Evolution of the Earth and Life
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Anthropocene and Future

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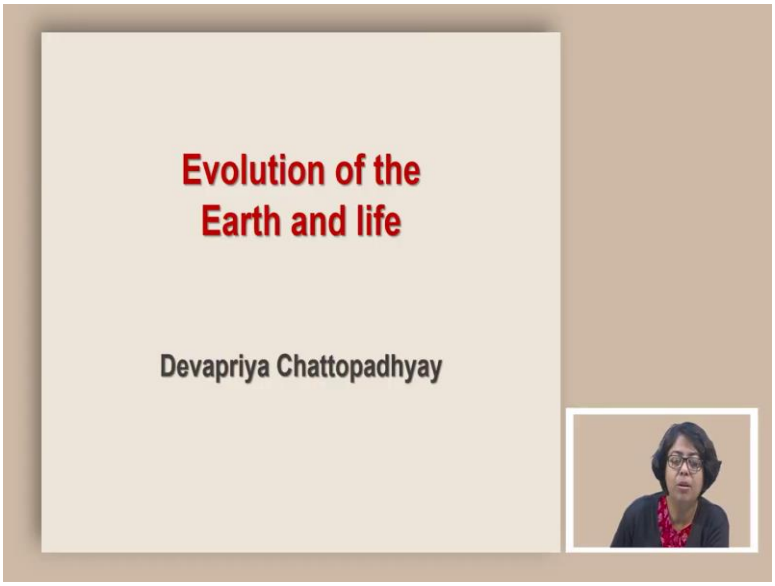

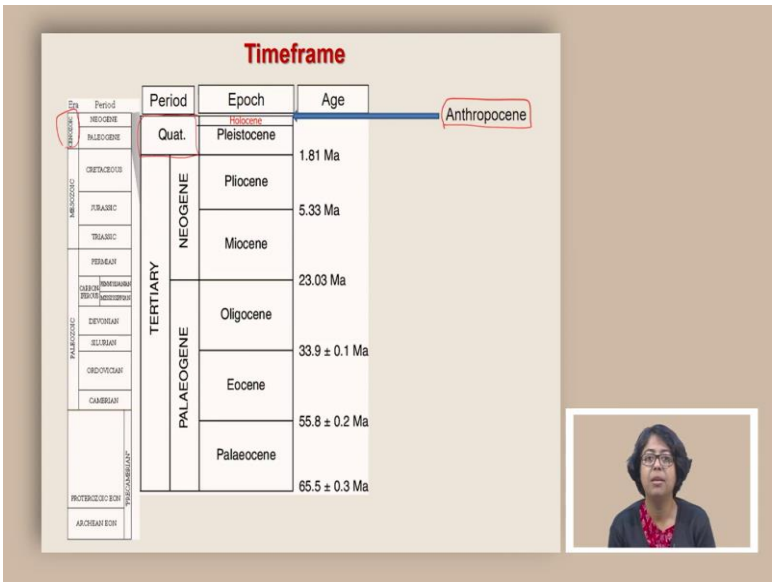

Welcome to the course Evolution of the Earth and Life. Today, we are going to learn about Anthropocene. Let us orient ourselves in terms of the time frame. As I mentioned we are at the very end of the time scale. So, we started with Cenozoic, which has periods Paleogene, Neogene and also there is something called Quaternary. Now, this Quaternary is further divided into epochs, one is called Pleistocene and one is called Holocene.

So, Holocene is the most recent one. However, the recent developments in the environment in the biodiversity made people to think that whether we should actually subdivide the Holocene into a time pre in time, whether we should subdivide Holocene into two times, a time which was before industrial revolution and the time after industrial revolution.

And this Industrial Revolution was primarily because it made an important change in the environmental configuration and therefore, people started to think the possibility of the most recent time to be called Anthropocene because of considerable human impact in on the environment.

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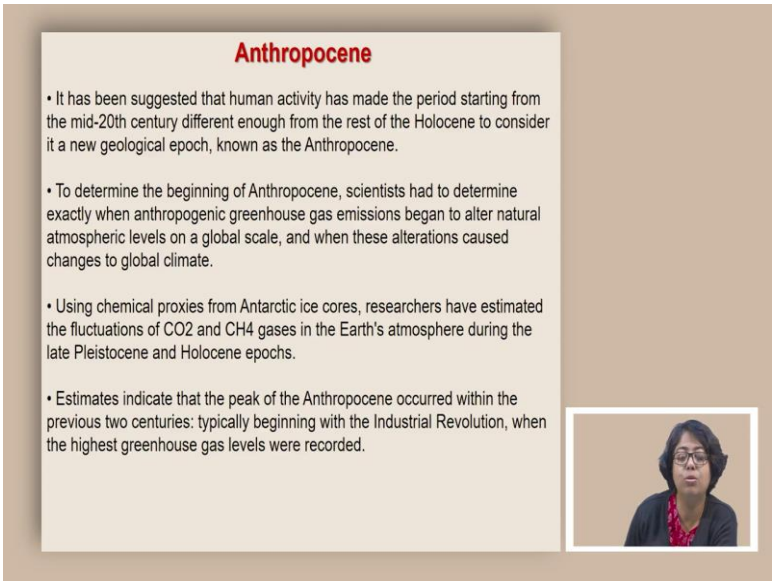

So, the definition of Anthropocene has a lot of controversy, where should we start it from? It has been suggested that the human activity has made the period starting from the mid-20th century different enough from the rest of the Holocene to be considered a new geologic epoch known as Anthropocene and that was the primary motivation of calling it a completely new epoch.

