Advanced Aquaculture Technology
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Lecture - 11
Polyculture, IMTA

Welcome everyone, my name is Professor Gourav Dhar Bhowmick; I am from the agricultural food engineering department of IIT Kharagpur. So, in this particular lecture series in advanced aquaculture technology today, I will be discussing about the polyculture and IMTA in details.

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So, the concepts that I will be covering in this particular lecture will be on the farming systems and their classifications. What is polyculture? What is the, what are the pros and cons of having polyculture integrated multi-trophic aquaculture systems; or in short, we call it IMTA. And what are the subsystems of IMTA; and what are the benefits of this particular IMTA systems. And what are the advantage advancement that is happening in this particular field of research?

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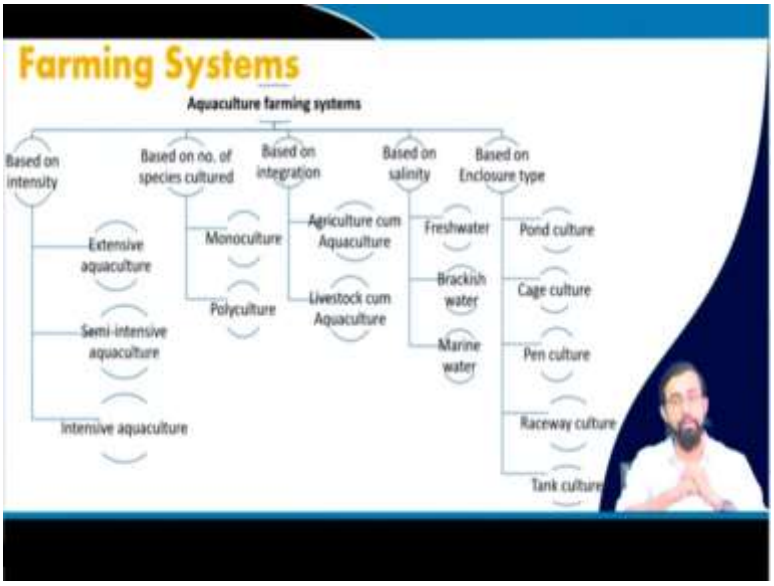

In general, the aquacultures farming systems are can be classified in the based on different criteria. First of all, based on intensity it can be extensive, semi-intensive and intensive; we have already covered this properly. We know what is this, what are these different kind of aquaculture systems. Based on the number of species cultured, it can be monoculture, it can be polyculture. I think from the name itself we can understand in what is monoculture and polyculture. Based on in based on integration, we have agriculture cum aquaculture, we have livestock cum aquaculture.

Based on this integration, this agriculture cum aquaculture, we I think you have heard of rice cum the fish field or fish farming systems. So, where we simultaneously we you, we go grow the rice as well as the fish in a same field; because, the rice or the paddy field, it needs the standing water all the time with it. So based on that funda, we use this agricultural cum aquaculture systems farming systems. So, another is the livestock cum aquaculture; I will discuss about all these things in details in later slides. So let me give you a brief before that.

Livestock cum aquaculture where I will be, where we will be doing the aquaculture, along with a say like poultry farming, see like pig farm et-cetera et-cetera. So, what is happening? So, all these poultries and all their droppings, like there is excreta are actually directly fed to the aquaculture species; so that the feed requirement can be minimized or completely nullified. And parallely we can grow livestock as well as aquaculture species together in our farm to increase the productivity and the economic return.

Based on the salinity we have freshwater, we have brackish water, we have marine water. I think you know it better what is brackish water, what is marine water, though I will be discussing in details. In general, the freshwater is the one mainly measure of the surface water which is available on the land, landlocked base, like on the on the side of the land. Or, I mean like specifically when the river starts from the mountain until the moment it reaches the mouth of the river or we call this it reaches the sea; this duration this part we have we call it normally freshwater. So, so then which has a very low salinity level.

