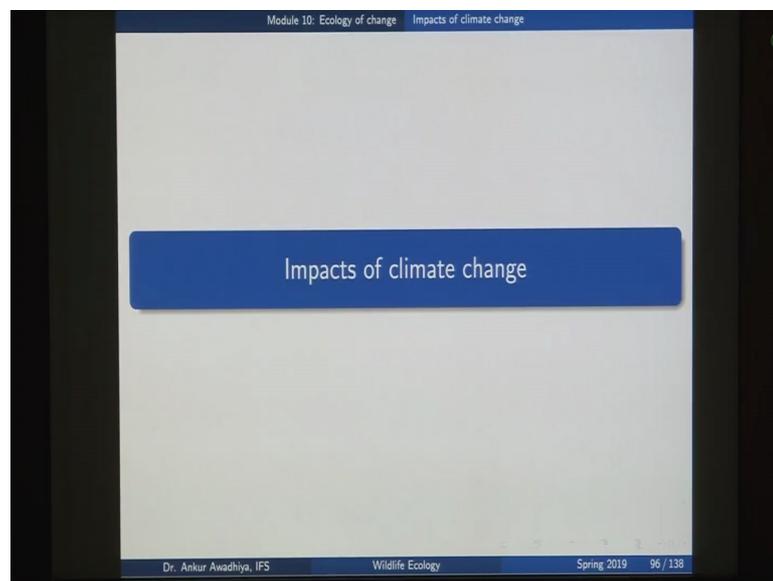


Wildlife Ecology
Dr. Ankur Awadhiya
Department of Biotechnology
Indian Institute of Technology, Kanpur

Lecture - 30
Impacts of climate change

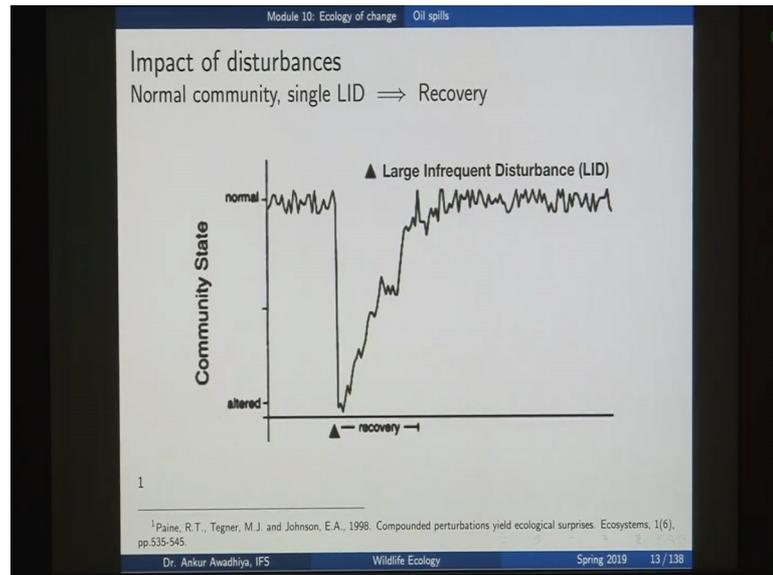
[FL] We move forward with our discussion of the ecology of changes and today we will have a look at the Impacts of climate change.

(Refer Slide Time: 00:21)



Now, climate change has become a hot currency these days. So, we see people talking everywhere about climate changes the question is how does climate change impact the ecosystems or what is its relation with ecology?

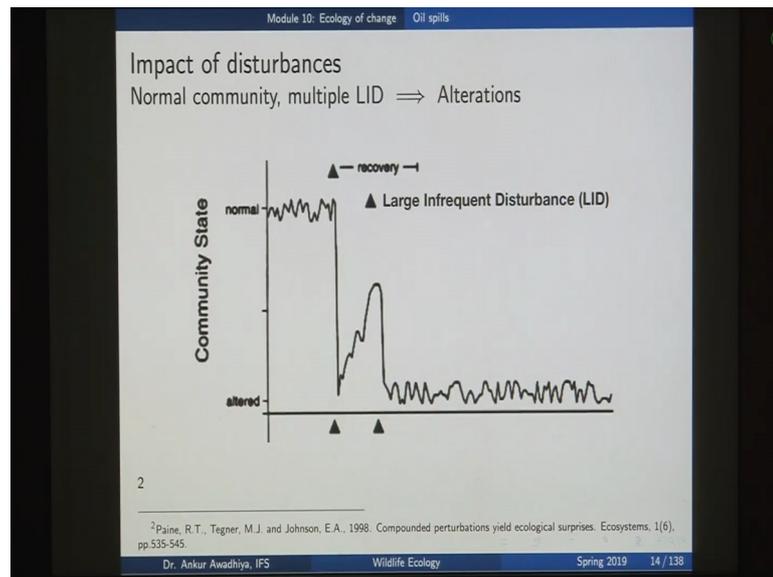
(Refer Slide Time: 00:41)



Now, we have seen earlier that for any disturbance climate changes also another disturbance. So, for any disturbance we can say that the impacts would depend on the size of that disturbance the frequency of that disturbance or how commonly that disturbance occurs and the initial state of the ecosystem.

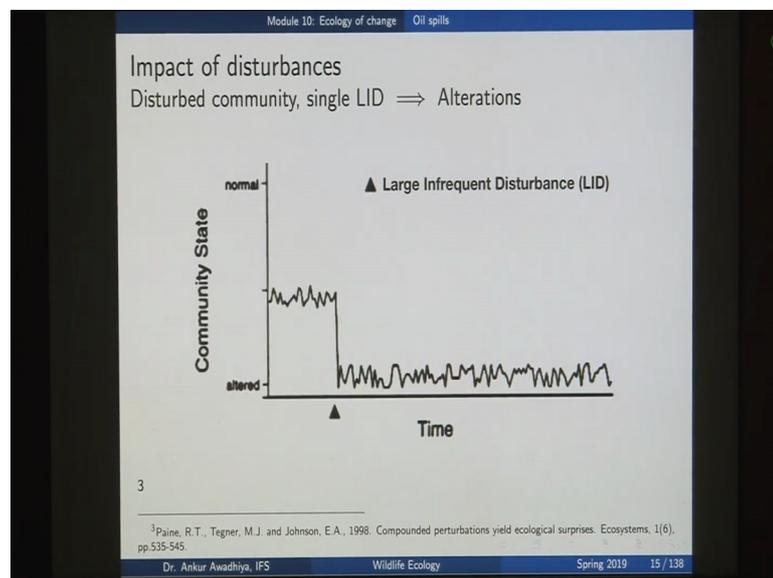
So, for instance, we saw that if there is a community that is normal you give it a signal large disturbance and you have the state that this community has moved from a normal state to an altered state, but in slowly and steady it is trying to move back and then is able to reach the normal state once again.

(Refer Slide Time: 01:23)



On the other hand, if you give multiple disturbances to this community, so in the first case it became an altered community it was trying to recuperate it back, but then you give it another disturbance and now it is not able to cope up any further.

(Refer Slide Time: 01:40)



Or the third case that we saw was the case of a community that is already stressed and if you have this stressed community you give it a disturbance and it is not able to you to recuperate back. Now, when we are talking about climate change climate change is also a disturbance and in certain instances, we can call that it is a large disturbance. But in most

cases a number of communities feel that the climate change is more of a stressor because it is acting not abruptly as in the case of a forest fire or it as in the case of an oil spill, but is it is acting gradually.

So, this is one of the stressors that a community might feel. So, climate change might be responsible to bring a community at this stage and at this stage when the community is already stressed. So, any disturbance would bring it to an altered state and it will not be able to recuperate back. So, we look at climate change in more detail in the current lecture and we will see what other impacts that it is causing on ecology.

(Refer Slide Time: 02:43)

Module 10: Ecology of change | Impacts of climate change

Climate

Definition

"A broad composite of the average conditions of a region, measured in terms of such things as temperature, amount of rainfall or snowfall, snow and ice cover, and winds"^a

^aRuddiman, W. F. (2001). Earth's Climate: past and future, Macmillan.

Timing

The classical period for taking averages is 30 years.

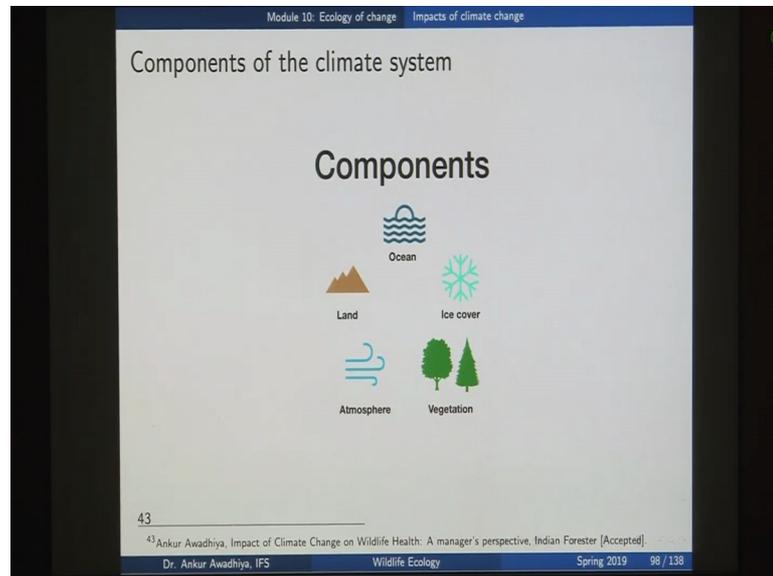
Dr. Ankur Awadhya, IFS | Wildlife Ecology | Spring 2019 | 97 / 138

So, we begin as always with the definitions. So, climate is defined as a broad composite of average conditions of a region measured in terms of things such as temperature amount of rainfall or snowfall, snow and ice cover and winds. So, climate is a composite of average conditions of a region. So, climate is not something that changes every day, it is a broad average. This broad average the classical period of taking the averages is 30 years.

So, over the 30 year period if we ask that in the month of August what is the climate of Kanpur for instance; so we will come up with a figure that over the past 30 years in every month of august what was the amount of a heat or what was the temperature, what was the rainfall, did we have any snowfall, what was the wind direction, what was the

wind speed and so on. And when we come up with this average, we say that that is the climate of that particular region.

(Refer Slide Time: 03:46)



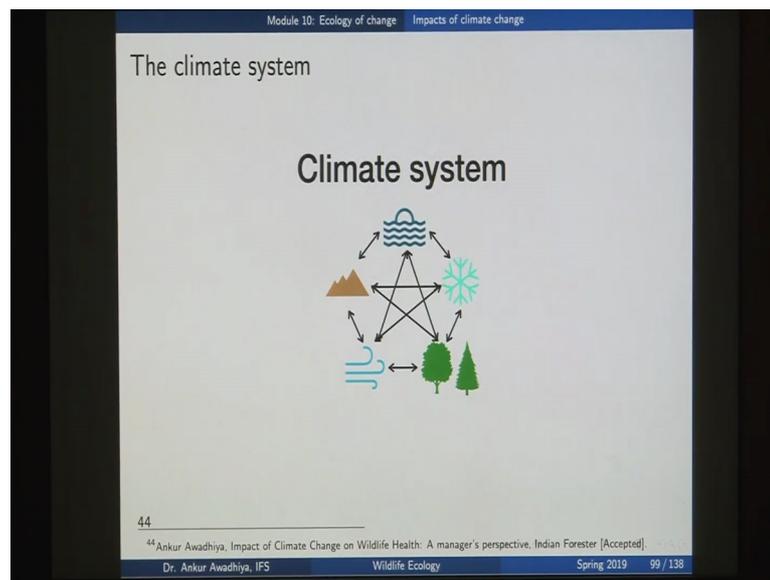
Now, climate is governed by five components. So, these are the five components that govern the climate on the planet. So, the first component is ocean, if you have an area that is close to a big water body that is close to an ocean. So, it will have an equitable climate. The climate will not show a very large amount of variations. The summers will not be very hot the winters will not be very cool. So, oceans play a major role in the climatic system.

The second one is land if you have an area that is in the interiors, so you will have a very great amount of climatic variations the summers will be very hot, the winters will be very cold and so on. And then both of these components act together. So, if you have a lot of heating on the land so that, will create an area of low pressure over the line and if because the oceans do not show that great level of heating. So, there would be a high pressure on the oceans and then you will have a wind that starts flowing from the ocean to the land. So, atmosphere is also another big component because these two are acting together along with that most feared to result in vents in the system.

Now, along with the atmosphere you have vegetation. Vegetation also plays a bigger role in the climate of a region. So, if you have an area that is full of plants, so the summers will not be that hot. And the fifth component is the ice cover that is present in an area.

