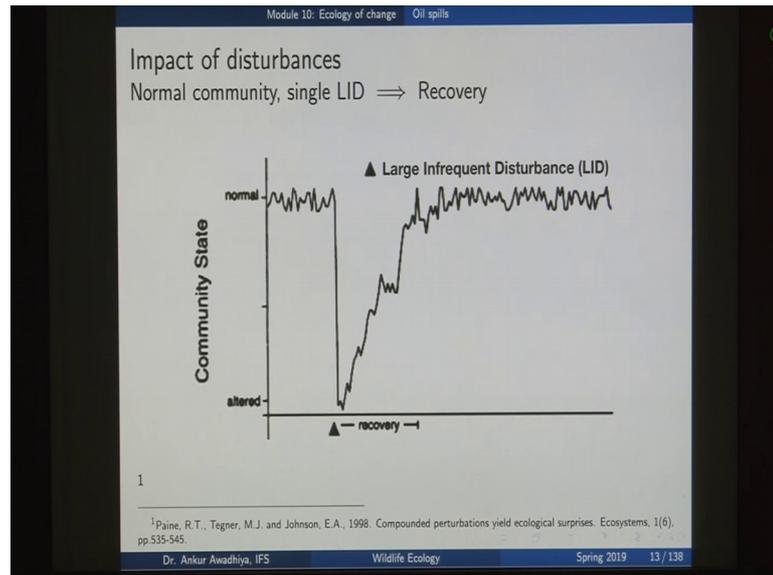


**Wildlife Ecology**  
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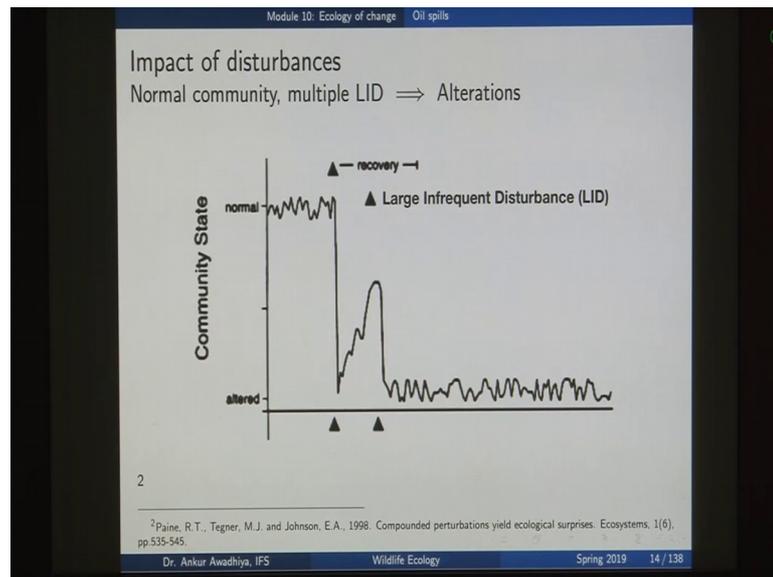
**Lecture – 29**  
**Plastic and biodiversity**

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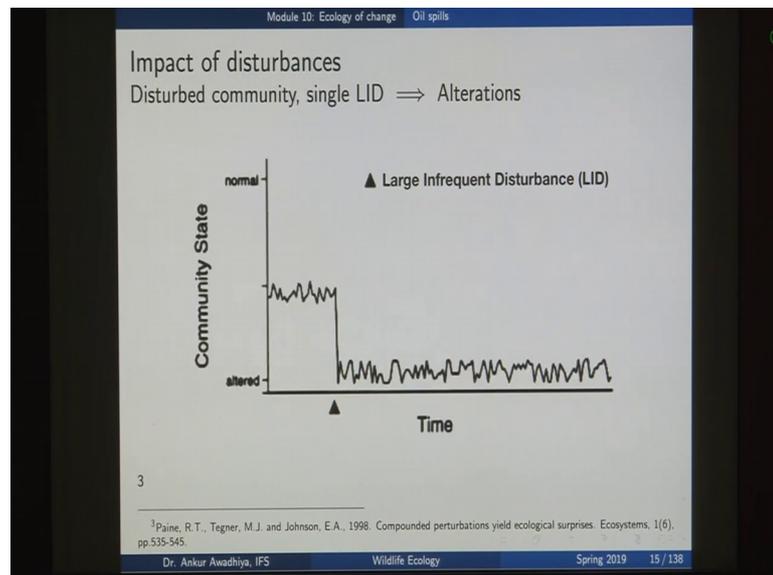
[FL] We move forward with our discussion of the ecology of changes. And today we will have a look at the impacts of plastics. Now, in the last lecture, we had seen that the impacts of disturbances depends on the kind of disturbance, how large it is and also the status of the community. If you have a normal community, you give it a large infrequent disturbance. So, the status moves from normal to an altered status, but then slowly with time it comes back to the normal status again. So, it tells us that this is a resilient community.

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On the other hand, if you give it more than one large infrequent disturbances, so you have this normal community, you gave it a disturbance, it became an altered community. Then it was trying to come back to the normalcy, but you gave it another disturbance, and it becomes an altered community for a very long time, it is not able to cope back.

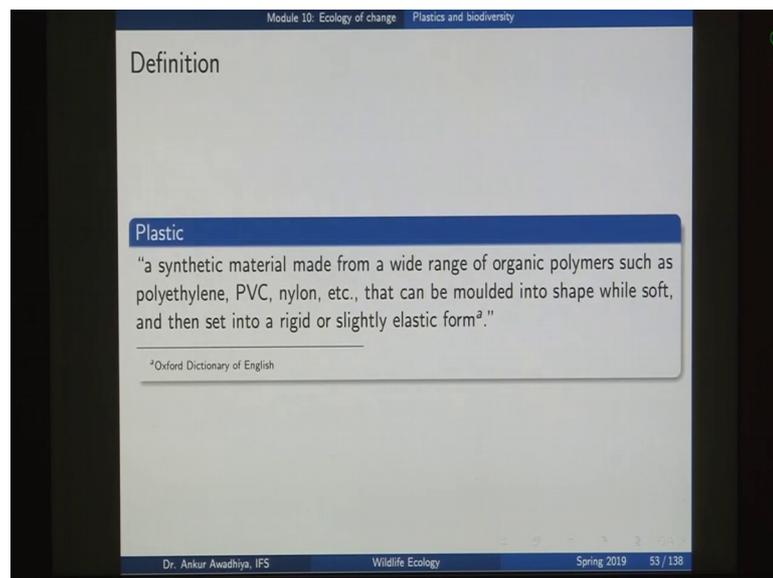
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And the third instance was if you have a community that is not a normal community, but it is already suffering some amount of stress or some amount of alterations and you give it a disturbance, and it is not able to cope up again. Now, in today's lecture, we will have

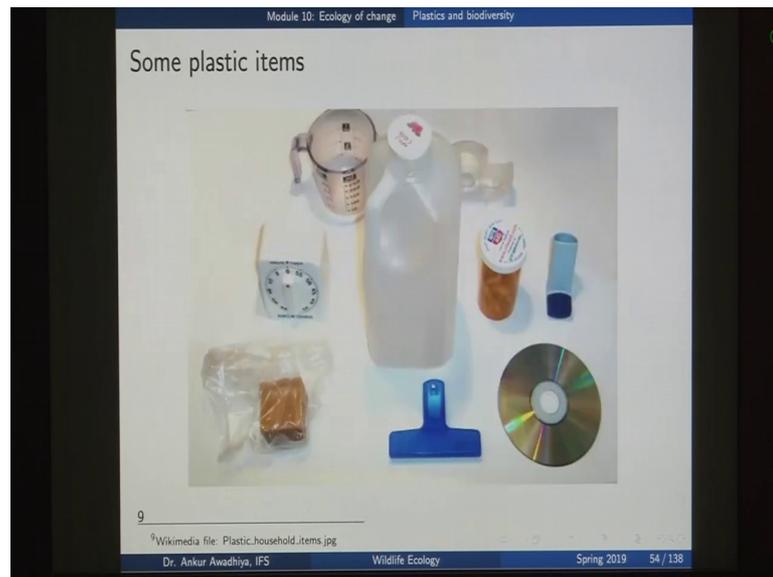
a look at such communities. Now, if you have a biological community, and there is an influx of plastics into this community. So, it is possible that the organisms become stressed and they are not able to reach their full potential, and that access bits the impact of any other disturbance that the community might face.

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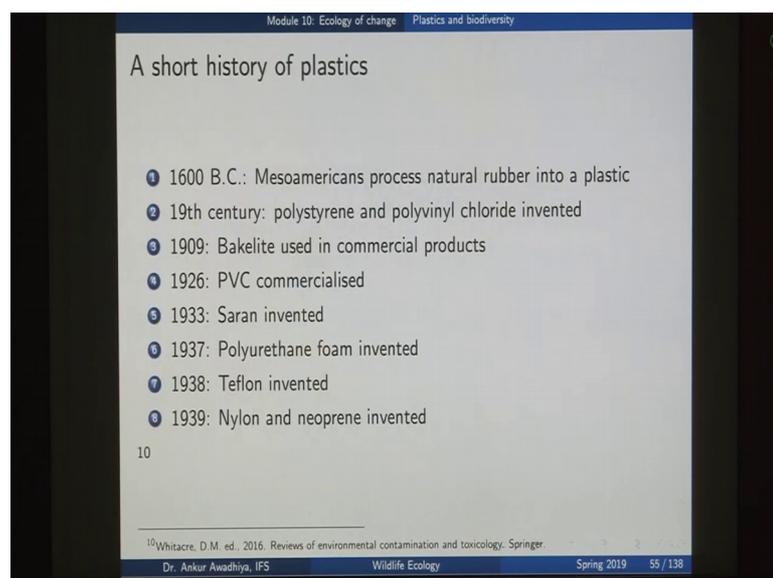
So, we begin with the definition of plastics. So, plastic is a synthetic material made from a wide range of organic polymers such as polyethylene, polyvinyl chloride, nylon etcetera that can be moulded into shape when soft, and then set into a rigid or slightly elastic form. So, we know plastics because plastic surround us.

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So, we find plastics everywhere. Even in this room even in the room, you are sitting in you will observe a number of plastic items, starting from your pins or components in your computers, took maybe chairs, to maybe buttons in your dresses and so on. So, plastics surround us, and so it becomes important to understand, the impact that plastics may have on different communities and ecosystems.

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So, we will look at a short history of plastics. So, the earliest use of plastics began in 1600 B.C, where Mesoamericans were processing natural rubber into a plastic. So, they

were converting natural rubber into balls, and they used to play with these balls, so that is the earliest known usage of a plastic material.

Now, in the 19th century, we started seeing plastics in a bigger way. In the 19th century polystyrene and polyvinyl chloride were invented. Then in the 20th century, in 1909 Bakelite was used in commercial products ok. By 1926 PVC was commercialized, and then saran was invented then polyurethane foam, but invented then Teflon was invented nylon and neoprene got invented. We are saying that all these plastics, most of the plastics that are surrounding us were actually invented in the 20th century.

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Module 10: Ecology of change Plastics and biodiversity

### A short history of plastics

- 1 1941: PET / polyester invented
- 2 World War 2: Metals become scarce, plastics widely manufactured to replace them
- 3 1951: HDPE and polypropylene invented
- 4 1954: Styrofoam invented
- 5 1979: Plastic production in the US exceeds steel production

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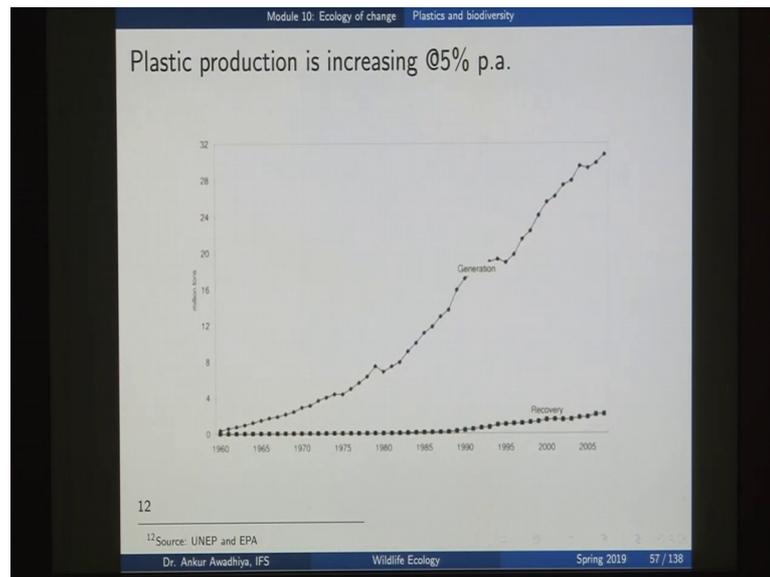
<sup>11</sup>Whitacre, D.M. ed., 2016. Reviews of environmental contamination and toxicology. Springer.

