Basic Course in Ornithology
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Lecture -28
Biogeography

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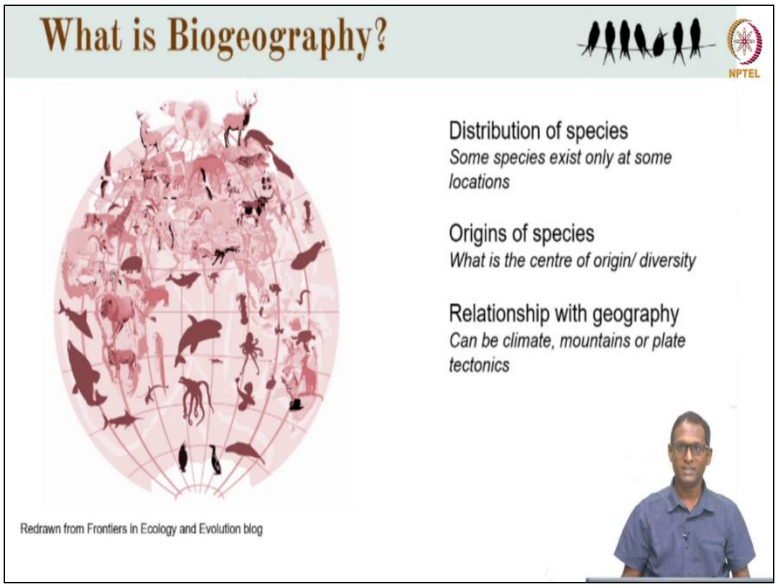

Hello! I am Robin, V. V. Robin or Robin Vijayan and I am a faculty at IISER, Tirupathi and today we are going to talk about biogeography. The lecture for the day is on biogeography. So, let us start with understanding what is biogeography? And as this figure kind of shows, this this figure is a good representation of biogeography. It shows the distribution of species but not just that, it is that some species are found only at some locations in the world.

It is not that you find tigers everywhere, you do not find lions everywhere, you do not find giraffes everywhere and that is essentially what biogeography is. That some species exist only at some locations. Biography is also the study of trying to understand the origins of species, what is the center or of origin or diversity and the relationship with geography which is you know the geography in the biogeography part.

And this relationship with geography can come from climate, it can be mountains or plate tectonics and we will talk about these aspects in detail.

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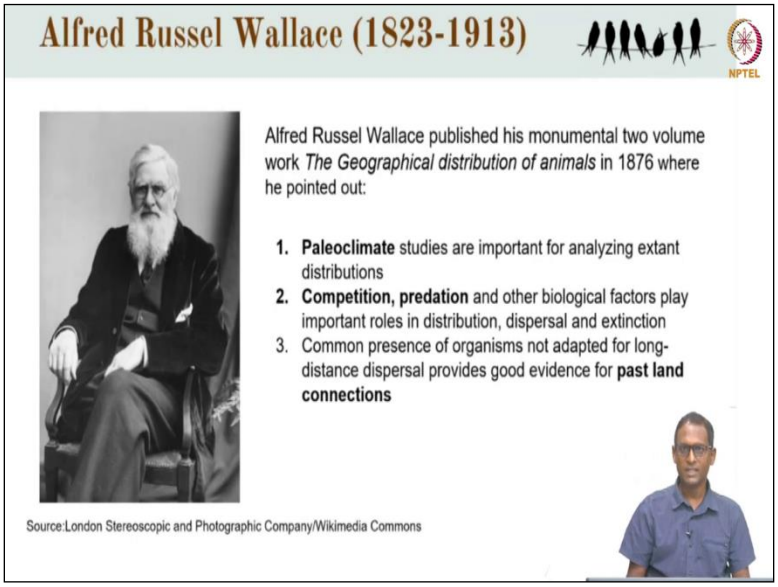

So, in some ways the idea of biogeography and a lot of the research on biogeography was heralded by Alfred Russell Wallace. And many of you may know Wallace as the co-proponent of the theory of evolution. And and of course, I think people can read up more about Wallace and his monumental contributions in in the book that is there on the slide. But he also… the main contributions were that he pointed out that historic climate or paleoclimate is actually important for analyzing or understanding the current distributions of species.

And other factors like competition, predation and biological factors play an important role in dispersal and extinction of species as well and in some cases, what also happens is that the current distribution of species is because of some historic conditions like past land connections and so on.

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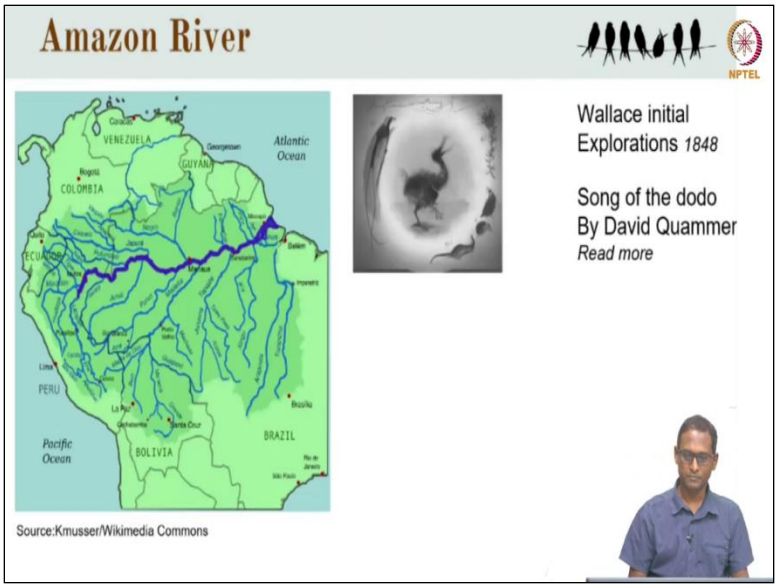

So, if you want to read more about Wallace, I think the best source of information, which is very easy to read, would be this book ‘song of the Dodo’ by David Quammen. I would recommend anybody interested to know more about him and by geography to read this book it is very fascinating. But for the purposes of this talk I will quickly summarize it. So, Wallace was actually he he spent a lot of time exploring different parts of the world.

And in 1840s he spent a lot of time exploring the amazon and he went into parts of amazon which were not well studied and he spent a lot of time documenting the flora and fauna of these areas and describing several species. And in and in those days as is the case even in for some taxa that today these museum specimens these specimens have to be deposited somewhere. And that is the actual record of the description of a new species.

And when Wallace had done a lot of work in amazon, he was ready to go back to London and you know submit his specimens. And unfortunately what happened was during the journey his ship actually sank with his life's work. And that you can imagine can be quite a tragedy. And it is also a tragedy economically for people, for explorers, at that time because some of them also sell their copies of their specimens to other museums and that is how they support the.. their subsequent explorations.

So, this was quite quite disastrous for Wallace but you know somehow, he picked himself up and then he went on and he went to Southeast Asia next, you know, after the amazon.

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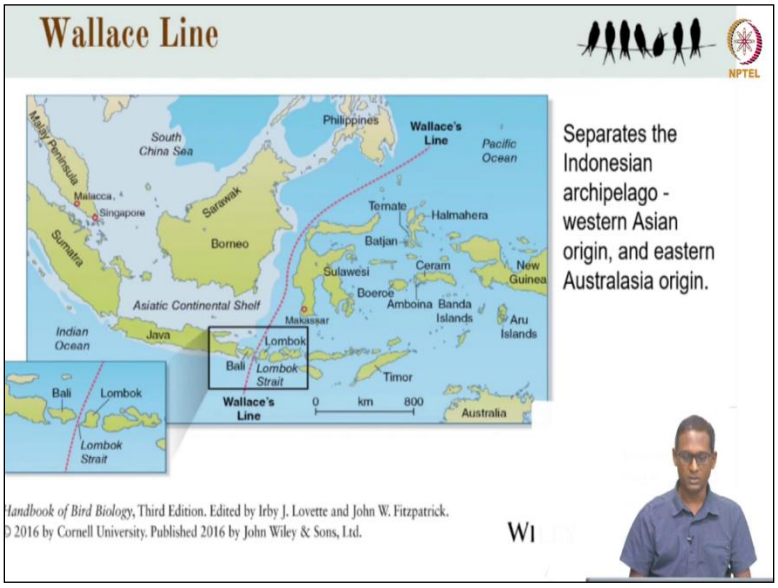

And that is where he kind of hit upon a lot of very interesting ideas and in Southeast Asia he was particularly impressed by the distributions that suddenly changed at some point. So, he was out exploring different islands but between Bali and Lombok which are shown here suddenly which is in this area suddenly he found that you know the distribution of species changed. And he, after much investigation and thought, he proposed that a lot of the species in the western side had an Asian origin and the eastern had an Australasian origin.

And what was what was surprising at that point was the line was very very sharp and this area that divides the two types of species distributions is later been described as Wallace line and is an important biogeographic barrier, it is recognized as an important biogeographic barrier. So, what that means is that species that are from Australia Australasia do not kind of cross this and the others, kind of you know, do.

So, this is like a distribution barrier for multiple species and that is what becomes a biogeographical barrier.

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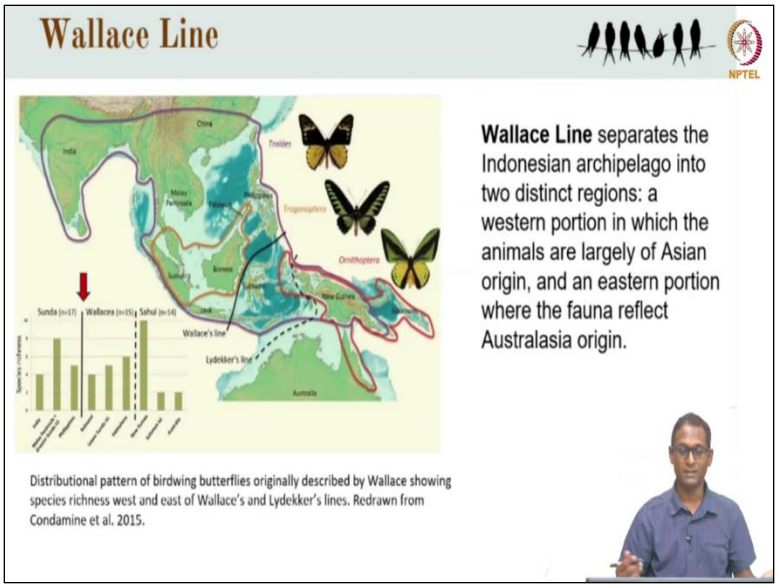

This a very good example of Wallace line and this biogeographical barrier is the distribution of these butterflies these bird winged butterflies. And as you can see there are different groups that are found only on the east or on the west of this line. So, this was later revised and there is another biogeographic barrier like the one that is shown in the dotted lines here and that kind of shows how there are these very narrow areas where the species distributions change and those are called biogeographic barriers.