Now, the question is where should we draw the line of beginning of Anthropocene? So, determine the beginning of Anthropocene, scientists had to determine exactly when Anthropocene greenhouse gas emission began to alter the natural atmospheric level on a global scale and when these alterations cause changed in the global climate.

Now, the question is how do we do it? Then we need to have a continuous archive of the climate change as well as the greenhouse gas emission, but when we think about the

instrumental record it only goes back to a few hundred years. But we needed a continuous record and which is detailed enough and correct enough to be compared before the industrial revolution and after it.

And therefore scientists started to think about the chemical proxies from Antarctic ice cores, researchers have estimated the fluctuation of carbon dioxide and methane gases in the Earth's atmosphere during the late Pleistocene and Holocene epochs and they provide a very good baseline that means it is a reference level with which we can actually compare today's emission of carbon dioxide and methane gas.

And if we do that then it will show us a fluctuation and a considerable variation after the industrial revolution. So, estimates indicate that the peak of the Anthropocene occurred within the previous two centuries, typically beginning with the industrial revolution when the highest greenhouse level were recorded. So, that is what marks the beginning of Anthropocene and we are basically a noun living in part of this Anthropocene epoch. Now, what are the major environmental changes that took place during this time?

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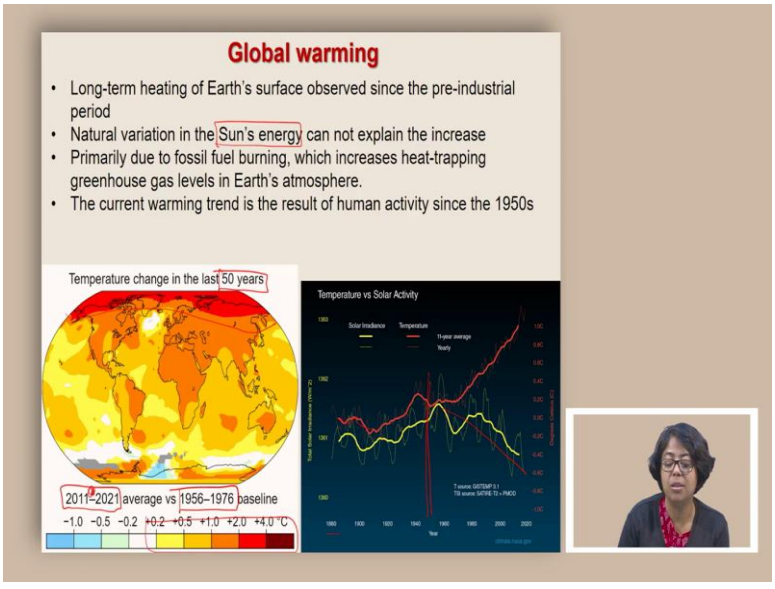

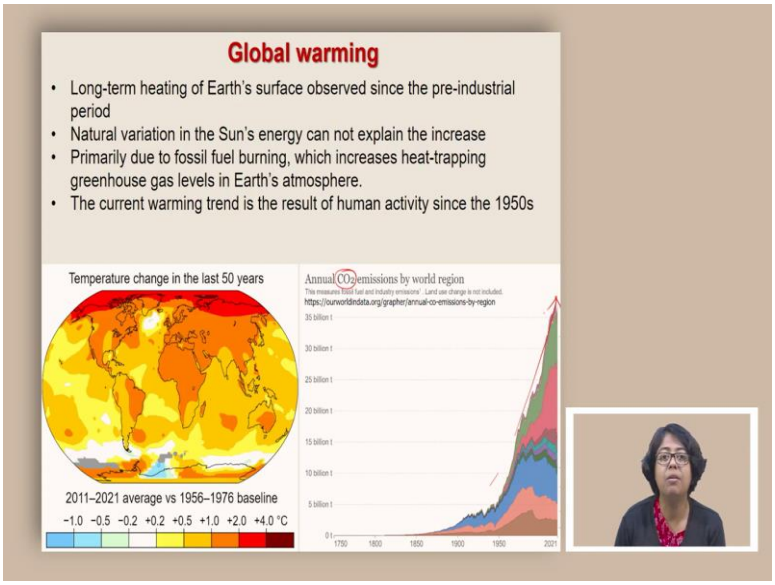

So, the first one that we are going to talk about is one of the common household points that we discussed, that we hear through media as the global warming. Now, it is important to recognize that global warming is not an event which is happening only today. If you go back in geologic history as we have done using Paleo climatic reconstruction there were times when the Earth was much warmer than today.