There are a brackish water. Brackish water in general, brackish water means the water that is available in the estuary region or the river mouth region, where the river actually drops in, and connects with the sea. So what happened in that region? The, it has a mixture of freshwater which is having very low salinity almost zero; and in the marine marine water which has which has a very high salinity of 30 to 35 even up to 40 PPT. So, brackish water has the salinity level in between that.

Then, comes the marine water or sea water which is based on the we know the mariculture; mariculture is coming from this marine water culture only. So, based on the salinity, we divide the farming systems into these three different subcategories. Based on the enclosure systems, we have pond culture, you know what is pond? Cage culture, we put the cage inside either in a stagnant body in the freshwater resources, freshwater reservoir or any stagnant lake and, lake or river, or stagnant lake or even moving river, or we can put it in the sea as well, the ocean surface in the offshore area as well.

So, there that is called cage culture when we put the cage, and we use the water which is inherently present there itself. Then, there comes pen culture. Pen culture is nothing but we just kind of enclosed one part of the oceanic body or one point of the lake body; and we enclosed it with the kind of make it landlocked with one portion open; so it is called the kind of pen. So, this is one example of pen culture where we do the all the do we culture the species that we target. And for that the water exchange is not a big issue because that is inherently present in the system itself, because of the its connection with the actual water bodies.

Raceway culture, we have already discussed what what is raceway culture, how the raceways are designed and all we have already discussed in last lecture series. The tank culture: tank Culture also you know how it is designed, what are the suitable designs and all, we have already discussed

in our last lecture series. So, these are the types of aquaculture farming systems that that involves based on the encloser type encloser.

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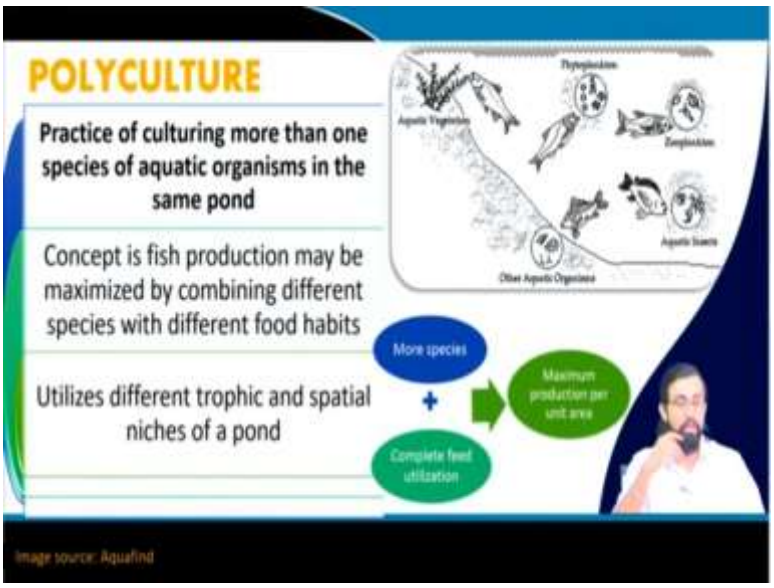

So, polyculture we if you remember, we discussed very brief about it in very first lecture, I think. So where, we have discussed about the practicing of culturing more than one species of aquatic organism in the same point. How to target them? Because, see if you are targeting more than one organism, aquatic organisms, but more than one species of aquatic organisms, but everyone likes to have zooplankton. So, there will be what will happen? There will be a high demand of zooplankton and there is a high risk of they they will not be fed enough.

They we cannot feed them enough because of the limited resource of zooplankton in a specific water body, or suppose you are in your farm itself in your pond. So, what will happen? What you need to search search for? You need to search for the species which have a different habit like different food habits. Suppose you can culture like if you say people who are vegetarian, non-vegetarian, or who are like only vegan, so it is like that. So, you have to have find out this three, four different kind of people; you have to like just the same way you have to find three, four different kind of aquatic organisms.

And you can just easily farm them together, because you do not have to worry about the specific demand of any specific food habit of any specific species. Because, they all are being fed by different other other different food different foods present in a natural or artificial whatever it is;

but it is available in the water body. Suppose some some fish they like to have the phytoplankton, some fish they like to have zooplankton; some of them like to have the aquatic insects on the larva. Some of them like to have the aquatic organisms which is present in the benthic region.