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Then we had the emergence of polyethylene terephthalate and polyesters. Now, PET is something that is there in all the plastic bottles that we are using especially the disposable water bottles they are all made of polyethylene terephthalate PET. Then (Refer Time: 03:56) World War 2, the best metals became more and more scarce. So, plastics were widely manufactured to replace them. So, this got a major boost during the World War 2 and then this boost continued.

So, in 1951 high density polyethylene and polypropylene got invented. 1954 you had the invention of Styrofoam. So, once Styrofoam was made out of polystyrene, so now it became available for a number of packaging applications. And by 1979 the plastic production in the US started to exceed the steel production and this is continued since then.

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And in fact every year, we see that the amount of plastics that are produced is more than what was produced in the last year. So, the plastic production is increasing at the rate of 5 percent per annum.

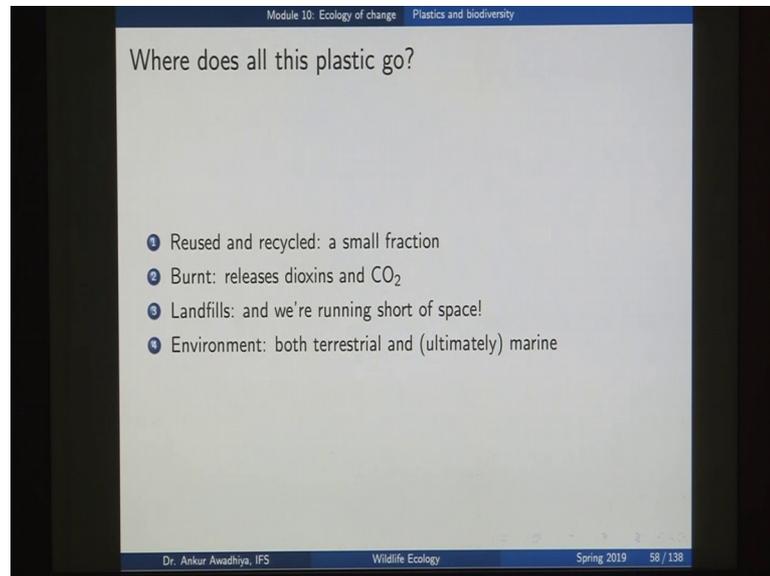
Now, what happens to all of these plastics, everything has a shelf life, everything has a usable life. If you are using a plastic pin, after its life is done, you throw it down in the dustbin. But, then what happens to this plastic pin, after it has been thrown into the dustbin? Does it get recycled, does it get reused? Because a big property of plastics is that a number of biological entities are not able to act on it.

So, for instance, if you have an item that is made out of wood, and after its usage, when you throw it down, so there would be a number of decomposers that would act on this wood, and then break it down. Once that is broken down, so the elements get released back into the ecosystem. But in the case of plastics, because these are manmade materials and because a number of organisms do not have proper enzymes to cut these plastics. So, they have a tendency to remain in the system. So, organisms will not be able to digest these plastics.

The only way in that is left out is that we should be able to recover these plastics, and maybe remould them into some other item. But, then if we look at how much of these plastics has ever been recovered, we see that it is a very miniscule fraction of what was

produced. So, it is like hardly 4 or 5 percent or less than 10 percent of plastics that has ever been produced, it has been recovered.

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So, if you are not able to recover these plastics, if we are not able to recycle them, where do these plastics go? So, as we have seen the reused and recycled portion forms a very small fraction of the total amount of plastics that is being produced. So, for the rest of the plastics, there are instances where people try to burn them off, because you have a heavy amount or a large of plastics, by burning them you can at least convert some of its hydrocarbons into gases, so that they get released and your amount of the waste gets reduced.

So, in place of having a very huge volume of plastics that you will have as part of a waste material, when you burn it down, so most of the gases would be released would be released, and then it will shrink down, so very small fraction which will then be put into a landfill. But then it has been observed that when you burn plastics, you release dioxins which are extremely toxic compounds, and you also release carbon dioxide or in most of our cities, these plastics go into the landfills.

Now, if you put plastics into a landfill, they are going to remain there for hundreds or even thousands of years, and we are running short of space for landfills or if you are not able to burn these plastics, if you are not able to reuse and recycle them, if you are not putting it into a landfill or even if you are putting it into a landfill and there is some rain

and some amount of these plastics get washed down, ultimately they reach the environment.

When there is the environment, they reach the terrestrial environment, and also the marine environment. Now, when we talk about release into the terrestrial environment, so you can have plastics that are reaching into your forests, you have plastics that are reaching into the croplands, and there are a number of animals that are getting exposed to these plastics.

On the other hand, when the plastics get washed down, they can move from small streams into larger streams into rivers, and ultimately they reach into the oceans. And then the plastics are then exposed to the marine organisms. So, both terrestrial ecosystems and the marine ecosystems are these days getting exposed to these plastics. So, it becomes important to know, what is the impact of these plastics on these ecosystems and even more so in the case of the marine ecosystems, because ultimately these plastics are going to reach into the marine ecosystems.

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Module 10: Ecology of change Plastics and biodiversity

### Fate of marine plastics

- 1 15% float on surface
- 2 15% wash ashore
- 3 70% sink to ocean bottom

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<sup>13</sup>Barnes KA, Galgani F, Thompson RC, Barlaz M (2009) Accumulation and fragmentation of plastic debris in global environments. *Philos Trans Royal Soc Lond B: Biol Sci* 364(1526): 1985 - 1998

<sup>14</sup>UNEP (2001) Marine litter - trash that kills. United Nations Environment Programme

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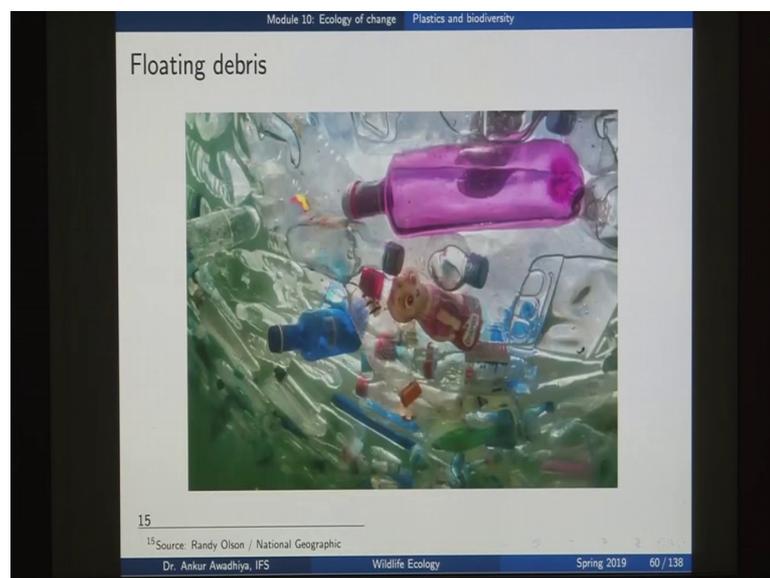
So, what happens, when plastics reach the seas or the oceans? The fate of the marine plastics is this 15 percent keep floating on the surface, 15 percent get washed ashore to reach the beaches and the shores, and 70 percent sink to the ocean bottom. So, what happens to the 70 percent? This 70 percent is now exposing itself to the benthic

organisms to the benthic ecosystems or the bottom dwellers, to the crabs for instance, to the starfishes for instance.

The 15 percent that remains floating on the surface, they are being exposed to the sun, they are being exposed to air, so they might break down into smaller portions or otherwise, they might get picked up by fishes that are they might get picked up by birds that are looking out for fishes, because these look like a fish that is that has come to the surface. So, a bird might not be able to distinguish, whether it is a piece of plastic that is floating on the surface or whether it is a fish that has come to the surface. So, a bird might pick it up.

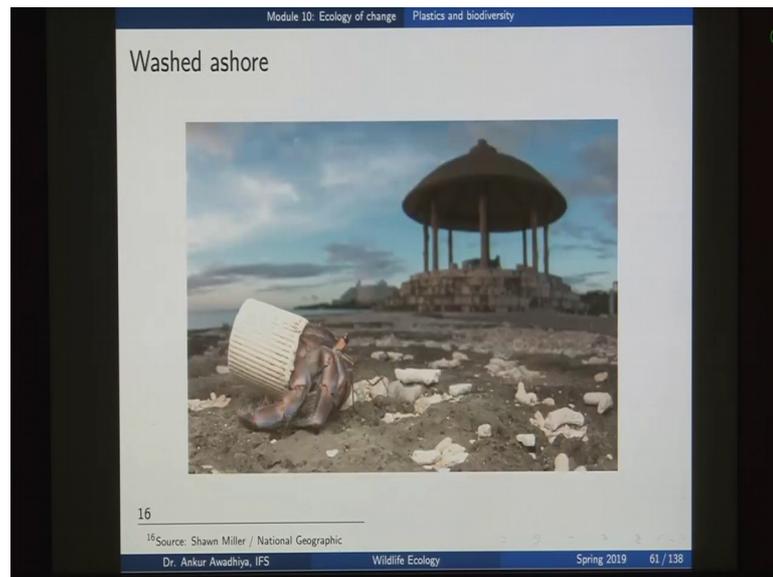
And if it gets washed ashore in that case a number of organisms that live on the beaches will get exposed to these plastics. So, we have 15 percent floating on the surface, 15 percent washed ashore, and 70 percent that is sinking to the ocean bottoms. So, how does that look like?

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This is what plastic looks like, when it is floating on the surface. So, these are all waste materials that have been released into the environment. And they have return into a water body, and because like this bottle it has lots of air inside or this doll, it has a lot of air inside, so it is less dense than water, and so it is floating on the surface of water or else when it gets washed ashore.

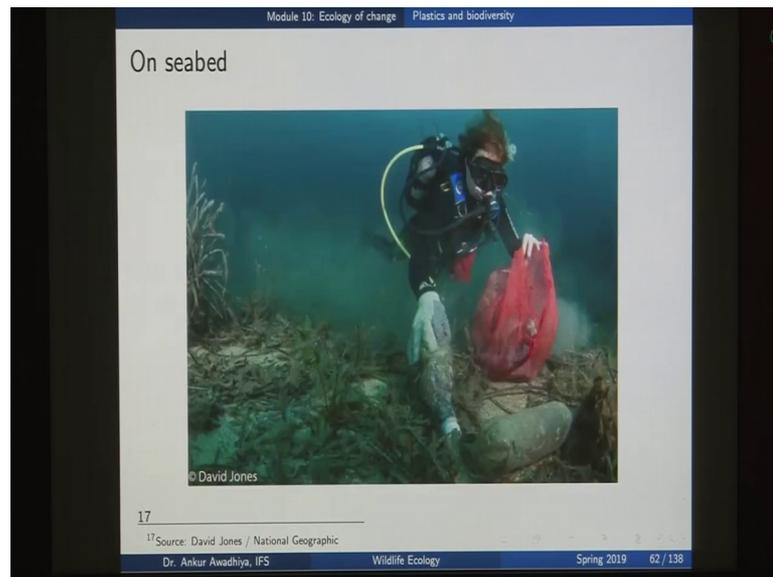
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So, here we are observing the example of a hermit crab. So, we had seen this example, when we were talking about the ecological interactions the positive interactions, where we had seen that a hermit crab is an organism that is very easily predated upon by a number of predators. So, to protect itself, it uses the shells of other organisms.

So, it uses the shells of mollusks. And so if there is a shell that is available, so this hermit crab would try to squeeze itself inside that shell, and it would carry that shell along with its body, so that it forms a protective cover. Now, in this example, we are observing that in this deplorable state of affairs, this hermit crab is using the cap of a bottle as its outer shell.