However, it is important to recognize that what was causing these global warming. There are natural variability of the climate and there are natural ways through which the Earth has become warmer, significantly warmer during times of geologic, during specific points or at geologic time. But this global warming is basically caused by human. So, long term heating of the Earth's surface observed since the pre-industrial period.

The second point is that how are we being sure about the fact that it is only caused by human contribution and not a natural variation. As I mentioned that even previously there were times there was a natural variation which caused the Earth to heat up during Eocene and the temperature were significantly higher than today. So, now the question is how can you be sure that it is not happening because of the natural variability?

So, for that people started to look at the data of solar Sun's energy and when you look at the solar activity and temperature of, from 1880 to present day, what we will find that the temperature is steadily increasing and this increase, you can see especially after this point it is increasing steadily and there is no going down. On the other hand if you look at the solar iridescence it actually drops down.

It does not really go up, and therefore, this does not explain the rise in the temperature, and therefore, it is concluded that this is not related to the solar activity and that is not causing the global warming. But it is true that if you look at the overall world, especially in the last 50 years, you will see that there is a major change in the temperature pattern.

So, if we look at the average of 2011 to 2021, a 10 years average versus 1956 to 1976, another 20 year average, there is a significant shift and where it is showing that most of these things are towards these warmer color, which means on an average any year which is sitting between 2011 and 2021 on an average was warmer than the same day in 1956, between 1956 and 1976 and it is throughout the world.

If you look at where these red colors are showing, this is also very problematic that the maximum colors are being shown towards the polar region, which shows that the polar region is warming up at an extremely high rate and that has impacted the overall circulation pattern, the overall environment, the overall weather and weather is only a point in change in the physical surrounding of us in a short amount of time and climate is a trend which is operating over a long span of time.

Now, what is causing these kind of abrupt changes and steady change of warming over the last 20 or 30 or 50 years? One explanation is the annual greenhouse emission. So, this is a plot which shows only the carbon dioxide emission, but I think it is clearly showing the pattern that if we look at the annual carbon dioxide emission pattern from 1750, we see a steady increase in the amount and this corresponds to how much temperature fluctuation we are seeing and the steady increase in temperature throughout the globe.

So, therefore, the finally, final conclusion was that the change in global climate or this particularly observed global warming is due to the fossil fuel burning, which increases the heat trapping greenhouse gas levels in the Earth's atmosphere and once the Earth's atmosphere started to become hot, it will start to influence various fears and then you will see an overall change in different components of the climate.

And this current warming trend is a result of human activity since 1950. Probably, the contribution since industrial revolution finally led to these changes, but the most drastic change and the steadiest change in global warming is observed after 1950 till today. Now, what are the changes that we are thinking of?

So, first we are going to talk about the Marine realm because it covers maximum of the Earth's surface, 70 percent of the Earth's surface is covered by marine parts. So, it is important to understand what will happen because of the global warming.

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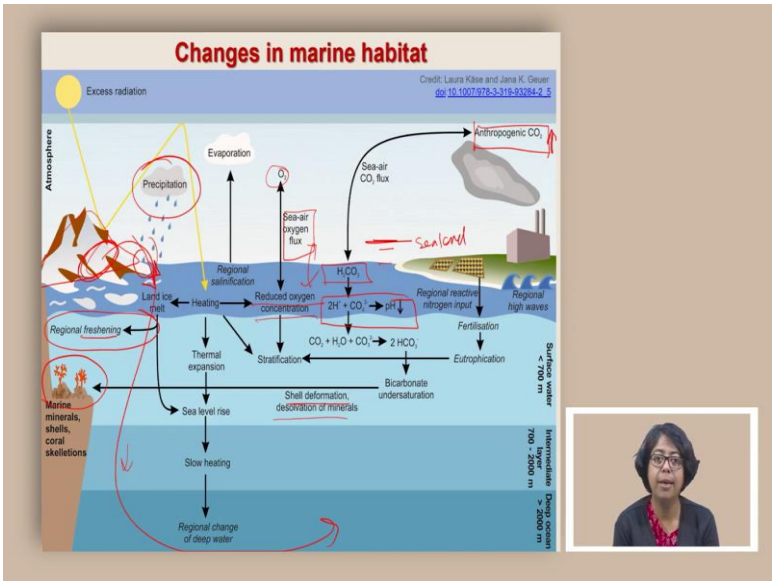

So, the first understanding of global warming and it is impact on the marine realm is, tells us that there would be a change in the sea level. Now, the sea level increase is going to be caused by global warming because of two reasons, one is as the ocean warms up it also expands in volume because the water actually expands in volume if you heat it up.

That is one part because of which the level of the ocean is going to go up, but the second point of it is that in today's ocean there is a significant amount of ice which is locked up on top of the continent. So, if you think about the Antarctica, there is enough ice cover, which is locked up in the continent, which is not really part of the sea.

And once the Earth warms up, part of these land locked ice will melt and they are going to add extra water to the ocean increasing the sea level to quite a bit. As a result the coastal areas of the all over world will be inundated, depending on how much temperature is going to increase the sea level is going to increase accordingly and that will determine only which parts of the world will be inundated.

