Environmental Biotechnology
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Lecture – 06
Microbial Ecology (Contd.,)

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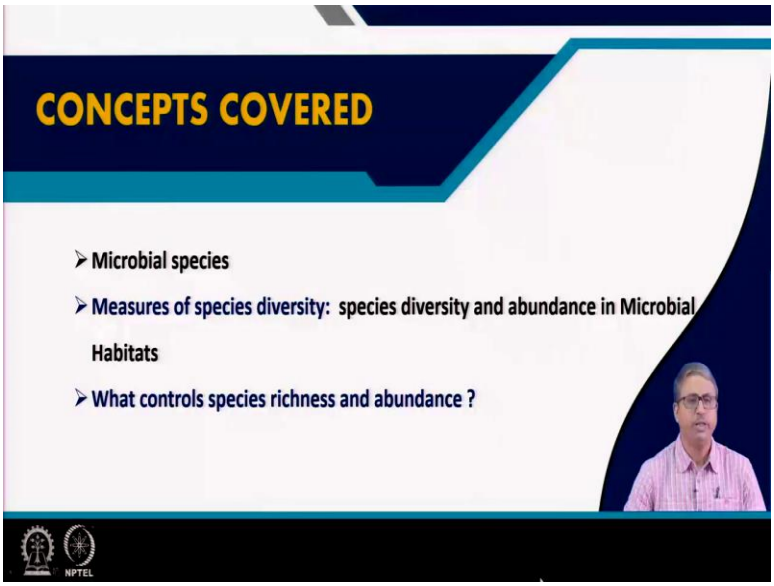

Welcome to the sixth lecture on environmental biotechnology and in this lecture we are going to continue our discussion on microbial ecology. The major concepts that are going to be covered during this lecture would be the microbial species concept, measures of microbial diversity including the species diversity and abundance in microbial habitats and what are the factors or what are the parameters that control the species richness, abundance and their function in any kind of environment would also be discussed.

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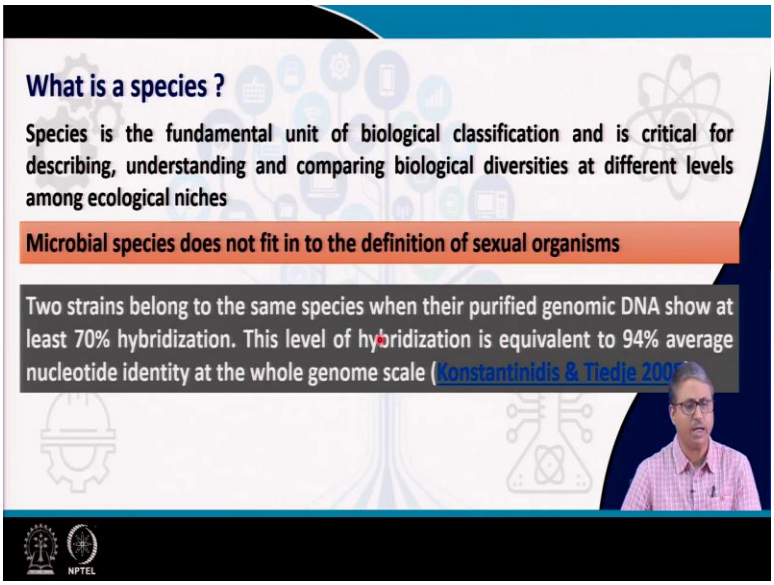

At first microbial species and microbial species diversity and abundance in microbial habitats: Now what is a microbial species? Now as we know that species is the fundamental unit of biological classification and is critical for describing understanding and comparing biological diversities at different levels among ecological niches. Now conventionally the definition coined for species considering the eukaryotic or sexually reproducing organisms is not valid for microbial species or microorganisms because microbial species they do not reproduce through sexual reproduction.

So, eventually a specific definition or specific idea is developed to describe the microbial species and that describes the two strains that is two bacterial strains or two archaeal strains belong to the same species are considered to be member of the same species only when their purified genomic DNA show at least 70% hybridization and this level of hybridization is equivalent to 94% average nucleotide identity at the whole genome scale.

So, basically it is the genome enabled definition or clarification that whether a member of or a group of organisms group of a bacteria present in an ecosystem would belong to a particular species or they belong to more than one species would be established only when we are able to perform the analysis which are connected or which are able to decipher their their genomic status. That how far the genome of one organism or one strain is different or similar with respect to other species or other members.