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So, we are observing changes in the behaviours of organisms or when it reaches into the sea beds. So, here we are observing a number of plastics that are there on the sea beds, you have these bottles, you have some bags and so on. And the organisms that are living on the sea bed are now getting exposed to these plastics.

Now, when we are talking about plastics, so all these plastics are of different shapes and sizes, you have some large pieces of plastic, you have some smaller pieces of plastics. And in the case of this bottle cap, we can observe that it is already in a degraded state so. Some parts of it have come out, they have become chipped out.

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Module 10: Ecology of change Plastics and biodiversity

### Size classification of plastic debris

**Macrodebris**  
> 20 mm in size  
Ghost nets are the main concern.

**Mesodebris**  
5 - 20 mm in size  
Dominated by 'nurdles': resin granules that are intermediates in plastic production.

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So, when looking at the impacts of these plastics, we classify these debris into three categories. The first category is known as the macro debris macro is large size. So, macro debris is a debris that is greater than 20 millimetres or 2 centimetres in size. So, when we are talking about the this bottle, so this bottle is greater than 2 centimetres in size. So, this is a part of a macro debris. And in this case ghost nets are the main concern. So, we look at ghost nets in more detail in a short while.

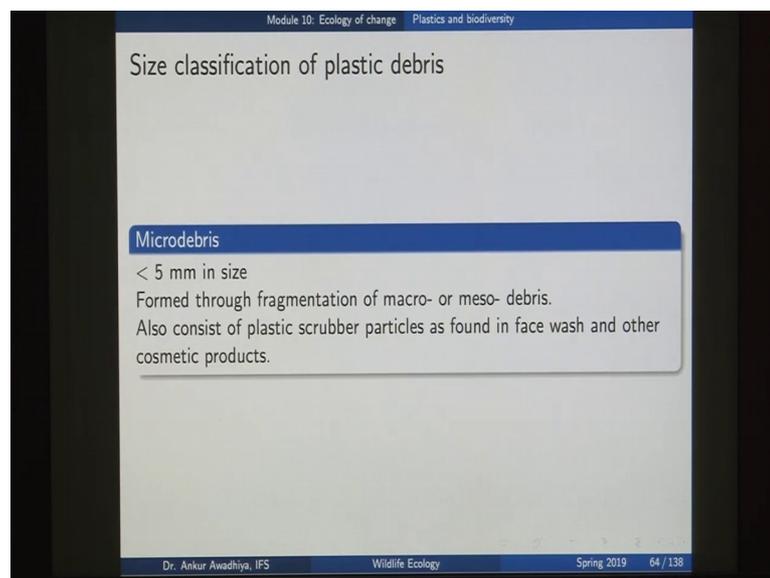
The second category is a Meso debris, meso is in between. So, 5 to 20 millimetres in size, they are meso debris. And these are dominated by nurdles, which are raised in granules that are intermediates in plastic production. Now, how are plastics made? So, you take out petroleum, you make chemicals out of it, then you polymerize those chemicals, so that you have the basic building blocks of plastic. Now, those basic building blocks are then made in the form of small granules, so that it becomes easy to transport and so that you can take this plastic from the place it was manufactured to the place, where it should be casted into some other useful shapes.

So, you will have small particles, small granules that will be taken from one place to the other place in these particles are known as nurdles. Now, in the factory where the items have been being manufactured; so in the factory where the spin was manufactured, these nurdles will be taken, they will be heated, so when they are heated they become soft, they become liquefied, and then it is casted into this shape; so those are nurdles.

Now, nurdles because of their small size, they are classified as Meso debris. Now, why should nurdles become debris? Suppose there is a ship that is carrying nurdles from one country to another country, so there is one country that is making the polymers, then it converts it into nurdles. And then it is shipping it to another country that will then use these nurdles to make items of use.

And suppose this ship capsizes or maybe a few boxes of nurdles become capsized out into the oceans. So, these nurdles have now come out into the environment. Otherwise also, if there is a factory that is using these nurdles to make safe pens, so some amount of nurdles may get released during the normal process of production. So, all these nurdles, when they reach into the environment, they are classified as Meso debris.

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And the third thing is known as micro debris, micro is small. So, micro debris is something that is less than 5 millimetres in size and they are often formed through fragmentation of macro or meso debris. So, if you have a large sized particle or a large debris, and it is getting broken down, so it will form a micro debris. And they also consist of plastic scrubber particles as are found in face wash and other cosmetic products.

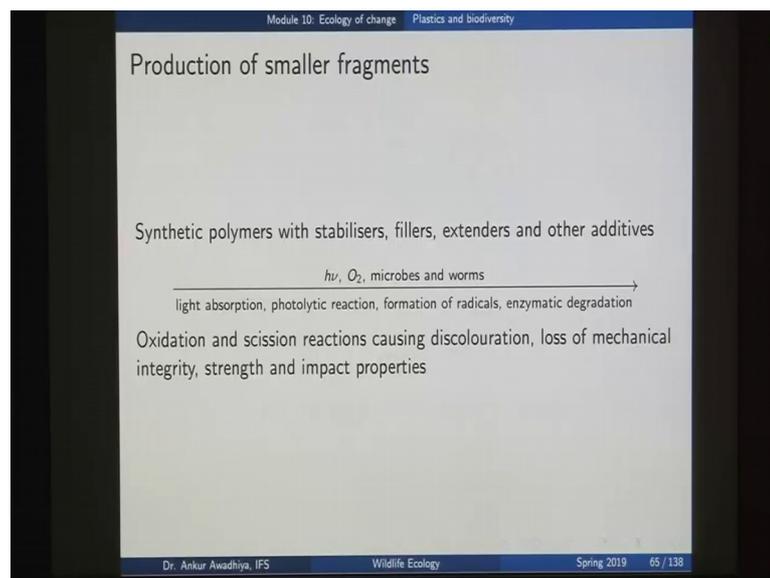
Now when we are talking about the formation of the micro debris, because in a number of situations micro debris play a very big role in the ecosystems; why? Because say you have a pen that is floating on the surface of water; now, there could be a few birds that

would identify this as food and try to pick it up and try to feed on it, but then that number will only remain limited to a few organisms or a few species of organisms.

Whereas, when we are talking about micro debris, they are so small that a number of organisms that are there in the ocean will get exposed to these small particles. So, even when they are looking out for food, these particles might get ingested along with the food or in the case of fishes that are using gills for their respiration, these small particles might get in inside and get lost into the gills of these organisms.

Even in the case of planktons, these micro particles this micro debris can get eaten up by these plankton, and reach into the food chain. So, micro debris become extremely important, when we are analyzing the impacts of plastics on the ecosystem. So, how do these micro debris form?

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So, the production of smaller fragments or the production of micro debris or even meso debris from macro and from macro debris and meso debris, it occurs like this. So, you have synthetic polymers that have stabilizers, fillers, extenders and other additives and when they are out in the environment, so they are acted upon by the UV light, so here you have  $h\nu$  that is photons. So, it is being acted upon by light, then it is acted upon by oxygen. So, there is some amount of oxidation reactions that are going on, then they are also acted upon by microbes in worms.

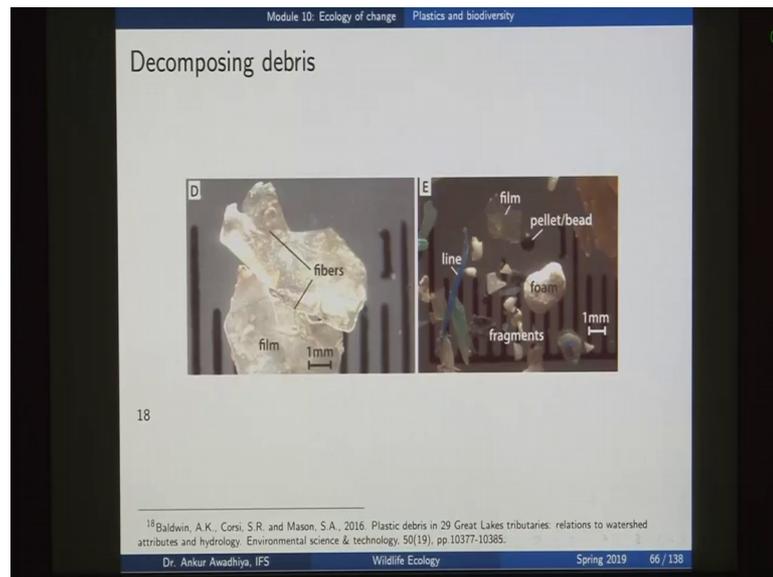
Now, when they are acted upon by these agents, so they we have processes of light absorption, photolytic reaction, now photo is light, lysis is breakdown. So, this is a breakdown reaction that occurs because of light. So, you have photolytic reactions, you have formation of radicals, and you have enzymatic degradation that then an oxidation and scission. Now oxidation we know is that is the action of oxygen or addition of oxygen, and scission is a breakdown reaction or a cutting reaction.

So, you have a scission reaction that causes discoloration, loss of mechanical integrity, strength and impact properties. So, essentially what we are saying here is that if you consider a plastic, so suppose you are considering this plastic bottle, and if I press this is this plastic bottle, it will be able to come back to its original size, because there is some amount of elasticity in this material.

But, then if I leave this plastic out there in the sun for some time, so you will observe that this transparent plastic starts getting whitish in colour. Now, when we are seeing that it is changing colour, it means that there are some chemical reactions that are going on. Once it becomes whitish in colour, it also becomes brittle. So, if we press that again, so in that case it is converted cells into a powdery substance. And this is what we are talking about here. So, we have all these reactions that are causing discoloration, loss of mechanical integrity, strength and impact properties.

So, now if two plastic particles collide against each other, two debris particles collide with each other or suppose you have this plastic that is going and colliding with a rock, so in that case this will start breaking off, small pieces will start chipping out. And if those small pieces are less than 5 millimetres in size, then we will say that these are micro debris.

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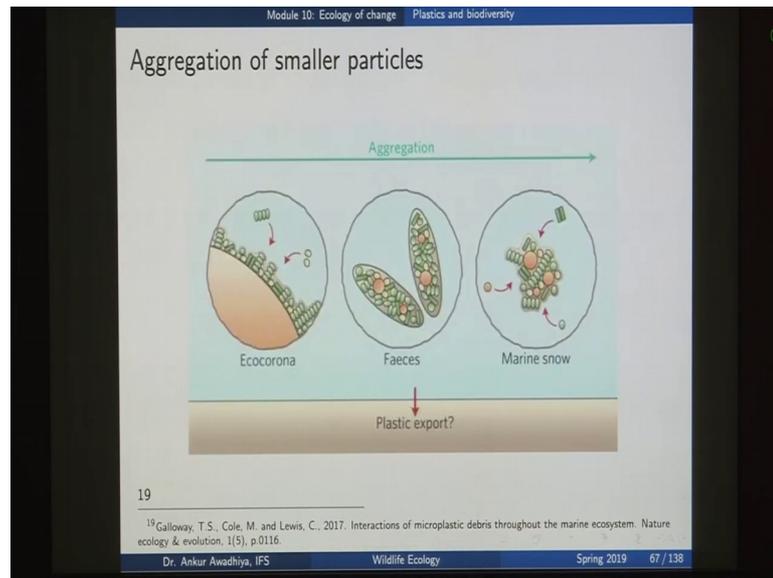
And we see examples of these everywhere. So, now if we talk about our decomposing debris, here you have a polythene sheet. And in this case, you have this film and small fibers that are now coming out because of the process of the decomposition. Now, mind you when we are talking about decomposition, this is different from the decomposition that we observe in the ecosystems. Because, in that case any material gets decomposed completely, so that it becomes the nutrients which are then taken up again by the food webs.

But, in this case, when you are converting your plastic into a smaller fragment, this is smaller fragment is not a part of the nutrition cycle anywhere. So, it is not taken up by any of the organisms for food or at least, it is not voluntarily taken up by any organism for food, and it cannot be used as a food. Even if it gets into the bodies of some organisms, it is only going to create a blockage, it will not provide nutrition to the organism.

Now, if you look at any pond or all most of the water bodies will observe things like, this a small piece of film. Now, here we have this size, so this is 1 millimetre. So, this piece of film that is floating around, this is a micro debris. You can even have some pellets or beads, so you can have nurdles or you can even have some pellets that are coming out of the cosmetic product just face washes. So, they are used as scrubbers in face washes, and they might also come out.

You can even have fragments that are made out of foam. So, when we are talking about Styrofoam, and we are talking about thermocol small pieces might come out, so they will have the property of a foam, but then they are also very small in size or you can have these fibers. So, this is a line that is made out of plastic.

