very good properties. They are cheap to manufacture, they are water resistant, they are light in weight, they are very strong and so on.

So, let us have a look at a short history of plastics. How did we come into this civilization of plastics? The earliest plastics in the terms of the synthetic material was made in 1600 B.C. when Mesoamericans processed natural rubber into a plastic. So, the natural rubber was converted into a plastic and this plastic was used as a ball. So, they used to play with this ball and the history of plastics is as old as 1600 B.C.

Then in the 19th century, polystyrene and polyvinyl chloride were invented and the 20th century saw the creation of a large number of plastics. In 1909 we had Bakelite that was used in commercial products. In 1926 polyvinyl chloride was commercialized and so it entered into the homes of a number of people. In 1933 Saran was invented. In 1937 Polyurethane foam was invented. In 1938 Teflon was invented. In 1939 we had Nylon and neoprene. In 1941 we had Polyester and PET and then a major change came in world war 2 when metals became scarcer and plastics started being widely manufactured to replace them.

Here again there was a trade-off - because people did not have access to metals and metals were very largely required for a number of things, so people started shifting towards plastics. This was a big trade-off during the 2nd world war. In 1951 high density polyethylene and polypropylene were invented. In 1954 Styrofoam was invented. In 1979 the plastic production in the United States exceeded the steel production

What we are seeing here is that the generation of plastics started and then it moved with a bang and then very soon it started growing exponentially. Plastic production is currently increasing at 5 percent per year and we see that a large quantity of plastics - more than 30 million tons is being produced every year.

We can relate this to the 10 principles of economics. A country's standard of living depends on its productivity. So, every country wants to manufacture more and more of the goods. And plastic again is one good that can be manufactured, that can be sold and that can be used in a number of ways.

So, a number of countries started to produce plastic. It was easy to produce. The raw materials that it required were easily accessible: petroleum and petroleum products, they are easily available, they are cheaply available and the technology to make plastics is also very simple. And so the plastics were produced in a very large quantity and soon we had plastic all over - all around us.

Now, the question is where does all this plastic go ? Plastics like every other material have a life. So, you take a bag of polythene, you buy some vegetables in it, you bring it to your home, you are going to use the vegetables, but then what do you do with the plastic?

Plastics because they are too cheaply manufactured and because of their good properties - they are manufactured in a large quantity. So, we have a large generation of plastic that is occurring in this world, but most of these plastics have a very short period of use . A number of plastics that are used in the manufacturing of bags - you bring your materials to your home in that bag and now you are not going to use this bag again.

So, what happens to all of these plastics? We use plastic disposable pens once we have used

these pens once they have stopped writing, what do you do with the pen? You throw them out into a dustbin. What happens after that?

In a number of biodegradable materials such as wood, once you have used a material once it has lost its properties once it is no longer useful if you put it out there in the environment there will be some organisms that will be acting on this wood and converting it back into the elements that find in the wood, mostly carbon hydrogen and oxygen - which is the basic premise on which our bio geochemical cycles work.

But in the case of plastics not many organisms can eat up a plastic and even if they eat a plastic very few organisms are able to digest this plastic. Now, the good properties of plastic that it is resistant to the impact of water it is resistant to the impact of chemicals and it is a strong substance also, means that it is resistant to the impact of enzymes in the bodies of organisms and that it is going to persist in the environment for a very long period of time.

So, what happens to these plastics? Well we have heard that plastics can be reused and recycled, but the fact remains that a very small percentage of plastics are ever reused or recycled. If we go back to this curve - this curve shows us the generation of plastics and this bottom curve shows us the recovery of plastics.

Recovery includes recycling. So, the amount of plastics that is being recycled is a very small fraction of the total amount of plastics that is being generated every year. So, a very small portion can be reused or recycled, but what happens to the rest of the plastic?

Well, some of the plastics are burnt, burning is an important method that is used in waste management because once you burn something you convert a fraction of it into gases that get released into the atmosphere and some portion that remains is of a smaller size and so can be handled easily.

So, for instance if you have large quantities of wood and you did not want to throw them out because you do not have access to landfills you can always burn the wood and if you burn the wood it will be broken down and it will be oxidized back into carbon dioxide and water, the substances that actually made the wood during the process of photosynthesis.

And the small amount of ash that remains will be rich in the nutrients, that is, like nitrogen and phosphorus and potassium. And this ash will be of a very small volume. It will be a very small mass and you can put this ash to some plant and this plant will use it back again because it is full of nutrients.

So, when you burn the wood the largest portion is burnt in the form of carbon dioxide and water and some portion that remains as ash can be used as a fertilizer for other plants. But, what hap-

pens when you burn plastics? When you burn plastics you release not just carbon dioxide in water, but a number of other noxious chemicals such as dioxins.

Now, dioxins are chemicals that can very easily impact the development of a young child or the development of a fetus. They are extremely dangerous chemicals and when plastics are burned a large fraction of plastics also release dioxins.

Then a major portion of plastics is also put into the landfills. Landfill is a simple option if you do not know what to do with these plastics. What you do is that you just take it to an area and you dump it in that area. Landfill typically is a depression in the ground that is being filled with these plastics, but then remember that they are generating plastics at an ever increasing amount.

We have a large quantum of plastics that is being generated and we are now running out of space in the landfill. Now, remember again that plastics are very light materials, now if it is a light material it also means that it is going to occupy much greater volume as compared to a denser material. So, landfills quickly get filled up with plastics.

So, what happens? You are only reusing and recycling a very small fraction of plastics, when plastics are burnt they reduce dioxin. So, burning is not a good option, landfills are an option, but then we are running out of landfills.

What actually happens is that quite a lot of plastics are getting released into the environment. And even when you are putting plastics into the landfills it also gets released into the environment because some organisms might go to these plastics because it is all full of rubbish and you can have animals such as rats that are being that are living on this rubbish and so, when a predator comes and attacks a rat to eat it it it is also possible that it may also take away some of the plastics.

Also when it rains the plastics being lightweight materials they can float in water. And so if you have a landfill and if there is a heavy downpour and if the landfill is full to its brim it is possible that some of the plastics will start floating in water and they will move away. They will move together with the rain water in the form of surface flow and they will ultimately reach into the water bodies. So, they can reach into your ponds, they can reach into your lakes, they can reach into the rivers and ultimately they will also reach into the oceans.

Now the situation is that we have a material that is lightweight, strong, resistant to chemicals and this material is now spread everywhere. It is there on the land it is also there in all the water bodies, some portion of it may even sink. Now, if you ever wanted to collect all of this plastic bag, how are you going to do that? So, plastics become a menace because they are not being disposed of properly.

What happens to these plastics once they reach the oceans and the seas? 15 percent of these plastics float on the surface, 15 percent of the plastics wash to the shores and as much as 70 percent of the plastics sink to the ocean bottom .

What we are observing here is that some fraction keeps on floating because of its light weight; some fraction is washed off to the beaches. Now beaches have sand. People like to go to beaches, but now our beaches are also getting filled up with plastics because the ocean waves are bringing these plastics to the beaches. And then a major fraction of the plastics as much as 70 percent it sinks to the bottom. And we will look at how a lightweight material is able to sink to the bottom in the next few slides.

But in brief what happens is that if you have a plastic and if the container gets filled up with water or gets filled up with some other substance which is heavy in weight then the plastic might sink down. And also in a number of cases the plastics get eaten up by animals and the animals dive down, so the plastics also dive down together with them.

And the third way is that from the plastics when they get degraded they form smaller particles and these smaller particles remain suspended for a very long period of time, but then ultimately they also come down.

So, as much as 70 percent of the plastics sink to the bottom once they have reached the oceans. So, this is what it looks like. So, you have this water body and you can observe these plastics that are floating on top. Now, these plastics comprise a majority of single use plastics. So, these bottles were not meant to be reused and so people use them and then they throw them into a dustbin from where it goes to a rubbish heap and from there it has reached into a water body.

Or plastics can come to the shore and when they come to the shore some of the animals may start interacting with these plastics. And at the same time it also makes it very dirty . Or you can find plastics on the seabed. Here you can see this person is picking up certain plastics that are there on the seabed.

Plastics are classified on the basis of their size into 3 categories. We have macro debris, we have meso debris and we have micro debris. Macro means big in size so any plastic that is greater than 20 millimetre in size we will call it a macro debris. 20 millimetre is 2 centimetre. Anything that is more than this big we will call it macro debris.

Ghost nets amongst these are a major concern and we will have a look at ghost nets in a short while. Meso debris: meso means in between so it is a debris that has an in between size and we call 5 to 20 millimetre size plastics as meso debris. And they are dominated by nurdles; nurdles are resin granules that are intermediates in the plastic production.