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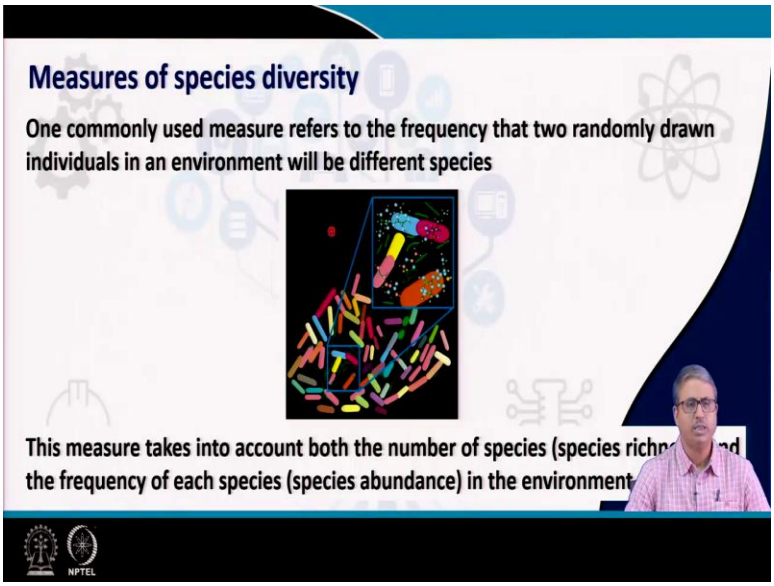

Now, these species that inhabit a given ecosystem. So, there are many species present in any particular ecosystem i mentioned some time ago that there could be 10 to the power 4 or 10 to the power 5 or species present in a simple agricultural soil system per gram of soil system. So, the species who are present in any given ecosystem are those who are best adapted to grow with the nutrients and other growth conditions that prevail there.

Because we; have also learned that the microbial community of any particular environment is basically controlled by the nutrients and the growth conditions which control their activities. Now if we want to see the measures of species diversity. So, if we take any kind of sample. So, with respect to that sample or any other sample it is possible to define or decipher the species diversity by simply adopting a technique one of them is the frequency that two randomly drawn individuals in an environment will be different.

So that is one hypothesis. So, if you have a assemblage of organisms or microorganisms if we just pick or or try to sequence the taxonomic marker gene of any of the organisms and then try to match it with the other organism we will be able to delineate how many species are there. So, again we are going to highlight and going to talk in detail about the methods the molecular methods adopted to decipher the actual number of species and their relative abundance present in any environment.

Now this measure that is that is the measure that refers to the frequency that two randomly drawn individual in an environment will be different species takes into account both the number of species present that is the total number of species that is the species richness. And the frequency of each species that is the relative abundance of each species which is determined from the from the data that we obtain from any kind of environment.

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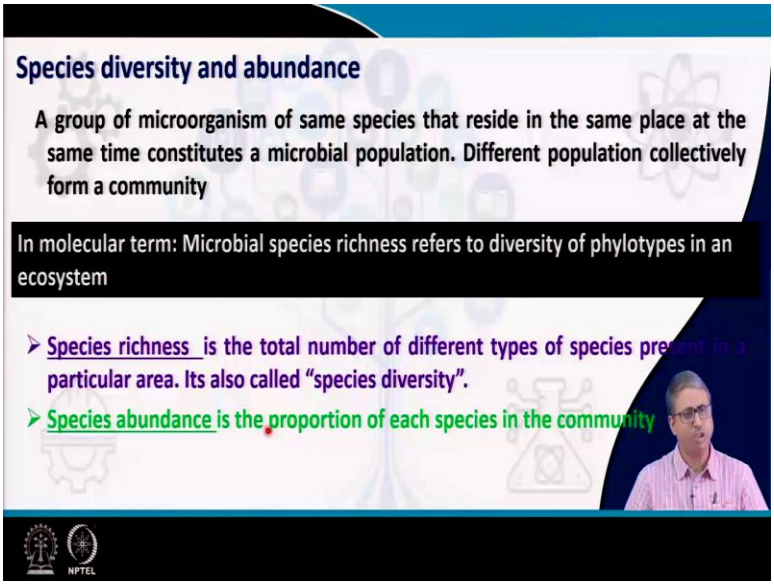

Now elaborating this species diversity and abundance further we also know that a group of microorganisms of the same species. Let us say the ischerichia coli or bacillus subtilis. So, they are the member of all the bacillus subtilies belong to the the species bacillus aptly. So, all the bacteria or bacterial cells they are they are identified as bacillus substances belong to the bacillus subtle species. So, a group of microorganism of same species, so, bacillus subtilis group that reside in the same place at the same time constitute a microbial population.

So, if I have a for example agricultural soil or a ground water sample or a lake sediment or a forest water I can try to identify what are the group of species present there. If I see that there are bacillus subtilies some bacterial cells are affiliated to bacterial sub subtilies that is that means that bacterial bacillus subtilis as a population is present there. Similarly it is expected that only bacillus subtleties will not be there.