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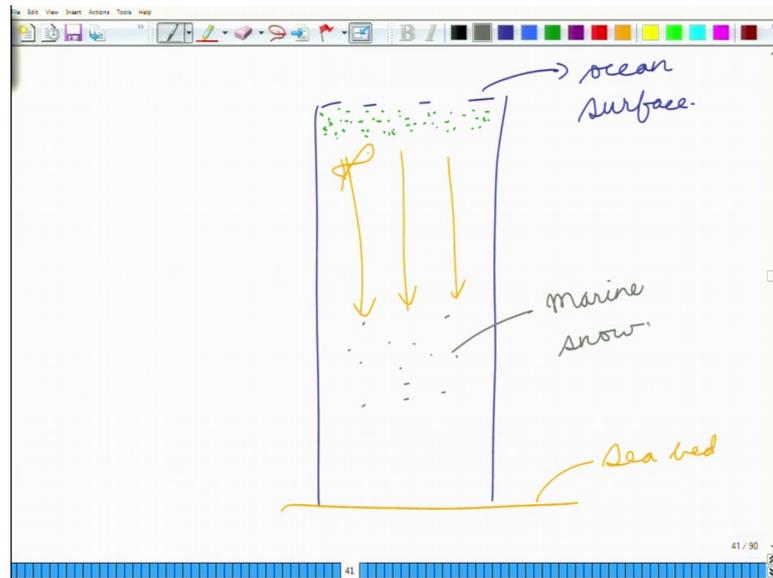


Now, not only do you have this process of decomposition that will happen, but at the same time we might also have the process of aggregation. Now, in the process of decomposition, we were moving from macro debris to meso debris to micro debris.

Now, in the process of aggregation, you can have situation in which the micro debris becomes associated with each other. So, it joins together with other particles of micro debris, and becomes a meso debris. Now, examples include the faeces of a number of organisms. So, probably there was an animal that was having these micro debris into in its environment and it was able to eat these micro debris and so these micro debris were able to reach the intestines.

Now, in the intestines the food gets absorbed that the plastics, do not get absorbed, they are not decomposed there and then after a while, when it is giving out the faeces. So, in this faeces, you have all of these small particles that are now together. So, this might convert from a micro debris to a meso debris or in might even convert itself into a marine snow. Now, marine snow refers to a number of particles of fragments or dead bodies of organisms that move in a top down manner in the ocean systems.

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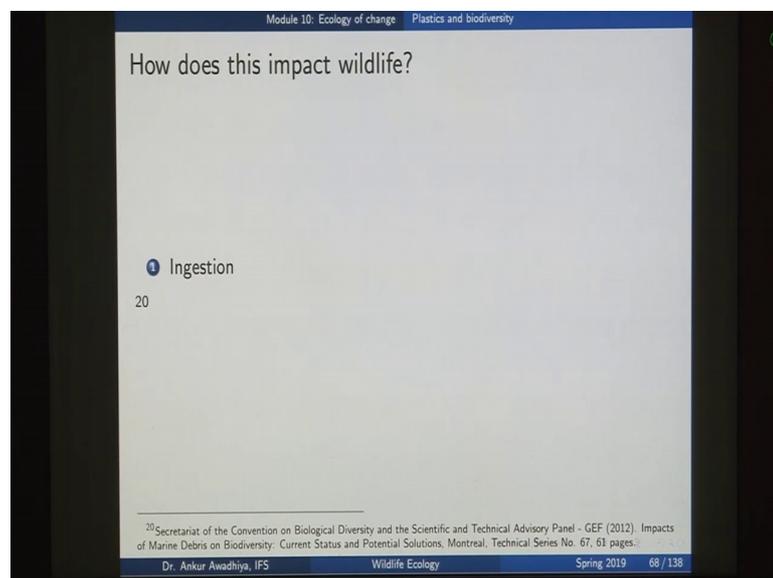
So, let us consider a column of the ocean. So, here we have the seabed and here we have the ocean surface. Now, near the ocean surface, we have a number of planktons. So, we have phytoplankton and zooplankton, now these planktons they are using sunlight, and they are doing photosynthesis. They also get eaten up by the zooplankton, and maybe even by the larger size faeces. Now, when they die out or maybe there was a fish in the water and it was predated upon, and probably this small fragment of the fish remained.

Now, such fragment, the dead bodies of the organisms are the fragments of these organisms or maybe pieces of faeces that are there in the organisms, they because they are they have a greater density than that of water, they start coming down. Now, they will come down in a process that will take number of years, because they are very small sized particles, and they take a very long time to come down because of the effects of viscosity, and also because they are because of buoyancy.

Now, in this case these particles, when they are coming down, they are known as marine snow. Now, in this case what we are saying is that these faecal particles which have so many plastic particles inside. They might get connected with each other, and they might start going down or else if there is already existing particle of the marine snow, you can have some plastics that come and aggregate with these, and then also they start coming down.

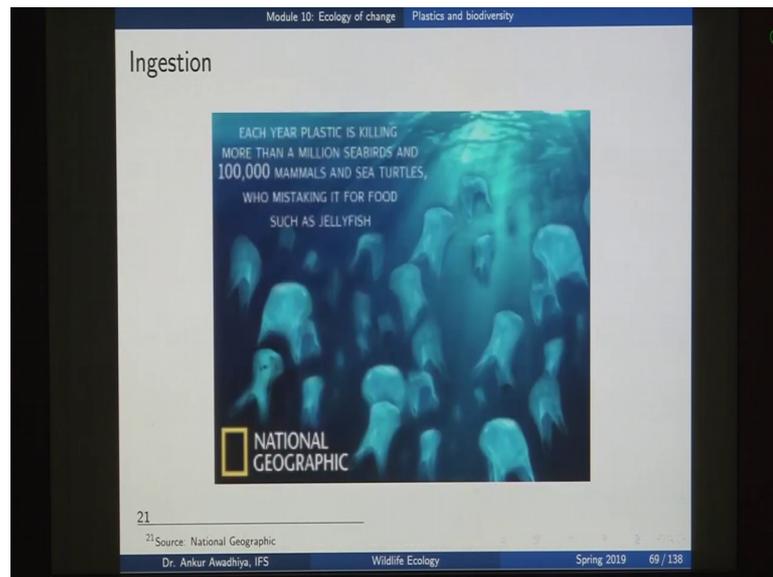
So, in this process, what we are observing is that in the case of a small piece of micro debris, it might remain on the top surface of the oceans, but then because it is able to associate with already existing particles, and with the faeces of organisms. So, it is also able to reach down. So, even the micro plastics or the micro debris are able to reach to the bottom of the oceans; now, if we talk about all of these debris, if we talk about macro, meso, and micro debris, how does that impact the ecosystem which that is what we are interested in knowing? So, there is a plastic, if it does not play any role in the ecosystem, we should we are with it. But, then if it impacts the ecosystem in a negative manner, then we have to be extremely value of it. So, how does it impact the ecosystem?

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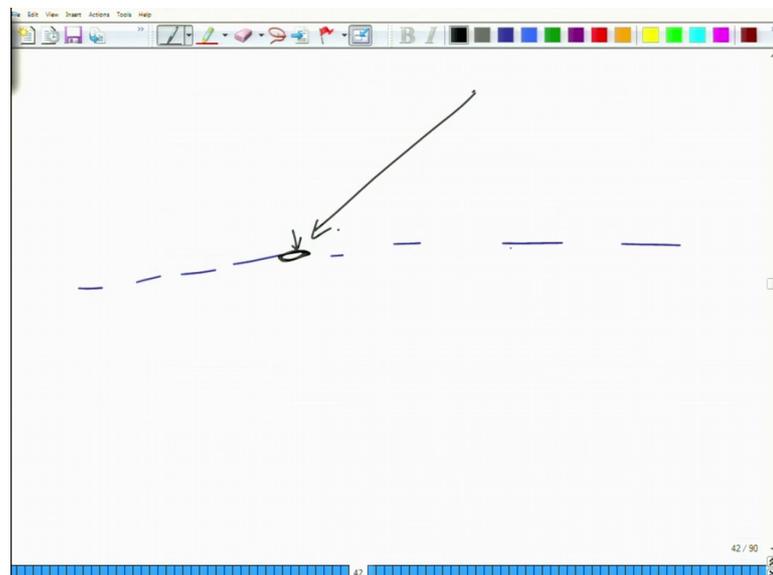
So, there are a number of things that happen. First is ingestion, ingestion is eating.

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Now, if you look at these plastic bags, now these are all polythene bags, and they are put into water. And now we can see that these are polythene bags, because we can see these handles. But, then do an animal that is living in the water, they might look like jelly fishes. And so these animals might would try to eat these plastic bags.

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So, in that way the plastics are getting eaten up by the animals or let us say in the oceans, so you have say a small piece of plastic say the cap of a pen that is floating here. So, you

might have a bird that may mistake it for a fish that has come to the surface, and might try to pick it up.

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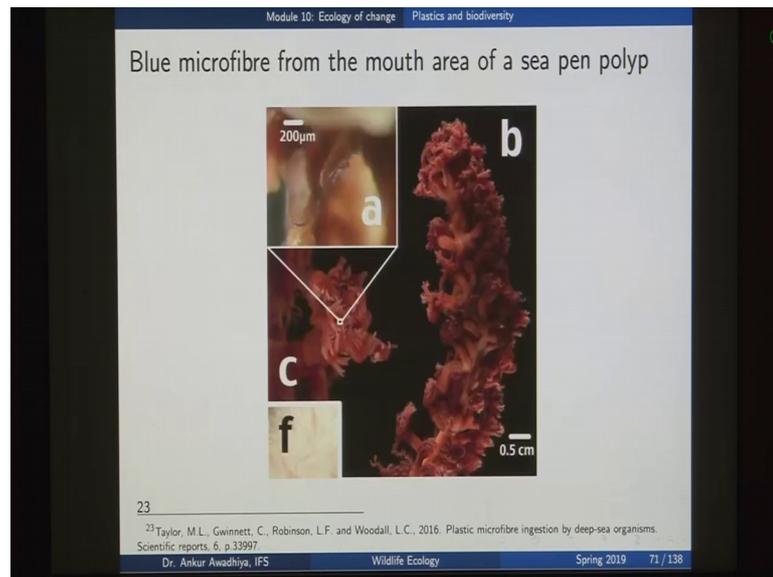


Now, here we have the situation of an albatross. Now, albatross is our very last size birds, and they are very long lived birds. They live for as long as 50 or 60 years. Now, in this case what happened was this is an albatross chick dead albatross chick. And in this case the parents because the chick is growing, so it has a huge amount of nutritional requirements. Now, a chick cannot go out, and catch birds can and catch fishes for itself, so the parents need to go out.

So, the parents went out. And the parents when they saw these plastic pieces that were floating on the surface of water, they mistook it for fishes. And then they dutifully brought all of these pieces to the chick, and then they fed their chick with all these plastic pieces, what happens later, these plastic pieces then block the elementary canal of the chick.

So, it is not able to gain anymore nutrition, and then it dies out of malnutrition. And here also we can observe that the whole body of the chick is getting decomposed. But, then these plastics remain, and then these plastics after the next streams will again go back into the oceans, and then might be picked up by another albatross. Now, this is how the plastics result in a havoc, when they get eaten up by organisms.

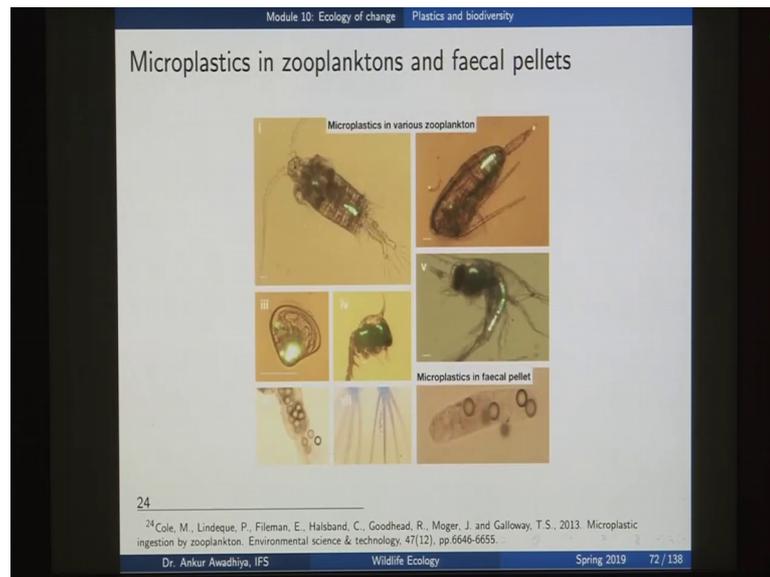
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And we see these plastics getting eaten up at all stages. So, this is an example of a sea pen polyp. So, these are small marine animals that normally live on the sea beds. And here we can observe that if we see the mouth area of this polyp, there is this small fiber that is made out of plastic.