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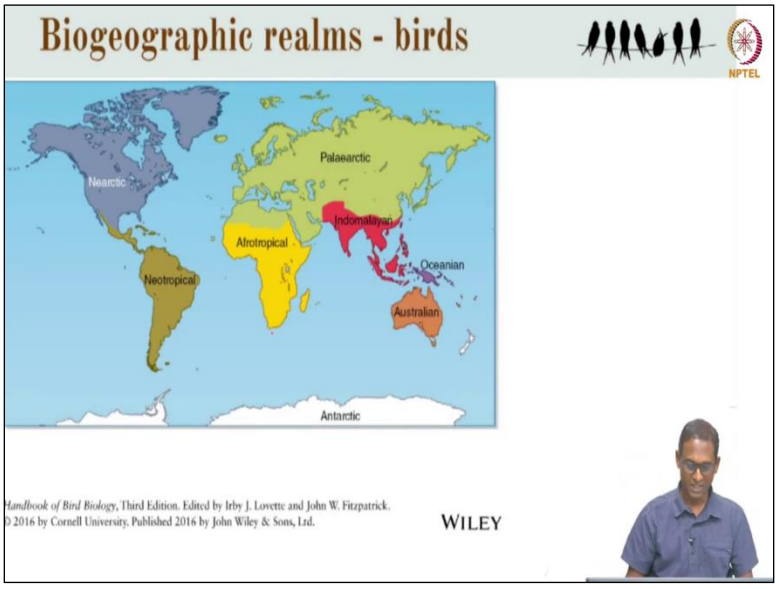

Now based on similar biogeographic barriers all across the world more recent studies have shown that there are there are some areas that have distinct species distributions. One of them is where

we are is the Indo-malayan region in the red, then you have the Palearctic which is further north over here and Afrotropical neotropical nearctic and so on. So, these are the rough biogeographic barriers when you look at species distributions at a very global large-scale perspective.

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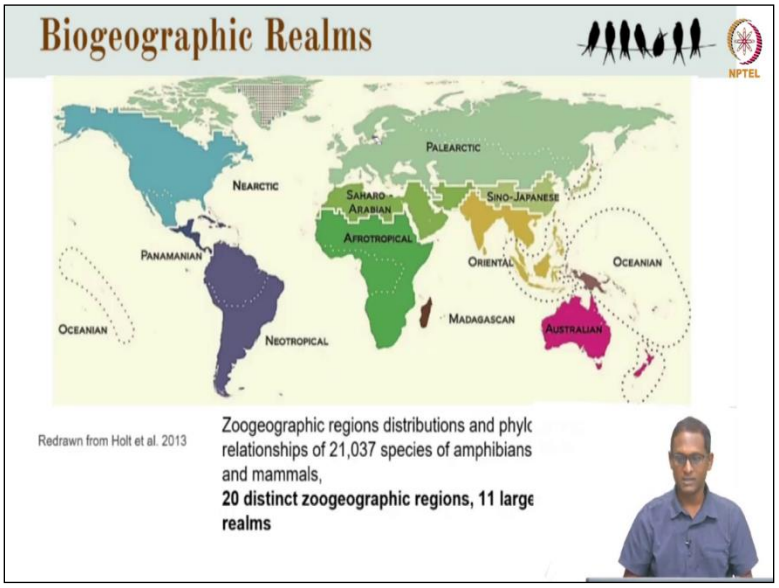

Other researchers such as Holt et al in 2013 have refined this, and they have other proposals as well. They have actually divided all of the area in the world into 20 zoo geographic regions and which they kind of club together to form 11 realms and those are the ones that you can see here. And you will notice that there is a new Sino-Japanese which has come here. Yeah. But we are still in the Oriental realm, which, kind of, you know, makes us kind of clubbed together with some parts of southeast Asia.

So, these were made by examining the distribution of about 21,000 species of amphibians, birds, and mammals. So, it is not just birds.

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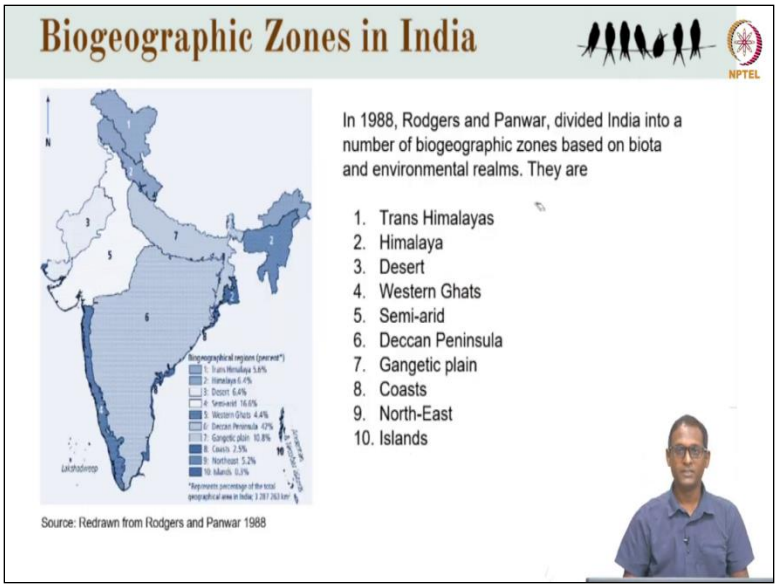

But what about biogeographic zones in India? Just because we form part of the oriental realm does that mean that we have unique, I mean -just uniform diversity, all across? No that is not the case, in fact there was a very monumental description of biogeography of India by Rodgers and Panwar and that was in 1988 was published in 1988. And they proposed various biogeographic areas which are still used even for conservation planning today.

And in this are you can see the list of the different areas: there is Trans Himalayas, Himalaya, there is desert, there is Western Ghats, Semi-Arid, Deccan Plateau, Gangetic Plain, Coast Northeast and also the islands like the Narcondam, Andaman and Nicobar island and the Lakshwadeep islands. But you will still notice that there are some areas missing you know for example there are no eastern ghats.

So, if you are from anywhere near that you would you would immediately say where are the eastern ghats. So, you have to remember that these are very broad. Brought by geographic barriers. Within each of this you may find further divisions in biogeography.

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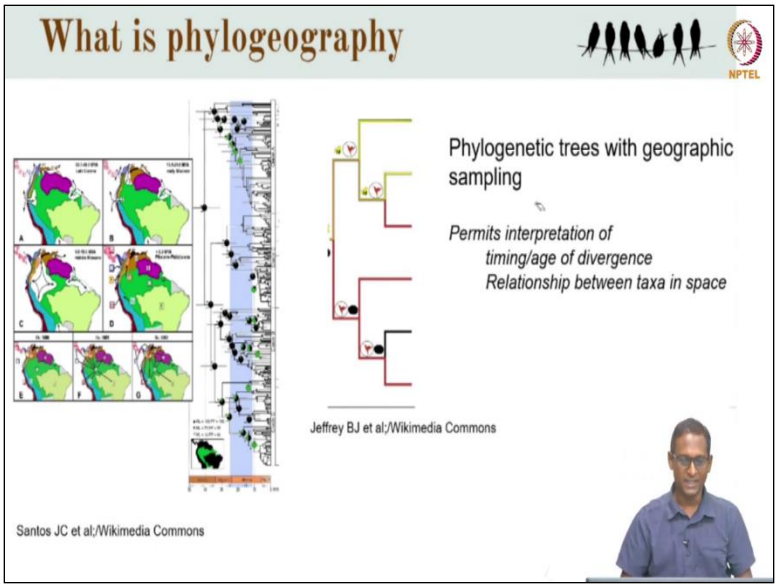

And how do people kind of come up with these ideas of distributions of geographic areas. So, today people understand the biogeographic barriers and biogeographic divides using something called phylogeography and I will explain what phylogeography is. At the heart of phylogeography are these phylogenetic trees which is what you see here. This is relationships between organisms based on genetic data.

Now how this actually happens is that researchers go out and they collect genetic data from samples across a geographical space. For example, the authors here have in this example that you see here on the left is poison frogs which are sampled from across south America. And this this results in this very complex tree that you can see here which you do not have to really understand. But the point is that with with such a tree with geographical sampling they are able to estimate where species originate from.

And in this case, they find that the northern areas are where these poison frogs originated and then they moved southward from there. So, essentially what it what it helps us is understanding timing and age of divergence and it helps us understand the relationship between taxa in space.

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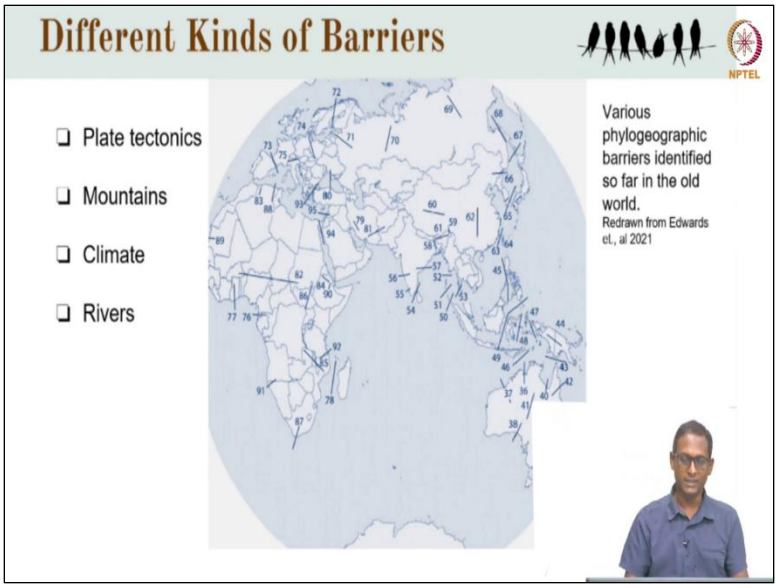

Now that comes that brings us to this question about barriers because at every biogeographic point of turnover is a barrier and there are different kinds of barriers and that really depends on what kinds of species we are talking about and what the nature of the barrier is and we will discuss this in detail. So, here is a map of a global distribution of various barriers that have been identified by colleagues Edwards, myself, and few others.

And essentially this shows a few potential barriers this is still not exhaustive and you know what are the major drivers sometimes it can be plate tectonics (and I will explain what that is), it can be mountains it can be climate climatic differences or it can be major big rivers and we will deal with each of these separately.