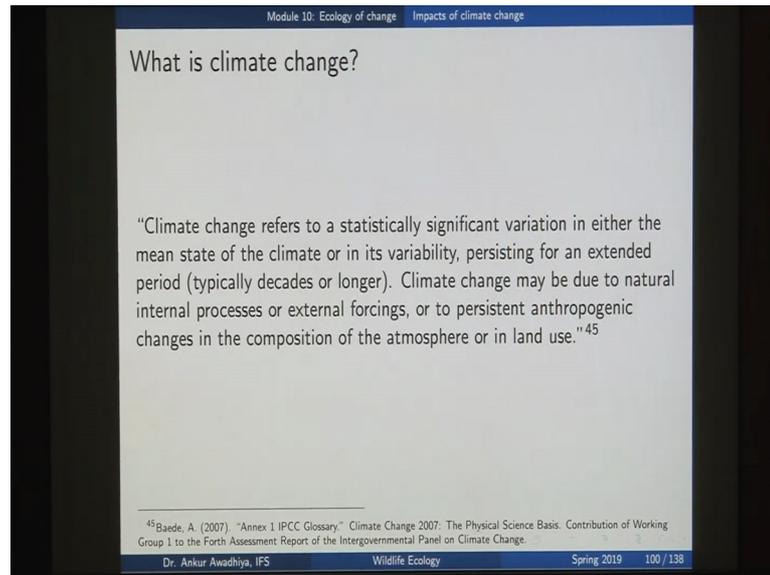
Now, if you have an area that has a nice cover say the polar caps. So, in that area with the sun shines most of the energy of the sun gets reflected back or in technical terms we say that the albedo of the area is very high. Most of the energy gets reflected back. So, the amount of heating that we will have in that area will be less. Now, when you have all 5 of these components they form components of the climate system, and then they form the climate system through their interactions.

(Refer Slide Time: 05:45)



So, we will have the hydrosphere that is interacting with the lithosphere with the atmosphere with the biosphere and with the cryosphere and similarly all of these components will be interacting with each other. And when you have a combination of all five of these that are acting together we see that this is forming a climate system.

(Refer Slide Time: 06:12)



And we talk when we talk about climate change then there is a change in the climate of a particular region. So, climate change refers to a statistically significant variation in either the main state of the climate or its variability.

So, when we say the main state of a climate it means that earlier we were observing that in April Kanpur was not having a very high temperature, but now we are observing for the past few years that the temperature has shot up. So, the mean state of the climate would say that the main temperatures of Kanpur in the month of April have gone up. And that if, that is a statistically significant variation then we would say that this area is showing the symptoms of a climate change. So, that is the mean state or its variability.

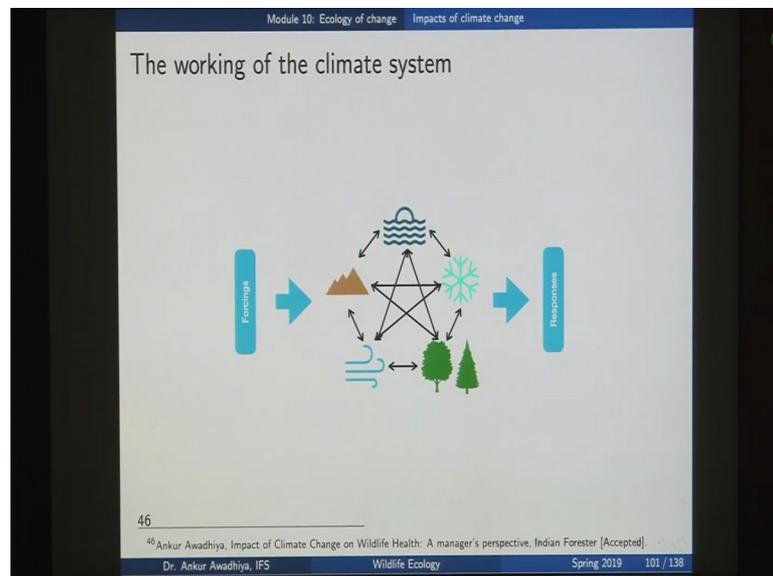
Now, when we say variability the question that we are asking is how many days do we have rainfall and how many days are the dry days. If we see a difference that more number of days are becoming rainier or more number of days are becoming drier days, then we would say that there is a change in the variability or earlier suppose we were having a cycle in which every 10th year we were seeing a major rot in the area and now we are saying that every third year we are seeing a major drought in the area. So, the variability of the climate has increased.

Earlier for roughly around 10 years the climate was stable and we were having a perturbation once every 10 years. Now, we are having a perturbation once every 3 years. So, we say that the variability of the climate has increased. So, that is also a climate

change. So, climate change refers to a statistically significant variation in either the mean state of the climate or in its variability persisting for an exceed for an extended period typically decades or longer. So, we cannot say that suppose this year in the month of April there the temperature shot up so that is climate change, no because this is climate in itself means an averaging out over a long period typically 30 years. So, when we talk about climate change this also has to persist for an extended period typically decades or longer.

Now, climate change may be due to natural internal processes or external forcings. So, it might be because of some natural processes such as changes in the intensity or the amount of energy that is given out by the cell. Now, that is a natural process or it could be because of some external forcings or to persistent anthropogenic changes in the composition of the atmosphere or any land use. So, anthropogenic changes are man made changes. So, you can have natural internal processes, external forcings or persistent anthropogenic changes and all of these can together gave rise to or all of these can individually gave rise to a climate change.

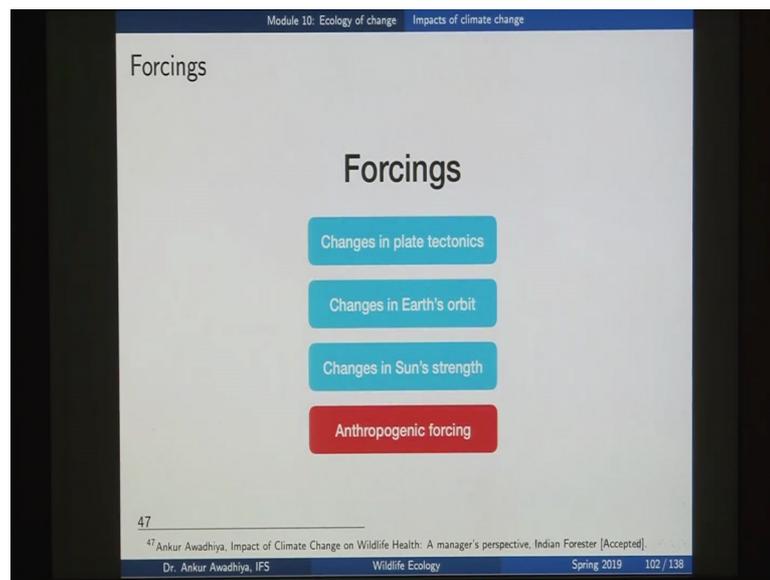
(Refer Slide Time: 09:11)



So, when we see the working of the climate system it means that you have this climatic system with all these five different components and you are forcing this system. So, essentially you are given some input to the system which is resulting in a response or an output and that is the working of the climatic system. So, a forcing or an input is suppose

the amount of energy that is given out by the sun if it increases. So, this climatic system would give out a response. So, that response might be that you will have a more hotter climate in any particular region or it might result in a situation where the snowfall in decreases in an area or maybe the biotic components change. So, there is a lot of variety of plants. So, all of these would be known as responses of the climatic system to the external forcing.

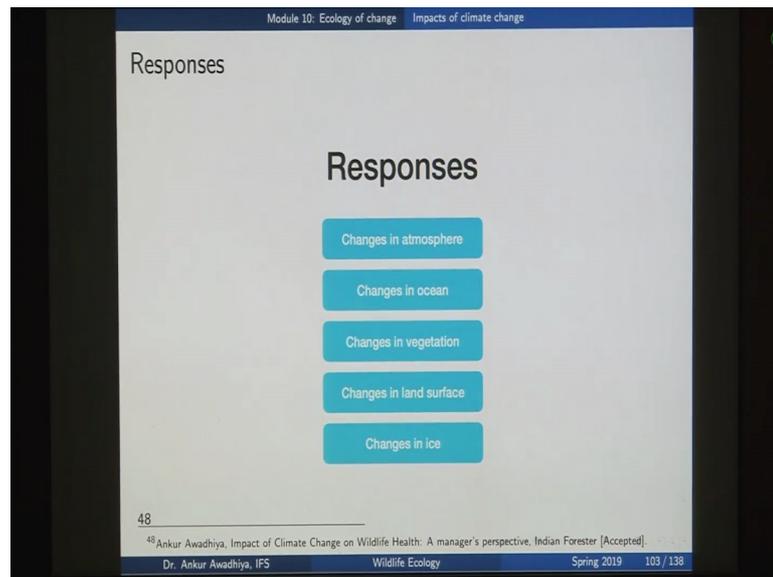
(Refer Slide Time: 10:06)



Now, what are the forcings? Forcings what are the inputs that you are giving to the climate system because of which it might give out a response. So, forcings can be changes in the plate tectonics. So, that is an internal forcing or changes in the earth's orbit or changes in the sun's strength or the anthropogenic forcing.

Now, when we say anthropogenic forcing and throw poses man genic it means that caused because of or formed out of. So, it is a forcing that is formed out of human beings and a good example is that of release of the greenhouse gases such as carbon dioxide and methane. So, if the concentration of carbon dioxide increases, so that is acting as a forcing on the climate system it is retaining more and more amount of heat in the climatic system and that is resulting in some responses.

(Refer Slide Time: 10:56)

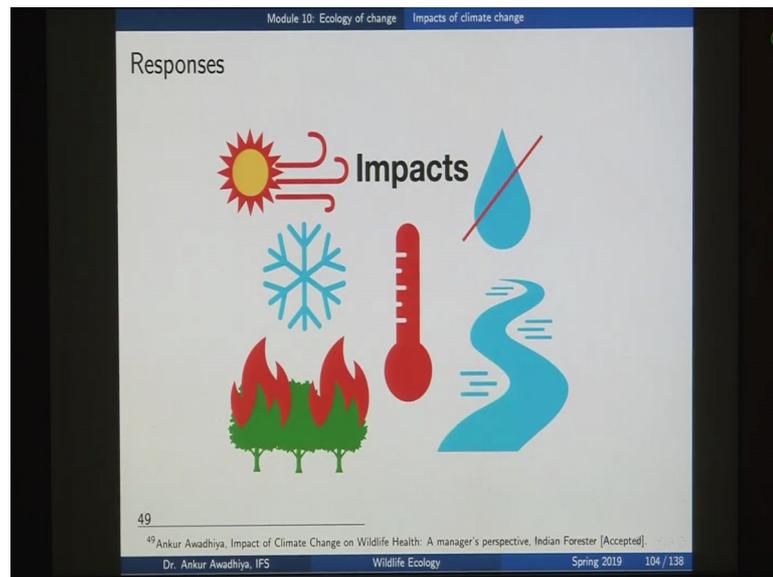


When we talk about responses, here are some responses. We have five components of the climatic system and changes in any of these would be called a response. So, changes in atmosphere, suppose the wind direction use the wind speed changes that would be called a change in the atmosphere or changes in the oceans or changes in vegetation or changes in land structure. So, probably because of a climate change the changes in the ice cover.

So, when we talk about all these changes probably because of climate change, the ice cover would melt which would increase the water level in the oceans which would then reduce the amount of surface that is covered by land. Because the lands will get inundated which would also result in changes in the vegetation, because a number of plants would get submerged and a number of plants will die out, and also changes in the atmosphere because you will have changes in the wind direction, you will have changes in rainfall patterns.

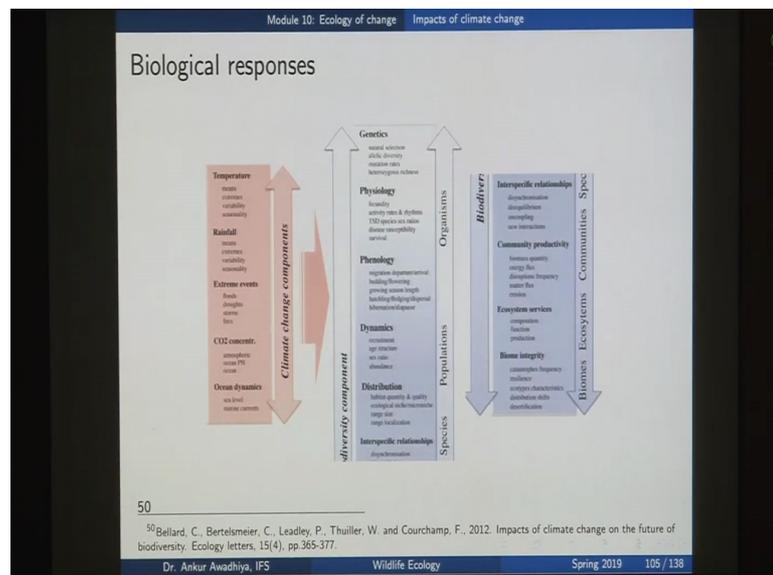
So, some areas will get more rainfall, some areas will get less rainfall which would then again influence the vegetation of those areas. So, some species will die out some more species will come into this area all of these are different responses that we can observe because of climate change or because of any particular forcing that is given to the climatic system.

(Refer Slide Time: 12:21)



So, these responses can be more vents draughts, floods, increased temperature, forest fires changes in the snow cover and so on. Now, these are the physical responses that we can see, but the climate change will also result in a number of ecological responses and a number of biological responses.

(Refer Slide Time: 12:37)



Now, what are those biological responses? So, we can observe changes and say the genetics of an area because the natural selection will change because currently if you have an area where you have a mean temperature of say 30 degrees. Now, if you increase

that to say 32 degrees. So, in the case of 30 degrees certain individuals of the population are being selected because they are more fit. Now, if you increase the temperature only those individuals that are able to tolerate this increase in temperature will be more selected. So, there will be a change in the natural selection that will observe which is a change in the genetics or a change in the allele diversity. Because it is possible that during this process when you have a higher temperature a number of individuals would die out and that will result in a loss of some alleles that are already present there in the gene pool.