Some of them are happy with the aquatic vegetations and weeds et-cetera. So, best see in this picture itself you can see five different cultures pieces are there which you can culture it together in a same pond. So, what will happen? They do not have any competition for the food; second thing, it will increase the economic return from your system. Third thing, it will completely interdependent, you will get a completely interdependent artificial ecosystem you can generate literally form formulate in your farm, or in your whatever the target land it target pond it is.

So, this concept of fish production maybe maximized by combining these different food species with these different food habits. And also we can utilize the different different trophic and spatial niches of a of a pond; and we can maximize the production per unit area.

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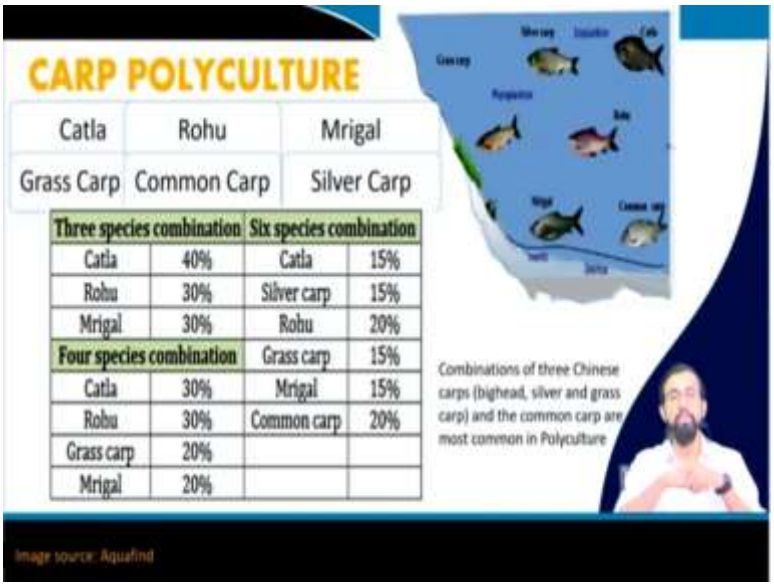

In general, CARP polyculture it involves catla, rohu, mrigal. Another another very important thing that I want to discuss with you, you can choose the polyculture, you can choose the type of culture type of species that you want to have in your farm based on their area of dwelling. See in this picture, catla is in the surface water body; almost on the surface of the water. Rohu is in the in the bottom dweller, there in, sorry rohu is in the column dweller there in the middle portion of the river; so we have this different name. If you remember limnetic, littoral, sublittoral zones.

So, I am not going into more details. So in general, just remember as a lemurs, it is like surface column and bottom. So, the bottom dwellers or the main thing dwellers are like mrigal. So, if you cultivate catla, rohu, mrigal at the same go, they will not be competing for each others food. So, at the same pond, you can increase the production and that is why it is called the Indian major CARPs. Indian major CARPs it consists of catla, rohu and mrigal; but, they dwell in the different regions. So, because of that you can increase the production by introducing three different species in combination with each other.

Same way, if you go for silver carp. If you go for grass carp and if you go for go for common carp, see they are also zoo; their dwelling nature is also different. Silver carp they like to have the zooplankton; and the grass carp, they grass carp and rohu they like to have the phytoplankton. And mrigal common carp they like to have the detritus present in the bottom of the pond. So, based on that you can have silver carp, grass carp and common carp also; you can cultivate together, you can cultivate it together in a in a same go.

Same way, why not to go for six species combination? So, there are recent studies which are like people are working on it. So, people what they are doing? They are combining all these six species together who does not have much of a competition in between each other. And they will happily be happily dwell in your pond, happily dwell in your farm; and they can increase the production in in multiple. This in when you go for six species combination, catla 15 percent, rohu, silver carp silver carp 15 percent, rohu 20 percent, grass carp 15 percent, mrigal 15 percent, and common carp 20 percent.