What that means is that when plastics are produced chemically: plastics are polymers - so we start with monomers, we polymerize those monomers and then we get to a polymer. Now, this polymer is then formed in the form of small resin particles - they are like this big. And these resin particles are then sold off to other companies that are going to make use of these plastics.

Now, remember that when we started with plastics; plastics have the property that they can be moulded into a shape when they are soft. What these companies do is that they buy these nurdles then they heat them up so that they become soft and then these nurdles are processed to make the plastic products that the companies are manufacturing.

So, these nurdles which are like this big - we will call them meso debris. And in a number of cases they reach into the oceans because when they are being transported on a ship and if there is an accident if these nurdles are just released because one of the containers broke then these nurdles will directly reach into the oceans.

The third category is the micro debris micro means small. So, these are debris of small size less than 5 millimetre in size and they are often formed through fragmentation of macro or meso debris and they also consist of plastics rubber particles as are found in face wash and other cosmetic products.

What happens is that when we have the macro debris and we have the meso debris and when these plastics are acted upon by the UV rays of the sun or they are acted upon by the oxygen that is there in the air or because of mechanical action because if there is a plastic piece that is floating on water and together with the waves it can get thrashed with rocks or 2 plastic pieces can bump into each other and once that happens these plastics may break into smaller fragments.

The macro debris and the meso debris will break into smaller particles and ultimately they will form the micro debris. But, micro debris also comprises certain small particles that are manufactured that way less than 5 millimetres in size for use and cosmetics. So, these are the three size classifications of plastics: macro debris greater than 2 centimetre in size, micro debris less than 5 millimetre in size and meso debris everything in between.

When we look at the production of these smaller fragments the synthetic polymers have a number of things together with them. If we look at any plastic container such as this bottle of water. Now, this is plastic, but it also has a number of other constituents, so it has a stabilizer, it has certain fillers and it has a plasticizer.

These chemicals are added to the polymer which is the plastic to improve the properties. So, the stabilizer will stabilize this material. You would also want to add certain other substances that make it look much more transparent or add colors to it and so on.

When the large sized plastics reach into the atmosphere, when they reach into the environment they have all these stabilizers, fillers, extenders and other additives that are together with the plastic. When they reach into the environment they are acted upon by a number of things light acts on and especially the UV rays of the light are able to break the bonds.

The UV rays have high energy and they are able to break the bonds in these plastics. The plastics are polymers. If you break the bonds you will convert them into oligomers or into the monomers, and in this process the plastic piece will start to fragment into smaller sized particles.

A good example is if you take this bottle and if you keep it on your rooftop for a few months you will start seeing that it will slowly turn whitish in color and then it will start to become more and more brittle. And after a while it will start converting into smaller fragments.

The other thing that acts is oxygen. Oxygen is able to oxidize some of these substances: not just the polymer or the oligomers that are being formed, but also the stabilizers, fillers, extenders and other additives. When these chemicals get oxidized then they lose their properties and so the plastic becomes more and more brittle. And some biotech organisms such as microbes and worms can also act on these plastics.

And then we have a number of reactions. We have the absorption of light, especially this UV light and when the light is absorbed you can have a photolytic reaction.

Photolytic: photo means light and lysis is breakdown.This is a reaction in which there is a breakdown because of the light. In certain other conditions when light is absorbed it also leads to the heating up of the material, and when there is heating up of the plastic and if there is a differential heating then that will also lead to some amount of expansion and contraction which may lead to some more amount of fragmentation in these plastic particles. Because of the presence of oxygen and because of the presence of UV light you also have the formation of radicals.

Radicals also accelerate the process of degradation of these plastics. Or you can have enzymatic degradation when the plastics are acted upon by biological entities such as microbes and worms. And because of all these reactions: you have oxidation and you have scission. Scission is again a process of breaking down or cutting down. So, oxidation and scission reactions will lead to discoloration loss of mechanical integrity, strength and impact properties of the plastics and slowly and steadily the plastics will start breaking into smaller fragments.

Is this breaking good or bad? Well it depends. In certain cases you want to fragment these plastics into smaller particles so that you can dump them into a landfill in a much concentrated manner, but in a number of other cases it accelerates the process of these plastics being eaten. Because this large sized plastic bottle - there are very few organisms that will be able to eat this plastic, but then if I have a small piece of plastic then it is possible that a fish or a bird may just

confuse this material with food and might eat it.

So, these smaller fragments accelerate the process of plastics entering into the biosphere. This is how the decomposition occurs. When the plastics are acted upon by light water, oxygen and so on. We will see that in a number of these rubbish deep heaps you will find that you have a small piece of plastic film, now this is 1 millimetre so this is around say 2.5 or 3 millimetres, which means that it has now reached into the stage of being a micro debris.

Then you have these small foam particles. If you look at a big size Styrofoam we will call it a micro debris, but then if you look at the smaller pieces that come out and especially when they are acted upon and broken down further they will become into micro debris.

We have all these small fragments of plastics that are coming from a line: a line means that it is coming from a rope, then you also have these pellets or beads and especially those that are used in the cosmetic industry as exfoliators. You find all these different kinds of plastics in debris, you will find fibers, you will find film and so on. And these smaller fragments will be formed in the water body; it is also possible that they may start to aggregate together.

When they when these small particles aggregate together they form a middle sized particle that has a much greater density and in that case this fragment together in the form of the the aggregate it will start coming down in the ocean waters and slowly and steadily it will reach into the ocean flow and we call such things as marine snow.

Now, it is also possible that these smaller particles get eaten up by certain organisms and they are ejected out in the form of faeces. And all these processes the formation of the ecocorona or formation of faeces or or formation of marine snow they all make it possible for these smaller fragments to start going down to the ocean bottom.

When you have all these plastics what is the impact on the environment? And especially what is the impact on the different organisms that are there in the environment? What is the impact on the biodiversity that we have? Let us have a look at that. The first thing that can occur with plastics is that it can be eaten and in a number of cases the plastic bags are confused by a number of organisms as food.

If you look at these plastic bags they look very similar to jellyfishes and if there is an animal that naturally feeds on a jellyfish it may confuse these plastics as jellyfish and it will eat these plastics. Now, plastics because they are strong substances which are able to resist the impact of most of the chemicals so these plastics will not be digested in the body of these organisms that eat them.

What will happen to these plastics in the body? These plastics may enter into the alimentary

canal these plastics may then start to block some portion of the alimentary canal. It is possible that these bags of plastics reach into the intestines and then they just remain there in the intestine and so there is a blockage that has been done.

Now, once that happens the animal will be unable to eat any food because there is a blockage in its alimentary canal and if that happens the animal will slowly and steadily start to die because it is not getting sufficient nutrition. This is an image of an albatross chick, now albatrosses are large sized birds and these birds also show a very great amount of parental care.

So, what happens in the case of an albatross is that the parents go out into the sea to catch fish and bring them to the baby. Now, if there is a piece of plastic that is floating on top of the water in the ocean it is possible for these birds to confuse this plastic as a fish. So, the parents will catch this piece of plastic, bring it to the chick and feed it to the chick.

And here we can observe that this was a chick whose body is all full of plastics. So, this is the amount of plastics that its parents had brought to it and fed it. And because of these plastics its alimentary canal got choked and this small bird died. So, albatrosses are facing a big danger because of these plastics that are floating on top of the water.

But we also observe ingestion in all sorts of organisms with their big or small. So, here is a blue colored microfiber. Here if you look at the size this much is 200 microns. This fiber would be like 500 micrometers that is half of a millimetre. And the thickness is a few microns and this sea pen polyp is a creature that lives in the oceans and here we can find that in this creature as well we are finding a plastic microfiber.

Now, remember that plastics are synthetic substances and before they were invented there were no plastics. All the other things that nature was making were biodegradable, but these plastics are not. So, we can observe plastics in large animals, we can observe plastics in small animals and we can even observe plastic in microscopic animals such as these zooplanktons.

Now, these green colored substances are micro plastics and we can observe that we have these micro plastics that have even impacted the microscopic organisms such as the zooplanktons. Ingestion is one big way in which plastics can impact the wildlife. Another way they impact biodiversity and wildlife is through entanglement, even smothering. So, what happens is that the plastics that are left out so they can be thrown out or probably they get out because of some accidents and these plastics can act as ghost nets.

Now, here we can observe that this is a fishing net that was there in the water body and the fishing net is meant to capture animals, it is very good at capturing animals and even when this fishing net is thrown into the ocean probably because its useful life was gone probably because it had lost its strength. So, the fisherman had just thrown it into the water body, but then this ghost

net was still capable of catching animals.

And here we can see that this turtle has been caught in this ghost net and when this turtle is caught, now this turtle is unable to move, this turtle is unable to feed and then slowly ends and steadily it will die out of starvation.

