Conservation Economics

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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 organism, 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 microorganisms 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!