That is a specific combination that is fine to be scientifically optimum for go for this combination of this this Chinese carps and common carps together in a polyculture pond or polyculture systems that you may design, or you may have in your farm. So, that is how the polyculture thing is work.

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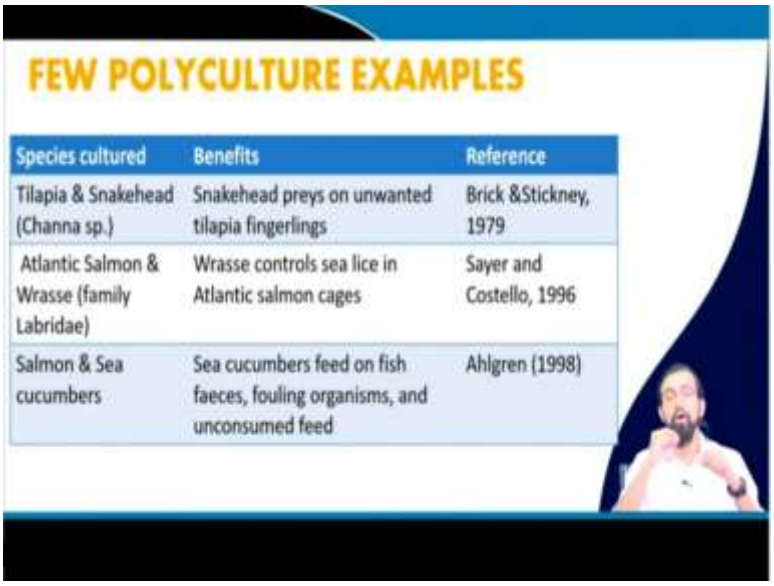

So, different kinds of polyculture examples are already given by very earlier studies in almost 30 40 years back. Tilapia and snakehead are the channa species. The snakehead preys on unwanted tilapia fingerlings; so they can easily they they can easily form together. The references also given if you want to know more in details, you can search for the details by Brick and Stickney newspaper in 1979. The details are given at the end of the lecture. Atlantic Salmon and Wrasse can be grown together which is one type of Labridae family species; and this Wrasse control the sea lice in Atlantics salmon cages.

So, because of that, they can help each; they are complementary to each other. So, in Sayer and Costello paper 1996, you will find this they have done this kind of study; and they have found out it is a very very promising and very standard way. You should go ahead with this kind of species culture polyculture in your farm to get the maximum benefit out of it. Salmon and Sea cucumbers sea cucumbers, they feed on fish faeces, fouling organisms and unconsumed unconsumed feed.

So, what will happen? Whatever the unconsumed feed the uneaten feed that is actually getting wasted from your farm. You can utilize it when you (cul) culture the sea cucumber and the salmon in the same pond, normally in the temperate region. Or, you have to have it artificially you have to in control the environment. In control environment, you can go salmon and sea cucumber together in this polyculture forms.

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The factors which affect the species selection and the stocking rates in case of polyculture, definitely the water temperature. So, you do not, you are not going to go for the salmon and sea cucumber in in a climate, where they are not adapted to adapted to or they are not getting accustomed with with those kinds of temperatures. So, you have to know at which temperature your target species can safely dwell in your nature; so that you have to target first. Second thing is the market value of the fish. Suppose you already have like three four big tilapia farm in your vicinity and you have your neighbor neighboring ponds or in neighboring farms and all.

And suppose then again you come and you know that the market is already fulfilling. The market demand is already being fulfilled by those tilapia that is being produced in those farms. Still, if you want to go ahead with the production of the tilapia that does not make sense. Because you are marking, you are actually what you are doing? You are reducing the market value of that price because of the demand available availability, huge availability of the fish. So, what you can do? You can simply search for some alternate fish species that you can culture and that you can that you can culture in your pond so to increase the production rate of your.

So, to increase the production and so to increase the get the maximum value from the market, Pond fertilization practice what type of fertilization is actually being practiced in your pond that is also very important thing. So based on that, you have the zooplankton availability; based on that you have the phytoplankton availability. I mean like all I am just giving you an example like what kind

of species can be available there; and which can be used as a feeding habit, which is actually a normal feeding habit for the target species. And based on that you have to arrange the system, arrange your farm, design your farm accordingly.