A number of other animals also require that they should be able to come to the surface, dive down, come to the surface for oxygen, dive down for food and so on. So, if these animals get entrapped when they are down at the bottom they will die out of asphyxiation, because they will not be able to come to the surface and breathe. If they get trapped on the surface they will not be able to dive to get their food. So, entanglement is also a major way in which plastics are decimating our biodiversity.

Another way is the example of the seal. Now, what happened was that this seal when it was a small pup, it got entangled with this piece of plastic. Now, plastics are very strong substances. This seal was unable to take it out, and then when this seal started to grow in size the plastic started to cut into its body. And here we can see that this plastic is cutting into the body of the seal.

And we can observe these things in a number of animals. I have seen some monkeys in the forest that have plastic that is tied across their waist and those monkeys are unable to feed because this plastic is pressing against their bodies. So, entanglement is also another way in which plastics decimate our biodiversity.

Another way is through the release of persistent bio accumulative toxic substances. Now, you will remember that plastics have these chemical stabilizers, fillers, extenders and other additives to improve their properties. Now, once you have released a plastic into the environment and this plastic is now floating on the surface of a water body these substances that were added into the plastic they can slowly get released out.

Now, these substances were added to the plastic to improve the properties and in a number of cases there was no consideration of how toxic these chemicals are when they are eaten up by organisms. And in a number of cases we find that these plasticizers are extremely toxic substances. So, if you release these plastics into a water body and these substances are slowly getting released into the water body, it is making the water body more and more toxic. It is leading to a degradation of the habitat that was earlier a prescribed habitat.

Another way in which plastics impact biodiversity is through the persistent bio accumulative and toxic substances. Now, bio accumulative means that these substances will accumulate in the bodies of organisms typically in the fat layer that is there in the bodies. These substances, because they are organic chemicals, can easily get dissolved in fat and so they will accumulate in the fat

bodies.

They are also persistent which means that they remain for a very long period of time. Which means that when these animals die these chemicals do not disintegrate, they remain persistent and so they will kill one animal because of their toxicity and when this animal dies these chemicals because they are still undegraded they again come back into the environment. And then they still maintain their toxicity levels and they still can kill some other organism.

So, these are persistent bio accumulative toxic substances. Good examples include bisphenol A which is an endocrine disruptor. Now bisphenol A is used as a plasticizer, when we say plasticizer if we look at this bottle it is able to maintain a certain amount of plasticity when you press it and it comes back into the original shape. It is soft and it is transparent.

So, chemicals such as bisphenol A are able to give these properties, but then bisphenol A is also an endocrine disruptor which means that it acts as a hormone, when it gets into the body and it disrupts the functioning of the normal hormones that are there in the bodies of the organism. So, this plasticizer when it is released into the environment can hamper the hormones that are there in the bodies of different organisms.

Another example of these chemicals is the brominated flame retardants that are used in the number of plastics. Now, brominated means that they are full of bromine and these are flame retardants that are typically used in things such as sofas or chairs. So, if there is a fire then plastics because they are made from petroleum and because they are hydrocarbons they can burn very easily.

And so to prevent accidents by law it is mandated that a number of these long term usage plastics should have brominated flame retardants. But, then these brominated flame retardants even though they are able to stop fires, but when these plastics are then thrown back into the environment and when these come out when they reach out they are also accumulative toxins. So, this is also another way in which plastics hamper biodiversity.

Another way is the accumulation and concentration of hydrophobic toxins. What does that mean? Plastics are hydrophobic substances. Hydro is water, phobic is fear of, so if you take a piece of plastic, if you add water to it then water does not wet the surface of the plastic, which tells us that it is a hydrophobic substance.

Now, if in water you add certain hydrophobic substances they tend to clump together. A good example is that if you take water and if you add a few drops of oil all of this oil will come together in the form of a layer. Now, when there is a piece of plastic that is out there in the water then all other hydrophobic substances will get attracted to this piece of plastic and they will accumulate on the surface of this plastic, because this particle was fearful of water this plastic is fear-

ful of water.

When both of these come together then at least this much part of the plastic as well as this particle is now not exposed to water. So, because of which these substances clump together.

Once that happens if you look at this water it has certain hydrophobic substances, probably toxic substances, but then they are there in a low concentration. But, if you put this piece of plastic and all these hydrophobic substances come and stick to the surface it means that now there is a much greater concentration of these hydrophobic toxic substances on the surface of this plastic. And we have seen before that plastics can get eaten up by different organisms both big and small, and once these organisms eat these plastics all of these hydrophobic toxins reach into the bodies of these organisms in a very high concentration.

This aids in the poisoning of our biodiversity. So, this is another way in which plastics impact our biodiversity. Then they also have the potential to alter habitats and behaviours. Habitat as we have seen is the natural home or abode of an organism and plastics have the potential to change the homes of animals. And once their homes are changed their behaviours also change.

For instance this is a crab that lives on the beaches and we have seen before that as much as 15 percent of the plastics get washed to the beaches. So, now the habitat of this hermit crab has plastics, earlier these hermit crabs did not ever observe a plastic, but now their habitats have these plastic pieces.

Now hermit crabs have this property that they make use of different shells of organisms as their protection layers. If you watch a hermit crab in most of the situations it would make use of the shell of certain molest animals and it will get inside these shells and these shells will provide protection to the hermit crab.

Now, what we are observing here is that this hermit crab is using a piece of plastic as its protection. Now, this is not a natural behaviour, this is an artificial behaviour which is there because this hermit crab is now finding quite a huge amount of plastics in its natural habitat. So, plastics have the ability to alter habitats and behaviours and this is also another way in which plastics impact wildlife.

This picture is showing us that there is a seahorse that is sticking to this piece of ear bud. Now, this is not a natural behaviour because in a pristine ocean, we do not have ear buds but now that there are ear buds in this portion the animals behaviour is changing. In a number of cases we find that animals are reaching into these rubbish dumps in the search of prey such as rats and now they are getting more and more exposed to these plastics.

We have the natural habitat of the hyena that has been disturbed, but at the same time the behav-

iour of these hyenas is also now getting disturbed. Because now they will look at plastic as something very natural and probably they will interact with these plastics. Earlier if it was a pristine environment and if a hyena found a red colored piece of plastic probably it would run away, but now it has been so much accustomed to these plastics then it might even try to eat up a piece of plastic. So, plastics have the ability to alter habitats and behaviours.

This is an image from Manas tiger reserve and this is the dung of rhinoceros, and what we are finding is that inside the dung we are finding pieces of plastic. This is a plastic bag, a blue colored plastic bag. So, even in a tiger reserve we are finding plastics have entered and animals are eating up these plastics.

Another way in which plastics impact biodiversity is by facilitating the dispersal and transport of invasive species. The dispersal as well as the transport and especially of invasive species. Now, what does that mean? A number of plastics are light in weight, they have a less density so they float on top of water.

Now, if an organism needs to move from one place to another it may just use this piece of plastic as a boat and together with this plastic it will move to some other location. Now, earlier the organisms did not have this option the only options that were there were say things like wood or a small piece of twig or a branch.

Now, those being biodegradable the organisms were unable to move to very far distances, but now that we have plastic in such huge quantities available to these animals these plastics are also acting as boats and rafts for a number of organisms for them and facilitating their movement.

Now, what happens is that a number of invasive species are also able to use these boats and rafts; plastic boats and rafts to reach other places and then they start to colonize the other places. And once that happens the local biodiversity may get decimated because the invasive species are able to out-compete the local species and then they establish themselves and they wipe off the local indigenous biodiversity.

So, this is also another way in which plastics are impacting our biodiversity. This paper showed us the incidence of rafting on marine debris by different taxonomic groups. And what are all the things? So, one is that you can find that different kinds of organisms are using plastics.

Sponges cnidarians worms sea spiders crustaceans molluscs bryozoans so many different kinds of organisms are making use of plastics. And they are using quite different varieties of plastic, ropes and netting fishing materials intact items packaging fragments and microplastics.

And if we have a look at the natural materials which are there in these colored forms and the artificial plastics that are being used by these different organisms. So, say in the case of crustaceans

this much amount of movement is happening because of the plastics and this much amount of movement is probably a natural movement.

So, we find that plastics have overwhelmed the system and they are increasingly being used as a means of transportation by different varieties of organisms and this is also increasing the possibility that a number of invasive species will be able to move from one place to another. And once that happens it will be a sad day for biodiversity.

Then, even micro plastics can influence the complete hierarchy. So, we can find that the microplastics are able to cause different impacts at different levels of the hierarchy. At the subcellular level we find that microplastics can influence enzyme activity; they can influence gene expression; they can influence oxidative damage. At the level of cells they can lead to apoptosis now apoptosis is programmed in death. So, microplastics may result in the death of different cells; it may hamper the membrane stability and may impact the phagocytic response.