There will be pseudomonas erogenous pseudomonas putida and many other type of bacterial species would be expected. So, if we see that there are 100 different bacterial species are there that means if we see there are one lakh cells are there and these one lakh cells are actually taxonomically affiliated to 100 different taxonomic species well defined taxonomic species. That means we can say that this particular sample of this particular environment has 100 microbial or bacterial populations.

Each of the populations are represented by in a particular species member or space taxonomic entity. Now, all the populations of these particles 100 populations for example in a particular sample, so, for that particular sample considering all those 100 populations that we are able to detect in that sample we can define the community. So, community is basically defined as all the different populations collectively present in a particular environment at a particular point of time.

So, the populations are the representation of the species present and all the populations together represent the community. Now the diversity of the microorganisms which actually belong to the population, so, the more diverse population means more diversity of the species in general of course for prokaryotic organisms like bacteria and archaea there are there are intra species diversity also.

Like if we have a bacillus subtilis that does not mean all the bacillus subtleties are going to be similar there could be the difference in their their genome sequences as well. So, we are not going to discuss that at this point of time. So, we are going to discuss that the species the group of members belong to the same species represent a population a microbial population and a group of microbial population or all the populations living in an environment at a particular time point is referred to a microbial community.

So, when we are referring to a microbial community of a soil we basically include all the microbial populations present in that particular environment. Now the diversity of the microorganisms in a particular community can be expressed as we mentioned earlier species richness and species abundance. Species richness is basically the total number of different types of species present in a particular area.

In my earlier example I said that in a particular soil sample if I am able to find 100 different species members representing the microbial community. So, that could be useful in delineating this species richness of that particular soil and it is obvious that from each sample to sample or each environment or each habited to habited within an environment this species richness is going to differ. The second point is the species abundance.

Species abundance basically refers to the proportion of each species that is the relative abundance of each of the species members of the in the community. So, for example if we say that there are 100 different populations in an environment. So, it is expected that 100 populations all are not represented by equal numbers or equal proportion there will be some population which will be higher or highest followed by some population which are slightly low lower than the highest one and there then will be there will be some populations which will be represented just by the minimal number or minimal contribution.

So, that means their relative abundance is on the lower side. So, in molecular term microbial species richness that is actually basically counting the number of or connected to the counting of the number of species present there. The microbial species richness refers to the diversity of the phylotypes in an ecosystem. So, these phylotypes could be determined in a microbial ecology context by determining the different type of 16s ribosomal RNA genes.

And the 16s ribosomal RNA gene is selected because it is one of the best taxonomic marker ah. So, far known and extremely well used in microbial ecology studies. So, we will be talking about how 16 s ribosomal RNA gene is used to define the microbial species composition. So, that means in molecular terms or in a molecular microbial ecology terms this species richness refers to the different types of 16s ribosomal RNA genes representing the phylotypes which are present in that particular ecosystem.

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So, it is it is expected that if we have for example again I am showing 2 pictures on the left side we have a very, very interesting ecosystem where this is a oil well. So, basically from the subsurface oil deposit the petroleum oil is actually pumped out. So, in an indian oil field we were doing some experiments. So, we could see that how this oil which is crude oil which is recovered from underground is peeled and you have a kind of oily sludge deposited around this area.

So, we try to decipher the microbial ecology of this system on the other hand we also have access to some of the mine sites where we can have the the mind tellings. So, these are actually not sand but per say but these are the mine tellings dried mine tellings which are deposited. So rich in iron and other minerals, so, these are deposited. So, if we want one to decipher or in fact we studied the microbial community or species composition in these environment.

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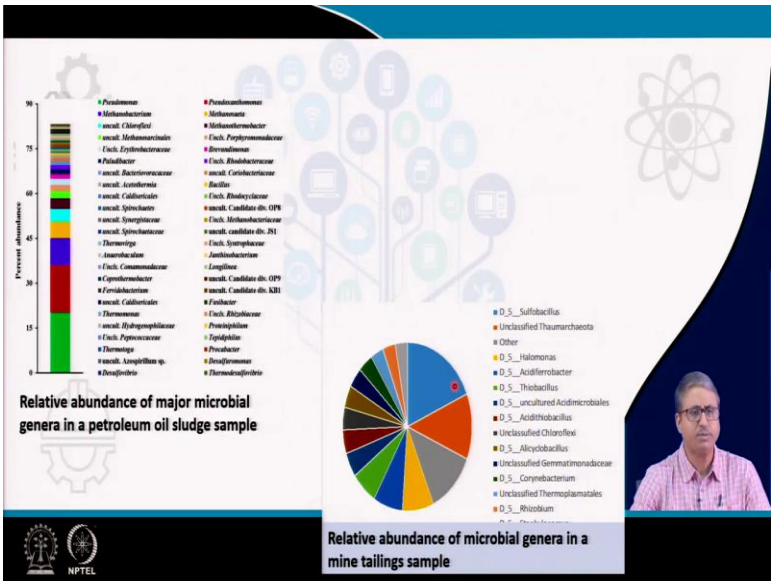

We have seen that the kind of species or kind of taxa at the genus level present in the petroleum oil spilled environment and the kind of microorganism present in the extremely oligotrophic the mine tellings environment are entirely different. Now it is it is easy to explain that why species abundance and all these nature of species present are different because the conditions the nutrients available the physico chemical conditions are all different.

