Course Name: I Think Biology

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W8L40_Species, Speciation and Biodiversity - II

Hi, my name is Jayanti Mukherjee, and as a part of the I think biology NPTEL course, today we are going to continue our discussion on species, speciation, and biodiversity of the week 8 section. As a part of this, we are going to continue and go into more discussion about what is biodiversity. So, these are the learning outcomes. We have already recapped evolution through understanding what species are, what are the controversies around species, how species came to be, or speciation for that matter, and now today's lecture, we are going to go to understand what is biodiversity and how can we measure it. So, let's get started. Biodiversity as we know is defined as the variety of organisms present and interacting in an ecosystem.

So, this is what normally we know whenever someone tells us what is biodiversity, we always think that it is the organisms present in the ecosystem. But is it always true and how do researchers or scientists define it? According to them, it is much more than only species. So, biodiversity does not only mean species diversity, it is much more than that. What is it then? So, they classify it that it could be species diversity, it could be genetic diversity, it could be the diversity of ecosystems and it could be the diversity of the function or the different roles that the species play in an ecosystem.

So, let's get into this in a bit more detail. Before that, we will talk a little bit about the importance of biodiversity. These are all very common and you probably have already studied this in your schools, but we will just quickly go through it. We all know that biodiversity provides us with food. The plants around us, the crops we eat, the cereals, and the fruits we eat, all come from plants.

Animals, if we eat meat, eggs, or fish, anything comes from animals as well as mushrooms. A lot of us love mushrooms, I do. So, it also comes from, it is a part of biodiversity. It gives us a lot of economic benefits through these food products and animal products and also timber as well as animal trade. Most of our medicines come from natural products.

Now we are manufacturing them chemically. So, a lot of the natural medicines are coming from

the biodiversity we have. Biodiversity often can also serve as a biological control of several diseases. For example, studies have shown that if there are a lot of animals or a lot of biodiversity around you, then it sometimes can reduce your chances of getting diseases like malaria or dengue or some other disease because the diversity around you is diluting that effect of disease to the other organisms present around us. So, we are not affected or infected immediately.

So, it is a very big advantage and we know that having biodiversity around us can also reduce the invasive species to come into an ecosystem. Biodiversity provides us with a lot of ecosystem services. This is the service that the ecosystem provides us free of cost with its pollination service, it gives us fertilizers, soil aeration, and a lot of things that nature does for us for free, but we don't value that. So, these are very important parts of biodiversity. Aesthetic value is what we know, its nature, and its benefits.

We love to go for long walks in nature or we love to hang around animals when we see them play. This is part of the aesthetic value. If can you imagine a world where there are only humans and nothing else, we cannot exist like that. So, it is a part of aesthetics as well as other kinds. Last but not the least is the scientific value.

So, we know today of evolutionary science, anatomy of physiology of behavior, and ecology by doing research on these biodiversity time after time. As for that, take the example that a lot of our medicines are till now, till today tested on animals before they test on us. So, they serve as a part of these scientific inspections or examinations that we conduct and we can learn a lot of questions that exist in nature by researching the biodiversity around us. However, one of the most important parts of biodiversity is something that scientists call, Biodiversity gives stability. Now, before we go into this part of the importance of biodiversity, I would like to talk about a few other things because only then this will make more sense.

So, now let's go into talking about the different levels of biodiversity. The first is say, genetic diversity. What is genetic diversity? We already know various numbers of alleles with different distribution frequencies in a certain population, right? But what does it mean? So, genetic variation refers to the variation in the genome at an individual level. So, for example, my genome will vary even from a friend in my class my colleague, or even my parents.

Even though I am very related to my parents, my genome has its uniqueness. So, that is genetic variation at an individual level. However, if you take it to another level, then it is between populations, okay. So, between populations genetic diversity is very, very important. If you remember our lecture when we talked about species, we talked about something called subspecies or varieties or eco-varieties, these kind of terms.

Those all belong to this species level or population variation, okay? So, for each population, say for example, there are four populations, four in different geographic regions. Now, that geographic regions put selection pressure on evolutionary pressures on those populations and that is how that genetic variation is evolving in that particular area. So, that increases the genetic variation of the whole species as such if you take the population into account. So, genetic diversity simply means a lot of variation in their genes.

With a lot of variation also comes the opportunity of mutation, more mutation. Now, let's take an example. Say these three cute little populations of fish. In this orange population, say they are subjected to polluted water and because they have genetic variation, they develop a mutation which can give them very much tolerance towards a lot of heavy metals or pollutants. Say the second population has been exposed to warmer water and they develop resistance or tolerance towards warm conditions.