Now, phagocytosis is the process by which a cell is able to eat. Now, if a cell starts to eat these microplastics then probably they will also impact the phagocytic response of different cells. At the level of organs they impact the histopathology, the metabolic demand of the organism and the energetic reserves that are there, because in the organs when plastics and special microplastics get accumulated then the energetic reserves are depleted.

At the level of individuals they may result in mortality; especially if an organism eats too much of these plastics and they impact a vital organ. Or they can impact the ingestion rates or the growth of the individual. At the level of population because the individuals are now not that fit and their organs are not working properly that will have an impact on the fecundity.

It may influence offspring viability because we have seen the case of this albatross in which the offspring viability was impacted because of the presence of plastics. And even and in the case of smaller organisms the micro plastics will also play a very similar role.

Now, the the saddest part here is that when this chick died because its body was all full and blocked by these plastics the body of the of this albatross chick because it is made out of biodegradable materials it will slowly degrade, but then these plastics because they are non biodegradable they remain persistent.

So, what will happen is that with the next range the these plastics will be able to come back they will again come back into the oceans and probably they will be picked up by some other albatross. So, this process goes on and on and so these plastics may result in the deaths of quite a large number of organisms. At the level of the ecosystem we have seen that plastics influence the behaviour of different organisms.

We have seen the image of this hermit crab which is now using this plastic or we have seen that a seahorse is using this plastic. Now, what happens is that if a particular species becomes too much acclimatized with these plastics it may change its behaviour to such an extent that certain other species may also get impacted.

So, for example, to take a simple example we can consider the pollination that is done by different birds and different insects. Now, suppose you have quite a large number of red colored or bright colored plastics that are strewn around on a field and suppose insects must take them for flowers and they land on these plastics and they spend all their time on these plastics in search of food.

So, they are not going to the flowers and in that case the pollination that these insects were doing in the flowers will get impacted. And so, because of the change in the behaviour of the bees and the insects the species of plants will also get impacted. So, at the ecosystem level as well we can observe different detrimental effects that are being brought about by these plastics.

So, how can we help? Well the good old technique is reduce reuse and recycle, reduce the amount of plastics that you use on a daily basis. As far as possible you reuse the components that are made out of plastics. So, if possible do not throw this bottle once you have used the water you probably fill this bottle again and you use it for some more time.

So, reduction in the use of plastics, reuse of plastics and recycling of plastics such as in this recycling facility are very important. But then if you want that people should go for reduction, reuse or recycling what needs to be done as we have seen in the principles of economics incentives need to be provided.

You need to induce people so that they shift away from plastics and they reduce reuse and recycle plastics as much as possible. And so economics plays a very important role here. Economics made it possible for plastics to come up in such a big way because they increased the living standards of different people, but then we can also make use of principles of economics to tackle this problem. Or we can induce people to go for lifestyle changes, use glasses in place of the straws or go for alternative materials such as bioplastics.

So, these days we also have biodegradable plastics that are made from natural products that have very similar properties. So, they are like this film of the bioplastic: it is completely transparent, it is flexible, you can mould it, you can bend it. And the strength of these bioplastics is similar to or greater than the strength of the common plastic such as the low density polyethylene. Or if we go for a bacterial cellulose composite of this plastic it is even greater than that of the high density polyethylene.

So, we have alternatives available with us, but then how do you induce people to shift into bio-

plastics? Again we have to make use of incentives. So, at all points of conservation we need to correlate the 10 principles of economics. Now, here the principles that are the most important are people and society face tradeoffs. Now, here the trade off is earlier. We shifted to plastics because the trade off was during World War 2, we did not have access to metal and so we shifted to plastics as a trade off.

But then once we shifted to plastics we improved their properties to such an extent that now plastics have become the mainstay and after a while they even overcame the amount of production of steel or of another material. So, there is always a trade off and this trade off has made it possible for people to shift to plastics.

But now again we are facing other trade offs. Now, the trade offers that we do not have sufficient landfills, our biodiversity is going down and these plastics are also leading to a large amount of pollution, they are leading to a large amount of filth and our beaches are dirty.

So, the use of this plastic started with a trade off because we did not have metals and the disuse of plastics is also being facilitated by a trade off. Because you have two options you can either use plastics and suffer all these consequences or you can shift away from plastics and save yourself from these consequences.

So, everywhere there is a trade off, and these trade offs lead to cost. Now, there is a short term cost and there is a long term cost. Now, in the short term manufacturing of plastics is cheaper so people shifted to plastics, but then the long term cost or the life cycle cost the cost of picking up all these filths and the cost of processing these filths is too large. The cost that we are suffering in terms of the loss of biodiversity is too large. So, this is an important economic principle that can save us from plastics; but we will have to emphasize the negative cost that we are facing because of the use of plastics.

Another important principle is that people respond to incentives. So, how do you incentivize people to reduce reuse and recycle? Well in a number of cases people have come up with an alternative that if there is a vending machine and if you put a used bottle into this machine you will get certain money out of it. So, this money is an incentive to promote people not to throw the plastic out into the litter, but to bring it to a machine where it can be easily recycled.

Another alternative incentive that has been formulated is provisioning of subsidies in the manufacturing of biodegradable plastics. Or provisioning of taxes in the case of manufacturing of petroleum based plastics. So, people respond to incentives and so if we want people to move away from these petroleum based plastics we will have to impose certain costs. And if you want people to shift towards biodegradable plastics or to reduce reuse or recycle we will have to facilitate that with certain incentives and here also comes the role of the governments.

Because these taxations and subsidies in most cases are given by the government they are implemented by the government. So, governments can improve market outcomes and in this case the market outcome in the case of plastics is not the most efficient one.

Because if the government did not intervene then there is a huge externality with the use of plastics because if I use if I use plastic I I carry all the benefit of the usage, but the cost of its littering the cost of biodiversity loss or the cost of making the surroundings dirty is born not just by me, but by everybody else.

So, it makes it possible for me to use the plastics more and more because I am not paying the cost, but then if the government comes up and says that ok we need to internalize these externalities through taxations and through subsidies . So, if somebody is using plastics we are going to tax it more, if somebody is using biodegradable plastic we are going to provide him or her a subsidy. If these things come up then probably the market will shift to a more optimum level.

So, the government can sometimes improve market outcomes and also a country's standard of living depends on its productivity. So, earlier we saw that the levels of plastics increased so much the production increased so much because most of the countries were emphasizing that we need to produce more and more.

Now, today as well we need to have more and more of different products, but then if we can emphasize that these products not only need to be cheap, but they also need to be environmentally friendly then probably we can shift away from the nuances of these plastics.

So, that is all for today. Thank you for your attention. Jai Hind!

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Module 3
Modern impacts necessitating conservation
Lecture 3
Oil spills and mining

Namaste!
We move forward with our discussion on the Modern Impacts that Necessitate conservation and in this lecture, we will have a look at Oil Spills and Mining . Now, before we proceed , it is important to note that disturbances can have different impacts on an ecosystem.
And the amount of impact or the quantum of impact depends on how large the disturbance is; it also depends on what is the state of the ecosystem when the disturbance came and it also depends on how frequently we are getting this disturbance. So, for instance if there is a normal community and here on the x y-axis, we are representing the state of the community; on the x-axis we are representing time.
If there is a normal community; there would be some ups and downs in the community state. So, there are some normal variations which are the natural variations that we observe in any community; none of the, none of the biological communities are a static community, there is always some level of dynamism.
Some populations would increase, some populations would decrease; there would be some changes in different parameters. But there is a level of natural variation, which is there and discover showing that this is the normal level of variation. And then if there is a single large infrequent disturbance; LID stands for a Large Infrequent Disturbance.
There is this disturbance at this point in time t and the state of the community shifts from normal to an altered state. So, from this normal curve, it comes down. But then because the community was a novel community; it would have some level of resistance and also some level of resilience.
After this disturbance is gone, the community would try to come back to its normal state. And which is what we are seeing here; there is this period of recovery and in this period of recovery, the community is trying to move back to its normal state. And after this recovery period, we find that there is this community which has come back to the state, where it was before the large infrequent disturbance.
In short, if there is a normal community and there is a large infrequent disturbance, the community will shift from a normal state to an altered state and after a time period for recovery, it will come back to normal. Of course, if the large infrequent disturbance is so large that the community has ceased to exist; then that is another matter .

But in most of the situations we observe that, after a while the community does prompt back. Now, what happens if you have another large infrequent disturbance? So, we are seeing a normal community here and then there is this large infrequent disturbance; because of it, it has come to an altered state.

Now, the community is trying to move back towards normalcy; but then you get another large infrequent disturbance. What happens then? So, in a number of cases it is possible that, because of multiple disturbances, the community is now no longer able to come back to the normal state. And in that case, the community will remain at this altered state for quite a period of time.