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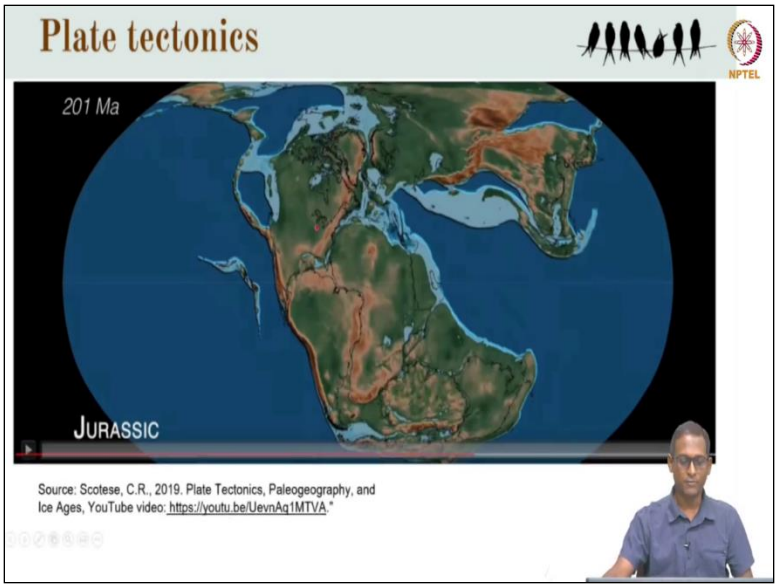

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So, plate tectonics I think that many of you would have you know read somewhere or the other about plate tectonics but just to bring everyone up to speed, I will play you this video which is created from a lot of careful data uh. So, this is in the Jurassic you can see the time running here and you can see that India… Indian landmass is here and that kind of splits yeah from the Pangea and as (follow this here) it splits from Madagascar yeah and then it crashes with the the Asian plate and that results in the rise of the himalayas and the ice areas.

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You will also notice that the light colors here are you know low oceanic depth which means that if some of these areas could be connected when the sea levels go down yeah. So, now the point is that at some point, some of these landmasses were connected and then they later separated. So, if you had organisms that were on a particular landmass there is a chance that that could have kind of moved along with these continents and this is this idea is called continental drift.

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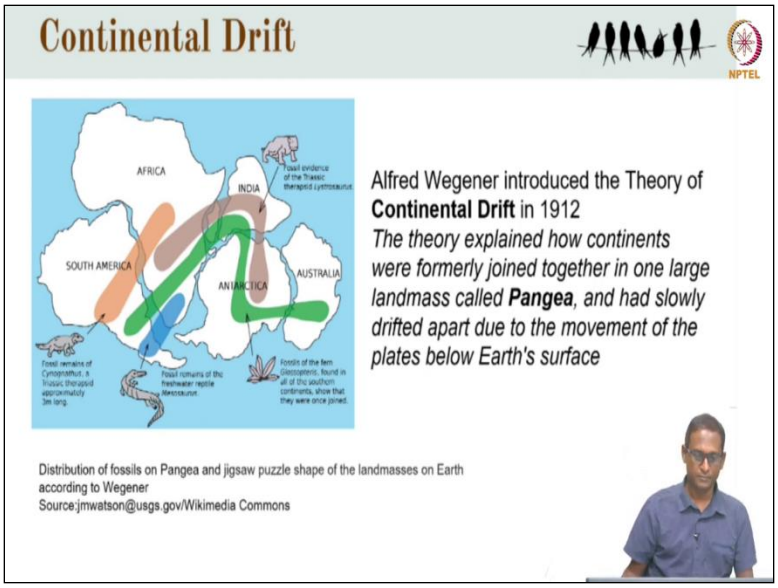

So, here is a very nice representation of what continental drift could look like. So, there are some fossil evidences of some Triassic species here and you can see how these connections run between continents. For example, some are found only in South America and Africa but some others are found in Africa, Madagascar, India and even Antarctica and some others across you know all of these continents.

And that is how people initially tried to kind of you know they were trying to understand how continents or how did these species get to these areas and slowly with data on the geology coming into place it was like a jigsaw puzzle and people put this data together.

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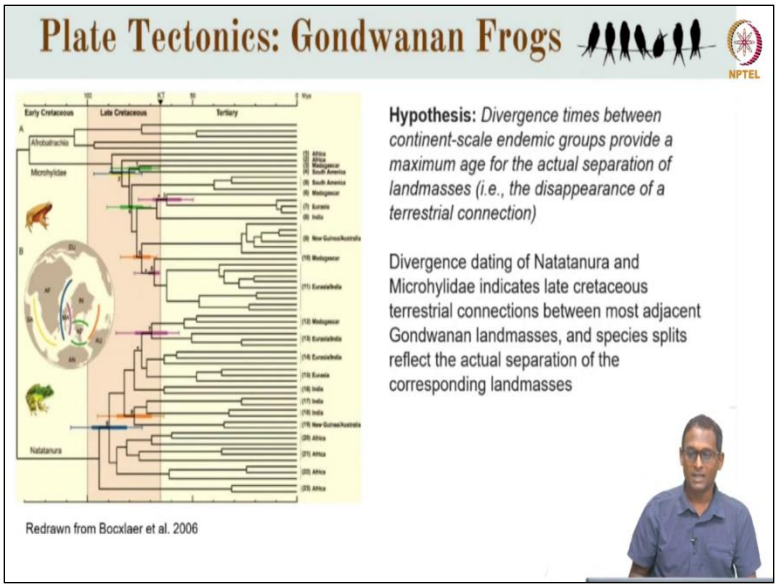

More recent data especially of relevance to India are these ideas of frogs that have been isolated from Madagascar for a very long time. For example, you will note that the Indian taxa are here and some are here. And how to read this - this is a phylogenetic tree and on the axis that you see here is the time. So, which means that we are here at zero time point and as you go back in this direction that is you know in the past.

So, this means that about 100 million years ago there was uh you know these two groups had split and then later on at the KT when the KT extinction happened that was around this time and if you follow this line that is when all of these species had split and you will notice that several of the Indian species split from the other areas around you know around the time that people describe the the you know the plate tectonics.

So, some of these dates coincide, and so this has been a hypothesis how people have used genetic data along with fossils to calibrate and get ages of the timing of divergences of different taxa and how that relates to the geology of of these landmasses. So, this is really fascinating. More and more data is coming out that show links between India (the Western Ghats especially) and the Madagascar. You must have heard of the purple frog that is a very famous example there are other examples also.

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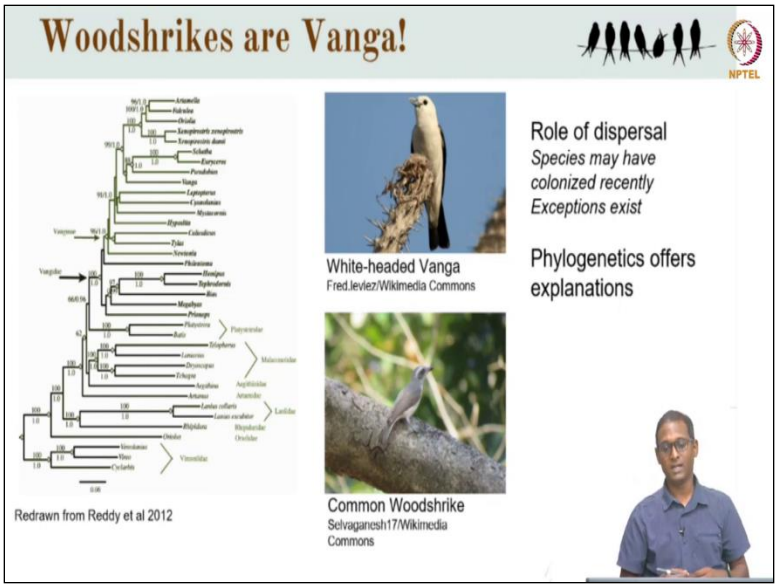

So, but how not everything needs to be with you know dispersal due to continental drift it can also be, there are also exceptions. For example, this bird that I think many of you may have seen in India the Common Woodshrike actually it turns out that it is not it is not a taxa that is related to other Woodshrikes but it is actually related to Vanga these groups of birds in Madagascar. And this was a fascinating paper by Sushma Reddy's group where they showed that some of these species are they they might have actually moved across from Madagascar to India.

So, this is not very old. That is an important point that I am trying to make. This is not a continental drift example it is a more recent dispersal through, maybe, jumping across oceanic islands and so on. But those are those are all hypotheses. But the fact remains that the Common Woodshrike is actually a Vanga.

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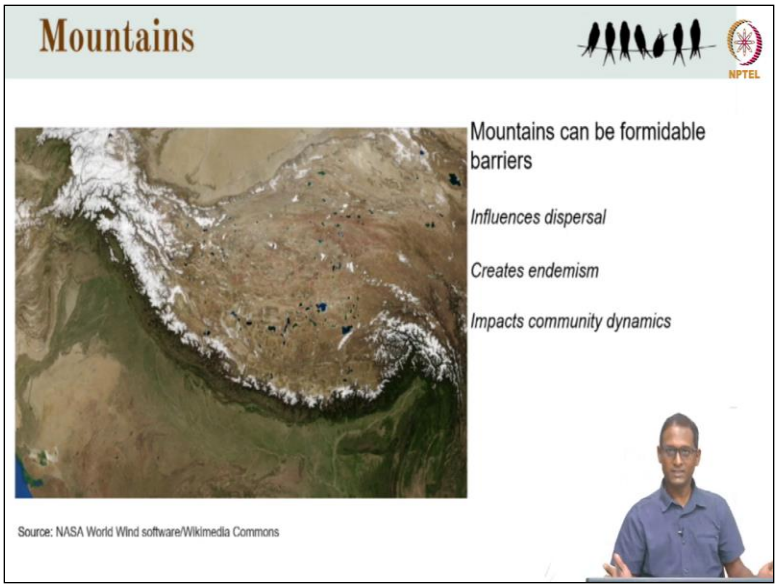

So, that is, that was all about the plate tectonics and some exceptions. We will now come to the other barrier which is mountains and mountains are actually formidable, they are of course in different different continents, different parts of the world and they can they can become formidable barriers because it influences this poses. So, some species are not able to move and cross across these barriers and it can sometimes create some kind of endemism which means that some species are restricted only to certain mountains.

We we will talk about a few examples here and how it can impact communities and community dynamics and we will have some examples on that as well.

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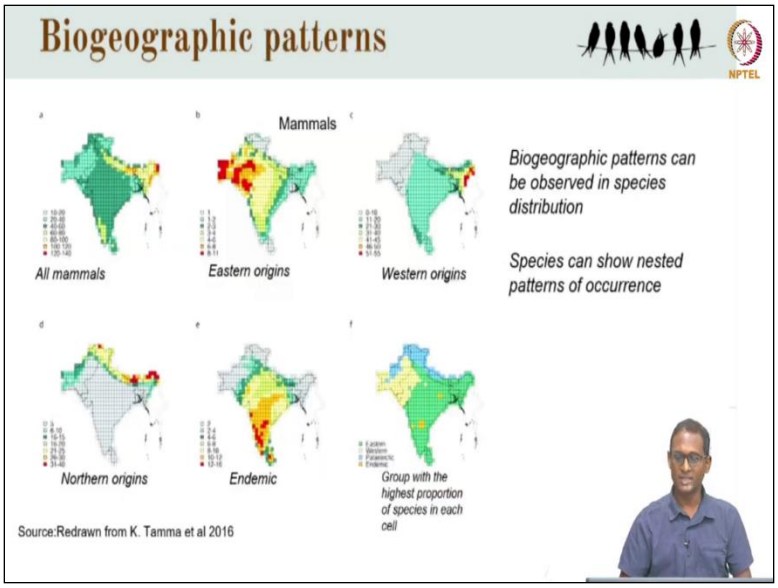

When we start with that in a fascinating study by Tamma et al in 2016 they showed how different biogeographic patterns can be seen in mammals. For example, not all mammals show similar diversity patterns for in these various maps that you see the first one here is for all mammals. Essentially, it says if you grid up India where do you, in which grids do you, find most of the mammals. And yes you find more of them in the northeast and then some here and so on.