Now, you can see that this is the scale bar, so this is 200 microns. So, the complete length of this fiber is say around 1 millimetre, the complete length of this fiber is 1 millimetre. And this is a plastic fiber that has gone, and that can be seen in the mouth of a sea pen polyp. So, we are seeing that not only are large pieces getting eaten up by birds, but also the very small pieces the fibers that are being eaten up by the polyps.

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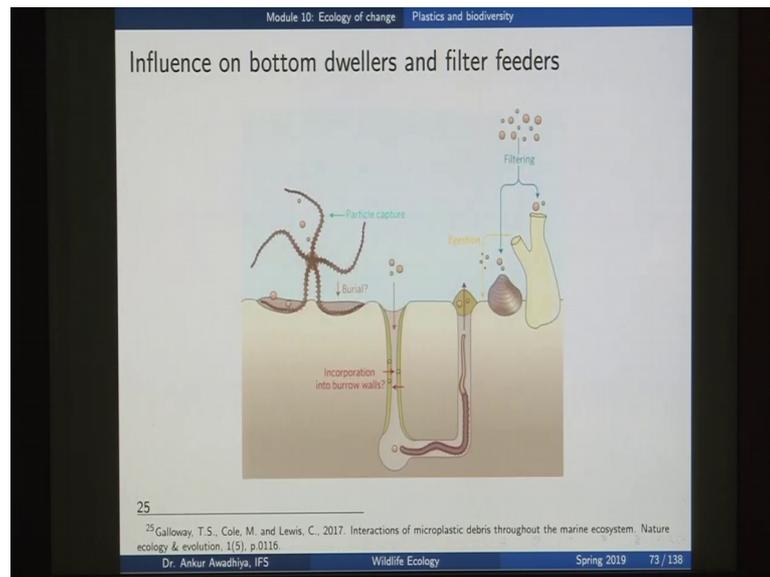


And nobody is left out even in the case of the planktons, now planktons are microscopic organisms. But, then if you look at planktons, you will observe that even their bodies will have plastics inside. Now, these images were taken using fluorescent microscopes in which the plastic particles are showing up in green. So, here you can see that this is a zooplankton, and it has a plastic piece here or plastic piece here.

In this another zooplankton, you have a plastic here you have a plastic here. And similarly, this is say a log of some organism, it is also a very small organism, and you are seeing plastics everywhere. Even see things like your micro plastic beads that are there in the elementary canal, they are also coming out in the faeces. So, this is a faeces of zooplankton, and we are seeing these micro particles of plastics inside. So, nobody is left out.

Now, if even the planktons are having plastics in their bodies, and when planktons get eaten up by other organisms, when they get eaten up by small fishes, then large officials, and then by birds and so on. So, we see that these micro plastics are now able to move throughout the food chain from the very bottom to the very top. Even the apex predators might be having some plastics in their bodies now.

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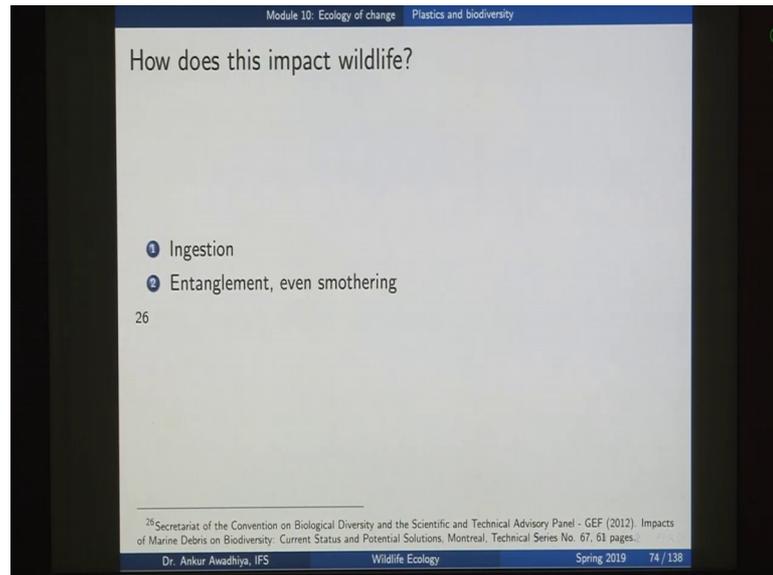


It has a very large role in bottom dwellers and filter feeders. Now when we were talking about the organisms that live on the floats of the oceans when we are talking about the benthic organisms. So, there are a number of organisms that are filter feeders. Now, what is the filter feeder? So, like if this organism is a field of feeder, it would try to get a large amount of water into its body. And then there would be a filter like system in its body, so that all the planktons get filtered, and those planktons are then eaten and digested.

Now, if you have micro plastics that are of the size of these planktons, then all of these plastics are also getting into the body, then they are getting filtered out, and then they are blocking the elementary canal of these filter feeders. In these plastics, may get captured into various body parts of these organisms or maybe when there are some organisms that are burning a hole into the seabed. So, they can get or they also get incorporated into the burrowed walls of the system.

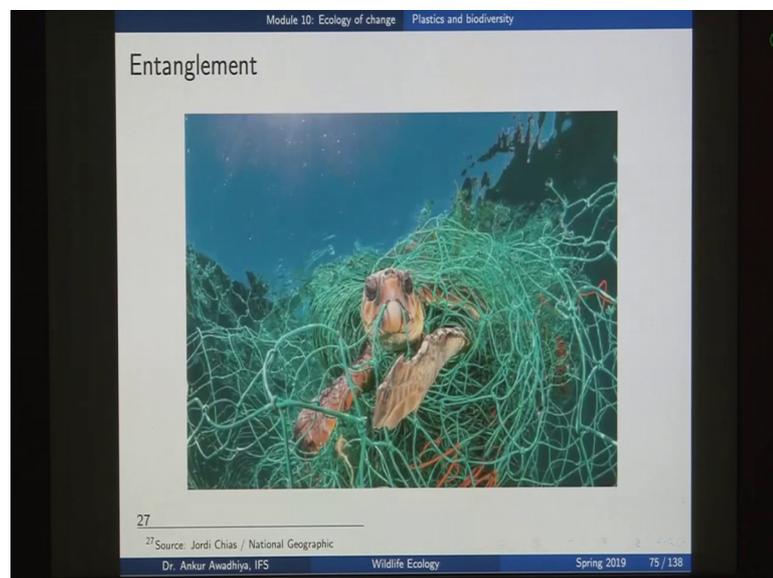
So, there these plastics are not just floating on the top surface of the ocean, they are able to move down along with the faeces, along with the marine snow. And even when they are down, they are influencing the organisms that up that are a part of the ocean ecosystem. And they are even able to get down into the seabed with these organisms. So, here we can see that there is a huge impact on the wild organisms or on the ecosystems.

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So, the first one is ingestion, the second one is entanglement or even smothering of the animals.

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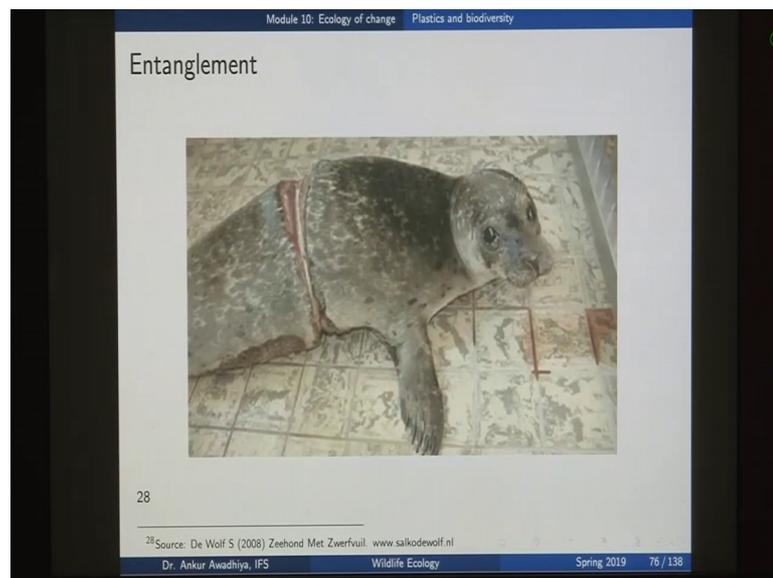
So, we were talking about the ghost nets, now this is a ghost net. Now, in the case of a ghost net, it was earlier a fishing net that was being used maybe in some ship. And probably at the end of its useful life, it got torn up or maybe the ship capsized or maybe this was just left out it by accident. And now if you have this net that is floating in the

water, it is still capturing animals. So, animals get caught up in these nets, there is no person who is using these nets, but animals are still getting caught.

Now, once you have an animal that gets caught here, so now this animal is unable to move. In the case of these tortoises, they are reptiles and they require air for respiration. So, even the sea turtles, they have to surface once in a while to gather their breath. Now, if they get entangled in one such net, they will not be able to reach to the surface, and they will die out of a lack of oxygen, they will die out of asphyxiation or probably if there is an organism, they gets caught here.

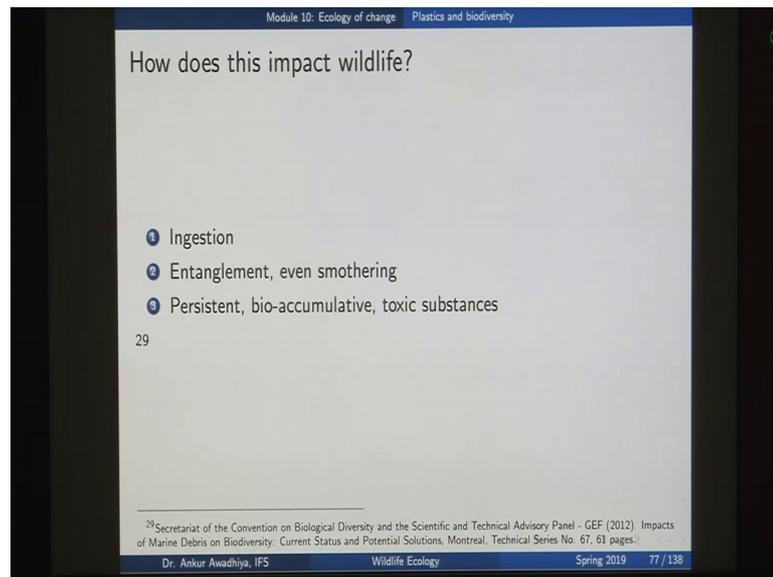
In this organism is not able to now move out, to catch its prey, to get its food. So, it will die out of malnutrition. So, entanglement is also a big way in which these plastics. Now, most of this rope, most of these nets are made out of nylon. So, this is one big way in which nylon is impacting the wildlife.

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Or there could be situations in which there is an animal, and this animal is now getting trapped in one of these plastic pieces. So, there is this plastic band which is now cutting through the skin of the seal. Now, in this case probably the animal caught this piece of plastic, when it was small. And now this animal is growing in size the time, but then the plastic is not allowing it to grow. So, it is actually cutting through its skin. Now, this organism will be exposed to a number of infections. And in this particular case, this animal actually died out, it could not be saved because of this plastic.

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Now, besides ingestion and entanglement, there are also a number of persistent, bio-accumulative, toxic substances that are there in the plastics. Now, persistent means that these chemicals will remain in the system for a very long time, they are very difficult to degrade. So, microorganisms or other organisms would not be able to break them down into non-toxic substances. There are a number of chemicals that are bio-accumulative.