This last population, the third one is subjected to cooler regions and they evolved a tolerance to colder variation. So, when you bring these all population individuals together and as such you look at the species' genetic variation, then the species gene pool will have all these variations and good genes for tolerating cold climate, tolerating warm climate as well as being resistant to pollutants. So, this is a big advantage of having a larger gene pool. So, safeguarding the genetic diversity of all kingdoms of life provides the necessary basis for populations to adapt to changing conditions, simply put.

Now, let's go to the next level of diversity, which is nothing but species diversity, the most common form of diversity that we know. Variety of species in an area. Now, here is the species-level variation. This is if you remember our lecture on what are species, there is a lot of confusion or controversies around what species are. However, irrelevant other than that, you can always say for example, if you take this figure, the green figure here, you can always say that this is a crab and this is a shrimp, this is a fish, this is a plant or something else. So, at least we know by looking at their morphology that they are different varieties or species.

So, counting those gives us an idea of the diversity of that area. So, species diversity is a measurement of species richness combined with evenness. These are the two terms that we are going to talk about a bit more, which means it takes into account not only how many species are present, but also how evenly they are distributed in numbers in these areas. So, what does that mean evenly? Let's take a look. Say, for example, there are two communities here, community 1 and community 2.

You can see that both communities have species A, B, C, and D, right? But in the first community, all these species are present as a proportion of 25%. So, one-fourth of them equally distributed, right? This is equity, equality you can say. All the species have equality, but in community 2 you will see species A is much more dominant, species B is very, very less

abundant, species C is also very less abundant, and D is a little bit higher, but not that high. So, species A is dominating this community on the landscape. Now, if you compare these two communities, what would be your diversity? This is what we are going to do in a while through an exercise using Excel, okay? But for now, just to know this species diversity can be measured using a lot of different indices.

Some of them are the Shannon-Weiner index, there are Simpson index, the Chow index, and many, many more. This field of research is so popular that even now scientists are working on different indices to measure biodiversity in an ecosystem. So, after species diversity, we will now talk about something called ecosystem diversity or habitat variation. Why that is important? Because ecosystem addresses the combined characteristics of biotic, which is biodiversity, and abiotic, which is geodiversity properties. Because these both are always interacting, right? They are not separate from each other and these interactions are giving rise to an ecosystem.

That is the reason, you know, a desert looks very different than a tropical rainforest which also looks very different from a scrubland and these interactions matter because these interactions are with the current climatic conditions. So, that is why ecological diversity also includes variation in both terrestrial and aquatic ecosystems. So, ecosystem diversity becomes also very important. So, these are examples of ecosystem diversity. These are, this is something called the tundra or the very, very cold region vegetation.

These are the deserts, very hot region vegetation. You can see hardly there is any vegetation visible, but if you go, very take a closer look, go to this area, you will see there are very hardy species of plants that still exist in this kind of habitat. These are lake ecosystems, these are forests surrounded by that, the tropical forest or temperate forest looks like this and these are some grasslands, beautiful grasslands and this, I don't know how many of you will know, but this is something called a Fynbos ecosystem. The reason I have put it here is because fynbos is one of the endemic ecosystems of southern Africa and endemic means this ecosystem occurs only in southern Africa. It doesn't occur anywhere else in the world, okay?

So, it is a very special ecosystem. So, these are ecosystem diversity. Now, we will come to last but not least, functional diversity, according to scientists, this is one of the most forms of, important forms of diversity we know of currently. So, what are these? Variation in function or role of an organism. What does that mean? Functional diversity is the range of traits of the organism in a community. For example, nitrogen fixers, apex predators, herbivores, and decomposers, are the roles that an organism plays in an ecosystem, right?

So, now let's talk about it a little bit more. Say, if you have a system or an ecosystem where there are only two nitrogen fixers, okay, only two species of nitrogen fixers whereas other plants are present but none of them are nitrogen fixers. So, what happens if the ecosystem now goes

through a very large-scale disturbance which is, which could be flooded or which could be a fire, and all the species are destroyed? So, if the ecosystem does not have seeds of a lot of nitrogen fixers, then the recovery potential of that ecosystem becomes very poor, okay, because that function is now lost. Say, those two species are lost from the ecosystem.

So, now that the full functional role of that ecosystem is lost it could be detrimental to the ecosystem in terms of its recovery. For example, after an ecosystem is disturbed, it has to recover back to its original, right, that is called the resilience of the ecosystem. So, after that happens, the function is lost, then it is very difficult for the system to recover to its original status. That is the importance of functional diversity. If you have fewer predators in an ecosystem, can you imagine, let's take a question here.

If you have fewer predators in an ecosystem, what will happen? I am sure you have thought that if there are fewer predators, there will be much more herbivores. The herbivore population will increase. If the herbivore population increases, what will happen? Then they will eat a lot of grasses and vegetation. So, the vegetation will start degrading, okay? That is the reason these functional roles or diversity or maintenance of diversity of these functions are very important in an ecosystem, okay?