But then this seems to be hiding some patterns. If you start looking for species that have eastern origins which means that they are from the eastern realm somewhere you know from Afro-tropical (this is mis-spoken – East is Oriental) or some other areas. So, those are clearly more found in the eastern parts. Similarly, you have some with western origins and some that are that have northern origins and understandably. So, you can see that some of them filter through and they are able to go further in inland as well.

This is not a very good example because as you can see most of the northern ones do not make it farther south. There are also some endemics which means that they are largely found only in India and are not found anywhere else and those are seem to be in the peninsula along the western ghats and some parts of the eastern the deccan plateau as well. So, what this shows is that there may be patterns even within a within a specific area and for specific taxonomic groups.

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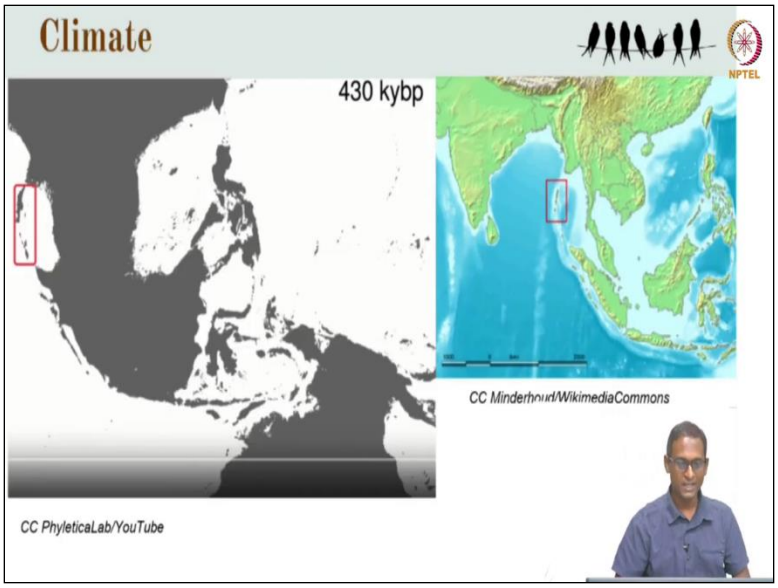

Another set of wonderful examples are on birds from Umesh Srinivasan and co authors. And here what they show is that not just, you know, babblers that they focused on, but also murid rodents. As you go from the eastern part of the himalayas towards the west there is some kind of decrease in species richness and this they find in babblers and these murid rodents. So, there is nestedness in in distribution that they find.

So, it is very interesting to understand that the patterns of distributions of species can be understood by looking at distribution along each of those small grids. Very fascinating.

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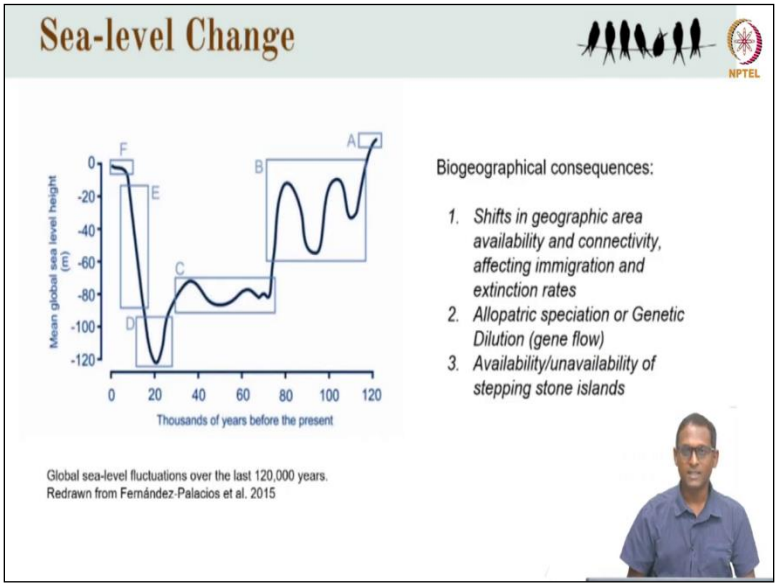

And here we would like to move on to another aspect which is climate. And on for climate I would like to, kind of, take a moment to say, climate climate can also be a barrier but there are different ways that climate acts on species and species distributions. I will start by first showing you a video of the Andaman Nicobar Islands. So, um. So, this is the Andaman Nicobar islands actually that is only the Andamans, the Nicobars go further down.

And which is this area here and what I want you to notice is how the how this area kind of changes and I have a video here again from the from a lab that has created this with data on how the ocean levels have varied through time. So, we will start with 4,30,000 years back and you notice that the land was much closer between Andamans and the mainland here and I am just going to start playing this video.

And you will see how the oceans kind of contract and expand through different points in time and time is here right. So, at some points they are very isolated and at some others the land these are called some kind of land bridges there are some bridges formed and these bridges allow for species various kinds of species to cross across them and this is colonization of some way or the other. So, this is 700060 yeah and this is our current scenario sea level changes.

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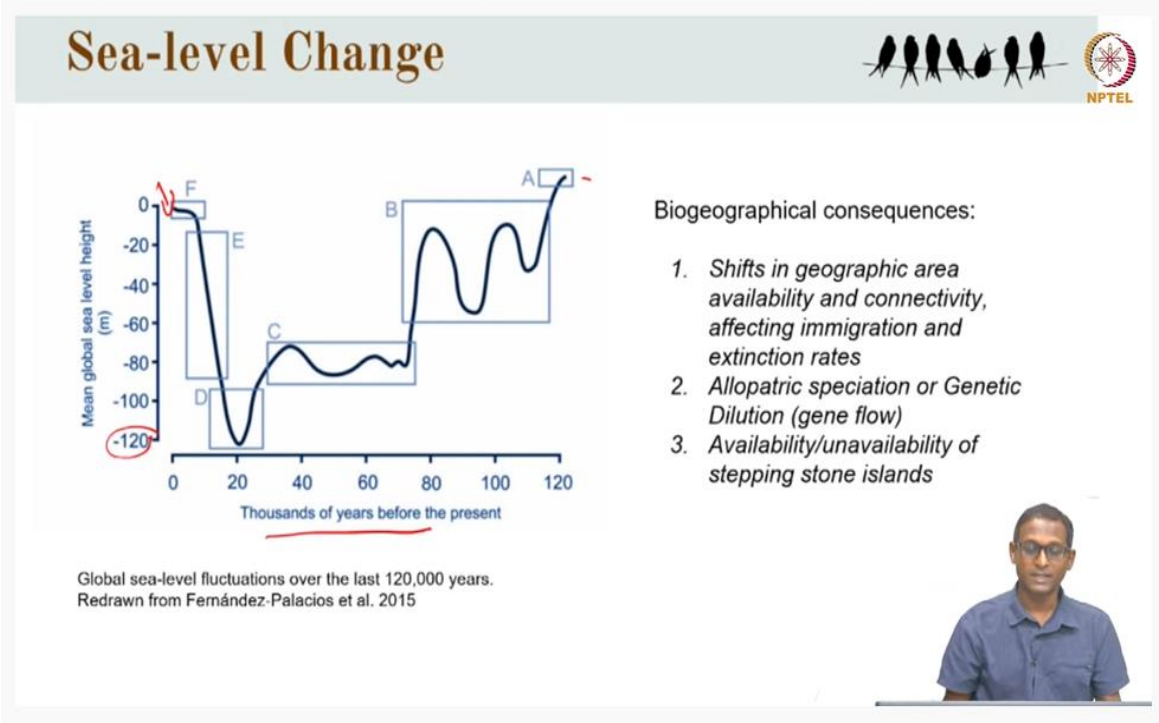

So, this is what we just saw an animation of but you can also see you can visualize this in different ways. You can think of time before present this is in 1000s of years right and as you can see that as you know at some point the global sea level was here and although we are very close to that. Now which is here, it has gone through times when the sea level was different by even 120 meters right. So, and at 100, at that kind of time point this is the LGM the Last Glacial Maxima.

That is about 18, 20000 years back and at at that time point a lot of the the sea level was much lower permitting movement of organisms between several areas connected by land. This was also time when there was a lot of aridity which means that a lot of the wet habitats moved up the mountains especially in the tropical mountain systems. So, you had only some areas on the tops of the mountains with some relic habitat. So, we will talk about that as well.

So, these changes brought about a lot of allopatric speciation and gene flow and create different levels of stepping stones of islands.

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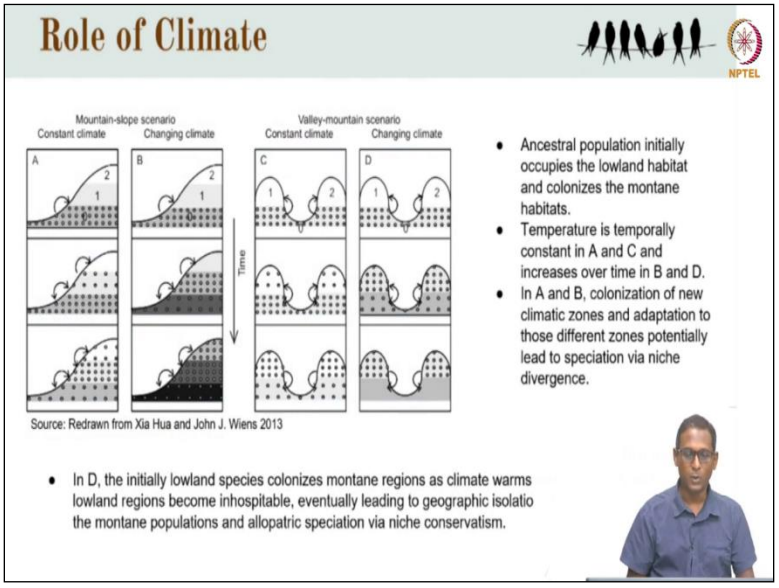

And mountains can obviously interconnect with the role of climate and this is very nicely illustrated by these different by these authors who show a possibility of how species change when

the different scenarios the different possible scenarios if when the climate is constant versus if it is a changing climate. And so, you have a mountain slope scenario and a valley mountain scenario.