But it is for sure that low-lying countries which are around the level of sea level or islands we are, which are generally at the sea level are really vulnerable at this situation and with the rate with which we are going there can be a increase in temperature of one to two degree

centigrade and if that happens then a significant portion of the Earth that we see today will be inundated, the land that we see today will be inundated and no human being, no organism that we see today living in those lands will be surviving in those areas.

So, therefore, it is important to understand how this mechanism works. The second point of it is so far we have only talked about the sea level increase and physically how the level changes, but there are chemical reactions which are also going to be affected. One major part is precipitation, so the precipitation actually changes with change in the global warming. There would be more frequency of extreme events, extreme rainfall.

Rainfall that used to happen over two months may happen in just a few days, as a result there would be more floods. So, the frequency of extreme events are supposed to go up when you have global warming. The second part of it is the oxygen concentration as well as concentration of the other gases. Now, because there would be melting of sea ice, there would be parts of the world where there would be regional freshening.

What that means? If you add too much of fresh water in parts of the ocean, they are going to appear not marine-like and they are going to have a drop in the salinity. So, they are going to appear as if it is a known marine region like a river and many marine organisms they cannot tolerate any change in the salinity, as a result they are going to go extinct.

The second thing is these amount of fresh water input and what is going to be their temperature all depends and all influence how much oxygen they are actually bringing in from the atmosphere to the circulation at the deeper region. And if we have global warming, there would not be enough cold water to carry the oxygen from top because of the density, because cold water actually has higher density, to supply oxygen in the bottom part.

As a result there would be development of bottom anoxia over the time. It might not happen today or tomorrow, but eventually there will be a problem in the circulation pattern of the ocean. Another point is the anthropogenic carbon dioxide. So, carbon dioxide is a gas which stays in the atmosphere, but if the atmosphere is always talking to the ocean and that is how the ocean actually gets it is oxygen.

So, the sea air oxygen flux is dependent on how much oxygen is there in the atmosphere and then how it is going down. So, if it is heated, then there would be a reduced oxygen concentration because it cannot really take up so much of oxygen from the atmosphere.

Similarly, if the carbon dioxide level increases, then it basically forces the ocean to take up some of these carbon dioxide.

Now, ocean always takes up a bit of carbon dioxide and once it takes up with the water it reacts and makes carbonic acid and if the carbon dioxide is too much, then the production of carbonic acid will be more, as a result the pH is going to drop. If the pH drops that means the water becomes acidic and these acidic water is not good for the shells that grow in the marine region such as clams, snails, corals.

All of them require a proper balance of pH so that their calcium carbonate shells are intact. If the ocean becomes more acidic, it is generally called ocean acidification, then many of these organisms cannot create proper shells and you will find shell deformation, dissolution of various calcium carbonate minerals and this is one of the major worries because that will then start to contribute to the diversity loss.

Many of the marine organisms they have calcium carbonate shells and they have evolved over millions of years and they are one of the most productive diverse communities in the shallow marine region, with acidification many of these organisms will die and eventually go extinct.

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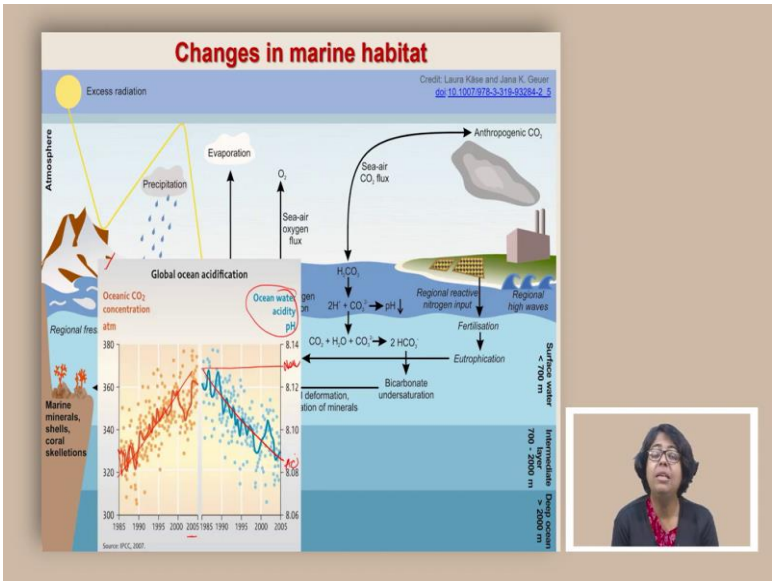

If we look at this particular plot it shows the change in the oceanic carbon dioxide concentration and from 1985 to 2005 there is a steady increase with some fluctuation and as a result if you plot it in ocean water acidity or pH it significantly goes down, that means it is

really really acidic at this point, instead of what used to be a neutral pattern in the ocean or more towards the alkaline side.

And this impacts the different types of skeletal organisms that we find in the ocean. Overall increase in the temperature also impacts some of the skeletal organisms.