So, that would be a genetic level change or changes in the mutation rates because when you have cells that are undergoing division, if there is a change in the ambient surroundings, if there is a higher temperature around. So, it is possible that the enzymes might not function properly in those situations it is also possible that you will have some more errors that creep up whenever there is a replication of DNA. So, we might observe changes in the mutation rates.

Or we might even see changes in physiology. So, the changes in physiology include things such as the birth rates or the activity rates and rhythms of the organism. The birth rates might change because the organisms are already feeling a lot of stress. So, when there is an organism that is highly stressed it might not want to give rise to the young ones because it does not find the ambient conditions good enough to raise and offspring or it might result in changes in the activity patterns of organisms. So, if there is an organism that is active during the daytime and it is too hot during the daytime. So, this organism might stop or might prefer not to go out during the daytime.

So, there would be a change in the activity patterns of the organism or changes in disease susceptibility because an increase in temperature will result in a lot of stress to the organisms. So, if an organism is already stressed it is more susceptible to a disease or changes in the survival rates of the organism or we might see changes in the phenology of organisms.

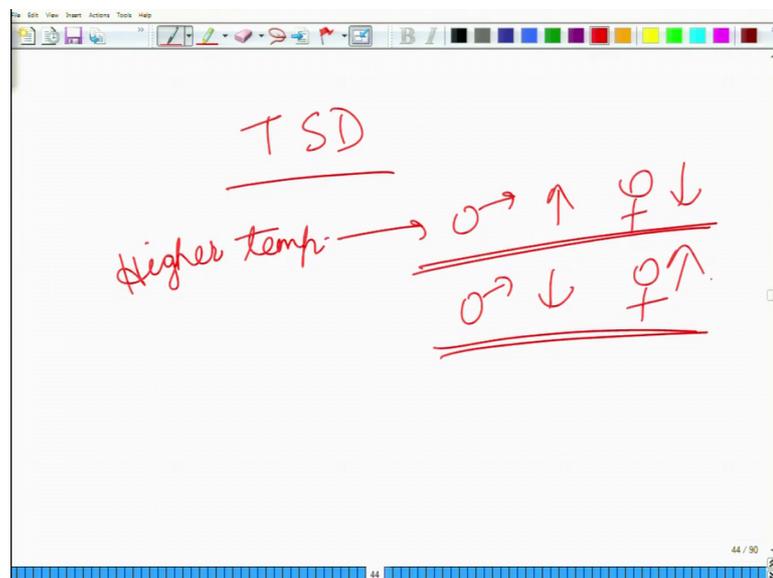
Now, phenology refers to the timing of organisms for different activities. So, for instance we might see changes in migration patterns, migration timings. So, if there is a bird that wants to move to India during the summer season and the summer seasons approach faster, so it might start coming in place of April it might start coming in

February. So, that would be a change in the phenology of the world and whenever there is a change in the phenology that might also have some other consequences.

So, for instance if there is a bird that is coming in April and it is having access to food if it comes in the month of February then probably it does not have access to enough food and then probably it might die out. So, in phenology we will see changes in migration departure or arrival; obviously, changes in budding or flowering of different plants or changes in the growing season length or hatching period or flaking period or dispersal period or hibernation period. So, all of these are changes in phenology that we will observe and all of these are biological responses to the climatic changes.

Or we can see changes in the dynamics of different organisms. So, in the case of dynamics we will we can see changes in the sex ratio of certain organisms. Now, organisms such as crocodiles have a temperature dependent sex determination TSD; so it is called temperature dependent sex determination.

(Refer Slide Time: 16:48)



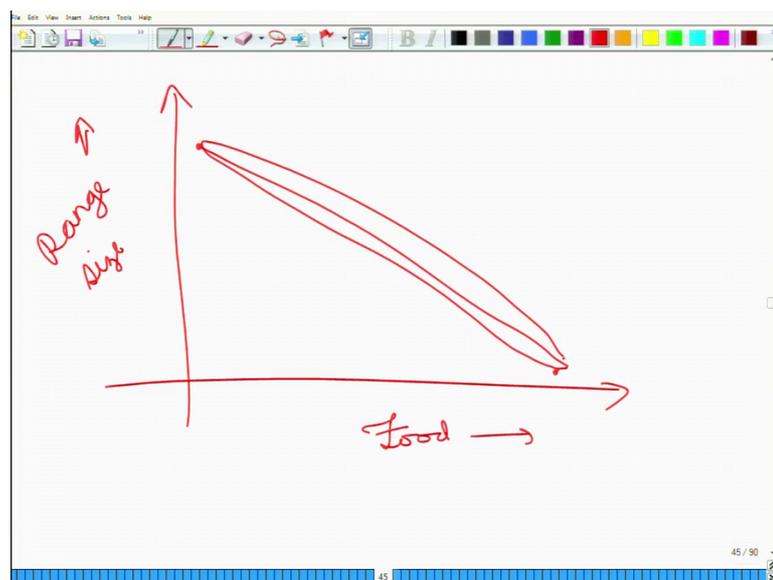
Now, what happens in this case is, if you have a higher temperature, so we have the eggs and the eggs are laid out and if the eggs get a higher temperature then in that situation you will have more number of males. So, the males would increase and the females would decrease in number whereas, in the case of animals such as the tortoises we would see a very different impact. So, if you have a higher temperature the number of males

would reduce and the number of females would increase. Now, this thing is known as a temperature dependent sex determination.

Now, if you increase the temperature there is global warming. So, in the case of crocodiles we will have a situation that there are too few number of females and so the population might go towards or collapse. Or in the case of tortoises as well we might see that there are enough number of females, but then there are not enough number of males to fertilize that more population. So, there as well we will start observing changes in the population growth rate. So, these are changes in the dynamics. The changes in the sex ratio or changes in the age structure or changes in the abundance are all what we will observe because of the changes in climate.

Now, these point also need result in changes in the distribution of organisms because habitat quantity and quality will change if there is an organism that requires a certain foreign species that grows in cooler climates. If the temperature rises, so this for this species would die out and the habitat will not remain suitable for this particular species of animal. So, then it might have to move out, it might have to migrate out or we will see changes in the ecological nations or in the range sizes of animals or in the range localization of animals because here again we had observed in the case of.

(Refer Slide Time: 18:48)

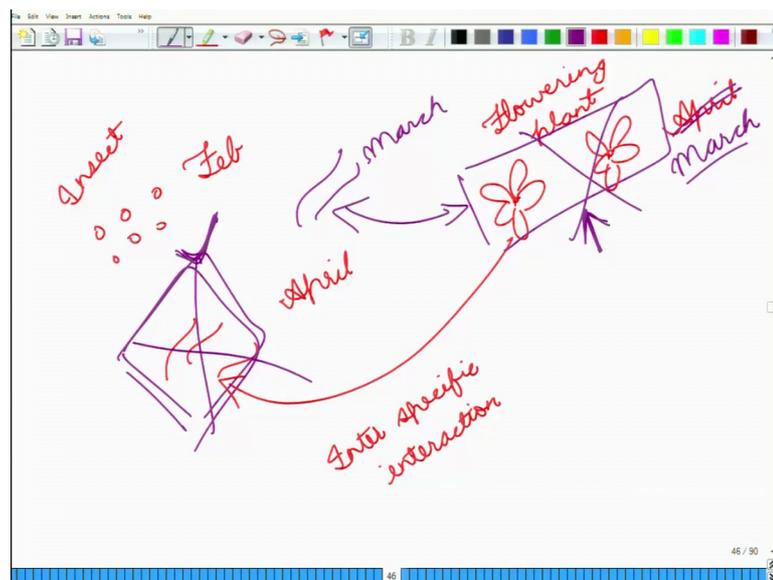


So, we had observed that in one of the earlier lectures, if you have the amount of food that is given here and if you have the range size we see that if you have less amount of

food the animal tries to maintain a larger range size as compared to a situation where you have more amount of food. So, if there is more amount of food that is available. So, you will observe that the animal has a reduced range size. Now, if you have a situation of climate change and if the food species die out if the plants die out if the flowers have changed their seasons.

So, that the flowers are not providing enough amount of nectar or pollens to their animals. So, then that would also result in a change in the range sizes. So, the ranges would increase in size. So, that is also another biological impact of climate change that we are observing, and all of these biological impacts will result in a change in the ecosystem dynamics of that area or changes in interspecific relationships. So, we have situations such as this synchronization disequilibrium uncoupling and new interactions.

(Refer Slide Time: 20:08)



So, what is what we are referring to in this type case is that suppose you have a species and in this species it give it lays eggs in the month of February and then the larvae come out in the month of say April. Now, these larvae come out in the month of April because in the month of April you have saved flowers that come up and these flowers are then eaten up by the larvae. So, these serve as the food source.

Now, in this case we are seeing an inter specific interaction. So, this is an inter specific interaction, inter specific because you have this one species which is the flowering plant and you have this other species which is an insect. Now, both of these species are

showing this interaction in terms of predation or maybe it could be some sort of mutualism. Now, in the situation of climate change, so suppose this was also in April. Now, if you have a situation of climate change then probably because you have an increased temperature in place of April this plant starts flowering in say March and the flowers remain for say 15 days. Now, what happens?

When these flowers come up in the month of March you do not have these insects around. Now, these insects probably are feeding on these flowers and probably are also resulting in the pollination of these plants. Now, when it is responding to the climate change it has changed its timing. So, in place of flowering in the April it is started flowering in March because the plants do not know when the larvae are coming out they are only responding to the ambient temperatures.

So, probably there is one species that is responding to temperature there is another species that is responding to the amount of daylight. So, in that case we will see this synchronization because when these flowers come up in the month of March there are no larvae around. So, there is no amount of pollination. So, these plants would start dying off.

On the other hand, when these larvae come out in the month of April there is no flower available for them. So, there is no food available for them and. So, this large also start dying out. So, just because now both of these species individually they are not being decimated because of climate change, but then because the synchronization between both of these species that was there in the beginning because that has been disrupted one is now coming up earlier the other one is coming up later. So, because of this might result in a decimation of both the species and this is what we mean by when we say a dis synchronization between these two species or in uncoupling of these species or probably there could be some new interactions that would come up.

So, in place of this particular species that was and that was fertilizing these flowers, probably now there will be some other species that gives out its larvae in the month of March and those species would now start interacting with these flowers. And we do not know what would be the impact of such new interactions. The uncoupling of earlier interactions and the start and the starting of new interactions what would be the impact of these on the ecosystem. Because the these interrelationships that have come up they have

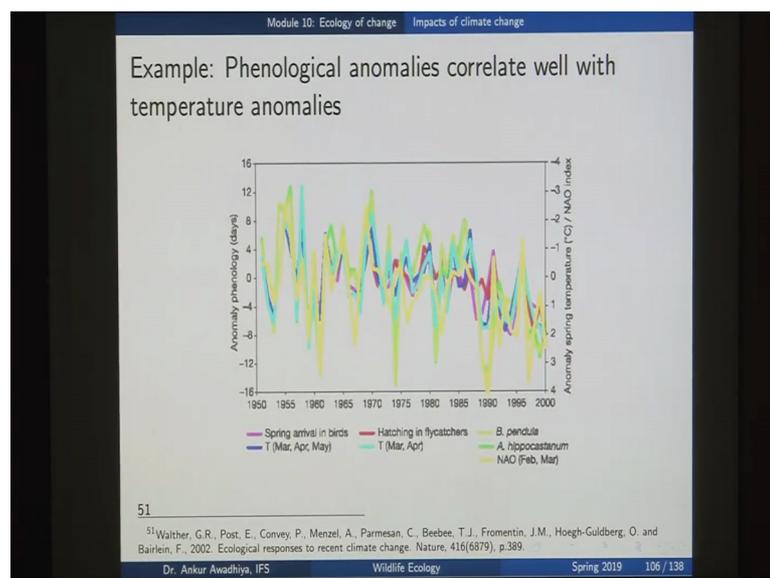
evolved through the millions of years of evolution, and if he changed them in a very short period of time in a period of say a few decades then probably it might result in a negative influence on the ecosystem.

The other biological impacts could be changes in the community productivity. So, the amount of biomass that is being produced in the community or the energy flux of the community might also see a change.

Now, all of these will next result in ecosystem services disruption. So, there would be a change in the composition function in production functions of the ecosystem. So, that would result in an ecosystem that is not able to perform its functions properly which would then further result in changes in the biome integrity. So, now, we can observe that just because of a single change just because of climate change we can anticipate that there might be a number of changes in the ecosystems.

Now, this is a theoretical background the question is are these changes actually happening because of climate change do or are these just a theoretical saying because we are just saying that because of these changes there would be a disruption in the ecosystem, but then are we acting a bit too prudent or is it that that we will not observe these large amounts of changes and we are just frightening ourselves.