And ancestral populations initially they suppose they inhabit lowland habitat they can colonize the upper mountains. So, that is one of the one of the ideas and in some cases the temperature is constant. For example, in A and C and it increases in time over in B and D and you can see how this colonization changes and it can lead to speciation by niche divergence. And niche divergence is when they kind of occupy they use different ecological aspects that a species use different ecological aspects.

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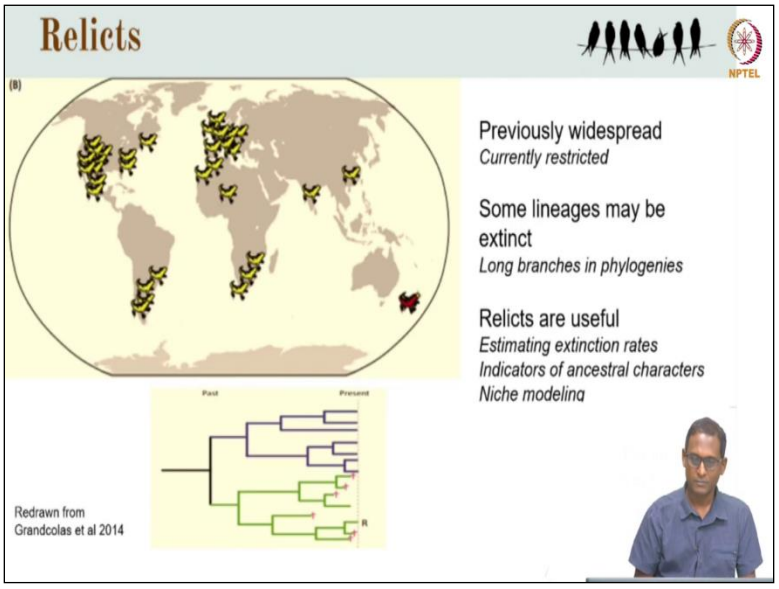

This is an example of relicts you can imagine a species which was found all across the globe but what what happens is that they go extinct some of the lineages go extinct. And you can study these such relicts by using phylogeny. For example this phylogeny here shows that if you look at current taxa it shows only these purple ones but and so, all of these have kind of gone extinct and here is one kind of relict species that is there. In this example you can imagine a relict on this on these island where they have gone extinct from all over the world.

So, relicts are they usually have long branches in the phylogeny. And one must not assume that you know that is the only diversity that is there today that is what you see today because of

extinction that has happened in the past. So, it is useful for understanding extinction rates they are indicators of ancestral characters for example this fossorial frog that has some kind of a Gondwanan origin the Purple Frog.

You know it that is very that is a good indicator of several ancestral characters like this is a Burrowing frog that comes out very rarely and it seems to have survived several of these climatic changes that have happened through in the earth through this period. One can look at how the niche has changed with niche modeling studies as well.

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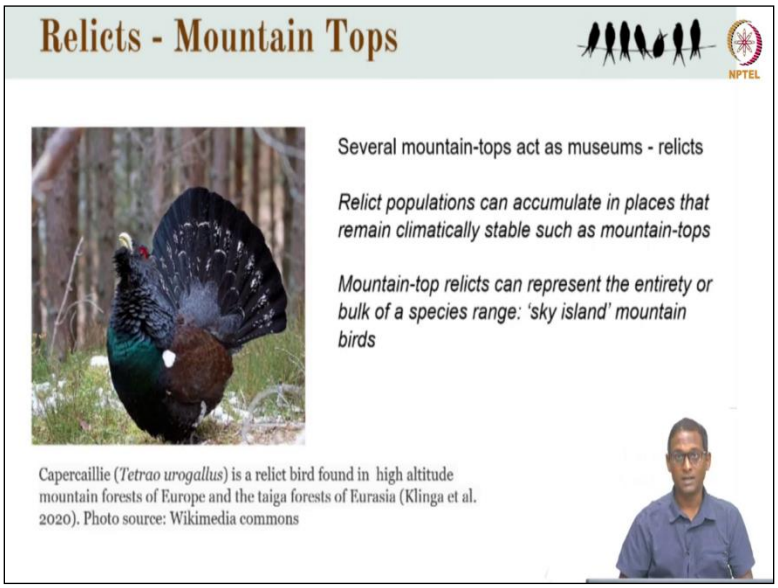

Relicts on are also found on mountain tops. So, several mountain tops (the tops of the mountains) host different kind of habitat and these mountain tops can act as museums where these relict species tend to accumulate and that is largely because these mountain tops tend to be climatically stable. So, while the climate changes drastically in the lower elevations on the tops of the mountains because of humidity and temperature differences the climate tends to remain more stable.

And these mountain tops if you have a series of mountain, they become a series of these museums and these are called sky islands because the habitats are found isolated from each other. And this here is an example of a relict bird which is found in the high altitude mountains of Europe. So, you can find there are other examples that we will come to even in even in India.

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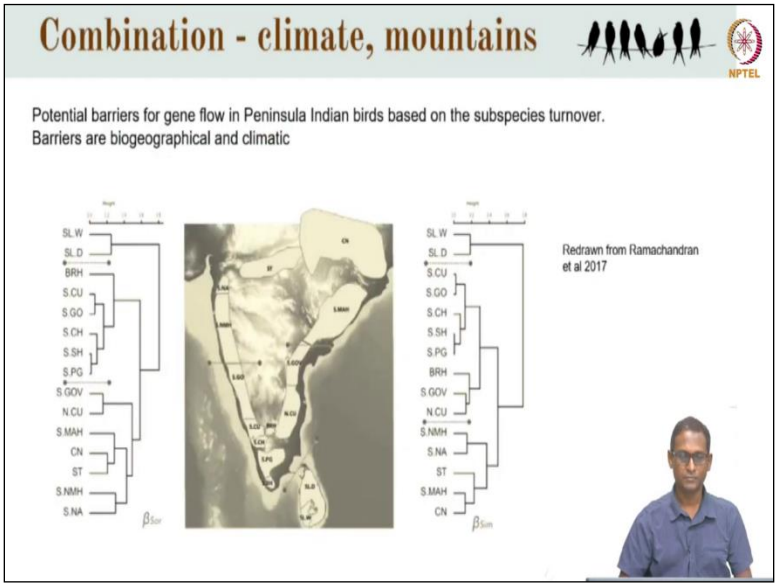

So, what can also happen is that it is not climate or mountain that act independently in some cases people are not able to differentiate between these barriers because you may have a climatic barrier and a geographical barrier (a mountain barrier). So, in this study let just to kind of keep you focused if you if you consider the diagram here (the map), there are these lines. So, these are three areas where these authors Ramachandran et al (which included me also) looked at bird distributions.

And what we found was that the major barriers major locations of turnover of subspecies - this was based on subspecies, it is not based on genetic data. So, these were the areas where there was a lot of turnover and you will note that there are several other minor areas which do not have these lines. So, let me explain this. So, all the areas with the red line are the ones with which are major barriers in turnover of species.

And then these little you know lines that you see the dots those are those are more minor areas of turnover of subspecies. Now what this means is if you go across for example the Palghat gap which is here, there are several subspecies that are not found on the other side. You know this is just like the Wallace line. And I am talking about only bird data here, but I am sure that this is the case with several other species as well.

And what they find is that despite this, the major barriers happen to be the one here which is considered -or very popularly known as the Goa gap and that one appears to be more of a climatic barrier than a geographical barrier. Yes, the western ghats are there but there is no mountain pass no geographical feature that you can identify with that barrier. So, this is primarily a climatic barrier which has resulted in different vegetation structure in the north, different type of habitat compared to the south.

And the Godavari area here is a big river and it is a it is kind of a paleo river plus there is a climatic difference. So, it is very difficult to tease apart what is the role of climate versus a geographical barrier in some cases. But what is important for us to understand is that there are different kinds of barriers some of them are mountain barriers. some of them are climatic and some of them may act in combination.

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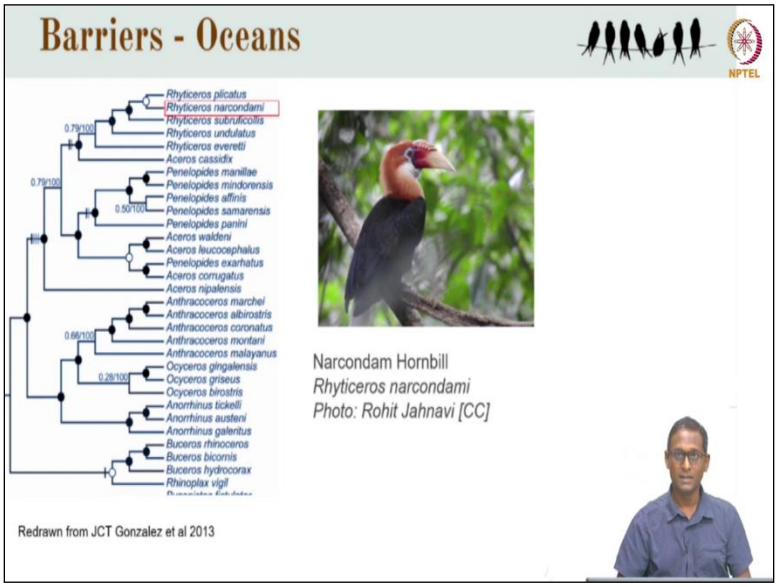

Going back to the barriers of Oceanic on Oceanic Islands, I think all of us know of this very famous example of Narcondam Hornbill (the image that you see here) and this is this population is found only on a single volcanic island, called the Norcondam, which is where it gets the name from. But interestingly the genetic data from 2013 seems to show that it is not very different from the other hornbill in the mainland.

So, this needs to be examined further. But, this may be because of how organisms can travel if they are able to disperse across some of these barriers then the gene flow is maintained and then they are not different species. So, in this case, there is no clear outcome so, far.

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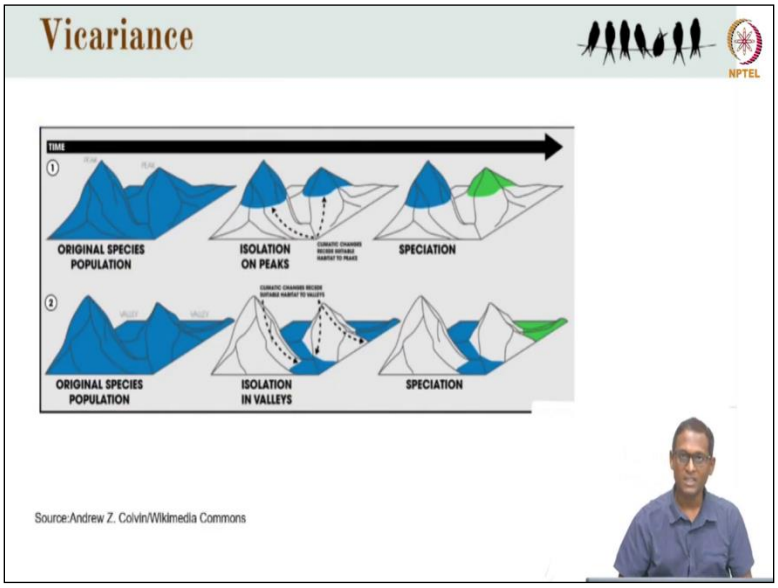

Some other aspects of biogeography some of the popular models of biogeography talk about vicariance and dispersal. These are two ways that species originate yeah and this is very beautifully illustrated here you can imagine that the original species a species is distributed over several mountains and the valleys in this diagram here. And the climate let us say changes and there are two possibilities that can happen.