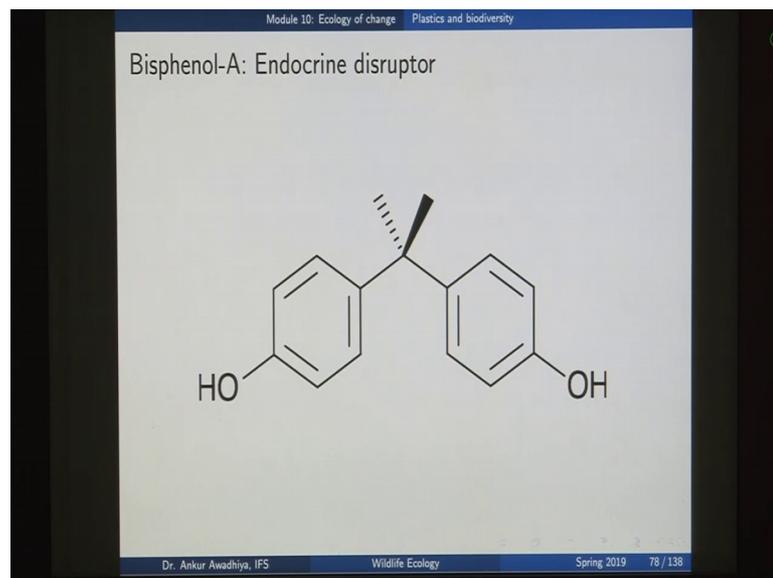
Now bio-cumulative as we have seen is the case in which there is a chemical that is getting absorbed into the body, and then the body is also trying to degrade it and to flush it out of the system. But, then if the rate of absorption is greater than the rate at which it can be thrown out of the body, then it starts getting accumulated in the body.

So, persistent toxic substances, and bio-accumulative toxic substances, these are also there in the plastics. Now, you might ask this question, why would somebody want to put a toxin in a plastic. Well people do not want to put a toxin in plastic, but then a number of substances that are used to make this plastic more and more supple might actually be toxic substances.

So, we have things that are known as plasticizers. A number of plasticizers are toxic substances or you could even have a situation in which, you want to put some flame retardants into a plastic why? Because a plastic is made out of hydrocarbons, and so it very easily catches fire; so you might want to put some flame retardants into a plastic, especially in applications such as automotive seat covers.

So, the seat cover that is there in your vehicle might be having a number of flame retardants. Now, that flame retardant is playing an important role, when it when we come to when we are talking about the automobile safety. So, it should not very easily catch fire. But, then once its life is over, and once this seat cover gets into the ecosystem what is the role of that flame retardant after that while, so that flame retardant might act as a will toxic substance for the ecosystem.

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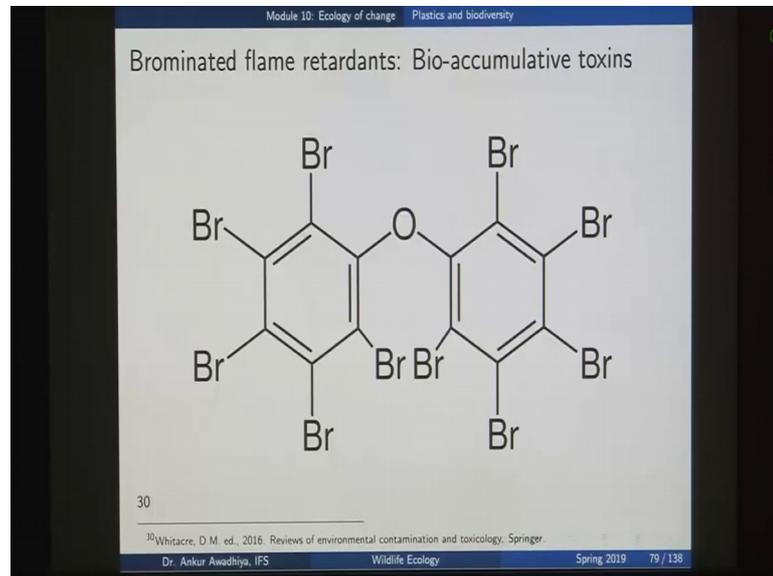


So, we have substances such as Bisphenol-A. Now, Bisphenol-A is used as a plasticizer. In the case of these plastic bottles, if you have this Bisphenol-A, so it will give you this amount of suppleness. So, if you are pressing, it will come back to its original shape, now that is because of a plasticizer which is Bisphenol-A. But, then Bisphenol-A is also an endocrine disruptor, what it means is that its structure is very similar to that of some hormones that are found in the body.

Now, if you take some tadpoles, now tadpoles are the young ones of frogs. And if you take these tadpoles, and you expose them to Bisphenol-A, they will all change their sex, why because this substance Bisphenol-A, it is very similar in its structure, and its action is similar to the sex hormones. So, then this might have an impact on the ecosystem. What happens if you have a pond, and that pond has a huge concentration of Bisphenol-A, and all the tadpoles that are born in that particular pond all of them are females, there are just no males in that system. So, the whole ecosystem would collapse, because you will not have

any more frogs in that ecosystem after a while, because there is no male to fertilize the females.

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Or if we talk about things like Brominated Flame Retardant, so BFRs, these are also by a cumulative toxins. They get accumulated in the bodies, and they are also magnified, when we move of the food chain. So, here we are observing that not only are these substances getting accumulated in the body, but then because all these organisms are part of some ecosystem. So, they also play a big role in the working of the ecosystems ok. So, this is how the plastics are able to disrupt the ecosystems or let us talk about accumulation and concentration of hydrophobic toxins.

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Module 10: Ecology of change Plastics and biodiversity

### How does this impact wildlife?

- 1 Ingestion
- 2 Entanglement, even smothering
- 3 Persistent, bio-accumulative, toxic substances
- 4 Accumulation and concentration of hydrophobic toxins

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<sup>31</sup>Secretariat of the Convention on Biological Diversity and the Scientific and Technical Advisory Panel - GEF (2012). Impacts of Marine Debris on Biodiversity: Current Status and Potential Solutions, Montreal, Technical Series No. 67, 61 pages.

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So, there are a number of these chemicals, now if you have these chemicals, it is possible that some of them might be hydrophobic in their nature. Now, when we see a hydrophobic substance, hydro is water and phobic is fear of. So, you have hydrophobic, it means there is a toxic substance that hates water.

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Module 10: Ecology of change Plastics and biodiversity

### Accumulation and concentration of hydrophobic toxins

The diagram illustrates the process of hydrophobic attraction. On the left, a blue vertical bar represents a hydrophobic surface. To its right, a red arrow points towards a cluster of various colored dots (black, yellow, red, blue, green, and grey) that have gathered near the surface, demonstrating how these substances accumulate on a hydrophobic material.

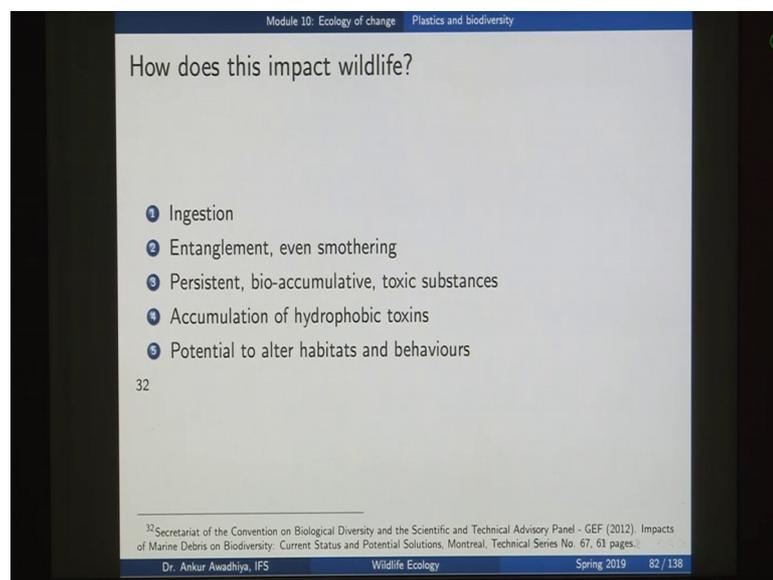
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So, in that case the hydrophobic substances might come together, now where do you get a hydrophobic surface in nature? You have it in the form of vaccines or if there is another piece of plastic nearby, a plastic is a very hydrophobic surface. So, now what happens is

if you have these hydrophobic toxins that are there in the water, and if you put a piece of plastic here, these hydrophobic substances will come and adhere to the surface of the plastic.

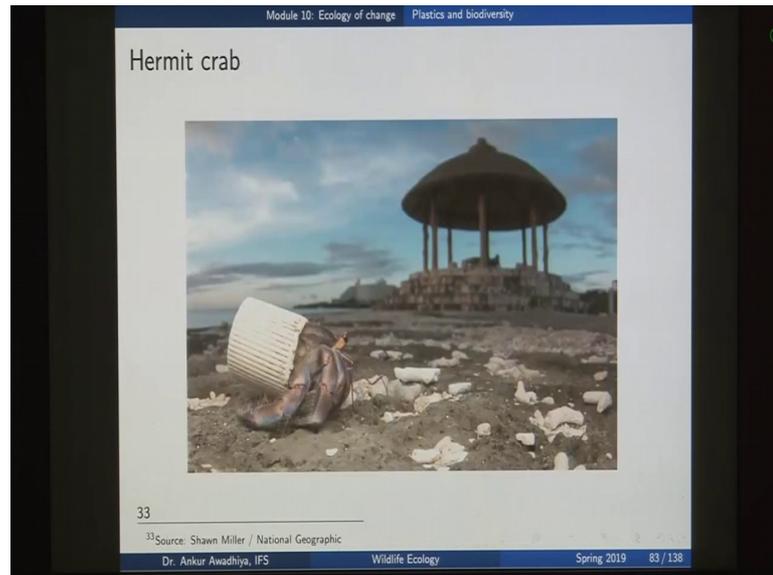
So, in that case the concentration of the hydrophobic toxins increases a lot, and because of this when they get ingested or when they get absorbed into the bodies of any organism, if they get a ingestion by say a plankton. So, all of these hydrophobic toxins will now be able to exert a very big role in the bodies of these planktons.

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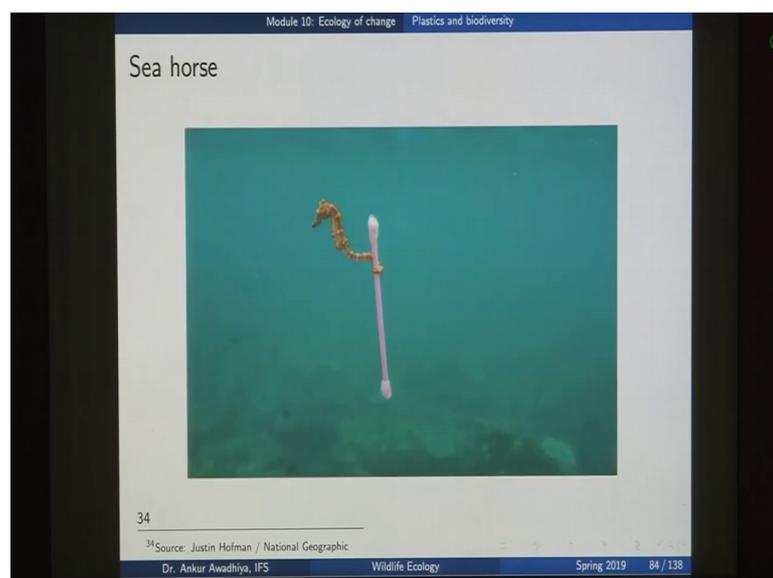
Another way in which plastics are harming the ecosystems is by their potential to alter the habits and behaviours of organisms.

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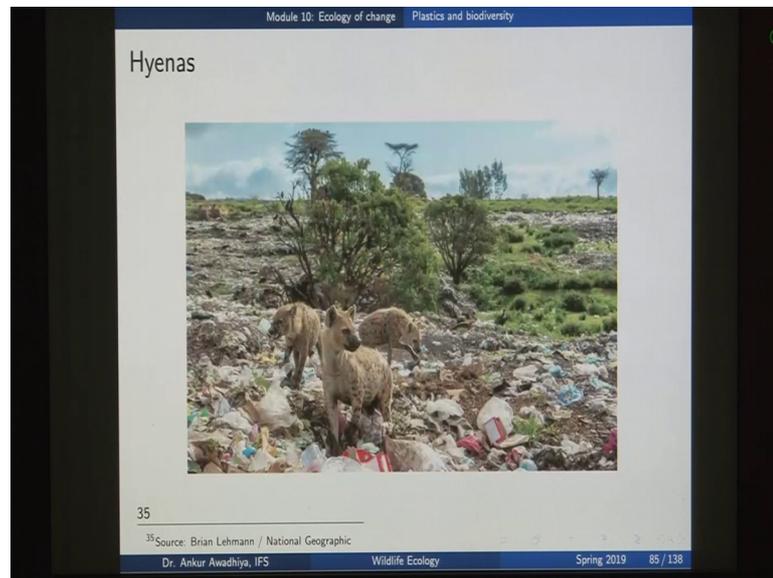
So, we looked at this example of hermit crab. Now, if you have a hermit crab which is using a bottle cap as its shell, this is not a normal behavior of the hermit crab. So, you are changing the behaviours of organisms. And then when there is one organism that is changing its behaviour, it might also have a cascading effect up and down in the food chain or let us look at the seahorse.