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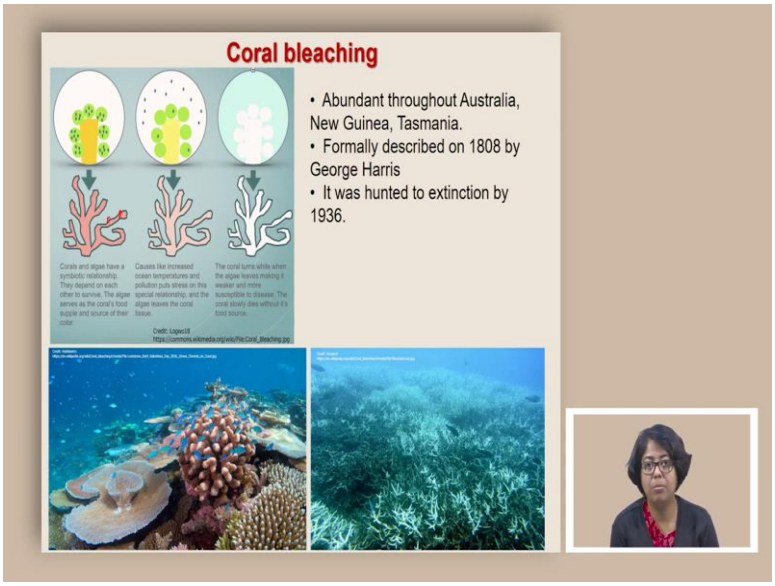

Coral bleaching is one of those cases where abundant growth of corals are impacted because of the warming. So, corals and algae they have a symbiosis, symbiotic relationship and generally corals look colored because they have all these zooxanthellae which are some algae which grow in them. So, when the temperature goes up these zooxanthellae or these some of these algaes they basically leave the coral structure.

Majority of them leave and therefore the corals become more pale. If the discontinues and if the temperature is really high, then these algae or any of these symbiance cannot live in the corals, in fact, they produce something which is harmful for the corals and corals throw them out and then the coral skeleton becomes completely white and that is what is called coral bleaching.

And coral bleaching means, now it has only calcium carbonate, skeleton which becomes quite soft and it is not as tardy as before where they were living in symbiotic relationship with the algae. Because the algae provides 90 percent of the energy of the corals and the corals become more disease prone and vulnerable.

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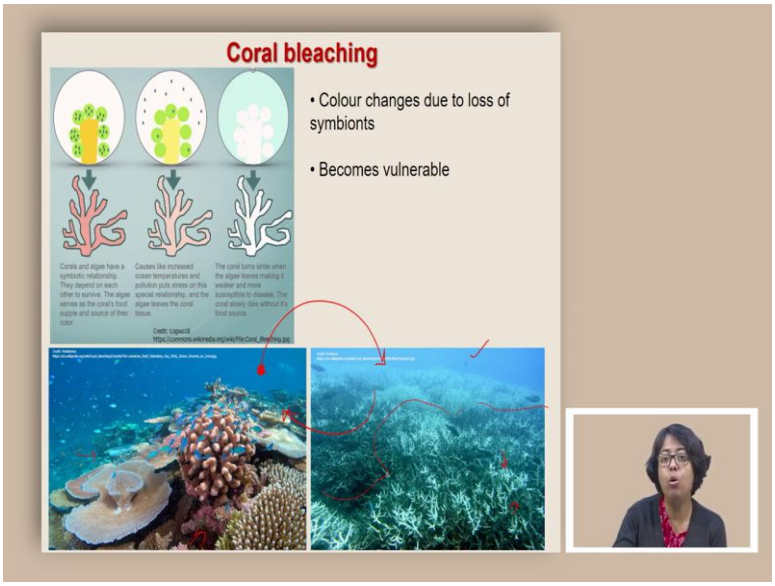

Let us talk about a direct effect of global warming on one of the most prolific marine organisms called corals. Corals live in the ocean and they create a large network of coral reefs. They also help in terms of maintaining the ocean water chemistry because they are made up of calcium carbonate and they often create a situation where other organisms can live in the vicinity of it and they can create their skeletons.

Now, corals have algae as symbiance, so that means, this algae lives in corals and supply 90 percent of corals energy through food and corals in turn give them the space to live and this has been one of the most effective symbiotic relationship in the marine realm. Now, during global warming in the last 50 years or so, there was a point where people started to realize that there are massive coral reefs which suddenly changed colors.

And the changed color is completely white, so if you look at this particular place all the coral structures are completely white, but they are naturally not like this, if you look at a coral reef, a healthy coral reef you actually see lots of different colors. Now, the question is what makes them go from a colored coral reef to a completely white coral reef. And this is what is called coral bleaching.

As it turns out that zooxanthellae or different kind of algae which lives in the coral reef cannot live if the temperature goes up. So, corals and algae have a symbiotic relationship. They depend on each other to survive. The algae serves as the coral's food supply and the sources of the colors.