One is that the species all move up they go up the mountain and they get isolated on these mountain tops. This is one of the scenarios that we discussed earlier. In some cases, species may actually move down and even they are kind of tracking suitable habitat that depends on where that you know what changes happen on these mountain tops. In some cases, where there was some form of glaciation or ice formation, when these mountain top became very cold especially in the northern latitudes they are known to go down into the valleys.

And over time so, as time goes by it is possible that you can have a species A and species B just by genetic drift over very long periods of time. It is also possible that even the valley species can

get isolated because of the mountain. So, you can have species A and species B here because of this. So, the point here is that this kind of model of speciation is called vicariance and this is an important idea in biogeography.

You can also have dispersal where you have one species which kind of colonizes moves into a different area and then gets isolated over a period of time. If you assume you know this species moving over or to this mountain and then gets isolated. So, that is that is another mechanism of speciation in that is popularly kind of discussed in biogeography.

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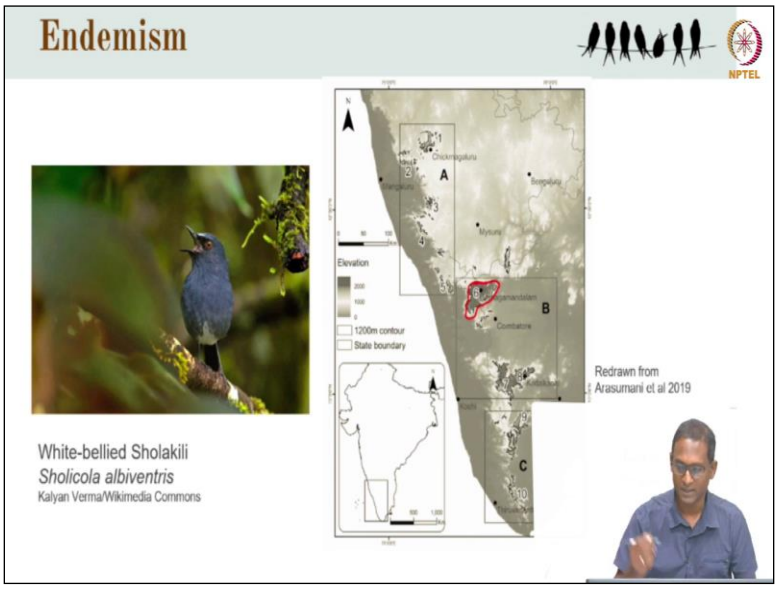

So, all of this can result in high endemism and one of the one of my favorite examples is of the White bellied Sholakili and this is found in the western ghats, this is a map of the western ghats and what you see against these numbers are mountains and this for example I am sorry my drawing is not very good but that is the nilgiris. You have the the town of Ooty there and this here you can see the similar contour here that has Kodaikanal and Munar which is the Anamalais and Palni hills, then you have other mountains that are again isolated from each other. So, these are all different isolated mountains yeah and all of them have populations of this sholakili right.

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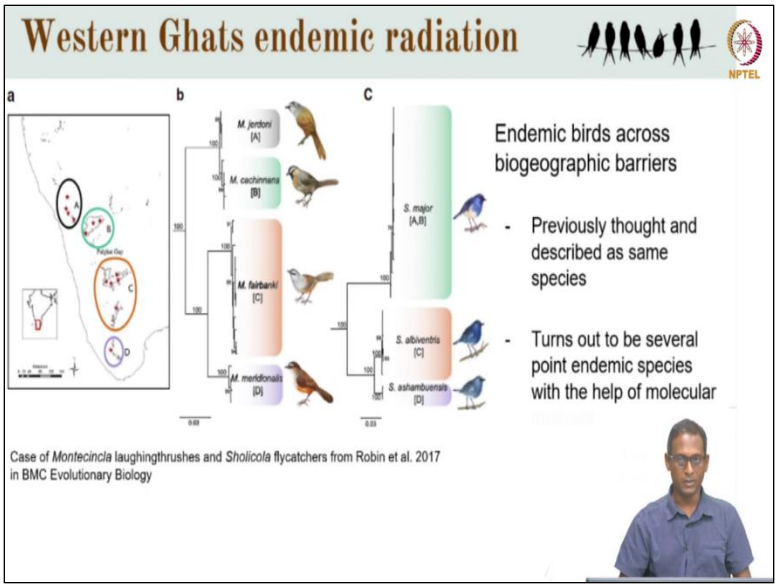

And earlier they were thought to be one species but later we conducted a detailed genetic study and you know we looked at plumage and we looked at song and we suggested that these are in fact different species. This was the case for the laughing thrush which is the *Montecinla*,these are the laughing thrushes and they are found in four distinct locations while the the Sholikola are have three distinct species.

So, they form for so for Sholikola a and b that you see here these two areas are very similar. So, you see essentially you see three groups you see A and B and then you see C and then you see D and we suggested that all three are different species and they are separated across the palghat gap here by about five million years. And there is a similar divergence across the palghat gap for the laughing thrush as well.

So, these endemic species are separated across these mountains and these are now endemic mountain top restricted species found nowhere else in the world and this obviously has implications for conservation as well. And this was found because we had molecular data - blood samples that we collected from birds in the wild from all of these different locations.

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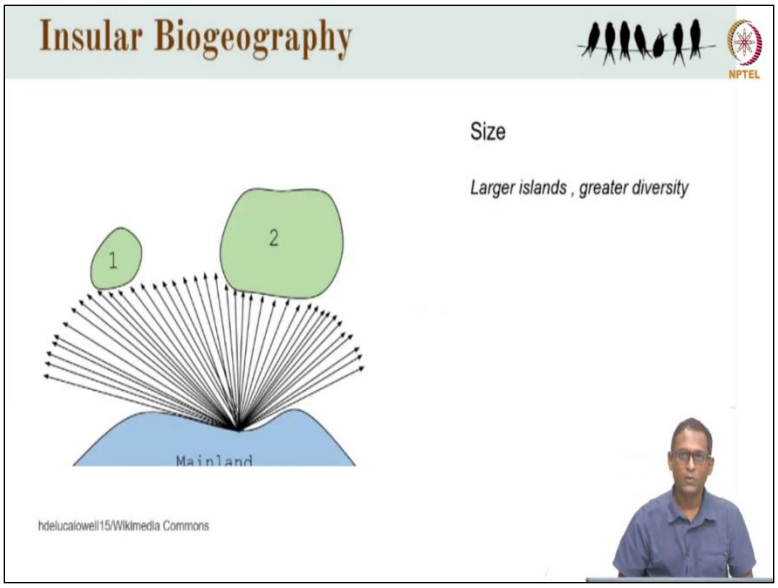

Now, we move to the idea of insular biogeography or island biogeography. This is a very important part of biogeography and sometimes it can be a little bit difficult to understand. So, I am going to illustrate this with a few cartoons and hopefully you can stay with me and you can understand the entire idea. So, essentially, the idea is that you have the mainland which is here and from the mainland species need to disperse to get to different islands.

And here there are two islands, island one and island two and they are of different sizes island one is small and island two is large. Now what happens is as species kind of move out from here, you can imagine you know individuals kind of let us say flying out from the mainland and the chances of them hitting a larger island is more and essentially you see more colonization given that they are at the same distance from the mainland.

The larger island will tend to have greater diversity there are other ideas that are you know that come into place for this but this is an important idea as well. The distance from the mainland and the size of the island has an important consequence on the diversity of that island.

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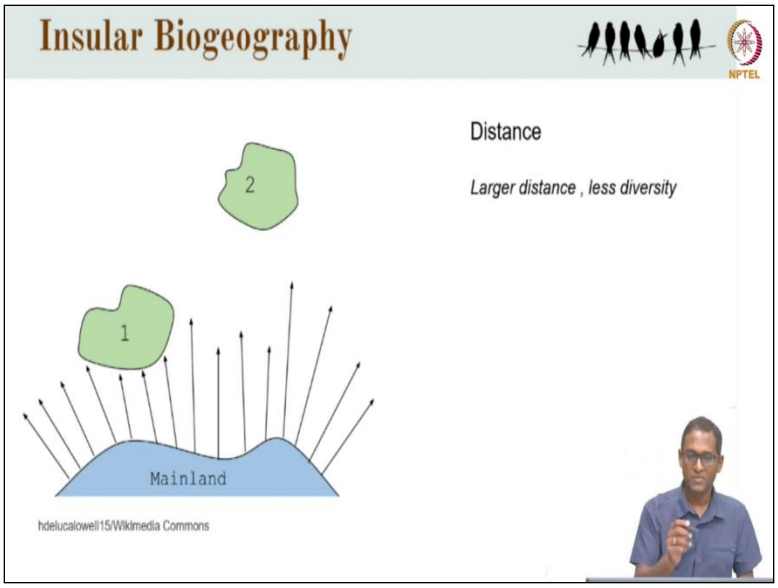

Now you can also have similar sized island like you see one and two here they are the same size but one is closer to the mainland than is two and what you can see is that there are probably more species that get to island one than two. So, you find fewer species in islands that are more distant from the mainland. So, this is again a very important idea in biogeography.

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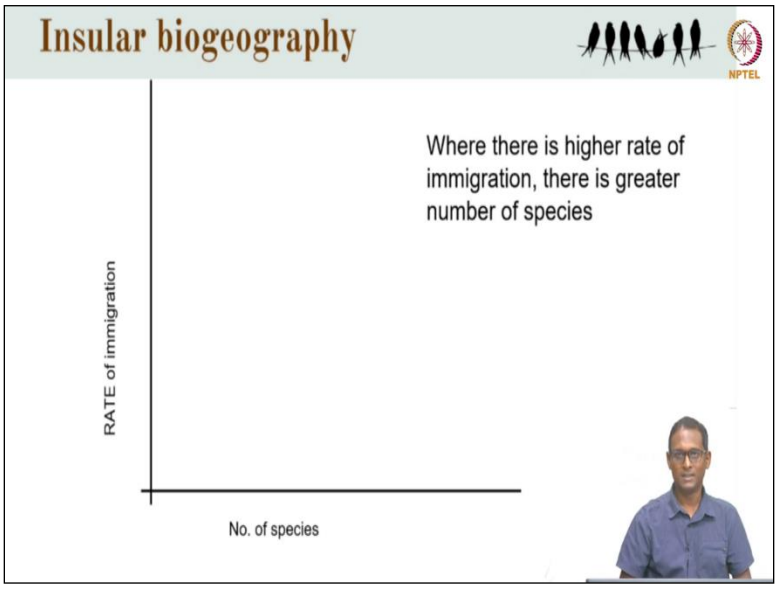

So, to get to there is an equation there is a way that people look at distance and size and how that affects the immigration and diversity. So, if you have rate of immigration and number of species the idea is that when there is more immigration there is greater number of species that come in something like this.