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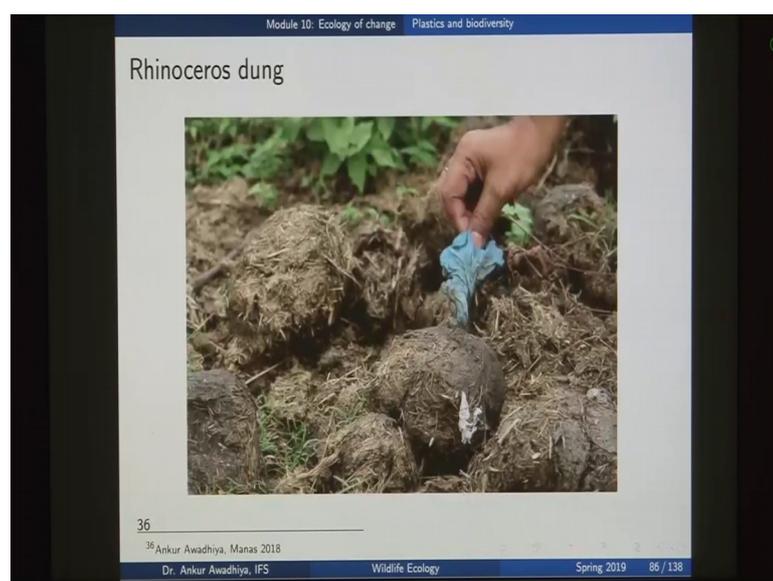
Now, you have the seahorse that in place of using a twig is now using an ear bud for its support, what will happen next? If there is an animal that feeds on seahorses, it might even feed on this ear bud or let us talk about these hyenas.

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Now, these hyenas are there in a trash shard, and they all they have around is plastics. Now, this is not a normal behaviour, this is not something that a hyena is exposed to or should be exposed to and the normal course of life.

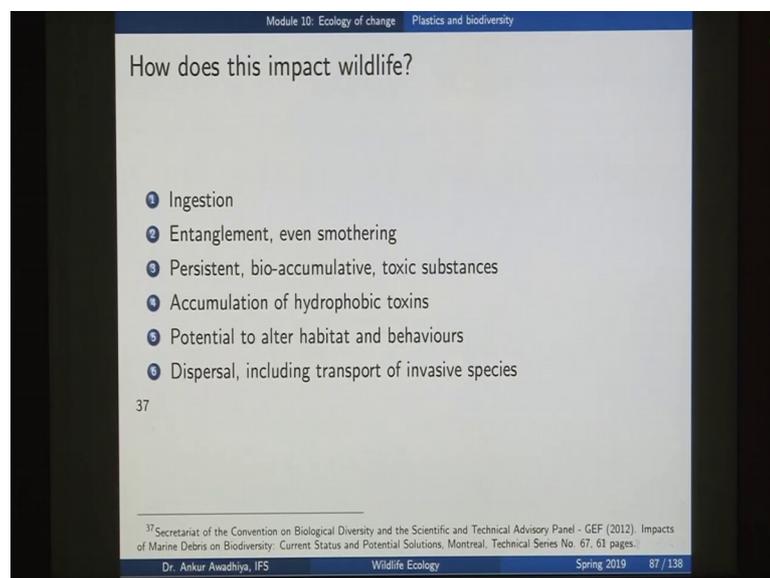
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We are observing days, we are observing plastics, even in the most pristine of environments. So, we went to the Manas Tiger Reserve which is there in Assam, and in this tiger reserve which also holds a very big rhinoceros population. So, we were moving around, and there we saw a pile of rhinoceros dung. Now, we prodded this tunnel, because we were seeing some bits of plastics here and (Refer Time: 41:09) and behold, we were able to find out this piece of polythene bag, which was there in the rhinoceros dung.

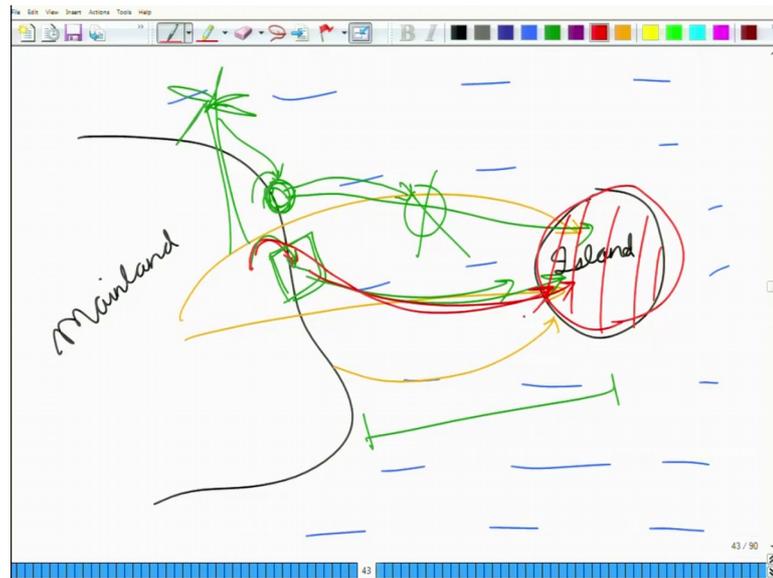
Now, if we have a polythene bag that is there in rhinoceros dung, it means that the rhinoceros had actually fed on the polythene, and where did it get this polythene from, because Manas Tiger Reserve is not an area that has a very big habitation nearby. And even then it was able to get hold of this polythene. So, these plastics because they are light in weight, because they are able to get carried away by wind, by water and so on. They are even reaching our tiger reserves, which are some of the most pristine areas some of the most protected areas that we have for the conservation of bio-diversity.

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Another way in which plastics impact wildlife is by acting as dispersal agents including transport of invasive species.

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Now, what is happening in this case is, suppose we have a situation in which this is your mainland, and then there is an island here, and then all this area water. Now, there will be some birds that will be able to move from the mainland to the island, there will be some small seeds or maybe some small insects that can float along with wind into the island, but what about the larger animals. So, there might be some animals that can swim to the island, but then there are a number of other organisms that require some mode of transportation.

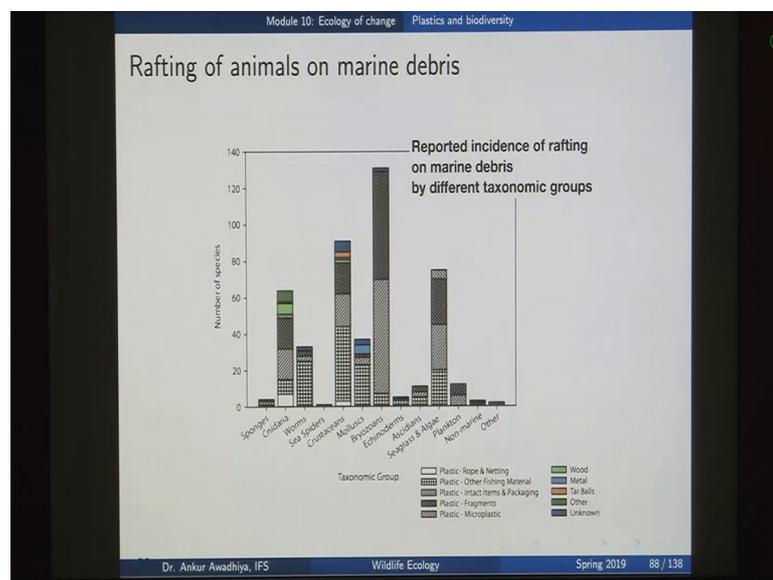
So, for instance, suppose there were coconut trees somewhere here, and then a piece of coconut fell into the water, and then maybe a frog jumped into this coconut, and then along with this coconut, it was able to reach to this island. So, such instances of use of transportation materials is common in nature. But, then when we are talking about naturally available substances that can act as transport materials, they are limited, not only because we have a limited number of things that are naturally available and are able to float from point a to point b.

But, at the same time also because all of these natural materials are also bio-degradable. So, for larger distances, you require those materials that should not biodegrade while enduring the process of transportation. Now, if there is this coconut, and if this island is very far from the mainland, then it is possible that by the natural process of degradation, this coconut will end its structure here. And so the organism will not be able to reach the

island. So, nature has its own ways to limit, to facilitate the movement of organisms from one place to another, and also to limit the movement of organisms from one place to another.

Now, how plastics influence in this? If in place of this coconut, there was a piece of plastic that was floating, and if an animal gets on top of this plastic. So, this plastic is not going to biodegrade, when it is being transported from one place to another. So, in most instances this organism that jumped onto the plastic will be able to reach the island.

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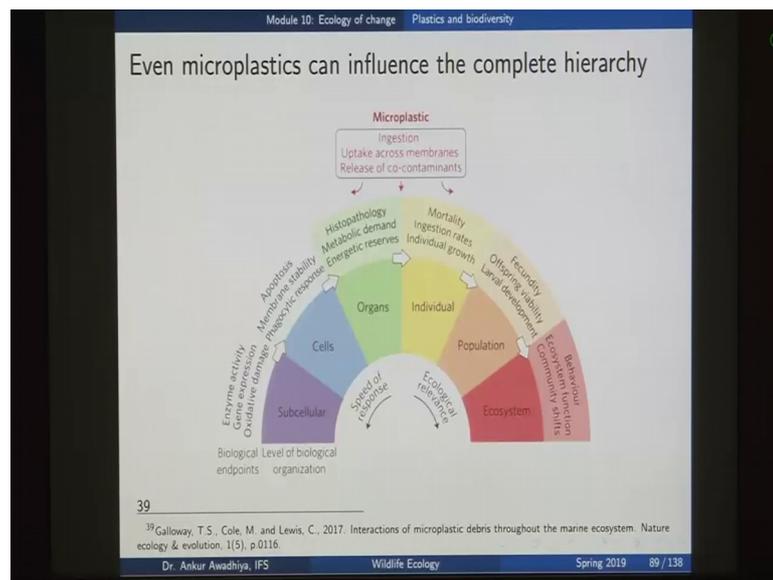
And if we look at the organisms that are being transported because of these plastics; here these coloured entities are the natural materials. So, these are the natural materials like wood or metal or tar balls or some other materials. And all of these darkened bars represent the plastics. And here we are observing how many number of species of all these different taxonomic groups are able to move from one place to another, and what proportion of it is using the natural materials, and what proportion of it is using the plastics.

Now, in the case of some organisms such as the brown zones, here we can observe that the natural moment is very small. But, just because you have so many plastic materials around, so these animals are able to move from one place to another place. Now, why is that important for us? When that is important, because there could be a number of species that are invasive species. So, if you have an organism that shifted from this

mainland use this plastic, and was able to reach the island, probably it would cause I have up to this island, because this organism is a invisible species it establishes itself on this island, and it is able to out compete all the other organisms that are there on this island.

So, these are the kinds of ecosystem impacts that we can foresee probably there is an organism that is a pathogenic organism or an organism that is say a predator organism. And there is this island that does not have any naturally occurring predators or maybe limited number of predators. And when this organism comes to the island, it is able to eat away all the birds of this island, so that might result in the collapse of the whole ecosystem of the island which is also another way in which plastics are impacting the ecosystems.

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Now, if you look at the hierarchy of things, we can see that there is an impact of plastics, even the impacts of micro plastics can be observed throughout the hierarchy. So, if you look at, so here these are sub cellular level, cellular level organ, individual, population, and ecosystem. And we are talking about the impacts of micro plastics. Now, micro plastics can be ingested, they can be eaten up or they can be up there can be an uptake across the membranes of some organisms or they can be a release of co contaminants that are there along with these micro plastics, and we are seeing the impacts of all of these.