Now, once the temperature increases and there is also a role of pollution, then it puts stress on the special relationship and these algae tend to leave the coral structure. With the absence of this algae the coral becomes completely white and because these corals are also lacking the food supply 90 percent of their energy, they are more susceptible to disease and these corals slowly die without the food source.

So, when you see these bleached corals they are basically indicating that their ecosystem health has already declined severely and they are on their way to the death. And this has been noticed overall throughout the globe in different coral colonies. And the only way to revert back to the normal coral health is by reducing pollution and reducing global warming which is a difficult task to do.

And without that the majority of corals are going to die eventually and they are also very disease prone, so they are either going to directly die because of lack of food or they are going to die because of more vulnerability to disease.

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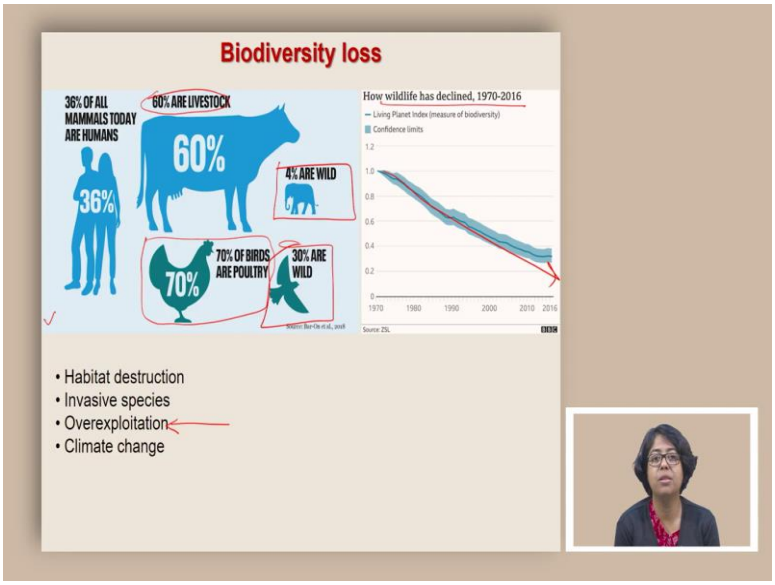

Now, when we think about the overall biodiversity of the world, we have already seen specific cases of the marine biodiversity including the corals where it is getting affected because of warmth global warming, there is also overall biodiversity loss in the land also and not all of these are directly related to only global warming, it is also about the human, interference the large population size of the human and the food production.

So, Anthropocene is marked by a significant biodiversity loss and the reason for such biodiversity laws includes habitat destruction, invasive species over exploitation and climate change. So, this over exploitation basically means how we get our food. So, it is not unusual to represent the overall biodiversity of the world in this cartoon framework where 36 percent of all mammals today are human, which is not a pattern which is which sustains biodiversity.

60 percent of all mammals are represented by livestock, it is the cows, it is the pig, everything that we use in some way as food source. Only four percent of all mammals are wild in today's world. The same is true for the birds. So, if you look at the birds only 30 percent are wild and 70 percent of the birds are poultry. It includes turkey, it includes chicken, includes hen, everything, but 30 percent of all birds are the only ones which are surviving in the wild.

So, if we look at the wildlife decline between 1970s to 2016, we see this major drop and unless we make conscious efforts to revert it, it is going to continue and as we have seen throughout that ecosystem is a very connected place and we really do not know removal of diversity or removal of a particular species how it impacts the functioning of the other species and as a result there can be a chance of overall collapse of the ecosystem functioning because of the diversity loss.

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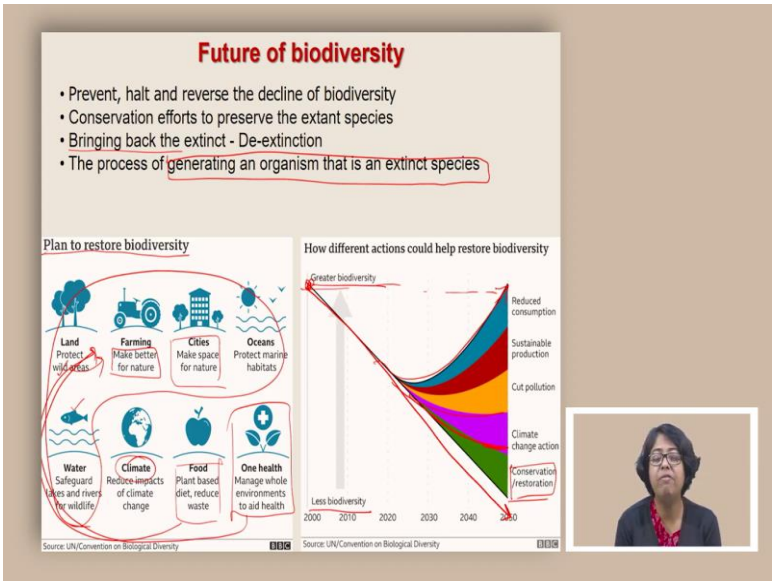

Now, what is the future of biodiversity? So, the general idea of protecting biodiversity or to stop this biodiversity decline is the approach where we should prevent, we should halt and we should reverse the decline of biodiversity. There are conservation efforts to prevent the extant species, there is a plan to restore biodiversity. So, on land we need to protect the wild areas.