That is the reason a lot of decomposers are needed, a lot of herbivores are needed, a lot of predators are also needed, and different varieties of predators. So, it is not only that species diversity is important. For example, if I have an ecosystem with 100 species and 90 of them are herbivores or 90 of them are of a particular functional role, whereas only 10 of different functional roles, then there is an imbalance in the system, okay. That is why functional diversity maintenance is considered to be one of the most important diversity currently, particularly in the era of climate change. So, what diversity brings is stability. This is what I said in when I was talking about the importance of diversity, right?

The reason I waited till now was the reason to explain what are, what is functional diversity concerning genetic species and other diversity. So, for example, genetic diversity can give you disease resistance, drought tolerance, or other traits like this. Species are insects, cats, dogs, and humans, whereas functions if you lose, then it is becoming very difficult to maintain the diversity of an ecosystem. That is the reason scientists say or consider today that a more diverse ecosystem, a diversity which has an ecosystem that has a diversity of species, diversity of genes as well as diversity of functions can be more stable. Now, what does it mean by more stable? It means that it will be more resistant to say a disturbance, it will be more resistant than to the invasive species intrusion, it will be more resistant to some diseases or any other things from outside.

So, diversity gives stability is something that is considered very strongly. However, a lot of

scientists have mathematically shown that in different situations it could not be the case either. So, just to keep that in mind. Now, if you have any questions of course, we can answer them you can write to us regarding what we covered, but now let us move to the section where we discuss how to measure diversity.

And here we are concentrating in this lecture we are going to concentrate only on species diversity because this field is very huge and if we go to other considerations like genetic diversity as well as functional diversity we cannot cover them, it is beyond the scope of this course. But one thing to remember is a lot of the indices that we are going to talk about now also apply to other diversity measurements.

So, these are the different ways or types of how diversity can be measured. First, is alpha diversity. What is it? Estimation of diversity within an area. Say, I live in Bengaluru, and if Bengaluru you can take it as a whole area the estimation of diversity in Bengaluru would be known as alpha diversity. However, in terms of alpha diversity what researchers consider it can vary from a size of 100 by 100-meter plot to a 1-hectare plot to a larger area like I just mentioned. So, mostly it is considered as a plot-based area. So, say take a 100 by 100-meter plot and you calculate the diversity in that region it becomes your alpha diversity. Now, there are other two forms of diversity, and we will come to that, but just for your information those are beta diversity where you compare two regions of diversity say I have four plots and I can compare four plots for its diversity or there is gamma diversity which is the diversity of a very large region. So, in this case, Bengaluru can also form a gamma diversity measurement instead of alpha diversity.

So, it is the way you consider it and very relative. So, now let us get into some ways that we can measure alpha diversity. Two things now as we already said become very important, one is the species identity, the number of species in a given area, and the species evenness or species distribution which is how abundant that species is. These two measurements taken together actually give us an idea of what is diversity of an area is. We are today going to talk about only one index which is the Shannon-Weiner index.

It is very commonly used to date and we are going to just look at how it is measured similarly if you are interested there are lots of literature references available you can always go and look it up do you know how to do the calculation based on those indices? So, for example, Shannon-Weiner might be very good and applicable for certain habitats or certain sampling designs whereas other indices could be more appropriate for other sampling designs. So, that is the reason we are just going to concentrate on one today. The Shannon-Weiner index is calculated, and H is the Shannon-Weiner index, calculated as with this formula which is($\boldsymbol{H = -\Sigma pi * ln(pi)}$) the P_i summation of P_i times log P_i. So, as you can see I have put here P_i is the proportion of individuals of the ith species.

Say, for example, this is a species A in the community the proportion is 25 percent or 1/ 4 right and multiplied by log proportion. So, this was developed many years ago by Shannon-Weiner and it was on a formula developed from the entropy model. So, we are not going to go into the detail of how it was developed and the mathematical calculations behind it which is beyond the scope of this, but you are welcome to go and look it up online. Now, the second form of diversity as we talked about is comparing diversity across different regions.

Now, let us see what depends on two things again, another two parameters, something that is called species nestedness. So, a lot of you have, might already, know what is alpha diversity and the Shannon-Weiner index, but a few people know about beta diversity, but it is a very important index when it comes to the comparison of two different areas. We will talk a little bit about its application pretty soon. Species nestedness is a measure of how similar are the areas in species composition, and second is species turnover, a measure of how unique are the areas in species composition. So, it is just the other side of a coin, one is similarity and one is dissimilarity.

So, let us see, take an example. In this figure you see species, so these are four sites, sites A, B, C, and D. And let us see, there are three plots in each of these sites, sites A1, A2, and A3. So, within this bigger site A, there are three different plots or sites you can say, same for all the others and there are species 1 to species 12. So, you can see from this area, let me take out the pen here, right? So, there are 12, 1 to 12 species in this first area.