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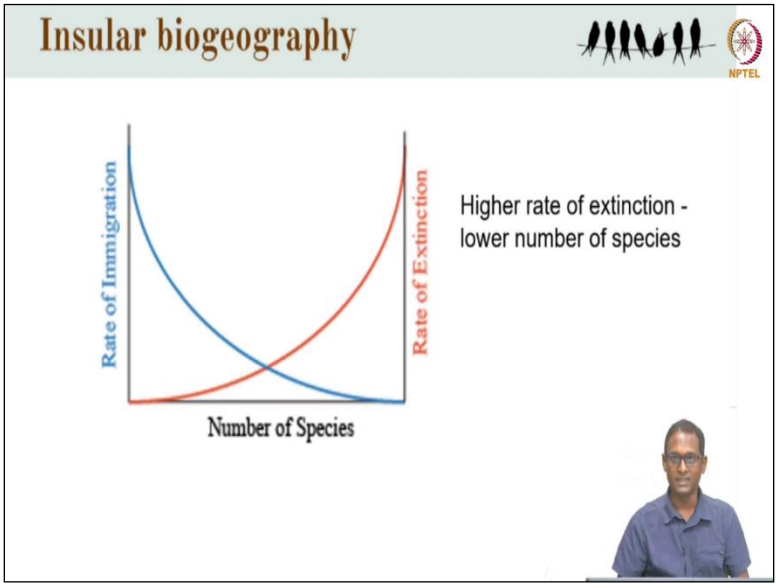

You can also have extinction here. So, in this case. So, in this case you have extinction on the other axis here the rate of extinction and higher the rate of extinction, the lower the number of species is. And if you remember that you know from our example earlier the illustration that we had earlier, we know that for the islands that are closer to the mainland, you will have greater immigration.

So, there is a skew in in this line that kind of pushes more immigration and lower extinction as a consequence also. So, it will have greater number of species. So, it will have a greater number of species and you get the number of species by kind of drawing a line here. So, that is the number of species that you have at the intersection of the rate of immigration and the rate of extinction.

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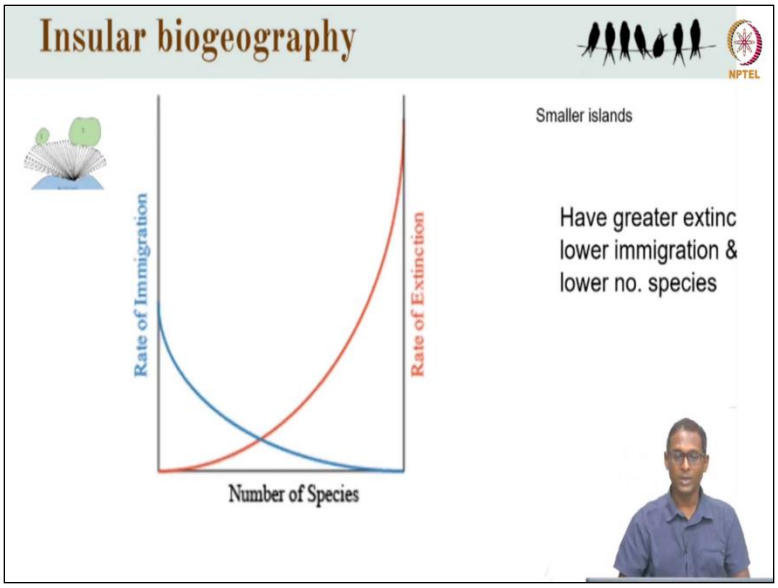

Now, if you have a small island again going back to the example that we looked at earlier, if you have small island then your rate of immigration is lower. So, you can see that here, but your rate of extinction is higher and your number of species on the x-axis is then a little bit less. So, essentially you have to kind of imagine this interplay between immigration and extinction which has a consequence on the numbers of species at in that area.

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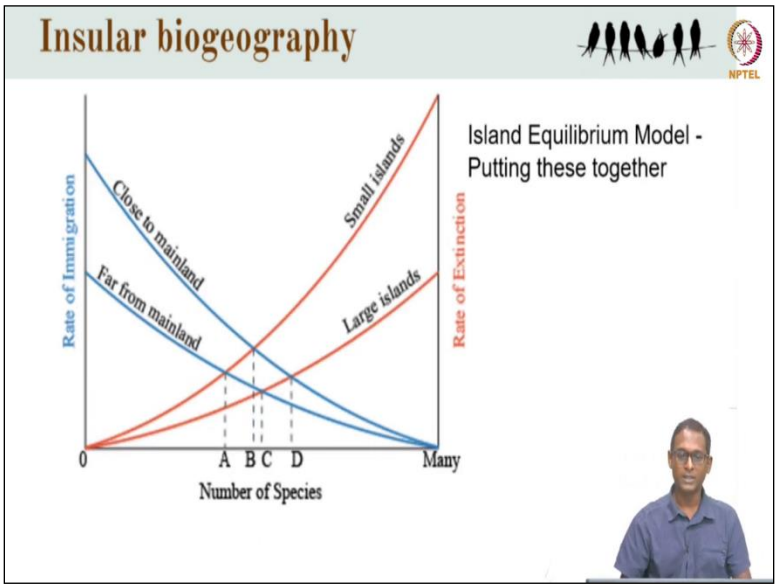

You can put these together and you get this island equilibrium model. So, usually people get very confused with this with the figure, but I hope that your you can see that you have at least if you can get the A and the D which is if you are a small island and far from mainland. You remember

that cartoon if you are small and far then you have lower number of species and if you are a large island which is close to the mainland, which is here close to the mainland then the number of species is more.

And of course, between the B and C things can change it depends on a lot of other aspects as well but essentially this is the island equilibrium model to kind of put it simply. All right!

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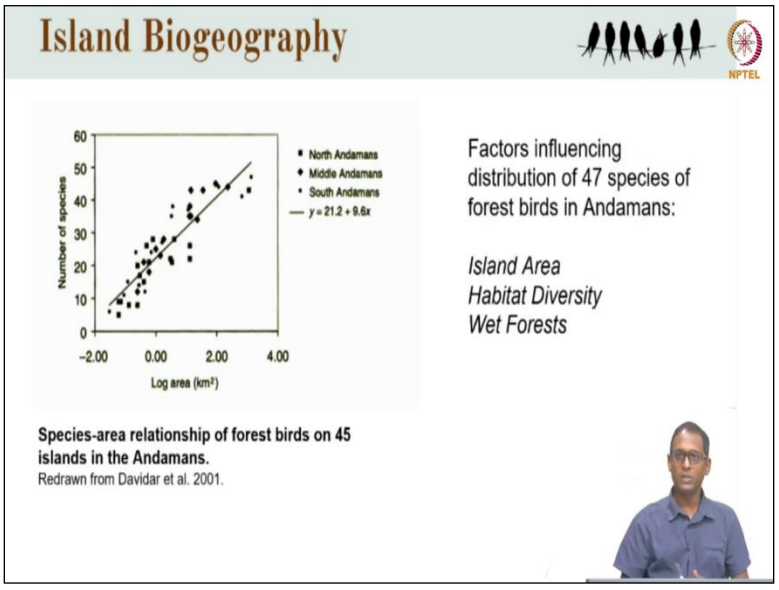

So, what do people find when they have examined some of these relationships another important relationship in island biogeography is a species-area relationship. This example is a wonderful example from Dr Priya Davidar's lab and they looked at birds in the Andaman islands and they looked at the distribution of 47 species of birds. And essentially what they find is that there is an impact of area on the numbers of species.

So, the larger the area, the greater number of species that you find on an island. Of course, they also talk about not just the island area but the habitat diversity and the fact that you have wet forests that can support a large diversity. So, there are other aspects that that play but one of the fundamental things to remember is that larger the area more niches that that are there available for greater diversity and then of course all the other island equilibrium ideas also come into play.

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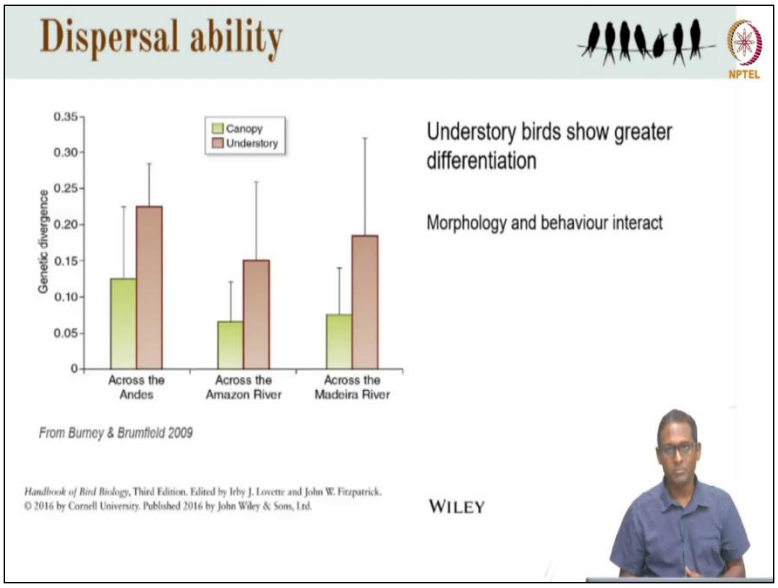

In biogeography one of the important things that people are beginning to understand is that the story is not the same for all kinds of species. Especially, in birds one of the concepts one of the ideas that that people are talking about more is about dispersal-ability which means how far can a species move. And we know that not all birds are alike, you have canopy birds essentially canopy birds are thought to you know look for resources which are more patchy.

And they can hence travel larger distances, especially frugivorous canopy birds they track resources and they you know kind of move much farther. And the hypothesis is that they hence they have lower genetic differentiation than understory insectivorous birds which are generally sedentary they are thought to be sedentary. And this group of researchers actually examined, they looked at genetic divergence which is here and across different barriers like for example across the Andes across the Amazon or across another Madeira river.

And what they found was across all of these barriers they found that the understory birds actually showed more genetic divergence than canopy birds which meant that the canopy birds were able to kind of move across these barriers much more than understory birds. So, this is a very interesting aspect that a lot of researchers are beginning to kind of examine more deeply. And essentially it is not that it is just driven entirely by morphology.