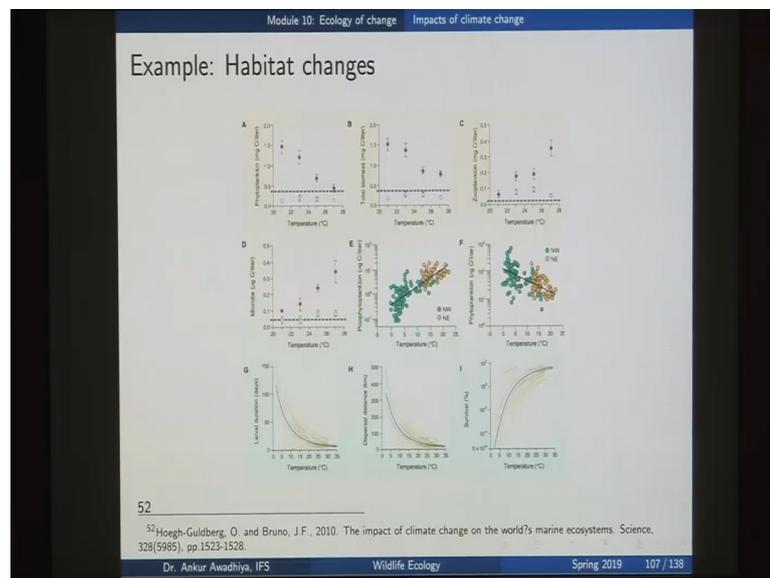
(Refer Slide Time: 25:11)



So, let us now look at some examples. The first example is that of phenological anomalies and the temperature anomalies. Now, in this graph here we have on the x axis we have the years 1950, 55, 60, 65, 70, 75 and so on. Now, the blue colour here the dark blue colour is showing you are either the temperature anomalies in the month of March, April and May. The blue color is the light blue color is showing you that the temperature anomalies in the month of March and April. And the pink one the pink lines are showing you the spring arrival of birds. The red one is showing you the hatching in fly catchers.

And as we can see all of these curves come one upon the other. So, essentially there is a very good correlation between temperature anomalies and phenological anomalies. So, in fact, if there is an increase in temperature or if there is a decrease in temperature that would result in a phonological change. So, this is something that we are actually observed in nature. And so, when we see that climate change would result in phonological anomalies we are not making a statement that is be out of proportion this is something that we are already observing in nature.

(Refer Slide Time: 26:31)



Or if we look at changes in the habitats; so, let us look at changes in different organisms when you change the ambient conditions. So, these are experimental results and a few field observations. So, on the x axis here you have the temperature, on the y axis here you have the amount of phytoplankton. So, you have milligram of carbon per litre and here you see that as that the temperature increases the phytoplankton reduce. So, with

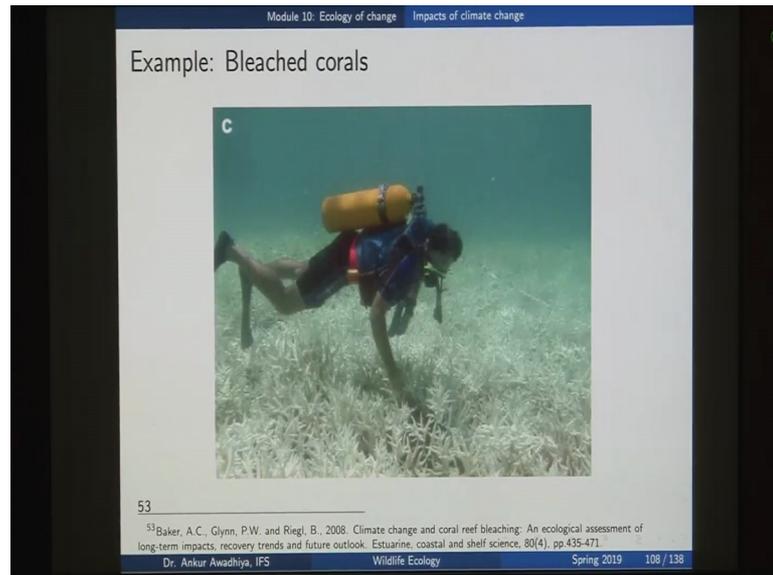
increase in temperatures you will have less number of phytoplankton, that are available in the ecosystem.

Now, phytoplankton are producers. So, producers are required because they produce food for all the other organisms and if the producers themselves reduce in their numbers then the ecosystem is bound to get a change. Here we see the total biomass of the system that would reduce with an increase in the temperature. Here we are observing the zooplankton, so zooplankton increase in numbers. So, you have reduced food and more number of zooplankton. So, what would happen to all of this zooplankton? Will they will start dying out to inline numbers because they are present in large numbers they do not have access to sufficient amount of food so they will start dying off.

Or if we look at the number of microbes that we have in the system; so, if you increase the temperature the number of microorganisms would grow would go up. Or if you look at the phytoplankton; so, this is phytoplankton and this is reducing and this is now a field observation or if you look at different other species. So, here we are looking at the larval duration of a particular species how many days does this does this species remain in the larval state and if we increase the temperature so the number of days it remains as a lava it reduces the dispersal distance also reduces.

The survival rate for this particular species it increases when you have more temperature around. So, we are seeing changes in different components of the ecosystem. So, the changes in the habitat are not just theoretical changes we can actually prove it through experimental observations and we can actually prove it through the field observations. Other large scale changes are changes in the coral ecosystems.

(Refer Slide Time: 28:45)



So, here we are observing all of these corals that have died out. So, this is a process that is known as the bleaching of corals. Then the process of bleaching they lose out all the corals and they die out. And more and more corals are getting bleached more and more corals are dying out because of the climate change.

Now, when corals die out it is not just the corals that will suffer the consequences, but a number of other species as well because corals are keystone species here, they play a role in the ecosystem that is much greater than their own numerical abundance because, corals act as nurseries for a number of fishes species. Now, if you do not have well functioning corals in the system the fishes would also die out.

(Refer Slide Time: 29:36)

Module 10: Ecology of change Impacts of climate change

Example: Other habitat-level destructions



Box 1. Marine ecosystems are already responding to the rapid pace of change in the physical and chemical conditions that surround them (see table 2.1 for summary of recent forecasts). One of the most important impacts has been on the organisms and physical processes that create habitat for millions of other species. (A) Heron Island, southern Great Barrier Reef. Coral reef ecosystems are declining because of anomalously warm sea temperatures, which are driving an increased frequency of coral bleaching and mortality. These impacts are combining with local impacts, as well as the closing of reef accretion due to the impact of ocean acidification. Complex coral-dominated reef ecosystems like this one are likely to be rare by 2050. (B) Kelp forest (*Macrocystis pyrifera*, with California bull kelp, *Mytilus californianus*) near San Clemente Island, California, USA. Warming ocean temperatures are driving a major contraction in the distribution of kelp forests worldwide. (C) Salween River, northeastern Australia. Mangroves are critically important coastal habitat for numerous coastal species. The loss of 52 to 20% of mangroves is predicted if sea levels rise by 1 m above today. (D) The loss of summer sea ice by 2040 in the Arctic will have a strong impact on a range of dependent organisms, both above and below the ice. [Credits: (A) and (C) © Hoegh-Guldberg; (B) Philip Colla, www.Oceanlight.com; (D) Daniel J. Cox, www.NaturalExpoures.com]

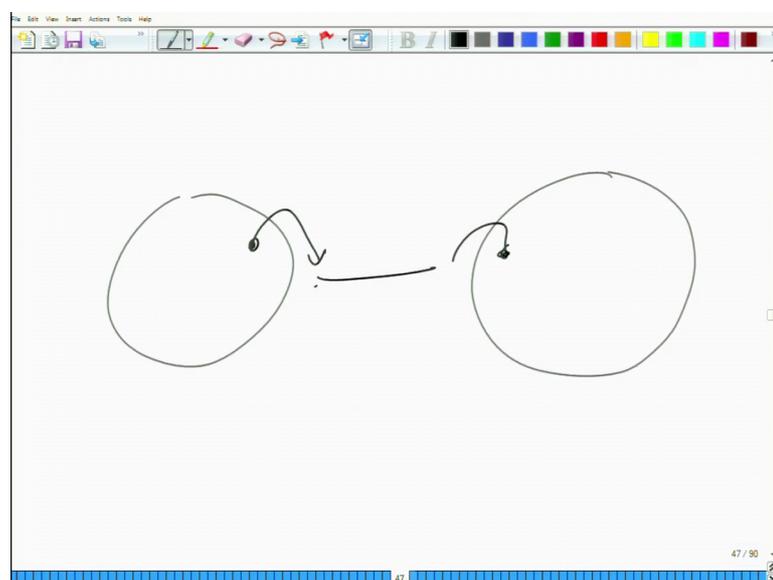
54

⁵⁴Hoegh-Guldberg, O. and Bruno, J.F., 2010. The impact of climate change on the world's marine ecosystems. *Science*, 328(5985), pp 1523-1528.

Dr. Ankur Awadhya, IFS Wildlife Ecology Spring 2019 109 / 138

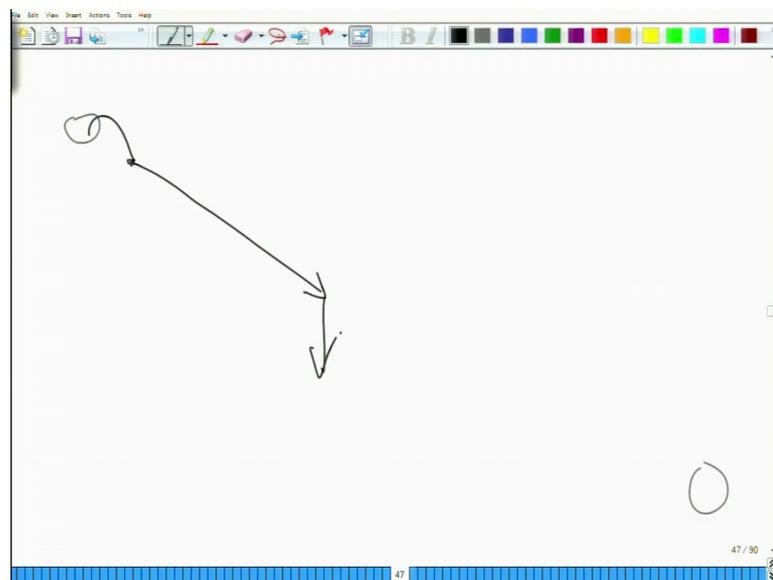
And not just the corals are showing an impact, but also we are seeing that other major ecosystems and major keystone species in the ecosystem such as scallops, scallops are dying out. Now, when scallops die out they are the habitats for a number of species and when scallops die out all of those species will also die out or things like mangroves. If mangroves are dying out that would also result in the death of a number of species. And not just these by these biological in changes are playing a role, but also the physical changes. So, in the case of the polar bear the polar bear requires a sheet of ice to stand, to rest, to look for its preys and so on.

(Refer Slide Time: 30:25)



Now, if you have a situation where you have a piece of ice here and a piece of ice here; so, you have a polar bear that starts its journey here, it gets into the water it, maybe swims for a while and maybe it catches a few fishes and then it is able to get to this stick in ice and then it is able to rest for a while. What happens when you have a situation of climate change? So, if you have more amount of heat in the system. So, these ice sheets are not shrinking in size. Now, in place of having these ice sheets that are close by you have a situation in which you have an ice sheet here and maybe in another ice sheet here.

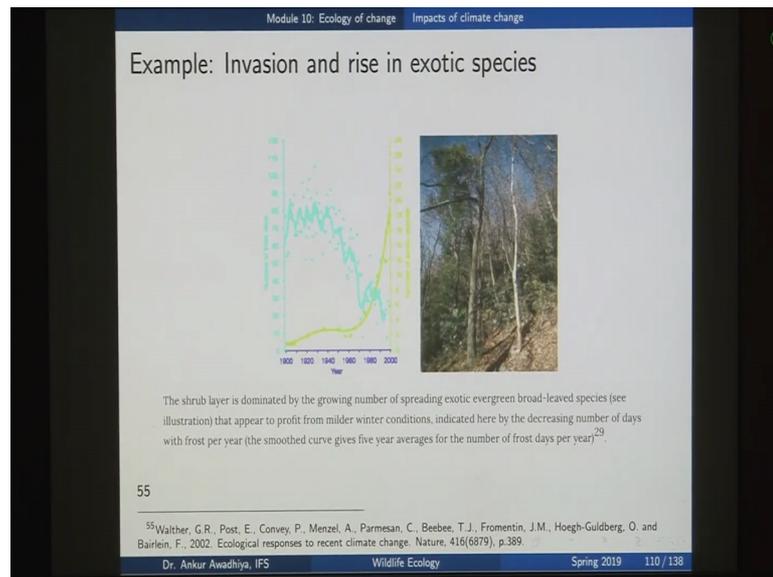
(Refer Slide Time: 31:03)



So, polar bears, now get into it gets into the water it starts down to the other side, but then does it is not a very good swimmer. After a while it will start losing its breath, after a while it will start getting tired and when it is tired it is not getting another sheet of ice to stand to rest. So, what is happened? The polar bear will drown at this stage.