And it is also possible that the community never comes back to its normal state . So, the moral of the story is that, if you have a normal community; it would be able to withstand a single or maybe just a few large infrequent disturbances, but if you give it a disturbance again and again and again, it is quite possible that the community will change completely.

It will become an altered community; it will have a very different set of species that are able to live in that area or probably it will turn into an area which cannot support any further species. But this is what happens when the community is there in a normal state.

What happens if the community is already disturbed from the beginning? So, you have a community which is not normal, it is not altered; but it is somewhere in between and it is continuing like this and then you get a large infrequent disturbance , the community shifts to an altered state and now it is no longer able to come back .

Now, what can be the reasons for such disturbance to the community? Well, there could be many reasons, such as pollution. So, there is a community; so, you are talking about a forest for instance and in this forest, there is such a huge level of pollution that most of the animals are already safe.

Or let us consider a lake and in this lake, if we are dumping industrial effluents or some municipal waste; then there is so much level of disturbance that the lake community or the lake ecosystem is already in a very disturbed state. And if you have an ecosystem of a community which is already disturbed, you give it any further disturbance and it might not be able to come back to a natural state .

Now, in this context, what are the large infrequent disturbances? Some very common large infrequent disturbances are things, such as fires such as a forest fire. So, if you have a forest and you get a forest fire, large number of organisms spirit; but if you have a certain patch of forest that remains, then the organisms that remain in that area they will be able to procreate, they will increase in their populations, the trees that are there they would give off seeds and these seeds would then repopulate the whole of the forest.

These animals would then repopulate the whole of the forest. So, in the natural circumstance if you have a single forest fire, it is ok; the forest community will be able to come back. But then if you have a forest fire again and again and again and especially if it is not a natural forest fire, if it is an anthropogenic forest fire.

Now, in our country we know that as much as 95 percent of the forest fires are of human origin . Now, if that is the situation in a number of areas, then it is possible that we are shifting the community from a natural state to an altered state . Another LID is a storm or tsunami . Now, if there

is a large storm or if there is a tsunami; then we will also observe that quite a number of individuals, quite a number of species perished in large storms or tsunamis.

But if it is only a single incidence; then probably the community will come back, if sufficient numbers of individuals of the species remain in that area . Another large infrequent disturbance is an oil spill or things, such as climatic extremes, in excess of floods, in excess of drought.

These are all disturbances that are large in nature and at the same time they are infrequent; we do not get a drought every year or things such as heavy pollution, especially one that is due to mining. Now, in the case of mining, a very huge quantum of toxic materials gets dumped and that leads to a very large infrequent disturbance in the form of pollution .

Remember that when we are talking about multiple disturbances, it is not necessary that they should be of the same category. So, it is possible that the first disturbance was say a forest fire and the second disturbance was a tsunami. So, any of these large infrequent disturbances can play a role in bringing the community or the ecosystem to an altered state.

And if you have multiple of these, then the community of the ecosystem will permanently come to an alternate state and it will never be able to bounce back . So when we talk about a disturbed community , such that the community did not start from a normal; but it started from somewhere between normal and altered, then these are the examples of disturbances.

A disturbed community could be one that is already diseased. So, if there is a disease in a community, the individuals are already weak; they will not be able to come back to resilience. Or a community that is weed infested , especially one that is infested with an invasive alien species, such as lantana.

If you have a forest that is all covered with lantana; then it is already in a somewhat disturbed state, because the seeds of different trees are unable to reach the ground. And even if they reach the ground, they find it difficult to germinate, because of allelopathic factors. And even if they are able to germinate, then they are unable to grow; because they are all covered with lantana, they are not getting sufficient sunlight.

Now, in such a situation, if there is a forest fire; then we would have a situation where a large number of trees get perished and also because we do not have a sufficient number of seeds that are there buried in the ground, because of the lantana; then it is possible that the community will permanently come to an altered state.

Or a community that is facing competition from livestock, especially for grazing activities or a community that is already suffering from pollutants, such as a lake in which we are dumping industrial effluent or municipal waste or a community that is already facing climatic changes, such as global warming . So, all these are examples of disturbed communities and disturbed communities are much more susceptible to the disturbances and if you disturb a disturbed community further; then it is quite possible that the community will never be able to come back to a normal state .

Now, in this lecture, we will concentrate on one such large infrequent disturbance, which is the oil spills. Oil spill is defined as the release of liquid petroleum hydrocarbons into the environment. Now, as we all know, the liquid petroleum hydrocarbon; petroleum the word root is oleum is oil and petro is rocks.

So, this is rock oil. Essentially petroleum is made from the remains of animals that were buried millions of years back and because of intense heat and pressure inside the earth, slowly and steadily they got converted into petroleum. These are here. We drill holes into the earth and we extract these oils.

And after refining, we get things such as petrol or diesel or kerosene or LPG and so on. Now, if this liquid petroleum is deep inside the earth, if it comes to the surface, either naturally or because of some accidents or intentionally; but if it comes to the surface and if it gets released into the environment, then we say that we have a situation of an oil spill.

Now, this oil spill can occur on land or it can occur in water. On land a classical example is the Kuwaiti oil lakes that were formed during Iraq's invasion of Kuwait. So, in this case the oil gets spilled over the land and it forms lakes. An example of the marine oil spill is the deep water horizon accident of 2010.

In the case of a marine oil spill, the oil gets released into the water; it may come to the surface, it may form an oil split, it may spread to a large area or it is also possible that a portion of it gets dissolved or it gets sedimented. So, according to the location, we have terrestrial oil spills and marine oil spills.

This is how a terrestrial oil spill looks like. So, this is an oil lake in Kuwait and you can see that this large area of earth is inundated with oil. So, these are the oil pools that were formed. This is the deep water horizon oil spill and we can find that in this marine environment, you have a large amount of oil that is there on the surface .

Now, on the basis of how it got spilled, we have three different categories of oil spills; we can have natural oil spills, such as the oil spills in the Gulf of Mexico. Now, because the oil is found deep inside the earth, it is possible that some amount of it gets leaked. And this leaking oil will be known as a natural oil spill. An accidental oil spill is when nobody wanted to or to spill the oil; but then just because of an accident, it got spilled out into the environment, such as the deep water horizon accident.

And we can also have intentional oil spills, such as the Gulf war oil spill, in which case the armies may try in the process of destroying the oil wells, they may spill out the oil. So, it was done intentionally; the intention was to destroy the oil wells and the effect was that the oil got spilled.

Now, this is an example of a natural oil spill. So, this is the Gulf of Mexico and we can see that these lines are the oil that is getting spilled out naturally. When oil gets spilled, quite a large amount of hydrocarbon comes out into the environment. So, what is a hydrocarbon?

A hydrocarbon is an organic compound consisting entirely of hydrogen and carbon and they form a major chunk of the petroleum oil. So, petroleum oil is composed of a large variety of hydrocarbons, which are organic compounds made entirely out of hydrogen and carbon.

So, hydrocarbon; hydro is hydrogen and carbon is carbon. So, these are some common hydrocarbons that you find in oil; we find alkanes, cycloalkanes and also organic compounds, such as benzene, toluene, naphthalene, anthracene and so on . Now, on the basis of their specific weights are classified into groups 1 to 5; the group 1 comprises very low specific gravity hydrocarbons, such as kerosene.

Now, very low specific gravity means that, when these oils get released into a water environment, say a marine environment or a lake environment; then these are going to float on the surface of water. Group 5 comprises very high specific gravity oils, such as bitumen.
And here the specific gravity is greater than 1; which means that when they get released into the environment, then they are going to sink. If they come into a water body, they will sink to the bottom. And group 2, 3 and 4 are there in between. So, this classification based on specific gravity is useful when discussing the fate of oil and the persistence of the oil spills.
Now, hydrocarbons are also classified in one other way, which is on the basis of how they are formed. So, the first classification is petrogenic; petro means rock, and genics genesis is formation. So, petrogenic means hydrocarbons that are formed out of rocks.
So, they are derived directly from the mineral oils; of course we are not saying that there are rocks that get converted into hydrocarbons, but then these are the hydrocarbons that are directly derived from petroleum, that is the rock oil. So, these are petrogenic. Another category is pyrogenic; pyro means heat and genesis is formation. So, these are those hydrocarbons that are formed through heating, which are derived from incomplete burning of mineral oils.
The third category is biogenic; bio is life and genesis is formation. So, these are those hydrocarbons, whose formation is related to some sort of processing in life or in a living organism. So, these are derived from biological processes that are acting on mineral oils. So, what are these kinds of processes? What is the fate of oil in the marine ecosystem?
When oil gets released into the marine ecosystem, some part of it, especially the one that has low density or low specific gravity that will come to the surface; whereas the other portion that is of a greater density that will sink down in the form of sediments. So, the first thing is that we find some portion floats and the other portion sinks. A third portion may even get dissolved in water.
So, there could be certain compounds in the oil that get dissolved in water. Also we can have some amount of dispersion. Now, in the case of dispersion, we can have very small particles that remain suspended in the water. So, and when you have this layer that has come to the top, we can have some amount that gets evaporated especially due to heat.
There will be some portion that gets evaporated, some other portion may be reacted upon; because of air and because of light, in a process that is known as photo oxidation, and most of the oil will spread. So, when it spreads, it may even get into a beach, in which case we say that it has stranded into a beach or it can spread out.
There is also the process of emulsification; in the process of emulsification, the oil reacts with certain other compounds and becomes emulsified, which means that it becomes more and more dispersed in the water. Then I mean it is there on the surface and also inside the marine environment, it can interact with living organisms.
Now, if there are certain organisms, such as say a dolphin that comes to the surface for breathing or a bird that comes to the surface to catch a fish; then this oil may result in coating of their bodies, some portion may even be eaten or dropped by these animals. There will be these processes of coating and injection.
And finally, the oils that remain in the marine environment, some portion of it may get degraded by the living organisms and some other portion may get accumulated into their bodies in the

process that is known as bioaccumulation. When the oil spills interact with the organisms, it can have several impacts on the ecosystem.