Yes, morphology has a big role to play in it the shape of the bird's wing or is one of an indicator there is a hand wing index that people use as a surrogate of dispersal ability these days. So, that is a good trait to use but there is also behaviour that you know how birds actually interact with the landscape are they tracking resources, the ecological aspect of it is also important in these biogeographic patterns that you see.

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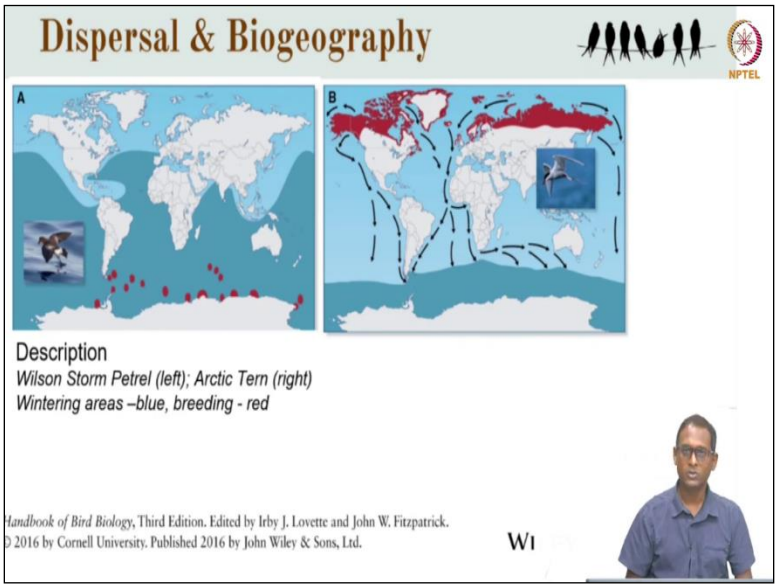

And I just want to also give you an example of you know what happens to biogeography when these birds actually have very large dispersal areas and on the left here is the Wilson Storm Petrel and on the right is the Arctic tern and the areas in blue are the wintering areas and the areas in red which are kind of here and for these birds they are here. So, those are the breeding areas. But you can see that you know these are they are found all across the world and they move across the world.

So, obviously when you are thinking of biogeography you need to think about the ecology of the species and how far they move. So, these birds have very large dispersal distances and hence the biogeographic impacts would be would have to be considered accordingly.

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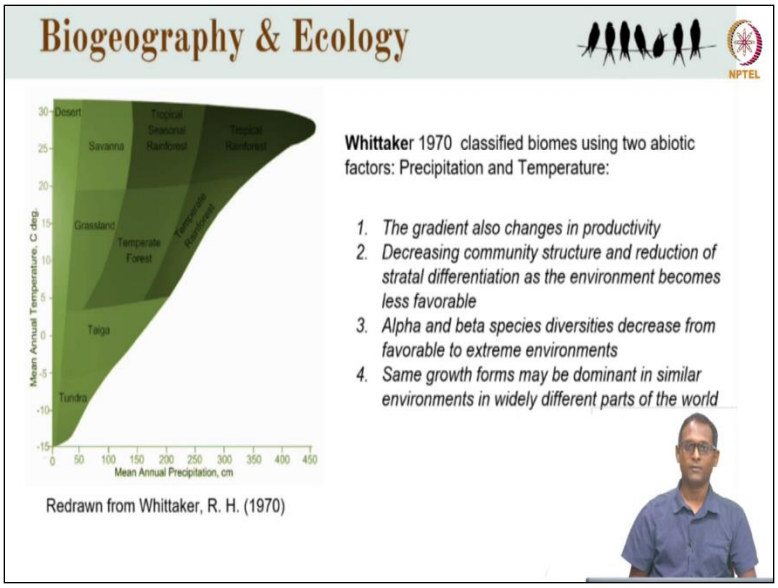

Another interplay of biogeography is with ecology and here this is a famous diagram called Whittaker biome diagram. You know it was proposed by Whittaker in 1970. And he used two abiotic factors to classify biomes. Now biomes are some forms of habitats. And you have mean annual precipitation here which is you know goes from low to high and you have temperature going from low to high on the y axis. You can also switch this out and you can have precipitation on the other and temperature you do find Whittaker diagrams that way as well.

But essentially what the important part of this diagram is that you have some area which has high precipitation which is here and also high precipitation and high temperature and those are the tropical rainforests and then of course you have the tundra which has low temperature and low precipitation which is here and in this case, low precipitation and high temperature which are the hot deserts right.

And then a lot of the other habitats kind of fall in between this. So, this is a way to kind of explain diversity of habitats just using two abiotic factors - precipitation and temperature. So, this is very elegant. Now it is also a gradient in productivity and you can find community structure changing, stratification changing and alpha and beta species diversity changes as you go from you know favorable to extreme environment and some growth forms are found in some parts of the world which have these habitats.

So, this is again another part of biogeography which looks at the interaction with ecology yeah this is a this is a very famous and fundamental aspect as well.

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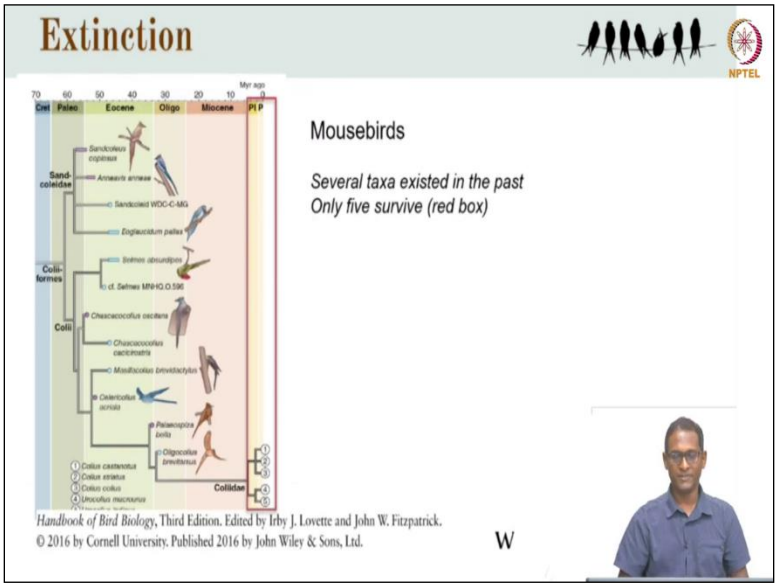

I want to… we did talk about we talked previously about the role of extinction with respect to relict species. I want to also stress a little bit more about the role of extinction in species diversity. And this is a very interesting example of this group called Mousebirds and we know today from various fossil data that several taxa existed in the past and here again in this graph this is time and this is now but so, what is happening is there are only these taxa that remain today these five groups of Mousebirds everything else is extinct right.

So, essentially what I am trying to say is that when we look at species diversity today that may not be you know an indicator of how diversity has existed in the past. there is a lot of extinction that has happened in the past and passerines especially birds also do not preserve very well with fossil records. So, there are very few studies that actually look at fossils and can look at how diversity was in the past. So, what we are seeing today is only a snapshot of diversity that has managed to survive through a fairly long period of time.

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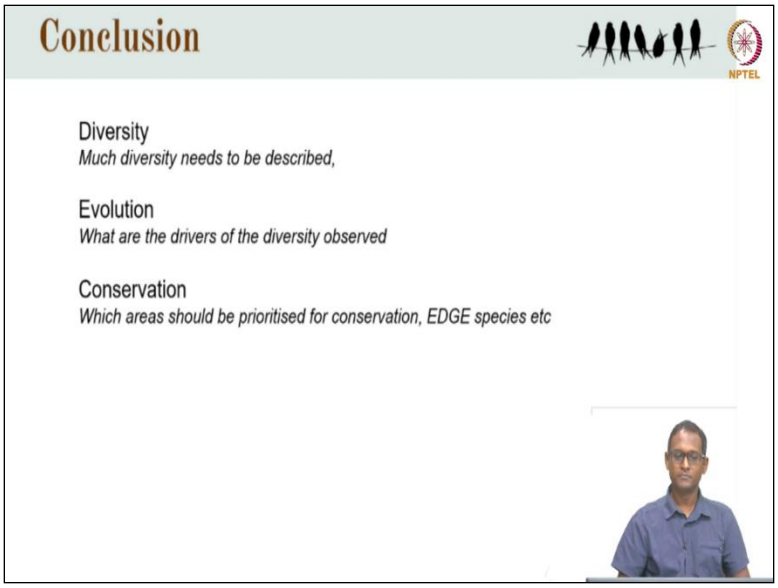

So, in conclusion biogeography is about understanding diversity and there is much diversity that needs to be described especially in a country like India where phylogenetic studies, phylogeographic studies are very limited. There are very few studies on evolution to understand what are the drivers of these biodiversity. How are where do species originate from how do they colonize and move.

These are again very fundamental questions that remain to be answered in the Indian scenario. Conservation, of course biogeography has a big role in conservation as well and some biogeographic ideas by geographic realms, how biodiversity is divided across space and how they are connected that can be used for a conservation prioritization. This is in fact done for species like tigers you have tiger conservation units.

There are also conservation programs that look at EDGE scores which also consider not just the population size but also the branch length that we talked about you know how much of a relict is the species. So, species that are long branch branches you know relict species would get a higher EDGE score and this is the case for several species including the Forest Owlet.

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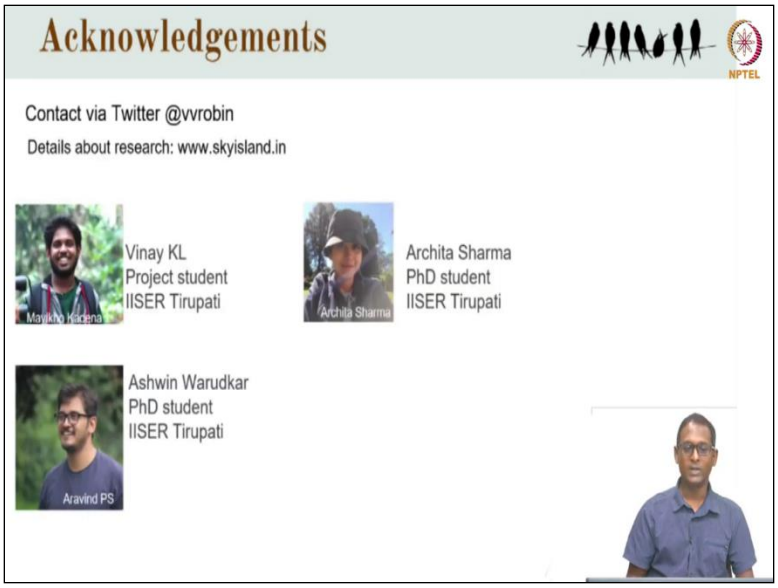

I want to end by a quick acknowledgement of some of my team members who helped me put together several of these examples. Vinay is a project student in the lab, Archita is a PhD student, and Ashwin is another PhD student. And if you want to reach out please use twitter @vvrobin and more details of my own research are at skyisland dot in which has a component of biogeography.