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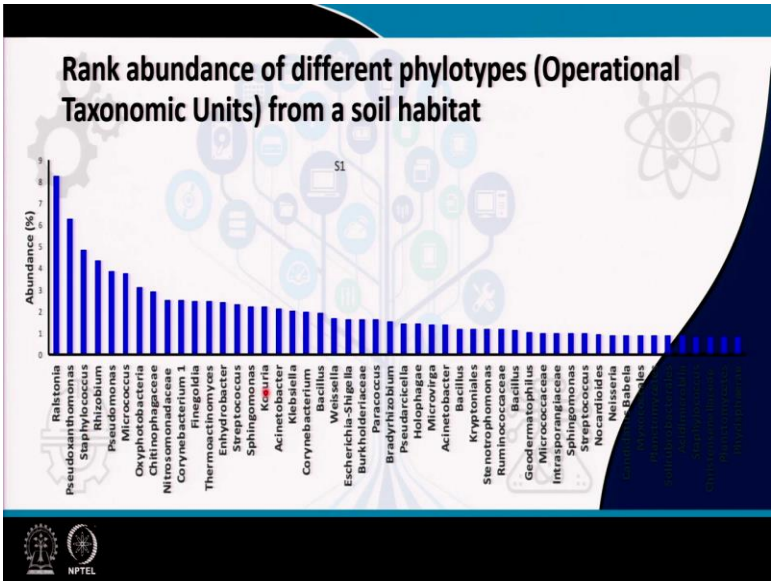

Now I will show you some data on the phylotype abundance which is basically reflecting the species abundance. So as I mentioned the one component is delineating the species how many species are there. So, in the age of molecular microbial ecology we use the 16s ribosomal RNA gene marker to identify how many species are there. So, here, now in the second point that is

what is the relative abundance of each of the species.

So, suppose I have shown here 50 species which are present in a agricultural soil sample. Now each of the species are unique and that is why you can see ralestonia, pseudo xanthomonas, staphylococcus, rhizobium, pseudomonas, micrococcus all are at the genus level we have identified these members. So, these are all unique to the extent they are 16s RNA gene is concerned because the 16s RNA sequence of this ralestonia is unique with respect to the pseudogenothermonas and pseudozyanthemonas is unique to staphylococcus and so, on and so, forth.

So, if we take the top 50 species present in that particular soil we can easily see that the relative abundance of each of the members are different. So, one of the members that is the ralestonia is the most abundant that is representing around 8% or slightly more than 8% of the total coverage given by these 50 members followed by pseudosynthemas. And there then you see that there is a there is a steady slope declining and eventually it is leading to some kind of a saturation where all these members are just represented by one% or 1.5% of their of the in the total community.

So, this is very important with respect to the community structure deciphering the community structure of any kind of microbial system or microbial habitats. So, as I mentioned earlier that the out of the two parameters one is the delineating the microbial species how many species are there. And the second is what is the relative abundance of each of the species member. So, both of these things are important.

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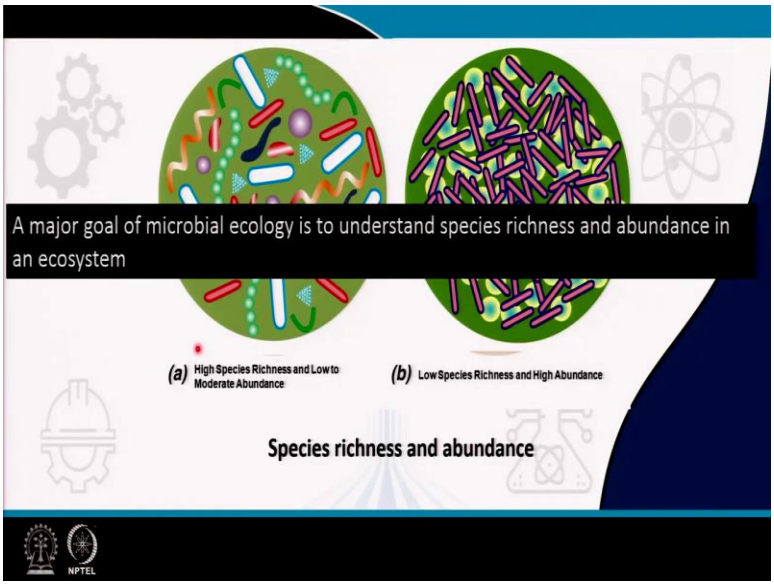

Now this species abundance and species richness are also can be can be explained very simply by this picture. Where you can see that on the left side we have the high species richness sample but it is also having a low to moderate abundance because if you can see in the background there are different types of cells. So, you can see white red black and green caucus type of cells and different type at least 5, 6 types of different type of species at least morphologically through this cartoon can be identified.