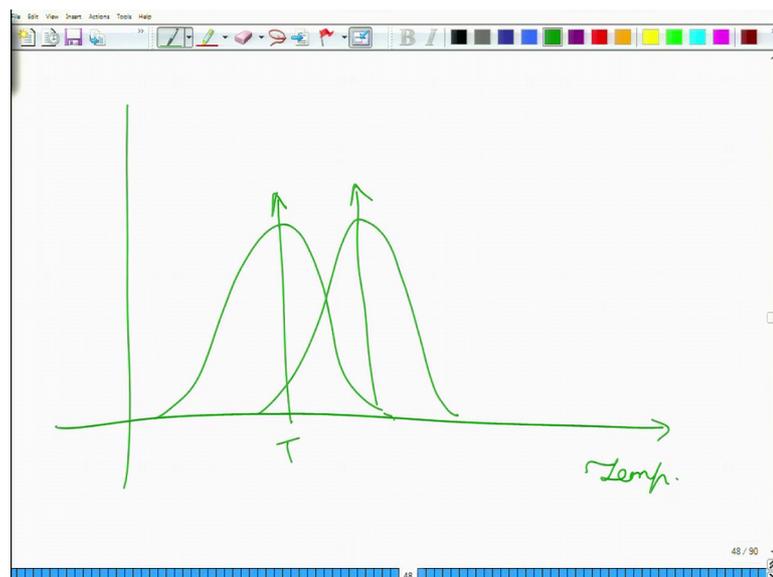
Now, these are the habitat level destructions that we are already observing, changes in the corals, changes in the scallops, changes in the mangroves, changes in the physical habitats high sheets and so on these are something that we are already observing in the system.

(Refer Slide Time: 31:42)



Another thing that we are observing is a rise in the invasion of exotic species. So, in this picture we are seeing this green portion is the amount of invasion and the invasion is increasing all through the years. Now, why is that invasion increasing? Because every species every member of the ecosystem has a certain range of conditions to which it is most suited.

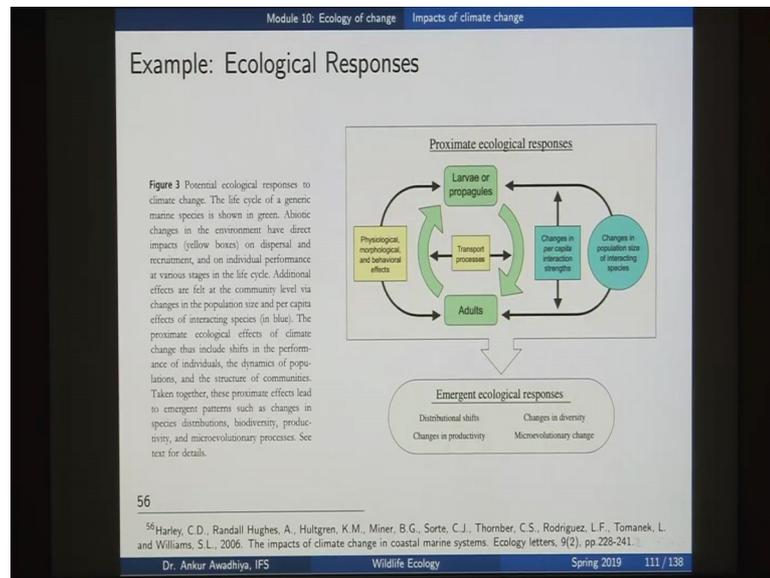
(Refer Slide Time: 32:16)



So, for instance you had this earlier situation you had this situation and this was the mean temperature. So, this is the temperature. Now, if you are shifting the temperature, so

probably in place of this particular species. Now, the environment is more suitable for another species and which is what we are seeing here, the original inhabitants of the forest are dying down and the invasive species are taking their place.

(Refer Slide Time: 32:47)



There are other kinds of ecological interactions that we can see is that suppose there is a species that that exists in the larval form and in the adult form. Now, because of climate change if there is a change in the transport processes. So, basically what we had seen earlier there is a larval form and the larval form does not remain for a very long period as a larval form it converts into an adult very quickly. So, it is not able to disperse properly. So, that the transport processes get altered or if there is another physiological morphological or behavioural changes these are the direct impacts that we will observe in the ecosystems.

Now, when that happens at the level of this species will start seeing changes in the community level as well. So, community level changes what we changes in the population size of the interacting species. So, if this is a species reduces in population then probably the preys of this particular species would increase in their size in their numbers and those species that were dependent on this a species for food they would reduce in their numbers. So, we will start seeing changes in a number of species.

Now, remember the process of trophic cascade. In the in the process of trophic cascade we made changes at one single level of the ecosystem. So, in the case of yellow stone

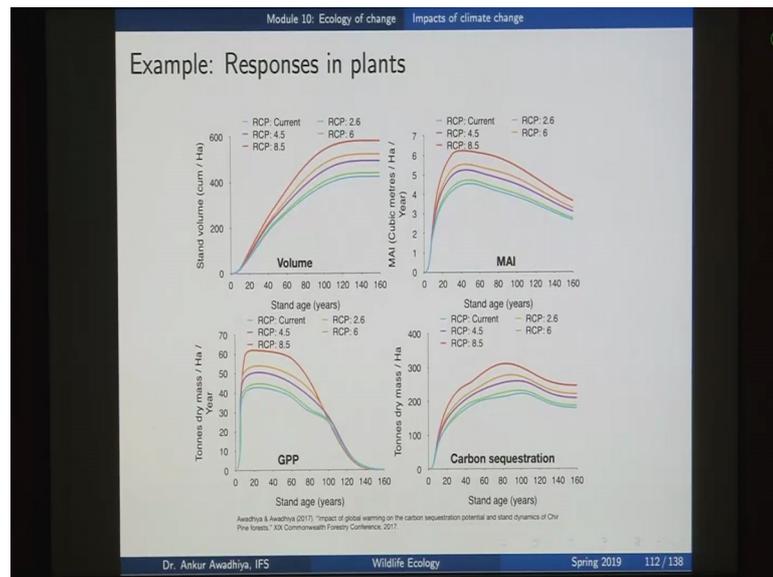
national park we made changes by bringing wolves into the ecosystem. The wolves are top predators when we brought in was into this system they started hunting deer's, deer's started showing behavioural changes they started moving from that area and. So, the prey of the deer which is the plants they started growing up.

Similarly, when these plants started growing up we were seeing more number of berries in the system. So, bears started increasing their numbers they reinforced the role of the of the wolves in the case of the bears. But then the number of small species such as the rabbits they started increasing in number which resulted in an increase in the number of eagles that we had in the system. Now, just change in one trophic level and bring about so many changes. So, that is it a trophic cascade.

Now, a similar trophic cascade will be observed here, if this particular species is say a predator species. So, their prey would start increasing in number and the next trophic level would then get decimated. So, we will start seeing changes in the populations and also start seeing changes in the per capita strength of different interactions. Now, these are all proximate responses and they will result in a number of emergent responses.

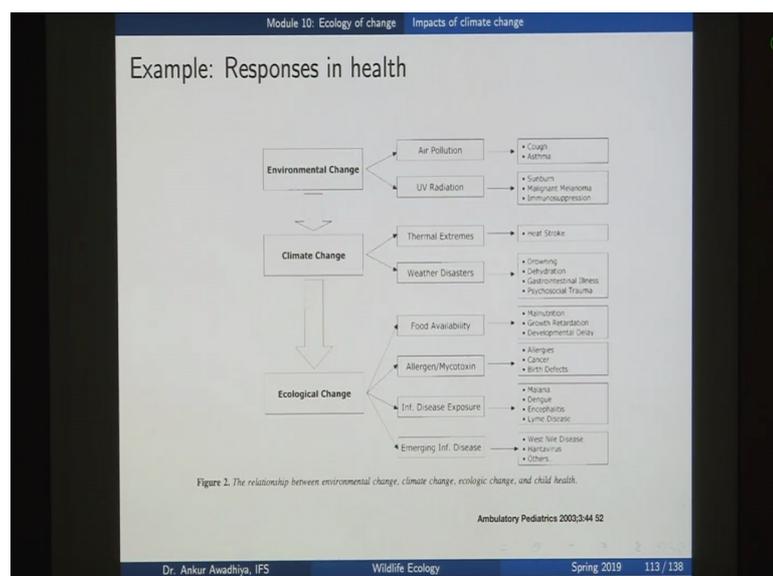
Now, these emergent responses are changes in the distribution of animal's, changes in the diversity of the ecosystem, changes in the productivity of the ecosystem, and changes in the micro evolutionary processes that are going on in system. So, when we see that climate change is having a small and gradual impact on some species that might result in a very blown out response in the whole of the ecosystem.

(Refer Slide Time: 35:56)



Similarly, in the case of other species such as plants we saw this example before that in the case of trees. So, here we were modelling, the chir pine trees that are there in the lower district of Uttarakhand and currently they peak in their carbon sequestration, but insulate around 110 years and with climate here it will move down to around 80 years. That is another big change because, that would also mean a change in the availability of food that is there in the ecosystem for different species.

(Refer Slide Time: 36:29)



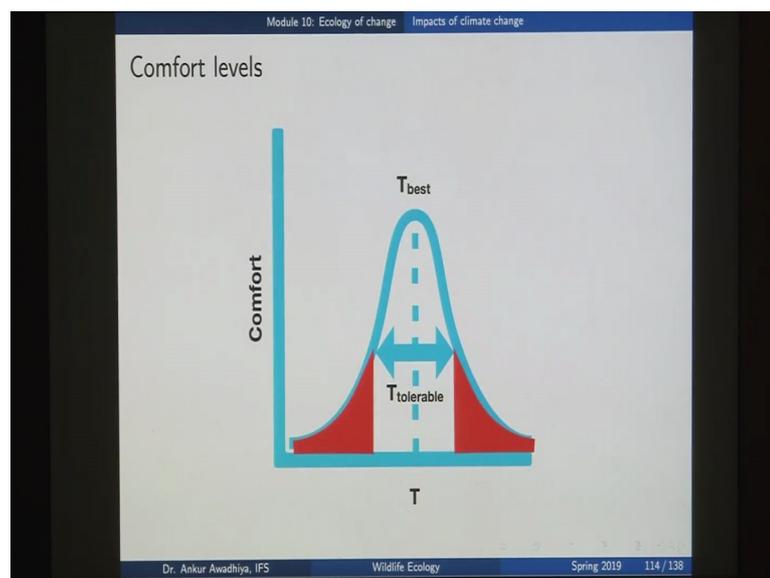
Now, apart from these changes will also start seeing changes in the health of different species or the amount of stresses that we will have in different species. Now, because of climate change if there are thermal extremes; so, we might start seeing more amount of heat strokes in different animals.

Or if there are weather disasters if there is more amount of reading if there is more amount of draught we might start seeing animals that get start dying because of drowning because of dehydration or because of some other microbial organisms such as gastrointestinal diseases because the microbes increase in their numbers if they get a warmer climate or changes such a psychosocial trauma in different organisms.

Now, climate change will also result in ecological changes as we had just seen. Now, if there is an ecological change and if that results in changes in the food availability of a know of an organism that might start suffering from malnutrition or growth retardation or developmental delays which would then further have impacts on some other species because of ecological changes because of phenological changes we might start seeing allergens in different times of the year.

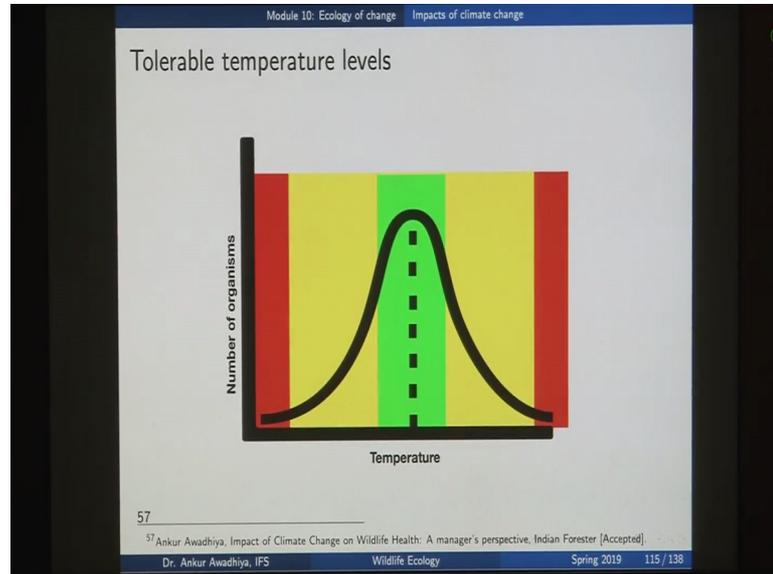
So, if there are more number of allergies. We will start seeing more allergies for instance more amount of infectious diseases or some more emerging infectious diseases some new diseases that we have not seen so far.

(Refer Slide Time: 37:59)



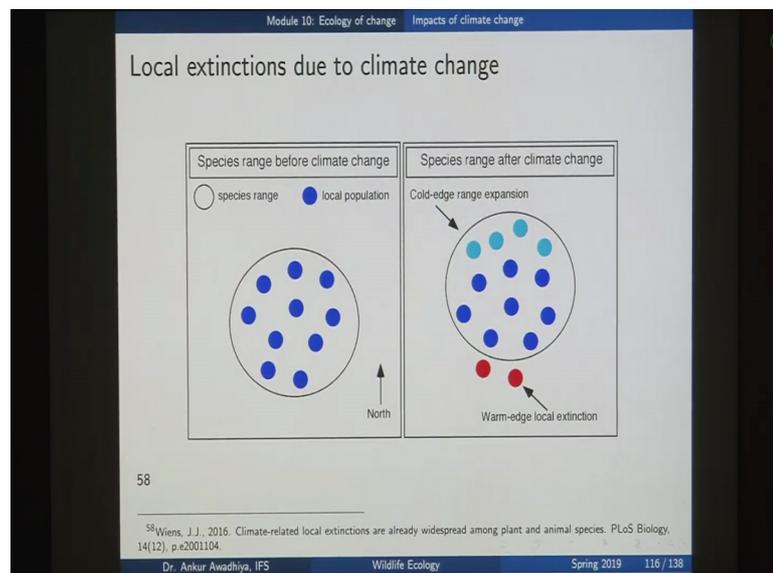
Another change that will observe is that because every organism has a certain temperature range in which it feels the most comfortable.