When we have to form we have to have better for nature, so we have to choose options which are not destructive to the wildlife. We are not encroaching into the forest cover. When we are making cities there needs to have more space for nature ensuring that there is a balance, oceans are very vulnerable and it, we should have a way of protecting marine habitats. Water, when we talk about only water it primarily means the water on the land.

So, aquatic region, rivers, ponds, lakes; we have to safeguard the lakes and rivers for wildlife because they are the major sources of fresh water or drinking water and also a very high biodiversity region. But all of these will not finally work unless one looks at the climate. So, we need to have some reduced impacts of the climate change and we have to ensure that it is not going beyond a point where it cannot be reversed.

The food that we eat it has to have a way, so that we are not wasting anything because wasting means we will again go back and use more land, you will use unsafe farming practices to produce more food. And finally, we have to have some way of managing the whole environment to aid health because again once the health declines that will also become very costly for the environment, because again it will go for more land use, more farming, more building, of more buildings probably.

Now, how can different actions could help to restore biodiversity? So, the conservation restoration if we do that by 1950s, this decline will only be like this. So, if we do not do anything, this is the low biodiversity mark, this is the great bio, greater biodiversity mark, this is where we are probably today, if we are starting from this, it is simply going to go down if we do not do anything and probably we are going to expect a major biodiversity loss by 2050.

If we go for conservation and restoration, then this line is going to change somewhere in between, if we make climate change action, then it will be something like this, if we cut pollution, sustainable production reduced consumption, all of these will eventually bring it back. Now, this is only a cartoon, it does not really have the actual values. So, therefore, it is hard to comment in terms of how long would it take, how much of the conservation and restoration one has to do in order to bring it back.

But there has been efforts, for example, these conservation efforts have been very strict in Europe and in parts of especially in parts of North America, where they have tried to reserve these forest sanctuaries, national parks, to ensure the increase in biodiversity. There has also

been efforts where people were trying to bring back the extinct and this is called de-extinction. This is a process of generating an organism that is an extinct species.

So now, are we talking about bringing back dinosaurs? No, the idea is to bring back those extinct species which when extinct during human time scale and because of their loss from the ecosystem, the ecosystem suffered and the ecosystem functioning was lost and because it has become extinct during human time scale, there is possibility of finding their genetic sequence and the samples of their soft tissue from which an organism can be created by using the genetic technology.

And this has been discussed for quite some time and the list of groups that may have been or they may, and the list of the groups which might be candidates for the extinction where the researchers will try to de-extinct them includes mammoths, includes organisms like, includes mammoths, includes organisms like passenger pigeon. Any organism which went extinct during the human time scale, especially in last 15000 years.

Also includes the marsupials that went extinct in Australia and New Guinea, New Zealand, Tasmanian Tigers. Now, we are probably looking at a future where we will see some of these so-called extinct organisms coming back and reoccupying their original (())(33:31). Now, the question is when we think about saving the Earth, we find that it is a contradictory position because there were times when the climate was considerably different than today.

There were times such as Eocene where the temperature was much higher than today. So, the global warming why are we worried about it and do we really need to save the Earth? The answer is probably we do not really need to save the Earth because Earth will survive. It is only the point where we are not going to survive and the biodiversity around us is not going to survive and the self-preservation motivates us to take action.

And when we think about the extinction, also when we look at the mass extinctions of the geologic time scale, every time the ecosystem has bounced back. So, even we do not, if we do not intervene, probably the ecosystem will bounce back, however, it will be a significant amount of time and in human time scale it is really really a long time.

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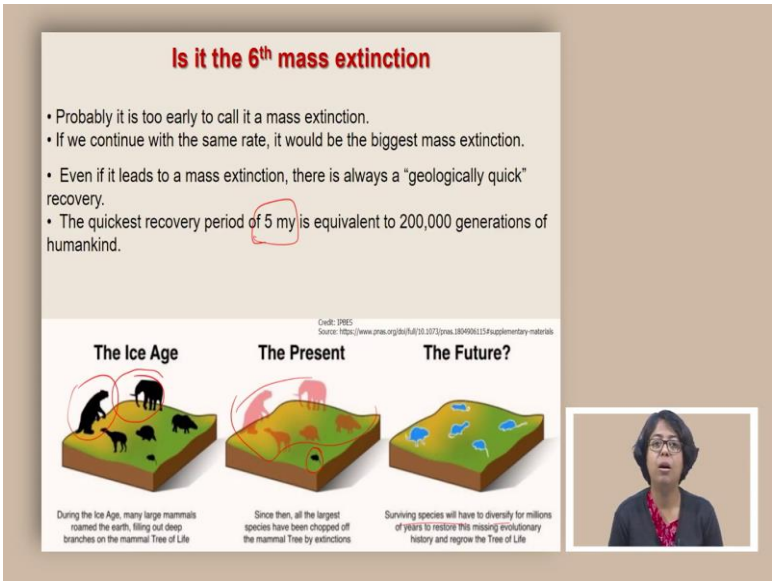

So, is it a sixth pass Extinction? So, probably it is too early to call it a mass extinction simply because we are looking at a very small time. But one thing is for sure that if we continue with the same rate, it would be the biggest mass extinction that the Earth has ever seen. Even if it leads to a mass extinction, there is always a geologically quick recovery as we have seen.