But what you can also see that none of the species member is very abundant like the white rod ciphered cells are only 5 or 6 cells are seen out of the total number of cells maybe this purple color caucus big size cell is only 3 cells are seen out of the out of all the cells. So, relative abundance of each of the members are not very high. So, that that is why it is said that it may be considered to have a high species richness because more number of species are visible compared to the picture that is shown on the right side but individual members are not that abundant.

In contrast to this if we look at the picture which is shown in the b we see that there are only 2 types of species are seen one is the caucus type another is the rod type. So, only two types of species are seen that means species richness point of view this is very low species richness however both these species members are very abundant there are numerous caucus as you can see over here and there are numerous bacillus or rod separate structure of the cells together.

So, in this case the species richness is low but the abundance of each of these members are very high. Now a major goal of microbial ecology is to understand the species richness and abundance in an ecosystem that is we are going to discuss later also that in any kind of microbial ecology study as we mentioned earlier that to define the the kind of organisms present and the kind of activities they do.

So, in the kind of organisms present category defining the species richness and species abundance forms a important part of the entire concept.

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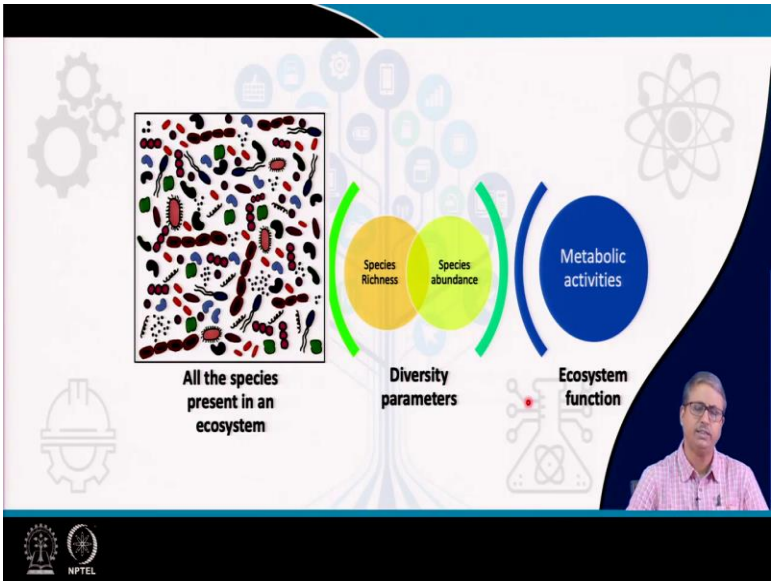

So, ideally all the species which are present in an ecosystem that is all the members if I use this particular cartoon. So, whatever species present in this environment would finally culminate into the fact that the species richness and species abundance are to be defined. So, these are the major diversity parameters. Now once this species diversity parameters are established we are able to connect the major metabolic functions of each of the species members who are the may be. Now some species member may be very abundant.

So, the metabolic significance of that particular member who is very abundant would be certainly very high compared to the species member who are very low abundant. So, their metabolic contribution would be at some other scale. So, together this diversity parameter will help us to understand the ecosystem function because through the metabolic activities of all these

cells or all these species present in that particular environment we can easily establish the metabolic function.

So, with respect to establishing the function of an ecosystem which is found to be one of the key points for environmental biotechnology delineating the species richness and species abundance through identification of the species and then they are establishing their interrelation and metabolic function is found to be very important.

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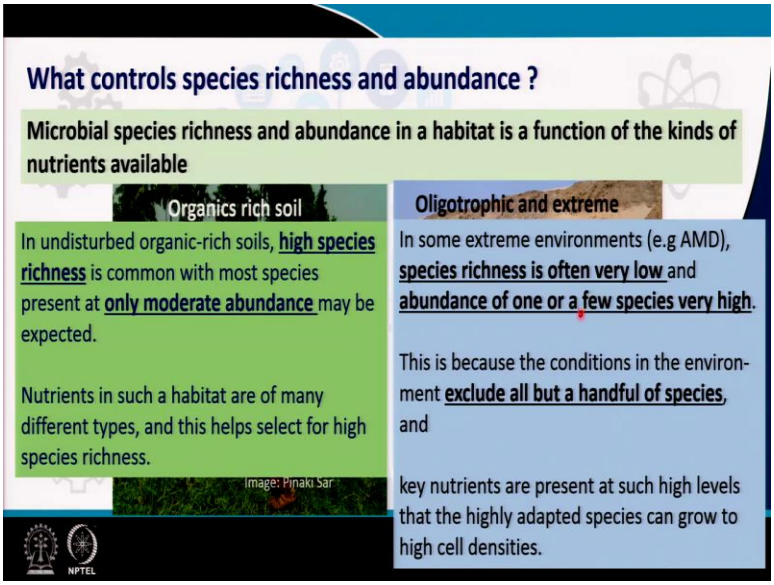