When the oil gets coated upon the bodies of the organisms; it may result in physical smothering, which will reduce the ability of the organism to move, to feed and also there will be a loss of thermoregulation, which means that the organism will not be able to maintain its own body temperature, so it may die out of hypothermia or hyper or hyperthermia.

Also upon coating, there will be some amount of hydrocarbons that get absorbed through inhalation of volatile hydrocarbons. So, they are coming in through the air passage. So, the animal is breathing these oils and the volatile components are getting into the body of the animal through the air passages and some of these hydrocarbons may result in toxicity to the animal.

Another portion may get absorbed through the skin and with the mucous membranes. Again there might be some level of toxicity, because of this absorption. Then we had seen that some portion of this oil gets dissolved and the portion that gets dissolved may get absorbed to the skin or it may get absorbed to the food and in both of these cases also, there will be some amount of toxicity.

Now, there are several factors that influence the quantum of impact that the oil will have on these organisms. So, there are factors such as seasonality, the breeding season. So, if the oil spill occurs in a breeding season; then it is the season where the organisms need more food, because they are preparing to produce the next generation.

If it happens during the breeding season; then the quantum of impact on the ecosystem will be much greater or if there are eggs or juveniles that are present. So, if the parents get to the marine environment to catch a fish. So, suppose there is a bird that has laid eggs and one of the partners goes to the marine environment to catch a fish and its body gets covered with oil.

Once it comes back and once it sits on the egg; then it is possible that the egg will also get covered with oil. When that happens; then because there is a chick that is developing inside the egg, it will also get impacted. Or if there are juveniles; because we have seen in a number of cases that, very young or very old individuals are much greater impacted by any of these disturbances.

If you have juveniles; then the oil spill will have a disproportionate negative impact on the species. Then it also depends on whether the species is playing a key role in the ecosystem. So, if there is an impact on keystone species, such as mangrove; then the overall impact of oil spill on the ecosystem will be much greater.

Now, what is a keystone species? A keystone species is one that has a function in the ecosystem that is disproportionate to its actual numerical abundance. So, for instance if you consider an ecosystem and there are a few mangrove trees in that ecosystem; the roots of the mangroves will be providing shelter to n number of species of the marine environment.

Fishes will be using the roots to lay their eggs, so that the eggs are protected from the predators. The frogs will be using this area; the reptiles will be using this area. And the branches and the leaves of the mangrove are also used as food by a number of organisms; the branches are also used by different birds for their personal and boosting behavior.

Now, if mangroves get impacted because of the oil; then it will result in an impact on all of these different categories of organism. So, if the species that gets impacted is a keystone species, then

the overall impact of the ecosystem will be much clearer. Then lifestyle factors also play a role. So, animals with a long life span and especially those that have a k selected reproductive strategy are more impacted.

Now, what does that, what is k selected? Now, in a number of organisms we find that there are two major sorts of reproduction strategies ; the first is known as an r selection or a rate dependent selection. So, what happens in the case of an r selected species, such as mosquitoes.

Every generation will have a very large number of mosquitoes; the parent mosquitoes will not take care of the offsprings and there will be a large mortality in every generation. But still because so many large number of mosquitoes have been formed, they have been produced. So, even if a majority of them die off; the few that remain will lay so many numbers of eggs that the species will continue.

So, this is in r selected species. And if because of oil spill there is an impact on r selected species, the impact will be much lesser; because even if a few individuals remain in this species, the species will continue. On the other hand there are certain other species that are constant selected or k selected, such as elephants .

Now, in the case of an elephant, each litter only has a single offspring . So, in any birth you will only find a single calf. Now, this single calf requires quite a lot of support from its parents. So, the parents will have to provide it with food; the parents will have to protect it, the parents will have to train it.

And it will spend a very long period of time with its parents and ultimately when it becomes mature, it will have secure maturity at a very late age and when it also gives rise to its offsprings in every batch, there will be only a single elephant that gets spawned.

This is a k-selected species. The k-selected species emphasizes parental care and it emphasizes having less number of offspring .

Now, in the marine environment, there will be a number of fishes that are r selected; because each generation will be having say hundreds of eggs or say thousands of eggs.

But then there are also species such as whales or dolphins that are k selected; because they only give rise to a single offspring and they do a lot of parental care. Now, if a species is k selected, then the impact of oil spill, oil spill will be much greater; because a few individuals that will remain after being impacted from the oil spill, they will not be sufficient to continue the species, because they in any case will be having just a single offspring.

The lifestyle factors also determine what is the impact of oil spills on the organisms. Another factor is the health and condition of the organisms; if there are organisms that are already stressed, because of some disease or if they are migrating, then the impact is much greater.

And because of these factors we connect two terms with the impact; the first is vulnerability , vulnerability describes the likelihood that a resource will be exposed to oil. And the second term is sensitivity, which assumes that the resource is exposed to oil and then describes the relative effect of that exposure.

For instance a deep water coral; because it is deep inside the water is not quite vulnerable to a surface oil spill, because the surface oil spill comes to the surface and so an organism that lives here is not that much vulnerable, because it is not getting exposed. But it is possible that this or-

ganism, while not very vulnerable, is sensitive.
A deep water coral may be sensitive, so that if it ever gets exposed to even a small amount of oil; the impact will be much greater. So, you can have some certain species that are vulnerable. So, the species that come to the surface, such as dolphins, are much more vulnerable than deep sea species.
And there are certain species that are sensitive, such as the corals and there are certain other species that are less sensitive. Also when we talk about the oil spill, one major impact is toxicity; toxicity is the potential or capacity of a material to have adverse effects on living organisms.
When we say that oil is toxic; we mean that it has an adverse effect on living organisms. And this toxicity may be acute toxicity or chronic toxicity; acute toxicity involves harmful effects in an organism through a single or a short-term exposure whereas, chronic toxicity is the ability of a substance or mixture of substances to have harmful effects over an extended period, usually upon repeated or continuous exposure, sometimes lasting for the entire life of the exposed organism.
Acute means something that acts in a short period of time. So, an organism gets exposed to oil and there is an adverse impact right away, then we will call it an acute toxicity. But if there is an organism that gets exposed to oil, probably in a much lesser concentration. So, when we talked about the portion of the oil that gets dissolved in the water.
What we are talking about is that, there is a portion that gets dissolved. Now, there are organisms that are living in the middle or they are living in the bottom. So, they are getting exposed to a very small amount of oil that was dissolved in the water. So, they are getting an exposure of a very small quantity over a prolonged period of time.
Now, this will also result in certain toxicity. And in this case, we will call it a chronic toxicity. And especially when we talk about deep sea organisms such as corals or when we talk about octopus; then the chronic toxicity is much more important than acute toxicity, but when we talk about those organisms that come to the surface, such as dolphins or the birds that come to the that do fishing and then come to and then come in to direct contact with the oil, in those cases active toxicity is much more important.
Then we also define the term exposure; exposure is the combination of the duration of exposure to the chemical and the concentration of the chemical, duration and concentration. Now, why is exposure an important term? Well, it is because, if there is an organism that is getting exposed to a very concentrated form of oil, such as an organism that has come to the surface for breathing and it is completely covered with the oil.
Then it is receiving the oil in a very concentrated format; it is receiving with roughly pure oil. So, in that case the impact will be large. On the other hand, if there is an organism that gets oil in lesser concentration; but it gets oil for a very prolonged period of time. So, the concentration is less, but duration is large; then also we will find that the impact will be much greater.
Exposure tries to join both of these things together; the concentration of the toxic substance and the exposure or the time period for which the organism gets exposed to this toxic substance.
A combination of both of these is known as exposure. And when we talk about exposure, we also talk about the exposure roots, which is the way the organism is exposed to the substance which can include ingestion, which is the organism is eating the oil directly or it is getting the oil