(Refer Slide Time: 38:10)



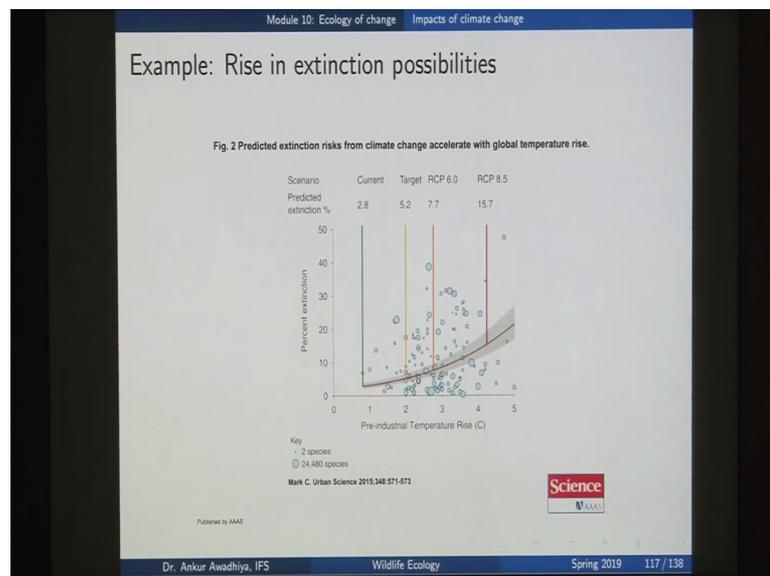
When we have changes, so we will see that in the current pattern of biogeography we find that the number of organisms is maximum at this particular temperature range. Now, if we shift this temperature to some other temperature then we might start seeing a reduction in the number of animals at that particular place or maybe an increase in the number of animals in some other place.

(Refer Slide Time: 38:35)



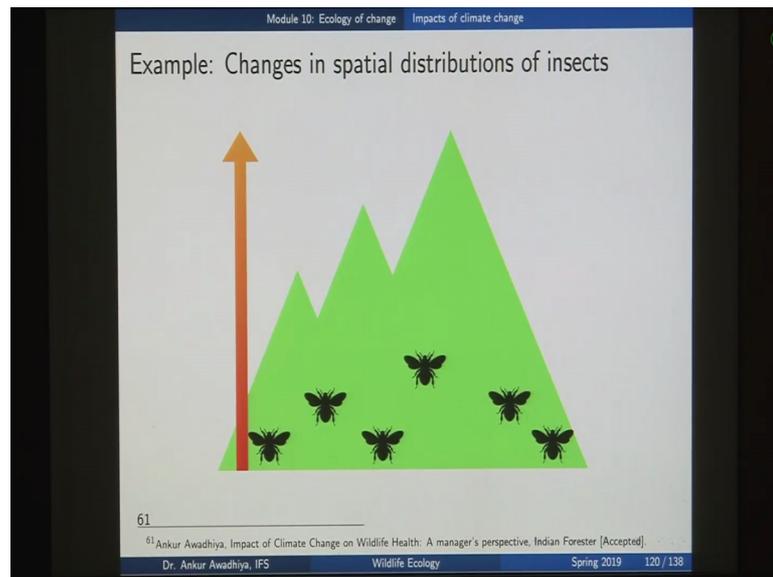
So, for instance if this is the current species range of this particular species and these are the local populations and here this is south, this is north. Now, with increasing temperatures this area has now become too warm for this species. So, both of these will die out and probably these areas that were very cold for this species earlier they now become habitable for these individuals. So, now they start up some new populations here. So, we will start local extinctions and cold edge range expansions. And this is not something that is theoretical this is something that we are seeing in practice.

(Refer Slide Time: 39:20)



And their extinctions that we will see in the cold edges they have also been quantified and we know now that with an increase in global warming we will start seeing more number of extinctions. Now, when we talk about a changes in the species range this is also something that we are now observing in the field.

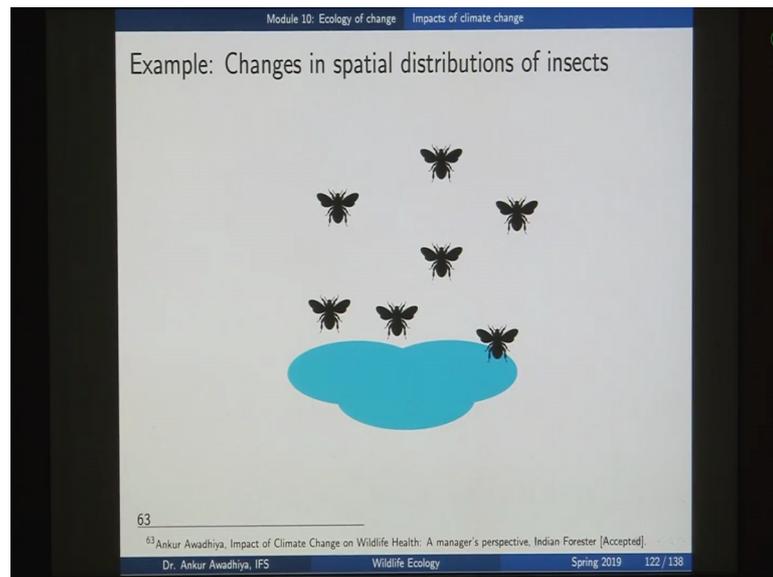
(Refer Slide Time: 39:36)



So, for instance in the case of a number of insect species that are living close to the mountains if; so in the case of a mountain we have a greater temperature here at the bottom and we have a lower temperature as we move up. This is something that we call is the lapse rate in the case of geography. So, the bottom areas are warmer though, the upper areas are colder.

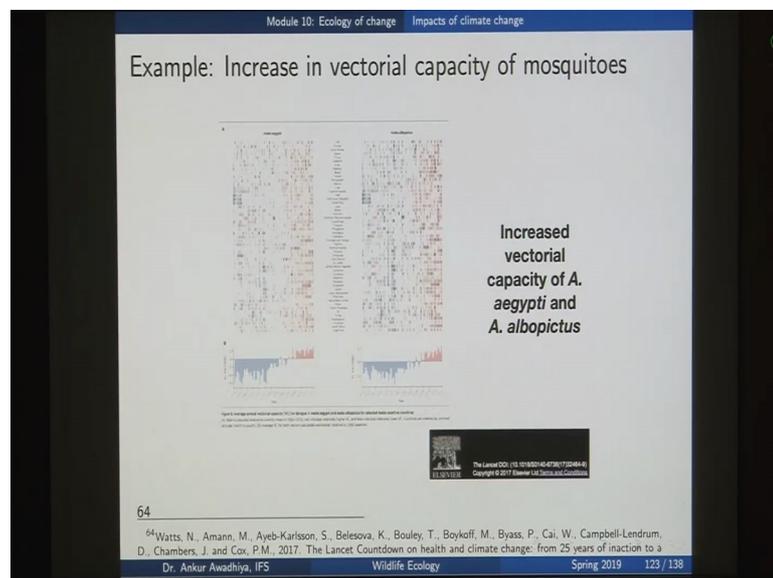
Now, if there is an insect species that prefers to live in the warm climates. So, currently it is living in these climates. Now, if the temperature goes up; so, in place of having this orange region in the bottom and the blue region on the top. Now, everywhere it is orange to yellow region. So, in that case this is species will now start coming up to a greater height than was earlier possible because of the biogeography of this species.

(Refer Slide Time: 40:31)



Or maybe because we will have more number of puddles, we will now start seeing an increase in the number of individuals that are getting born out of this species. And this is something that we are already seeing in nature.

(Refer Slide Time: 40:40)

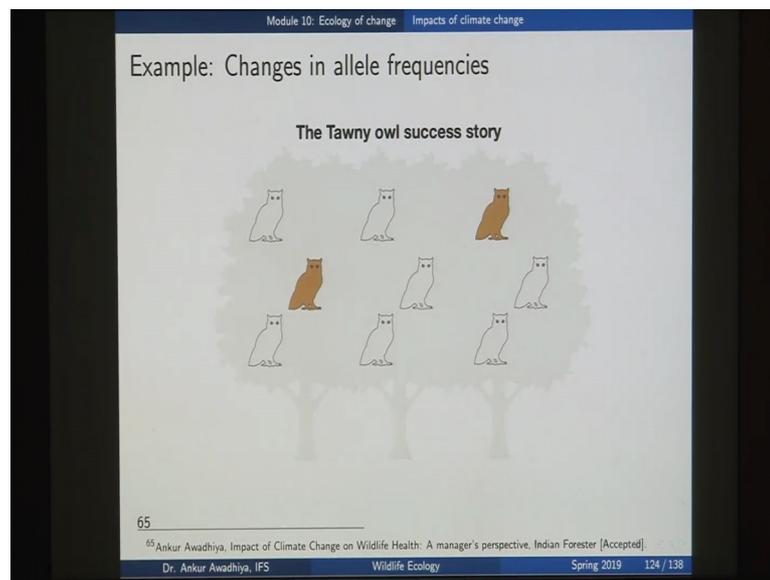


So, if we look at the vectorial capacity which essentially tells you the efficiency of transmission of diseases because of the vectors and here we are talking about (Refer Time: 40:52) which is the mosquito that is responsible for diseases like dengue. Now,

because of an increase in temperature we are already seeing an increase in the vectorial capacity of these mosquitoes.

Now, if you have an increase in the vectorial capacity of these mosquitoes then more number of people would start dying of dengue or maybe more number of animals would start dying off because of their own diseases because their vectors are also increasing in the vectorial capacity.

(Refer Slide Time: 41:22)



We might also start seeing changes in the allele frequencies and this is also something that we have seen in nature. So, there is this particular species of owl which is known as tawny owl and this species is present in two different colours.

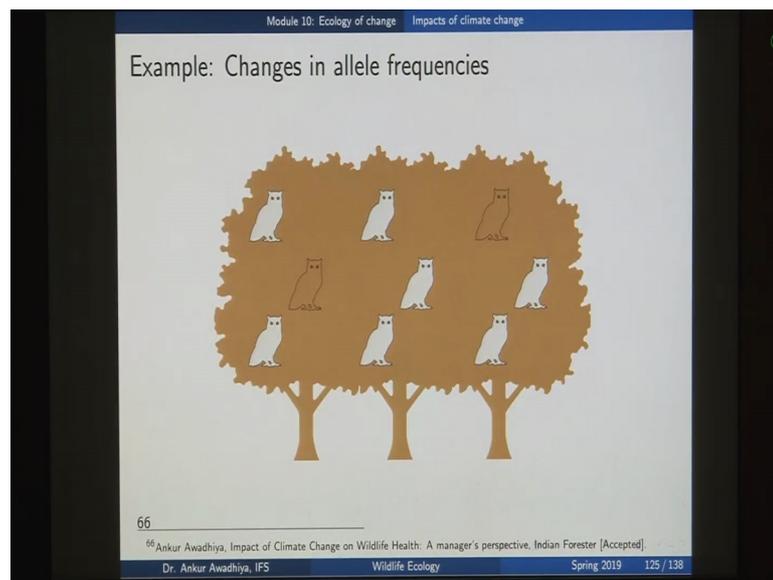
Now, when we are talking about these changes it may help you to remember the case of the peppered moth. So, in the case of peppered moth we saw that there is this moth which is present in two colours the light colour and the dark colour. The and in the pre industrialization days when the barks of the trees were covered in lichens; so, the light colored moth was able to camouflage itself and the dark colored moth was preferentially eaten.

Now, when we had industrial revolution; so, the lichens started dying out the (Refer Time: 42:10) became more and more exposed the (Refer Time: 42:12) became more and more darker and so the dark colored moths were able to camouflage themselves much

better and in that case the light of mosque started dying out. And similarly, when with the passage of the clean air acts again we saw a reversal. Now, that was a change in the allele frequencies because of industrialization. And we are seeing a very similar scene in the case of allele frequencies and changes because of the climate change.

So, now, this tawny owl which is present in these two colours the light colour and the dark colour, and it lives in those forests where these trees are covered with snow for a very long period of town time. Now, when you have snow in the background the lighter colored owl gets camouflage very easily and now when this owl needs to hunt small rodents. So, the rodents are not able to see this owl and so the lighter colored owls are able to hunt much more preferentially or much more easily as compared to the darker colored owls.