So, now what controls the species richness and abundance. Why not two systems one is organically rich a soil system without a much of stress present over there and another oligotrophic and extreme environment where you can see that the low ph high sulphate and iron containing leachates are coming out naturally from a mine site. So, why we think that these two systems might have a difference in their species richness abundance and obviously the microbial activities as well.

Now the microbial species richness and abundance in a particular environment is a function of the kind of nutrients available because the organisms who are going to live there are going to be controlled by the kind of nutrient and the conditions which are prevailed there. Now within this organic rich soil it is relatively undisturbed to some extent compared to this because it is not a very extreme or stressed environment we can expect a high species diversity or high species

richness and with most species present at only moderate abundance.

So, that means if we plot the similar type of abundance graph as I showed you earlier we can have a kind of a distribution where most of the species will have on an average equal contribution or a moderate abundance within this particular community. Why we expect such high species richness and only moderate abundance within this type of undisturbed organically rich or nutritionally rich ecosystem?

The reason is very simple because reason is the nutrients available in such a habitat are of many different types because there could be different type of organic carbons, electron donors, electron acceptors, nitrogen, phosphorus sources other required elements or minerals which are plenty. So, there is no dearth of different type of nutrients. So, as there is no dearth of different type of nutrients and also there is no specific stress or no stress or mostly stress level is very minimum or on that type of environment.

These are not exposed too much of toxic substances if that is the case then that will help select for a high species richness. So, many species and most of the species will have kind of a moderate abundance that we will be able to see over there like we have seen that the highest one is 6% compared to the other one but if we consider an oligotrophic and extreme condition we may we may not see that the highest species is 6% rather we can see the highest species might have 20, 30% contribution.

I will explain why. Now in oligotrophic and extreme ecosystems like for example the acid mine drainage where the picture shows the acid mine drainage released from an environment species richness that is the number of species present is often very low because the condition is not very favorable for most of the organisms. So, species number of species different type of species will not be expected and abundance of one or a few species would be very high.

So, firstly the different number of species may not be expected compared to organic rich soil or natural undisturbed ecosystem. So, in this kind of oligotrophic and extreme ecosystem we can have a reduced number of microbial species and we can also see that abundance of one or few

species member will be very high compared to other. So, it is not a case of the moderate abundance across all the or most of the species member.

Now why we expect that the there will be less number of species or there are actually a high abundance observed to be observed for one or two species within this kind of extreme or oligotrophic environment this is because the condition in this environment excludes all but a handful of species. So, it is extreme this type of environments are often extreme with respect to different type of stress or different types of the nutrients which are available.

So, obviously all bacteria all archaea, all fungi cannot grow there. So, they the some members will be obviously excluded well they will not included for the active growth within these environment. So, only a handful of organisms will be able to grow. Now key nutrients electron donor carbon source which are present at size high level that are highly adapted species can only grow in height cell density.

So, it is not a substrate that is to be consumed by all members of the community or all the members who can present there. So, it is it is in this kind of environment we observe that certain nutrients like the electron donors for example in case of acid mine drainage we can see the iron Fe 2 plus is the key nutrient, one of the key nutrients because it provides the electrons. Similarly the availability of non availability of organic carbon that means mostly the autotrophy is preferred.

So, any member who is able to oxidize iron to get the electrons and also able to fix carbon dioxide available in the atmosphere would be preferred. So, therefore only a handful of species would be found to be dominating in those kinds of environments.

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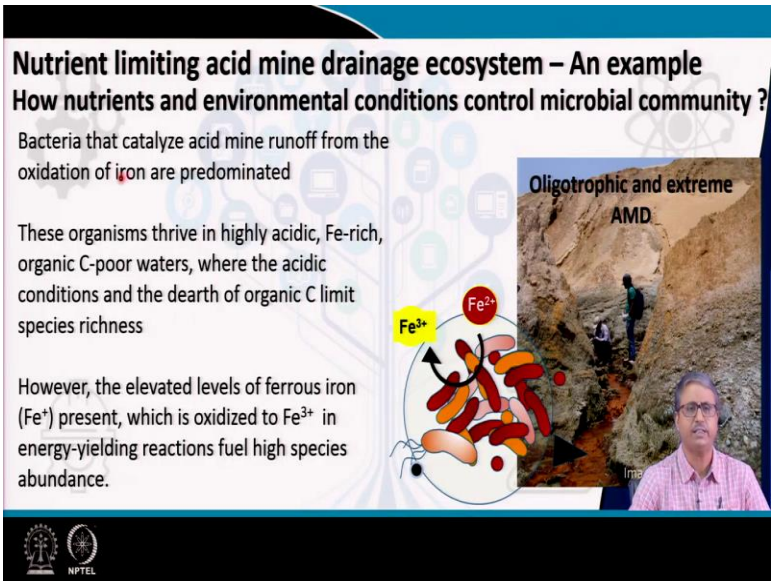