Compared to that, site A2 has 1 to 4, compared to that site A3 has 1 and 2. So, now if we consider alpha diversity here, then you can see that site A has more richness which is species identity, than site A2 which has just four different species compared to site A3 which has only two, which is the least diversity among these A, right. But when we talk about beta diversity, now see what is nestedness. So, the measure of how similar these species are which means that 1, 2, 3, and 4 is also found in site A.

So, this site A2 has no unique species. But it is fully nested within site A or fully, there is an overlap of within site A. Now, if site B or site A2 had species like 13, 14, or something else, then it would have a unique species which we can see in the site, next thing which is site B. Let us take a look at site B1. It has 1, 2, 3, 4, 5, 6 species. So, site B2 which has 1, 2, and 3, is a little bit similar to site A, but it also has three other unique species which makes it more diverse than site A2 or more unique than site A2.

This is how beta diversity is measured. So, nestedness means a similar number of species. So, you said beta, B1 has a lot of three species that are nested which means it is similar, whereas B2 also has three species that are unique and B1 also has three unique species. So, there are three species turnover. Now, we come to the term turnover. How many unique species are coming into

that area? So, these two other D and C are also the same way you have to look at it.

Pause the video and take a look at this picture which will give you an idea of how beta diversity works. So, now we will see what index can be used. This is called Sorenson's similarity index and it is measured using this formula (**β_{sor}= 2a/2a+b+c)** $\beta\, sor = \frac{2a}{2a+b+c}$ which is Sorenson's similarity index and A is the species common to both sides. B and C are species unique that is the turnover that we just talked about to two different sides.

So, this formula we will also use in Excel. Now, we will go and we will see how we can compare these communities or sites using this beta diversity index. Now, one thing to keep in mind, so is sometimes you may be confused because there is a lot of information available outside. Sorenson's similarity index and there is also something called Sorenson's dissimilarity index. It is nothing but it is also called D equals 1 minus beta Sorenson. So, sorry for this writing, but it is D is equal to 1 minus beta Sorenson means it is 1 minus similarity is equal to dissimilarity.

So, not difficult at all. So, before ending today's lecture, we are just going to talk about a few threats to diversity. Particularly about India, India as you know is one of the 25 biodiversity hotspots in the world. Hotspots means they are demarcated or recognized worldwide as one of the mega-diverse countries or regions. So, it is a very prestigious thing to have in such a small country.

India is one of the hotspots in the diversity in the world. So, what could be some of the threats to our diversity? It is a land use change. One of the biggest enemies of diversity today in this era is land use change and it is, as you know, how significantly or faster rates urban systems are growing. We are converting agricultural lands or natural regions to construct houses for development and other things and hence losing diversity at a very fast rate in this era. It is not unknown to any of us and we recognize this, but still, this keeps on happening.

Similarly, climate change. As of now, we know that human interventions have caused global warming, is causing global warming and this global warming is making the weather patterns very unpredictable weather patterns very unpredictability is impacting diversity which is not able to cope with this unpredictability of weather or actual severity or extremity in weather conditions. So, a lot of biodiversity is a threat because of this changing climate pattern. Pollution and nutrient load is one of the most important ones. A lot of species are dying or getting loaded with pollutants, some of them we don't even know. So, if you see this graph on the right-hand side, you will see threatened species, the threats are still low, right?

This is because of insufficient information, ok. It's not that it is the threatened species are, it's much safer, but it's, it's a lot of threatened species which are impacted by climate, being impacted

by pollution, we have insufficient information even to study them. So, that's the reason some of these species don't even know what are the threats, ok? Over-exploitation, the humans have caused exploitation. So, not only animal products, now we are going to, we have eaten a lot of animals and drove them to extinction. Every day basis there are, you know, wildlife trade and all these things have, you are aware of that is happening simultaneously and we are now, you know, going into moving towards exploiting insects for food, exploiting other things for food.

So, whichever we are doing, we don't seem to be doing it in a very sustainable way. So, that is the crux of everything. Over-exploitation can lead to degradation or the detriment of other species, but if we do this exploitation more sustainably, right, then it becomes better or we are in a balance with nature it is called.

So, then we limit or reduce the threats to diversity. And also invasive species. So, a lot of this urbanization as well as, you know, interaction or global transport systems these days have caused the increase in invasive species which are intruding into new areas and causing the threats to native species in that region. So, some of these things are very important points to remember which can cause threats to our biodiversity. With that, we will end this lecture and hope you learned something new, how to measure diversity, alpha and beta diversity we talked about. We talked about the diversity of genes, species, ecosystem, and function and then at the end threats to biodiversity. Thank you and we will see you in the next lecture.