through its food or absorption through the gills or through contact with skin.
And we also define magnitude; the magnitude of a toxic substance depends on the sensitivity of the organism to the chemicals and is also a function of the concentration and the duration that is the exposure. So, essentially what we are saying is that, if you have an organism that is exposed for a very less, to a very less concentration for a very less period of time and is also very less sensitive; in that case the magnitude of impact will be less.
But if the exposure is medium and the sensitivity is high or the exposure is large and the sensitivity is high; then the magnitude of impact of oil will be much greater . And when the impact is large, then we may even see lethal effect; lethality means death of the organism.
So, you have an organism that is exposed to a substantial period of time itself at sufficient concentration and the organism is also sensitive; then it is possible that the animal will or the organism will die, in which case we will say that the oil is having a lethal impact on that organism.
But we can also have sub-lethal effects, which do not result in a death; but they result in a reduction of biological function or health, such as the ability to grow, ability to reproduce or the condition of the skin. Now, whenever we find an oil spill, the lethal effects are much more pronounced and they are much easier to quantify; but the sub lethal effects take a huge quantum of time to manifest themselves.
And in a number of cases, we may not know even after the passage of a few years or a few decades about the complete impacts of oil spills that were there in different categories of organisms; which is why it is always prudent to avoid oil spills as far as possible and to manage them as soon as possible.
Now, we also define bioavailability, which is the extent to which a chemical is available for uptake into the organism; and in the case of oil spills, it is closely related to the display of toxicity and the rate of biodegradation. So, bioavailability is the extent to which the chemical is available for uptake.
Now, if the substance is bio-available, which means the oil has been spilled out and so is now available for uptake; then we may observe bio accumulation. Now, in bioaccumulation, the organism absorbs the toxic substance through the roots of exposure and it absorbs it into its tissues at a rate, which is greater than the rate at which the substance is lost from the body.
It means that, whenever the organism is taking oil through one of its exposure root; the organism will be processing this oil in its body to remove its deleterious or harmful impacts. So, there will be some amount of processing that happens in the level and then it will also be released through the kidneys.
Now, if the rate at which the organism is getting the oil is greater than the rate at which the oil is removed from the body; then we will have a net accumulation of oil in the body of the organism and this is known as bioaccumulation. And we also observe in a number of cases bio-magnification or bio-amplification
Now, bio-amplification or bio-magnification is the increasing concentration of a substance, such as a toxic chemical in the tissues of tolerant organisms at successively higher levels in a food chain. So, what it is saying is that, if there is bioaccumulation. So, say the oil gets stored in the lipid tissues of the body.

So, the organism that is lower in the food chain, such as planktons, they will have a lesser concentration of oil in their bodies; but those organisms that eat these planktons, they will be getting the oil that is there stored in the bodies of so many planktons.

If we say consider a zoo plankton that is eating up the phytoplanktons; the concentration of oil in the body of zooplanktons will be greater. And it will be further greater in the case of a fish that is eating of the zooplanktons and even further in the case of a fish that is eating up these fishes that were eating the zoo planktons. So, as we move up and up the food chain, the concentration of the toxic chemicals, in this case the chemicals from the oil it goes on increasing.

And we have demonstrated evidence of biomagnification especially in the case of chemicals such as DDD. And you can observe that, if the concentration is in water it is as low as 0.01 ppm; the planktons have 5 ppm, the fish have 4 to 300 ppm and the fish eating birds have 1600 to 2500 ppm.

Now, the important thing here is that, the planktons may not be impacted by such a low dose of DDD in their body; 5 ppm is a very small dose. But at this dose of 1600 to 2500 ppm; these birds will start showing symptoms and impacts of DDD in their body. So, biomagnification results in a greater concentration of the toxic chemical in the bodies which results in a much greater impact of the toxic chemical in the bodies of these organisms that are higher up in the future.

We can also quantify the impacts on different animals. So, the planktons are sensitive and the oils may result in acute chronic and sub lethal effects. However, they recover quickly, because they have short generation times. But the seabed life, it gets ecologically significant concentrations of dissolved or dispersed oil.

So, it is not getting exposed to the soil to the oil directly; because it is not there on the surface, but being in the seabed, it is getting dissolved or dispersed oil, but the impact is rarely below 10 meters. The subsea blowouts on that on the other hand, now here we are talking about the natural oil spill; so the subsea blowouts may have a higher potential for seabed impacts and deep water and sedimented hydrocarbons may also pose a risk to the bottom dwellers.

If you remember, here we said that a portion of the oil gets sedimented and when it gets sedimented; then the impact on this life on the seabed is much greater. Then in the case of fish, we see acute chronic and sub-lethal effects and from the point of view of fisheries industries, we also see a phenomenon that is known as tainting.

Now, tainting means that these hydrocarbons even in very low concentrations can be tasted or smelt in the meat and when that happens, then people do not eat those fishes. And so, the industry suffers a lot, especially economically; because the consumers no longer prefer these specials.

In the case of marine mammals that need to surface periodically for air, they get exposed in very high concentrations of oil. There is soiling of fur that impairs insulation and thermo regulation and also water repellence. The cleaning of fur when the animal tries to lick its body to clean it, then it may result in ingestion into the body, smothering of airways may also occur.

In the case of marine reptiles, that need to surface periodically for air, again there is exposure to higher concentrations of oil. Smothering of air which may occur and a seasonality of nesting and egg laying behaviours may increase the magnitude of impact. Now, here we are talking about marine reptiles, such as turtles. So, if it is the season of turtles laying their eggs and there is an

oil spill; then it will have a very tragic consequence on the turtle populations.
In the case of birds, physical oiling of their feathers may cause hypothermia; because it results in a loss of thermoregulation, it may also lead to a reduced ability to move, because their feathers are soiled; a reduced ability to feed, because they have ingested these toxic chemicals. Injection may occur through preening.
Now, preening again is the behavior of birds in which they are trying to clean their feathers or consumption of contaminated food, especially in the fishes. And transfer of oil to eggs or the young ones may reduce the survival of the next generation. In the case of shoreline and coastal habitats, the seaweeds are much better protected from oil impacts due to their mucus coating that resists the oil.
But the mangroves, which are keystone species; they can get killed by viscous oil that covers their pneumatophores. Pneumatophores are special adaptations, in which case the roots go against the gravity and come up for air and if these get blocked, then the plant will not get air. Burrowing crabs may get killed when their burrows are penetrated.
And so, it is important that we reduce the impacts of oil as soon as possible. Now, in reducing the impacts, the first thing is cleaning; cleaning is defined as the return to a level of petroleum hydrocarbons that has no detectable impact on the function of the ecosystem. So, in the case of cleaning what we are doing is that, we are reducing the concentration of these oils that have been spilled to such a level that they no longer pose a risk to the ecosystem.
And we will look at the methods of cleaning in a short while. The second thing that we need to ensure is a recovery; the recovery of an ecosystem is characterized by the establishment of a biological community, in which plants and animals characteristics of the community are present and are functioning normally.
What we are saying is that, in the cleaning operation, we will reduce the oil, we will remove the oil; but then because the oil already has had certain impacts on the ecosystem, we will ensure that the ecosystem is also able to recover back. Now, how do we ensure that it recovers back? If there are certain species that have become locally extinct, we may try to bring them from other areas and repopulate this area or we may try to ensure that there are no further disturbances to this area.
So, recovery operations also play a key role. Now, in cleaning operations, the first thing is containing and scooping. Now, in the case of container and scoop operation; we use booms to contain a spill and a skimmer to collect the oil from the surface. So, because a majority of the oil comes to the surface; so we can contain this oil by using serpent surface structures that are known as booms. And once the oil is contained, then it can be scooped using the skimmer.
The second operation is burning, in which case the oil is ignited on the site. The third is dispersal using chemical dispersants that break the oil into droplets and that this leads to emulsification and facilitates natural biodegradation. And a number of these dispersants are detergents and nothing else, but detergents.
Now, in the case of a detergent, it has a hydrophilic head and a hydrophobic tail. And so, when there is an oil droplet, it will be surrounded by these detergent structures to form a missile. Now, in the case of a missile, all these tales are pointing towards the oil droplet and all the heads are