Now, nutrient limiting acid mine drainage ecosystem that we discussed. Now is a kind of a perfect example to describe how nutrients and environmental conditions control the microbial community. So, I will explain it little more in detail that the bacteria that catalyze the acid mine runoff from the oxidation of iron or predominant because it is mostly Fe 2 plus dominated environment.

Now these organisms who are dominated different iron oxidizing species who are dominating in this environment these are the as I mentioned very the species diversity is very less or relatively less. So, only few members can survive and function very actively their abundance is going to be very high. So, these abundant members who are able to thrive in this extreme condition like high highly acidic condition iron rich condition organic carbon deprived condition.

These iron oxidizing bacteria who are autotroph that means they can fix atmospheric carbon they can utilize Fe 2 plus and convert it to Fe 3 plus that gain electrons out of it and by gaining electrons they metabolize the carbon dioxide they fix the carbon dioxide and produce the they are necessary cell materials. And they often also produce the necessary other products which might be supplied to other organisms.

So, that is how other microorganisms are also observed but not as dominant or as abundant as these iron oxidizers.

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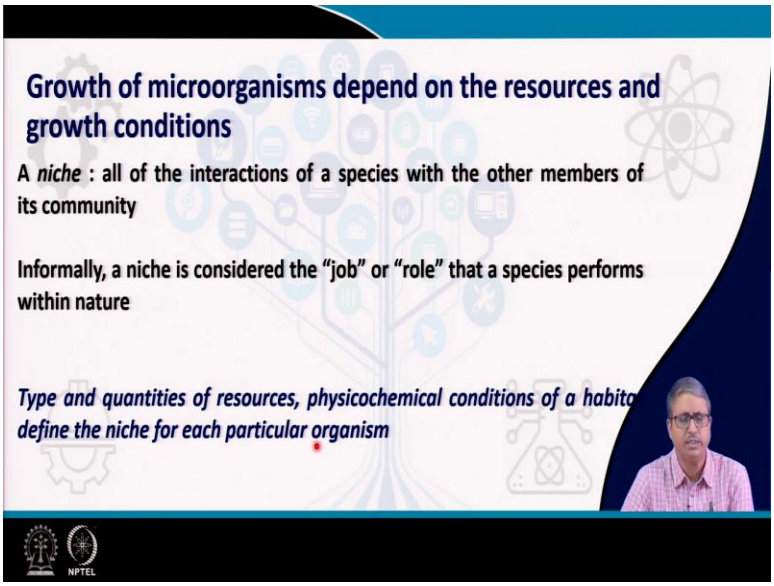

Now growth of the microorganisms in any environment to explain it further depends on the resources and the growth conditions. So, one of the perfect examples could be this kind of acid mine drainage environment where we can see how iron oxidizers or chemolithotrophic iron oxidizers are predominated over any other members. Now in this context i would like to introduce you to the term niche.

So, a niche is all the interactions of a species with other members of its community. So, often we will be using the term niche within an environment or environmental biotechnology context. So, it includes all the interactions of a species with the other members of the community present there and informally a niche is considered as the job or the role that a species performs within the nature. So, it is a kind of a together to all together the particular species is able to interact with its members and carry out the function.

So, what is the function performed that is also reflected by the niche. Now type and quantities of resources what type of resources nutrient resources electron donors electron acceptors nitrogen source phosphorus source and carbon source and other parameters physical chemical conditions like the pH, the dissolved oxygen level the redox condition etcetera of the habited define the niche for each particular organism.

Now why iron oxidizer rising acidity thio bacillus prevails in acid mine drainage but not so, much in organic carbon rich soil system because the resources which are prevailing in the acid mine drainage system the pH and the organic carbon deprived condition of the acid mine drainage system dictates the condition that acid mine drainage environment would be naturally predominated by because that is the niche for the acid thyroid bacillus type of iron oxidizing chemolithotrophic bacteria.