Now, at the sub cellular level because of these chemicals that are being released, you can have changes in the enzymatic activity or changes in gene expression or oxidative damage to the cells. At the level of cellular structures, we can observe apoptosis. Now, apoptosis is a process in which a cell performs a suicide, so it is a programmed cell death that we observe in a number of cells.

So, what is happening in this case is that you have this micro plastic that was able to get into these cells, it was able to influence the sub cellular structures, it was able to cause some damage to the cell, and because of this damage the cell committed cell death which is apoptosis or you can see a change in the membrane stability of the cell or changes in the phagocytic responses of the cell. Now, phagocytic response phagocytic means that the cell is eating up some other organism for food.

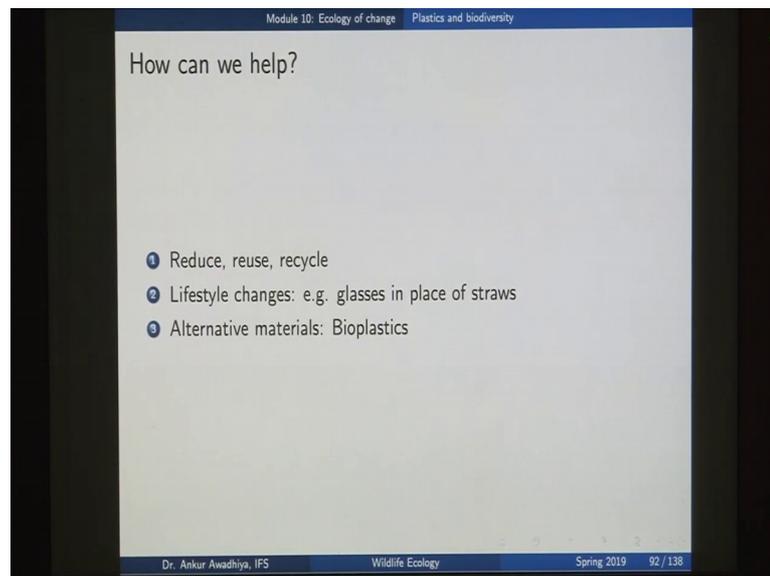
And in this case a change in the phagocytic response would mean that by eating of this plastic, now this cell is not no more able to eat or to show its phagocytic response. At the level of organs, we can observe histopathology, histo is a tissue, and pathology is a diseased state. So, here we are observing histopathology or a change in the metabolic demand of the organs or a change in the energetic reserves of the organism.

At the level of individual, we can see mortality. So, we have seen so many organisms that die because of these plastics. So, we can have changes in mortality, changes in ingestion rates, ingestion rates why, because you are there the elementary can are of the organism is thumb full of micro plastics. So, there is not enough space. So, the organism is always on getting a feeling of fullness, but then it is not getting any nutrients or they can be changes in the individual growth, because the organism is not getting enough nutrients.

At the level of population, if there is changes in the level of individuals will also observe changes in the level of population, so they can be changes in fecundity or the birth rates or we can have changes in offspring viability or changes in liability development. Now, here again as we have seen even in the case of larger size plastics, they can be changes and the in the viability of the offsprings, like in the case of the albatross chick. So, the albatross chick died, because it is a element you can always all full of plastics. We can also see the same impact in the case of smaller organisms as well.

So, from the population level changes, we can also observe ecosystem level changes. Changes in the behaviour of organisms, we saw in the case of larger organisms like the hermit crab, there was a change in the behaviour, because now this hermit crab was using a plastic bottle a cap has its shield. And the same a very similar thing can also be seen in a number of other organisms as well. They can be changes in ecosystem service in ecosystem functions, and community shifts. So, essentially even a very small thing like a micro plastic can have impacts all over in the ecosystem.

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Now, that we know that plastics cause a deleterious impact. And even micro plastics cause a deleterious impact, what are the options available for us, how can we help? Through the first way we can help is to reduce our requirements of plastics, to reuse the plastics, and to recycle plastics. So, when we say to reduce our demand of plastics if they are if we have an option available, whether you should go for a plastic straw or whether you should grow go for a glass, when you want to drink a soft drink.

So, you can go for a lifestyle change, you can say that in place of using the straw, you would prefer having the soft drink either directly from the bottle or say in a glass. So, in that way you will reduce your demand for straws. Reuse, when we say reuse, if you have to use a plastic bottle, why not fill it up again. So, in that case you will reuse the plastic bottle, and again reduce the demand. And at the end of its lifecycle, the plastic should be put through a recycling process.

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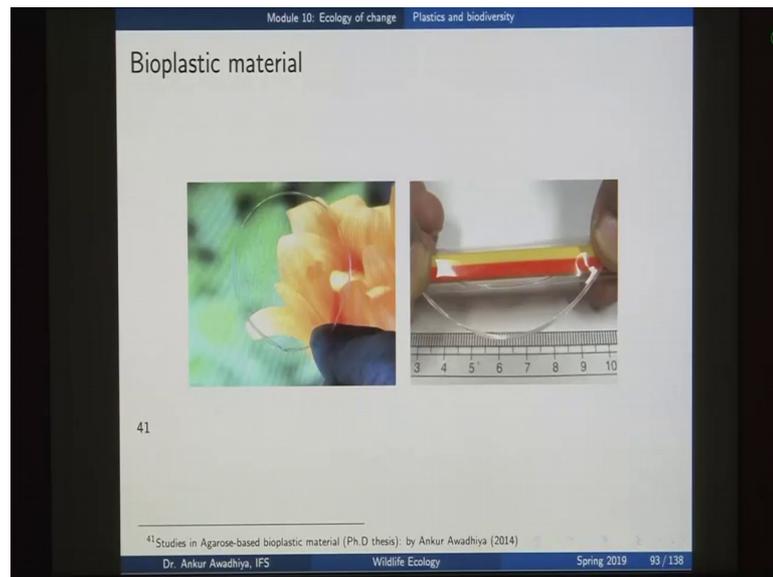


So, in the case of recycling, you have all these plastics that are then clumped together in the form of these big bundles. And then they are reheated, they are re melted, and then they are converted into some other products. So, reduce, reuse, recycle, lifestyle changes, glasses in place of straws, and use of alternative materials like bio-plastics.

Now, bio-plastics are biodegradable plastics. So, unlike the petroleum based plastics that we see all around us, these are those plastics that have the properties of the plastics, but they are at the same time they are biodegradable. In most cases, these are made out of biological macromolecules.

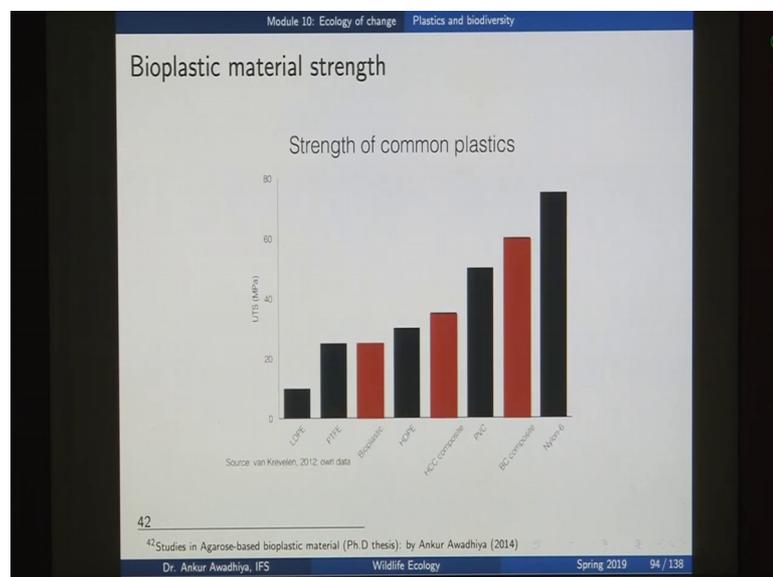
So, for instance, when we talk about a normal plastic and you say talk about polyethylene, now polyethylene is made out of long polymer chains that are made by polymerizing the ethylene molecules. Now, in place of those long chains, because these long chains are giving the properties to the plastic, we can make use of some other biologically available polymers. So, those polymers could be things such as carbohydrates. So, you can have here you can make use of chains of carbohydrates or you can make use of chains of proteins. So, these plastics, when they are made out of these biological polymers would give you the properties of the plastics, but at the same time they will also be bio-degradable.

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So, we created some bio-degradable plastics at IIT, Kanpur. And here we can observe that this is an agarose based bio-plastic material, it is completely transparent, it is completely flexible. So, you can roll it up, just like any other piece of polyethylene sheet.

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And also the strength of this plastic is much greater than that of many of the existing plastic materials existing petroleum based plastic materials. So, when you talk about low density polyethylene, this is the strength of low density polyethylene. This is that of poly

tetra fluoro ethylene, here we have the strength of the normal bio-plastic. So, the normal bio-plastic is already somewhere like twice the strength of the low density polyethylene.

Now, this is the strength of high density polyethylene, which is a bit greater than that of the bio plastic. But, then we can tinker the bio plastic by using some composite materials to increase its strength, so that it becomes even greater than that of the high density polyethylene. Here we have PVC, the polyvinyl chloride. And then we can use some other composites, so that the strength of the bio-plastic is even greater than that of the PVC. And is actually approaching the levels of nylon, which is one of the most high strength plastics that we have around.

So, in this lecture, we began by looking at the impacts of large infrequent disturbances on different ecosystems or different communities, so that was a revision in which we saw that if there is any community or any ecosystem that is not in the most normal state, but is already a bit altered already a bit stressed, so any large infrequent disturbance might lead to a collapse of that ecosystem.

Now, one of those stressors that are available today is plastics. So, we looked at plastics, we began with the definition of plastics went through a short history of when plastics were manufactured, how are they manufactured, how much amount of plastics is being manufactured, how its production is increasing 5 percent every year and then we looked at the impacts of plastics on the ecosystem.

So, we saw the impacts of different sizes of plastics, the macro debris, the meso debris, and the micro debris. The impacts that they caused are things such as ingestion impacts in which animals eat them, and then they get lost into the intestines, and then the organism dies out of malnutrition or things like smothering. So, if there is a sheet of plastic that has come and attach itself to the mouth parts of an organism, so this organism is now no more able to feed or it is no more able to respire, because it has clogged the airways, so that is the impact of smothering.

We looked at the impact of ghost nets. So, there is an animal that gets entrapped here, and this animal is non-over able to move or things that are acting at a smaller scale. So, there are a number of chemicals that these plastics are releasing which were earlier used as plasticizers or as flame retardant and after the usage of plastics, they are now becoming a nuisance toxic molecule, when they are there in the ecosystem.

We also looked at micro plastics. So, in the case of these micro debris or micro plastics or micro fibers, we saw that how these particles are now able to reach to all the organisms by getting into the food chain. So, they enter into the bodies of the plankton, and from the plankton they get eaten up by other organisms, and then slowly and steadily all the organisms get exposed to these plastics.

We also saw that even in the case of the bottom dwelling organisms, these plastics are able to reach even to the bottom of the season oceans in the form of marina snow, in the form of other aggregates, in the form of faecal pellets and so on.

And they are even seen in those organisms that are found at the bottom of the ocean such as the sea pen. And then we also looked at, how these organisms are how various organisms are using plastics to transport themselves from one place to another, how it is causing a change in the behaviours of organisms, how it is even reaching our most pristine locations such as tiger reserves. And then we looked at various ways in which we can reduce these impacts, by reducing our usage by reducing the demand, by reusing these plastics, by recycling these plastics or by shifting to other materials such as bio-degradable plastics.

So, these materials have the good properties of plastics, but at the same time they are also bio-degradable, so that they do not cause this have up to the ecosystem. If there is an organism that eats up a piece of bio plastic, so because it is made out of carbohydrates, this bio-plastic will get digested in its elementary canal, it will only provide nutrition to this organism, it will not occlude the intestines of the organism.

If you burn a bio-plastic, it will only release carbon dioxide in water; there is no toxins that is going to be released. And if these plastics are just left out into the environment, a number of decomposers will start acting on these, so we will have the action of bacteria, we will have the action of a number of fungi which will then biodegrade these plastics into their into their elements, and which will then become a part of the food chain without causing any of the negative consequences, so that is all for today.

Thank you for your attention. [FL].