outside.
This ensures that this oil droplet remains in the droplet form and it is able to disperse off. And because it is small in size; so it can be acted upon by a number of organisms, especially micro-organisms that can easily break it down .
Or in certain cases, we just leave it as such; because even addition of dispersants or detergents can have a negative impact. And if you have a very small amount of oil spill, then it is also prudent to just let nature act; because there are so many organisms that will be acting upon this oil.
So, it can be left as such for nature to take care of or we may make use of biological agents and fertilizers; which means that we can add the microorganisms or we can add nitrogen and phosphorus that promote their growth. So, if you have more microorganisms that are acting on the oil, then the oil will get cleaned up faster. So, this is the idea behind the use of biological agents.
Now, similar to an oil spill, another major large infrequent disturbance is mining. And mining has several impacts on the ecosystem, such as deforestation. So, this is an area in Balaghat district of Madhya Pradesh in the year 2006 and then when mining occurred, this is the result. So, you can observe that all of these forests, these thick forests, are now gone.
Mining results in deforestation, it results in soil erosion; because now all of the soil is exposed. And so, when it rains, then the soil will get washed away; if there are heavy winds, the soil will be removed. So, it increases soil erosion. Mining results in the creation of sinkholes; because now this area has been mined and in that case, it results in the formation of certain sinks in this area.
Now, these sinks can accumulate water in them and they may accelerate the process of weathering of the calcium rich rocks in that area, which will result in the formation of sinkholes. It also results in water pollution, especially in the case of tailings dams. So, tailings dams are those areas where the effluents are stored. So, in the case of this Balaghat mine, this is a tailings dam. So, the water that is rich in copper and other toxic elements is stored in this area.
And if you look at these trees that were there in 2006; in 2018 all of these trees are gone, because this is toxic water. Nobody is coming here to cut these trees; but the trees die themselves, because the water is toxic. So, it results in water pollution, there is a loss of habitats; direct loss, because the trees are gone and indirect loss because of pollution.
Now, this is an example of Ok Tedi Mine, which is there in Papua New Guinea and we can observe this mine through the years using satellite imagery. Now this is the mine in 1984. So, this is ok and we can see that this is a small area. Now, the important thing about this mine is that these people did not have a very good system of waste management.
Whatever effluents or whatever noxious chemicals were created by the mining operation, they were just dumped into the river. So, here we can see that we have this river and we have a river here as well. So, any of the dumping would be dumped into the river.
This is 1984, this is 1991. So, you can observe that this area has grown in size; we are also seeing a small growth in this side. But then the important thing is that, because of the polluting action of these minings that have been dumped into the river; we are also observing that the trees around the river are dying off.
This is the image from 1995. So, you can observe that on both sides of the river, now there is a

large portion of trees that have died down and the mine has increased even further . This is 1998. This is 2002. This is 2006. So, in all of these cases we are observing how these forests are getting destroyed.

From this: 1984, we get 2006, 1984 and 2006. So, what is happening here is that the trees are getting lost, the mining area has increased. So, here you can observe that the mine has increased in size 1984, 2006; then here as well there has been deforestation. So, this is an example of the impact of the mining operation on the local ecosystem.

Now, because oil spills and mining have such a huge impact on the ecosystems, we require strategies to protect the ecosystems. The first strategy is to avoid setting up oil rigs and mines in especially vulnerable spots. Now, in our country, it is mandated that there are certain go areas and there are certain no go areas. Now, certain no go areas especially those that are there around the national parks or wildlife sanctuaries or tiger reserves.

In those areas, if somebody wants to have a permission to set up an oil rig or to set up a mining operation; then this permission is frequently denied, because these areas are especially vulnerable. If there is anything that goes wrong, quite a large number of species will die.

In those areas where permission has been granted for oil rigs or for mining operations; we require better technologies, better technologies to prevent the spills, better technologies to reduce the amount of pollutants that are generated, better technologies to ensure that all the tailings are disposed of properly without polluting the environment. So, better technologies are required.

We need to develop models to anticipate the spread. So, if there is any oil spill in any area, which direction will it take. If you know the direction, then you can concentrate your cleanup operations or recovery operations in those areas. And so, we need to have mathematical models that can tell us where to concentrate our resources.

Similarly, if there is a mine that is being set up; we need to know where we can have situations of say landslides or if the tailings are being put into a dam, then where the dam can break, where can accidents occur, so they need to be known. So, we need to develop models to anticipate spread.

We need to maintain rapid response teams and technologies; because accidents can occur at any point of time, so it is always prudent to be better prepared. Utilize studies on long-term impacts and mitigation options. Now, we may not know everything; but there are a lot of studies in a lot of countries and most of these studies can be implemented in the local situations as well.

It is always a good idea to make use of these studies and try to improve the degraded habitats. Because if a habitat is already degraded and if you give it one more disturbance; then probably the ecosystem will collapse, the community will collapse. So, it is also important to improve the degraded habitats.

Now, in improving the degraded habitats, we have certain options that are available with us; the first option is recovery or neglect. So, in this case, we just say let nature take its own course; we may ameliorate the degraded habitat or we may even make it more degraded through such an operation.

When we say that we are following the root of the recovery or recovery through natural needs or of neglect; what we are saying is that, if there is a mind that has been set up and the mind has a

result, it has resulted in a huge area of earth that has been excavated, then we just leave it as such, because we say that ok nature will take its own course, the trees will come up and in a short while it will be, ok.

Now, it is possible that the site may become better by itself with time; because the trees will come and occupy this area. But it is also possible that if we do not do anything; then because of the heavy amount of soil erosion, this area will be even further degraded. Other option that we have is rehabilitation or reclamation, which is shifting the degraded habitat towards a greater value though not necessarily the original state

So, in the case of rehabilitation or reclamation what we are doing is that, we are not targeting to bring this degraded state back to the normal state. So, for instance in the case of our mine, the area that has been excavated; we will say that ok, we are not aiming to bring it back to the natural forest, but probably we will bring it to say an artificial plantation.

That is better than leaving the land excavated as it is, though it is not as good as bringing it back to its natural state. So, this is the second option, which is known as rehabilitation or reclamation, where we convert it into, where we will shift the degraded habitat towards the greater value though not necessarily the overall state.

If we aim to bring it to the original state, we call it restoration; restoration is actively trying to return the habitat to its original state. So, in the case of restoration, we are trying to bring it back to the same natural forest that was cut down for the mining operation.

Another option is enhancement, which is improving the value of the habitat. So, in this case we say that ok, we will not do much of the activities; but we will at least try to improve the value of this degraded habitat for the wild animals, such as construction of water holes for animals.

Another option that we have is replacement, which is creating a new habitat in place of the degraded habitat. So, for instance there was a forest that was mined; you have a mine pit. So, you do earthwork and water filling and convert it into a marshy wetland. Now, this marshy wetland is a very different habitat as compared to the original forest; but this is at least a habitat for certain organisms, it is better than leaving it as it is.

So, these are the improvement options that we have. If you have this degraded habitat, say, because of mining in a state of neglect, in which case it may remain degraded, it may further degrade or it may improve to some extent. The other option is reclamation.

Now, if in the case of reclamation; we try to change it or we try to bring it to the original habitat, but not to the full way . The third option is restoration, where we try to bring it back to the original habitat. And we may even do an enhancement, where we try to enhance its utility even further.

A replacement in which case we have converted this degraded habitat into our wetland habitat. So, we are not trying to bring it back to the normal state, we are not trying to bring it back to the forest state; but we are developing a different kind of habitat. So, these are the improvement options.

Now, in the case of mine restoration, there are different methods that we can use or different operations that we can do, such as flattening of waste dumps and landfills to prevent erosion. So, in this case what we are doing is that, the waste dumps that are left out. So, it is easier for water and

when to erode them.
So, we will try to level them down, so that the amount of erosion is reduced. We fill up the dug pits, so that the amount of leaking of chemicals into the water table is reduced; because these are now filled up with the earth or we cover with a layer of clay to prevent access to rain and oxygen.
So, in this case we are covering it with clay, so that rain water is not able to seep into those areas that have these toxic elements. And so, we are trying to again stop the amount of or reduce the amount of leaking into the groundwater. Or we can cover the area with a layer of topsoil and perform a plantation operation, so that you have trees in this area.
Or in the case of tailings dam; because they have a huge quantity of water and they also have a huge quantity of these toxic elements, we may try to evaporate the tailings dam to concentrate the waste materials in that area and once they have been concentrated to an extent, they may be removed from the area.
And these days it is also important to perform the environmental impact assessment, whenever we are trying to to give permission for any such activity. Environmental impact assessment is a process of evaluating the likely environmental impacts of a proposed project or development.
This is done before the permission is granted. Before giving somebody a permission to set up an oil rig or to mine in a particular area; we try to study what could be the likely impact of this activity on the local environment; taking into account, the interrelated socioeconomic, cultural and human health impacts, both beneficial and advanced.
In the case of environmental impact assessment; we also take into account the related socioeconomic aspects, cultural aspects and health aspects. So, we try to ensure that all the stakeholders are positively benefited by any of these projects; if they are negatively impacted in a large way, then the permission should probably not be granted.
So, in this lecture, we had a look at two major large infrequent disturbances; the oil spills and mining. So, that is all for today.
Thank you for your attention, Jai Hind!