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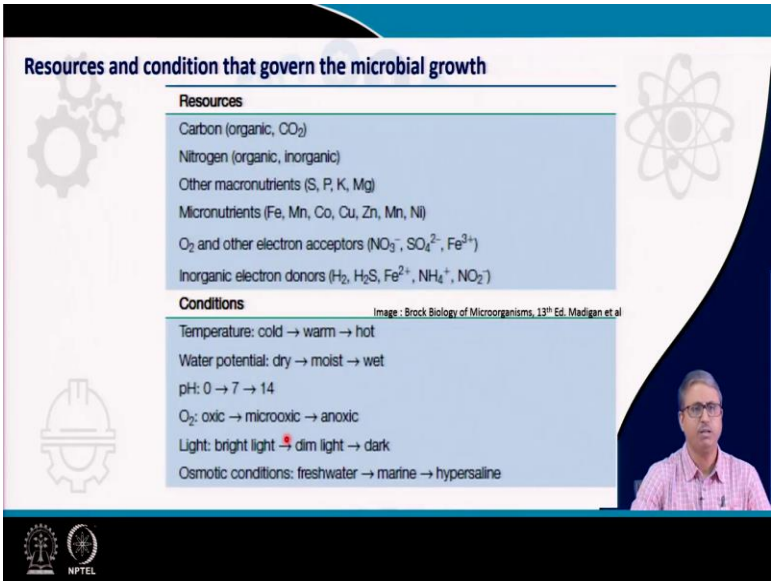

Now the resources and conditions that govern the microbial growth could be multiple like the resources could be carbon, nitrogen different type of other macro nutrients. Micro nutrients oxygen and other electron acceptors inorganic electron donors and the conditions could in include the temperature water potential, pH, oxygen level light osmotic condition etcetera.

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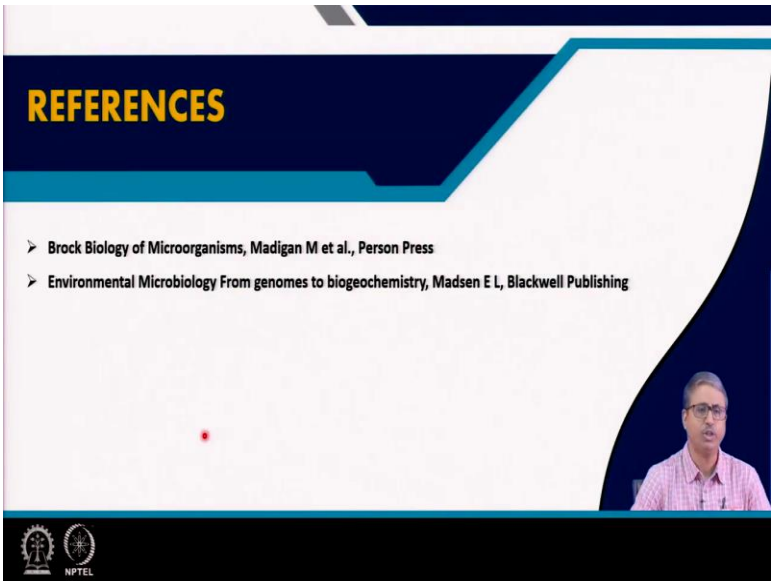

So, for this part of the lecture I would use the following references like the Brock Biology of Microorganism as well as the Environmental Microbiology from genomes to Biogeochemistry by Madsen.

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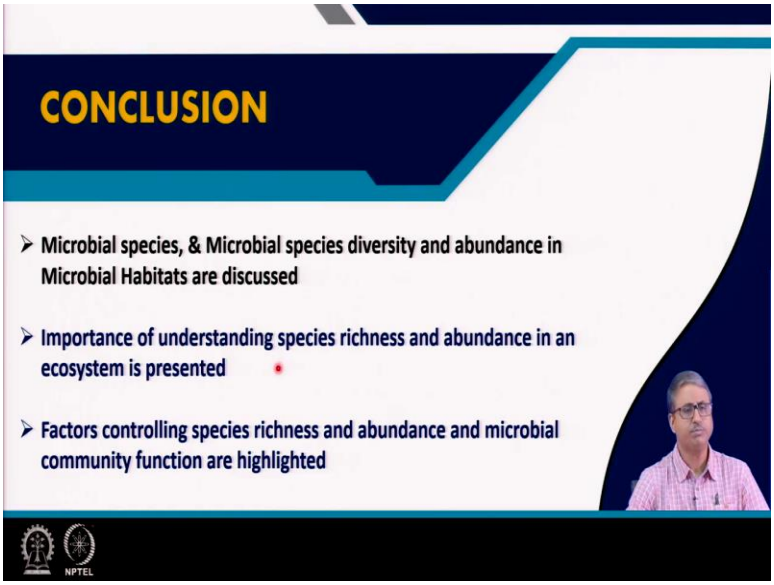

In conclusion microbial species and microbial species diversity and abundance in microbial habitats are discussed. Importance of understanding species richness and abundance in the ecosystem is presented, factors controlling species richness and abundance and microbial community function is also highlighted, thank you.