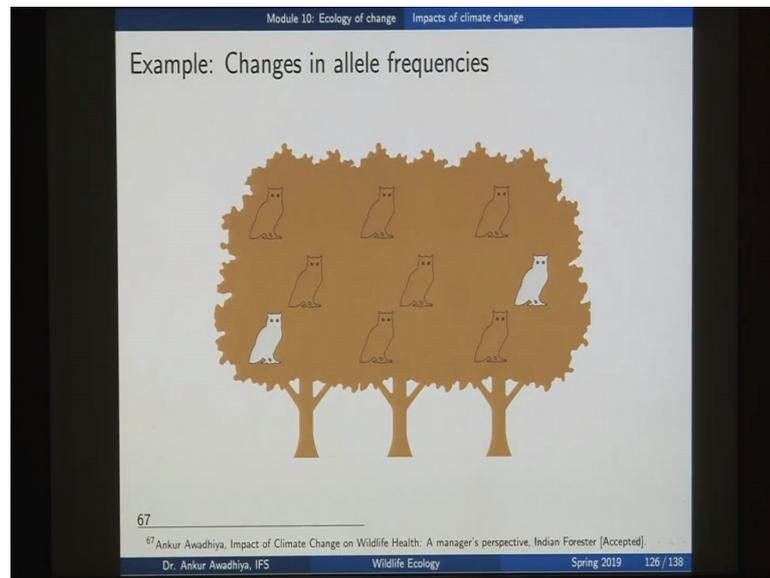
(Refer Slide Time: 43:22)



So, essentially the fitness of the lighter colored owls is much greater. But then because of climate change what we are observing is that there is less amount of snow on these trees. So, when there is less amount of snow on these trees. So, the colour or the background of the trees has; now, shifted from a lighter colour to a darker colour. The colour of the foliage or the colour of the (Refer Time: 43:37) or the colour of the branches. But one when that happens, now these lighter colored owls are now very easily seen in the darker colored backgrounds whereas, the darker colored owls are now more camouflaged from their preys.

So, then when this situation arises then the fitness of this particular individual it increases and this particular individual decreases. Why? Because now the prey of these owls are not able to see the darker owls.

(Refer Slide Time: 44:13)



And we are actually observing that with time the frequency of the darker colored allele is now increasing in this population. So, when we are talking about the impacts of climate change on different ecosystems on different populations, different communities, it is not just a theoretical construct it is something that we are actually observing in the field and something that we can actually prove through experiments.

Now, in the case of this tawny owl, this was a lucky species because it was already available in two colours. Now, probably if you have a situation and this where this owl was only present in say this lighter colored variant. If we did not have this darker colored variant, so in that case if climate change happened it would not have anything to fall back to and when all the individuals are easily spotted. So, all of them would start dying off because all of them would lose their fitness they would not be able to hunt properly. So, we will also start seeing a number of extinctions in a number of species.

(Refer Slide Time: 45:19)

Module 10: Ecology of change Impacts of climate change

Mitigation & adaptation

Mitigation

"A human intervention to reduce the sources or enhance the sinks of greenhouse gases."^a

^aBaede, A. (2007). "Annex 1 IPCC Glossary." Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Adaptation

"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."^a

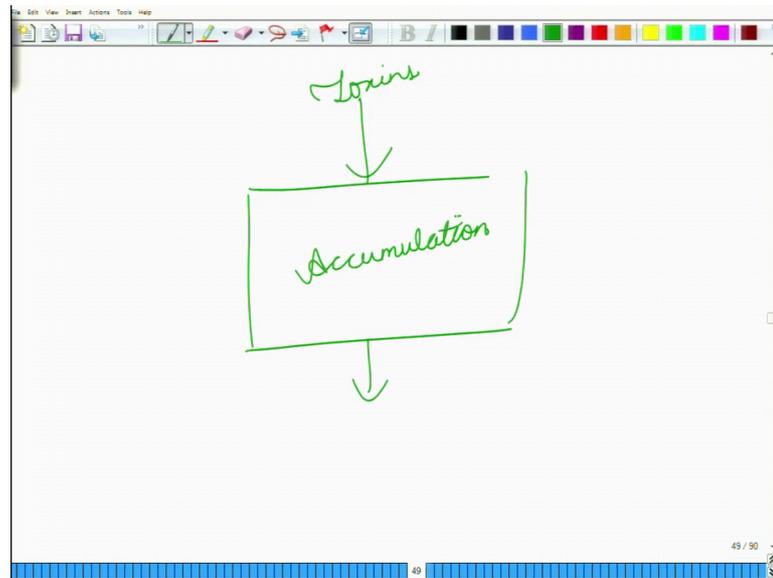
^aUNFCCC. (2014). "Focus: Adaptation." Retrieved 2017-08-06, 2017, from <http://unfccc.int/focus/adaptation/items/6999.php>.

Dr. Ankur Awadhya, IFS Wildlife Ecology Spring 2019 127 / 138

Now, what can we will do about it? We know that there is climate change that is happening. So, what can be our response as ecologist or as people who are working in the conservation sector? How can we help these ecosystems? How can we help these communities? So, there are two kinds of responses that we can put up, the first one is called mitigation, the second one is called adaptation.

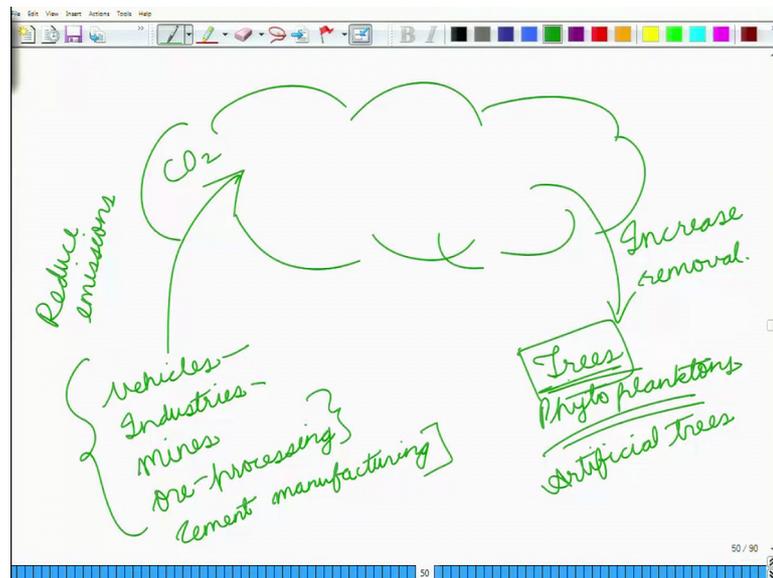
Now, climate change mitigation, so medication refers to a human intervention to reduce the sources or enhance the sinks of greenhouse gases. Now, because we know that these climate changes are happening because of greenhouse gases like carbon dioxide if we can reduce the concentration of carbon dioxide in the atmosphere that would be called as a mitigation strategy. Now, how can you reduce the amount of carbon dioxide in the atmosphere. Well there can be two ways.

(Refer Slide Time: 46:12)



Again, as we talked in the case of bioaccumulation in the case of bioaccumulation you have some amount of toxins that are getting into the system and then there are some amount of toxins that are getting out of the system. If the amount of input is greater than the amount of output we will see accumulation.

(Refer Slide Time: 46:35)



Now, similarly in the case of greenhouse gases we have the atmosphere. So, let us say that this is the atmosphere. Now, in the atmosphere we are adding in carbon dioxide through a number of sources. Those sources could be your vehicles, those could be your

industries or probably those could be situations such as the mines or maybe areas where your ores are getting processed; so, maybe ore processing.

Now, all of these processes or maybe safe cement manufacturing; now, all of these are adding carbon dioxide into the atmosphere, but at the same time there are also some other processes that are taking carbon dioxide out of the atmosphere. What are those? We saw it in ecology in the case of primary production you have the trees that I know that are taking out carbon dioxide in the process of photosynthesis. We have things such as the phytoplankton.

So, when we talk about mitigation. Mitigation would say that let us reduce the amount of carbon dioxide that is coming out from these sources. So, in the case of vehicles you could go for a more efficient vehicle or probably a vehicle that uses electricity in place of your gasoline. In the case of industries, you could look for processes that are much more efficient. So, that they release less amount of carbon.

In the case of mines and ore processing probably you could shift to something else that releases lesser amount of carbon. In the case of cement manufacturing, you could go for a process that is more efficient or probably you could try to replace cement with some other material that does not release. So, much amount of carbon dioxide. So, that is one way, that is to reduce the emissions.

The other way is to increase the removal from the atmosphere. So, you can go and plant more number of trees. So, more number of trees there are there is more amount of removal from the atmosphere or in the case of phytoplankton. So, we saw it in the lecture on primary productivity, that we have a number of oceans and seas that are deficient in iodine. So, if you put in iron. So, the number of phytoplankton would increase we will see more amount of phytoplankton. So, probably iron seeding could be one other way of mitigating or for instance you could go for things that are called as artificial trees.

Now, artificial trees are devices that artificially take out carbon dioxide from the atmosphere and then they are able to fix it or you could go for situations in which you install equipment that takes out this carbon dioxide from the atmosphere and probably puts it into a geological sink. So, you can create more sinks. So, all of these together will be known as the steps of mitigation.

And all of these would require a lot of effort. So, for instance, if you want to replace the iron and steel with wood because if you have more trees and you are taking this wood out. So, when you are taking this board out, so you are fixing this carbon for it is that period of time till which you have this wood out that you are using. So, it has till it is burnt. So, you are keeping that carbon fixed outside of the atmosphere.

Now, if you want to use what you will have to reduce the cost of wood or probably come up with technologies that make the use of wood more attractive option as compared to that of iron and steel. So, more amount of technologies will have to be created more amount of work will have to be done. Now, this is mitigation and mitigation is difficult.

(Refer Slide Time: 50:33)

Module 10: Ecology of change Impacts of climate change

Mitigation & adaptation

Mitigation

"A human intervention to reduce the sources or enhance the sinks of greenhouse gases."^a

^aBaede, A. (2007). "Annex 1 IPCC Glossary." Climate Change 2007: The Physical Science Basis. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

Adaptation

"Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities."^a

^aUNFCCC (2014) "Focus: Adaptation." Retrieved 2017-08-06, 2017, from <http://unfccc.int/focus/adaptation/items/6999.php>

Dr. Ankur Awadhiya, IFS Wildlife Ecology Spring 2019 127 / 138

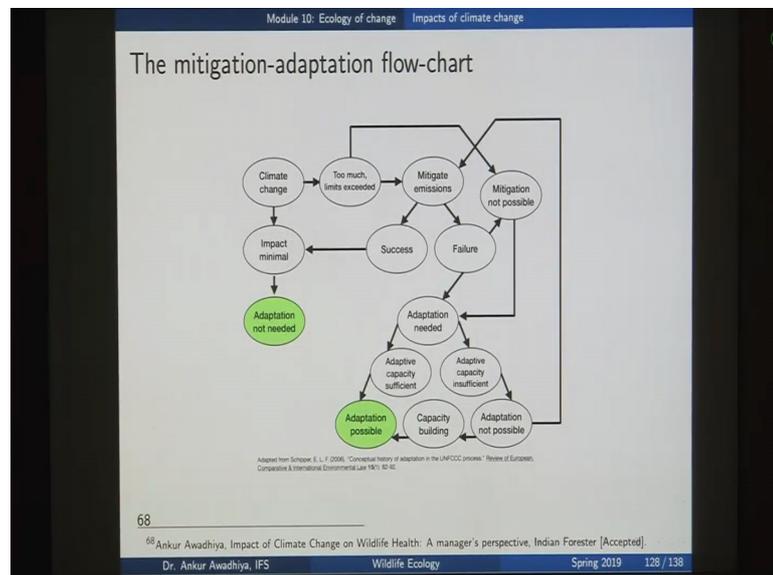
So, the other way out is that of adaptation. Now, mitigation ask the question, how can be what climate change? How can we make sure that climate change does not happen? How do we reduce the rate of climate change? Adaptation says, climate change is going to have what can we do about it how can we adopt ourselves or how can we adapt our ecosystems or how can we adapt our communities. So, adaptation is adjustment in the national or human systems in response to actual or expected climate stimuli or their effects which moderates harms or exploits the beneficial opportunities.

So, in the case of adaptation you would say that probably because of our modelling we know that say Kanpur is going to receive less amount of rainfall. Now, if Kanpur is going to receive less amount of rainfall what we will do? We will set up more number of

dams, so that more amount of water gets accumulated here we will probably set up more number of tanks and in that way we will compensate for the for the reduced rainfall that we will observe in this region or probably we could go for things such as artificial cloud seeding. So, that there is more rain from the clouds.

So, these kinds of mechanisms would be called as adaptation strategies. So, to have more amount of water in an area or for instance Kanpur is heating up, so let us install more number of a season into this region. So, that people are able to live properly these kinds of measures are known as adaptation measures.

(Refer Slide Time: 52:04)



And if the question is not whether mitigation or adaptation; the question is can be incorporate both the strategies together and in a number of situations, we will have to incorporate both those situations together because adaptation can help, but it cannot help us completely. Mitigation can help us completely, but it will take a very long period. So, in the intervening period, so we need to go with mitigation we need to reduce the amount of greenhouse gases that we have in our atmosphere, but till we are able to reduce that we have to go for the adaptation possibilities at the same time.