But the quickest recovery period is 5 million years that we have seen in the geologic time scale and it is equivalent to 200,000 generations of human kind. So, again for our interests, selfish interest we should be trying to ensure that we can stop the loss of biodiversity. So, there is this study which looks, looked at the Ice Age mammals.

So, during Ice Age there are many large mammals which were roaming the Earth, filling out the deep branches of mammal tree of life. Now, almost all of them are lost in the present except for the rodents, which are small mammals. Now, these largest species have been chopped off from the mammal tree by extinction. What is the future? Are we going to get to a point where we are going to see more diversity, maybe not these mammals but appearance of other mammals?

Now, the surviving species will have to diversify for millions of years to restore the missing evolutionary history and regrow the tree of life. So, unless it goes on for let us say 5 million years, we are not going to see any difference, we are not going to see any growth in biodiversity, especially in the case of mammals and hence, we really need to protect, conserve, halt and reverse the biodiversity decline that we see today.

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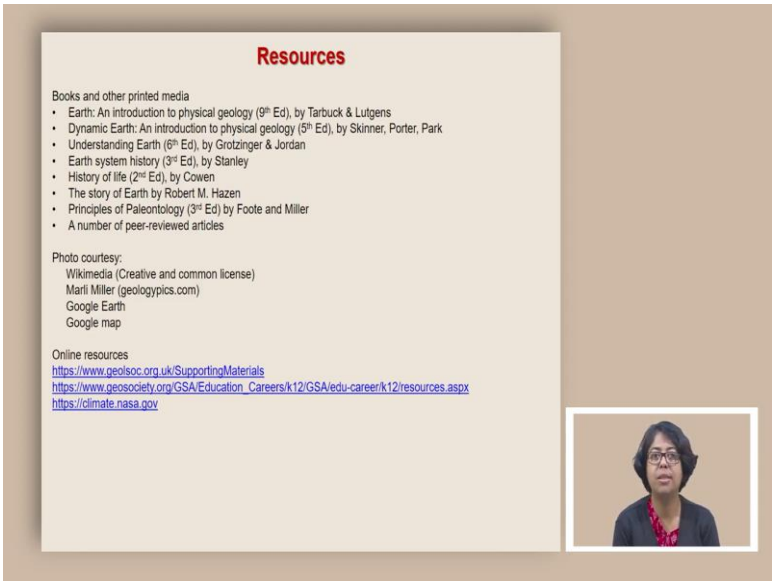

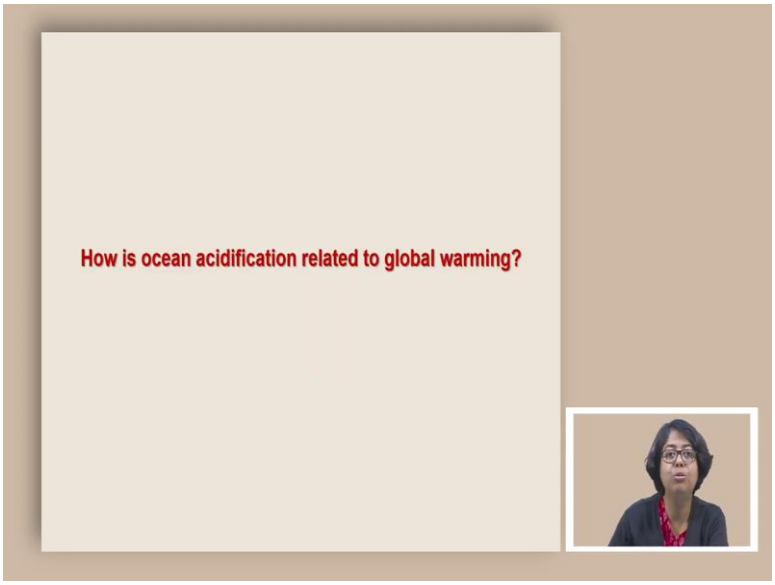

So, in summary in today's class we learned about Anthropocene and how do we define the beginning of Anthropocene. We also learned about the global warming, what are the causes of it and how it is different from the natural variability of temperature that is observed in the geologic past? We learned the effect of global warming on the marine habitats.

We also learned how the biodiversity is impacted by global warming through ocean acidification, bleaching of corals. We learned that there is a major biodiversity crisis that we are in the midst today, there is a loss of wild organisms every day and if we continue like this there would be the biggest major mass extinction of all times.

And even if it happens there can be a recovery, but that recovery in human time scale is going to be really long and therefore, it is important to be observant about the environment and try to reverse the biodiversity decline. Here are some of the resources that I used for making the slides and here is a question for you to think about, thank you.