(Refer Slide Time: 52:42)

Module 10: Ecology of change Impacts of climate change

Mitigation options

1. Reduce emissions: Laws, Green energy, REDD (Reducing emissions from deforestation and forest degradation)
2. Create sinks: Artificial trees, carbon sequestration in geological sites, Afforestation, REDD+ (conservation, sustainable management of forests and enhancement of forest carbon stocks)

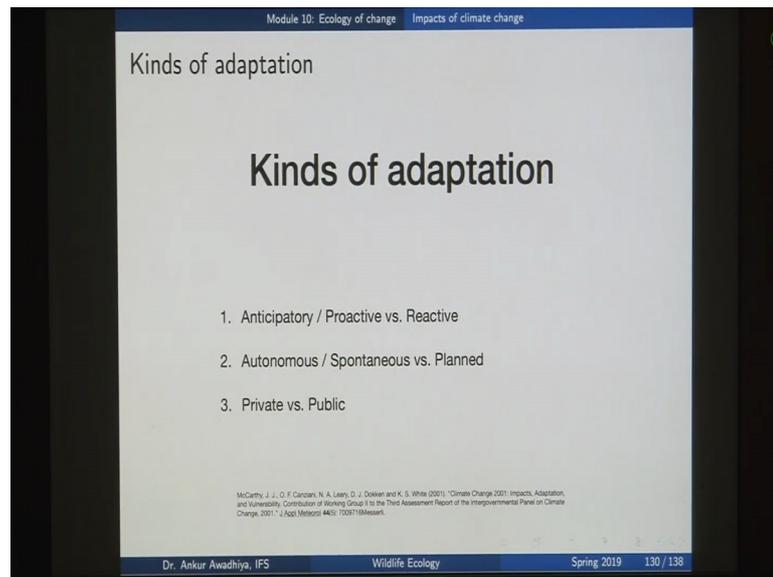
69

⁶⁹ Ankur Awadhya, Impact of Climate Change on Wildlife Health: A manager's perspective, Indian Forester [Accepted].
Dr. Ankur Awadhya, IFS Wildlife Ecology Spring 2019 129 / 138

So, what are the mitigation options? And what are the adaptation options? So, mitigation options include reducing of emissions. So, you can set up laws you can go for green energy alternatives or you can go for red mechanisms which is reducing emissions from deforestation and forest degradation because again the forests are storehouses of carbon if you have a forest that is getting degraded or a forest that is getting converted into some other land use. So, all that carbon that was stored in the forest will get released back. So, you can try to work on reducing the emissions from deforestation and forest degradation. So, that is about reducing the emissions.

Or you can create more number of things most things are artificial trees or carbon sequestration in geological sites or afforestation or REDD plus mechanisms. So, REDD plus is in this case we will go for conservation sustainable management of forests and enhancement of forest carbon stocks. So, in this way we try to create more number of things more amount of things for these for the carbon or the carbon dioxide that is present in the atmosphere. So, these are the mitigation options.

(Refer Slide Time: 53:52)



Now, when we talk about adaptation; we can have different kinds of adaptation we can have anticipatory or proactive adaptation or a reactive adaptation. Now, proactive adaptation is an adaptation that we this is a step that we take before we are already in a soup. So, we know that that this region is going to receive less rainfall in future. So, we already start our adaptation processes which already start making more number of tanks in this area that would be called as proactive adaptation.

Reactive adaptation is in a situation that we have already started seeing less number less amount of an rainfall. So, let us now at least make more tanks. So, that any amount of water that falls into this area is now saved that would be called as a reactive adaptation. Now, adaptation can also be spontaneous or planned in the case of policymaking or it can also be spontaneous well were different people autumn by themselves come up with different adaptation mechanisms or it can be public or private kind of adaptation. So, it can be adaptation through a government scheme or it can be an adaptation at the level of private individuals.

(Refer Slide Time: 55:03)

Module 10: Ecology of change Impacts of climate change

Adaptive capacity

Adaptive capacity

"The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."

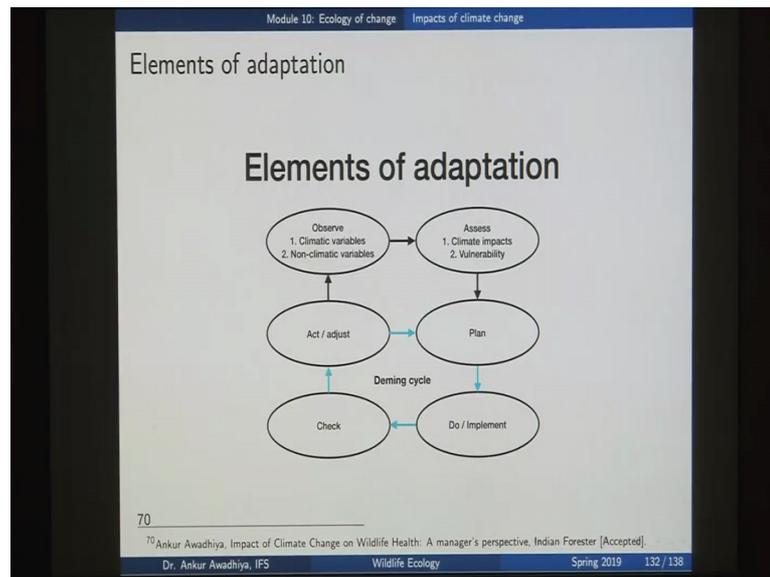
McCarthy, J. J., D. F. Carrigan, N. A. Leary, D. J. Dokken and K. S. White (2011). "Climate Change 2011: Impacts, Adaptation, and Vulnerability, Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change, 2011." J. Appl. Meteorol. 44(5): 702-716 (Access).

Dr. Ankur Awadhya, IFS Wildlife Ecology Spring 2019 131 / 138

And when we talk about adaptation we also have to talk about the adaptive capacity. Adaptive capacity is the ability of a system to adjust to climate change including climate variability and extremes to moderate potential damages to take advantage of opportunities or to cope with the consequences.

So, when we talk about adaptive capacity what we are asking is does the system does an ecosystem have the wherewithal that it would be able to cope with climate change. Does it have the capacity to adapt? Or if we have a system that does not have a capacity to adapt then probably it is going to be doomed in near future can we increase this capacity.

(Refer Slide Time: 55:51)



So, when we talk about adaptation here are the elements of retardation. So, we begin by our observations. So, observations of climatic variables, non-climatic variables, from these observations we come up with an assessment of the impacts and the vulnerability. Here again we are talking about vulnerability. So, when we talk about vulnerability what are the ecosystems that are more vulnerable to climate change, what are more exposed to climate change and do not have the adaptive capacity.

So, those are the ones for which will have to make a planning. Once we have a planning then we can move through the naming cycle. So, from the plan you do an implementation of the plan from there you move to the checking stage in which you check about the effectiveness of that plan from the chickens stage you move back to the acting or digesting stage and from there you can come up with more number of points about which observations need to be made. So, that is about the element of adaptation.

(Refer Slide Time: 56:52)

Module 10: Ecology of change Impacts of climate change

Adaptation options

1. Create **resistance to change**: reduce effects of fires, insects, diseases: better protection, removal of invasives, resistance breeding
2. Promote **resilience to change**: surplus seed and sperm banking, intensive management during establishment, promotion of biodiversity-rich ecosystems
3. Enable ecosystem to **respond to change**: assist natural adaptations and transitions, assisted migration to newer areas, increase redundancy, manage for asynchrony, establish neo-native forests considering past spread, promote connected landscapes

Milne, C. L., N. L. Stephenson and S. L. Stephens (2007). "Climate change and forests of the future: managing in the face of uncertainty." Ecological applications 17(8): 2145-2151.

Dr. Ankur Awadhya, IFS Wildlife Ecology Spring 2019 133 / 138

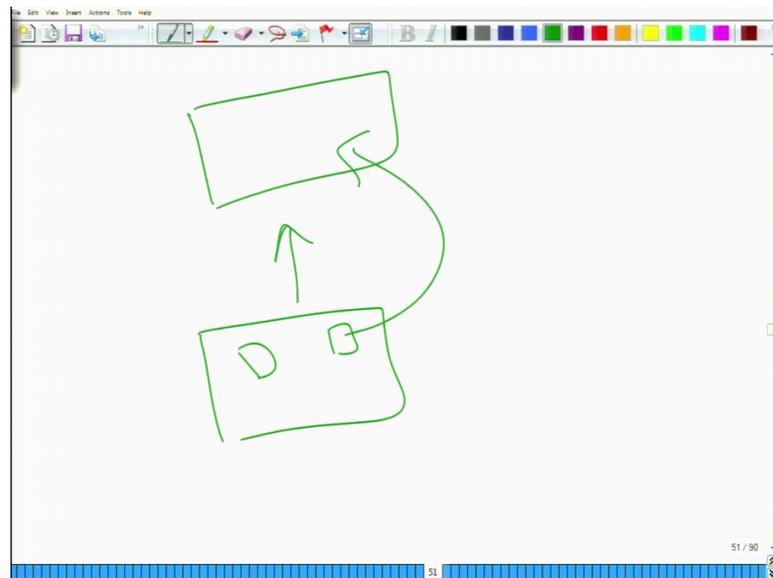
So, what are the options available for us for adaptation? So, there are these options are divided into three categories creating resistance to change, resilience to change and response to change. Now, resistance to change says that you want to create systems that reduce the amount of impact that your climate change will bring. So, you want to create a situation that is able to resist the impacts of climate change and things would be to reduce the effects of forest fires, to reduce the effects of insects, diseases, through better protection removal of invasive species, resistance breeding in which case you breed for resistance in the tree species.

So, you go for planting those particular individuals that have such traits as are better able to resist climate change. So, probably these are plants that require less amount of water or probably these are plants that are better able to be wade of diseases that would come because of the stresses and so on. The second option is to create a resilience to change. Resilience is the ability to bring back once you have all when you already have the climate change. So, resilience to change would be say a creation of surplus seed banks or sperm banks. Now, this is something that we already saw in the case of ex-situ conservation.

So, in this case you are creating a resilience because you are creating a seed bank. So, even if your ecosystems die out because of the climate change you can use these seeds and you can bring the system back to normal again or you can go for intensive

management during the establishment promotion of biodiversity rich ecosystems. So, this will also require a lot of intensive management. So, resistance to change, resilience to change, the third option is the response to change. So, you assist natural adaptations and transitions you assist migration to newer areas.

(Refer Slide Time: 58:55)

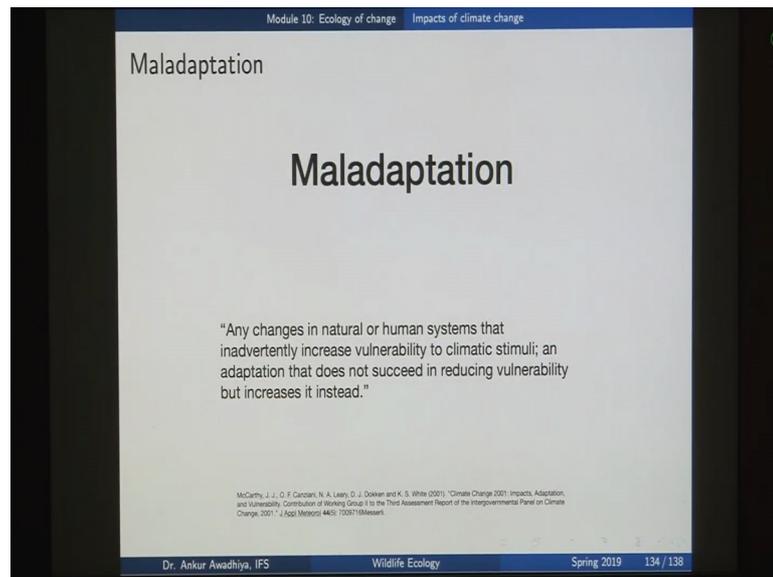


So, essentially you have a species that was living in this area and because of climate change it now needs to move more northwards. So, when we say that we are allowing this species to respond to change we are taking these individuals and we are translocating them to the other area. So, that is enhancing the ability of the species to respond to change.

So, we are assisting natural adaptations, we are assisting natural transitions, assisted migration to newer areas, increase in redundancy, manage for asynchrony. So, management for it a synchrony would be if you have a case in which the fodder species is not able to synchronize with the life cycle of the organism, then probably you can go for giving an artificial order from outside to the system to the organisms that are not able to get their food in time.

So, that would be a management for asynchrony. Or establishment of neo native forests considering the past spread or promotion of connected landscapes, so that the organisms are able to move by themselves. And whenever we are talking about the adaptation options it is also important to talk about the maladaptation.

(Refer Slide Time: 59:59)



So, probably we also need to think about the situations in which we are trying to help the adaptation, but it backfires. Any changes in natural or human systems, that inadvertently increase the vulnerability to climatic stimuli, an adaptation that does not succeed in reducing vulnerability, but increases it instead. So, it is an adaptation that does not work

So, in today's lecture we began by looking at the climate tech system, the components of the climatic system, how they interact with each other, what is climate, what is climate change. And then we started looking at the impacts of this climate change on different organisms, on different habitats, on different ecosystems and we looked at the proximate level changes that is the changes that would come up in the ecosystem and we also looked at the emergent changes that would also move up in the hierarchy.

And then we also looked at the options that we have available with us to thwart the climatic change what changes, what are the options of climate change mitigation, what are the options of climate change adaptation, how do we go about saving our species saving our ecosystems and our communities from the climate change. So, that is all for today.

Thank you for your attention. [FL].