The potential and the uncontrolled spawning in grow out pond that is also very important, when you when you they when you go for this grow-out ponds and all; they are they are sometimes. What happens sometimes? You do not you cannot control the spawning and you may have additional amount of fishes or additional amount of unwanted species available in your pond, which is not acceptable.

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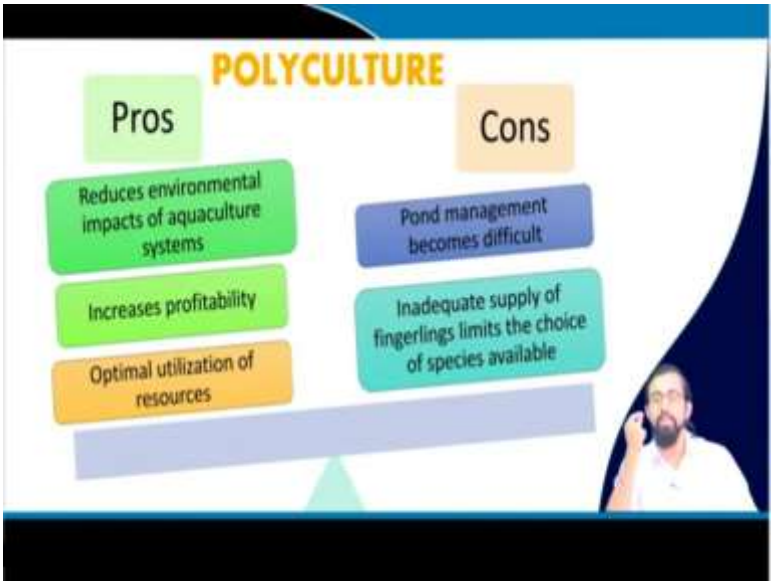

So, what are the pros and cons of polyculture? First of all, it reduces the environmental impact of aquaculture systems; I think you already know the reason behind it. As I give you as I already gave you one specific example which is very important, which you can (rem), you can memorize like the sea cucumber and the Salmon case. Whatever the uneaten fish uneaten feed and also the excreta from that fish is being consumed by the sea cucumber. So, what it happens? It reduces the environmental impact. So, it increases the profitability because you are having higher amount of species that your high number of species that you are culturing in your pond.

And you have more amount of output that you are getting from your farm; so definitely you will get a more economic return. Optimal utilization of the sources resources, you are utilizing each sector, each part of the pond, each part of the of your farm precisely with providing the all the

optimum species that is available, that they are dwelling natural dwelling positions and all. Based on that you are categorizing, you are culturing the species the target species and all. So, which will definitely utilize them optimally, whatever are the resources that is available in your pond.

So, what are the cons part of it? It is sometimes the pond management becomes difficult definitely. When you have more than one cultural species that is available and you have to think about; you have to have a proper expertise on each and every culture species that is available in the in your pond.

And you have to know more precisely about how they can be treated properly. And if they there is some disease outbreak, how they can be properly maintained in a quarantine pond and all. Inadequate supply of the fingerlings limits the choice of species available. Sometimes suppose you want to go ahead with this six species culture, six species polyculture with all the Chinese carps, all the major carps. But what happened? Sometimes you may not find proper ample amount of green carp, the fingerlings for the green carp. So, what you have to do? You have to limit your resources; we have to go ahead with without having the green carp.

Because it is not actually always possible to have all the species at the same go and all the fingerlings in the same go. Either you have to go for some specific this banks nowadays in according to the Government of India is supporting these kind of activities, you will find in different states. They started having their own kind of seed bank. So, they call it a seed bank where they will be having all the all type of crop, all type of fish species and all these fingerlings available.

So, available of these fingerlings is very important. So, to or maybe the proper broodstock management area is there, where the they are actually culturing the. They are always available with the fingerlings for different species; so that you can just borrow from there, you can get it from there, and you can go ahead with your farm.

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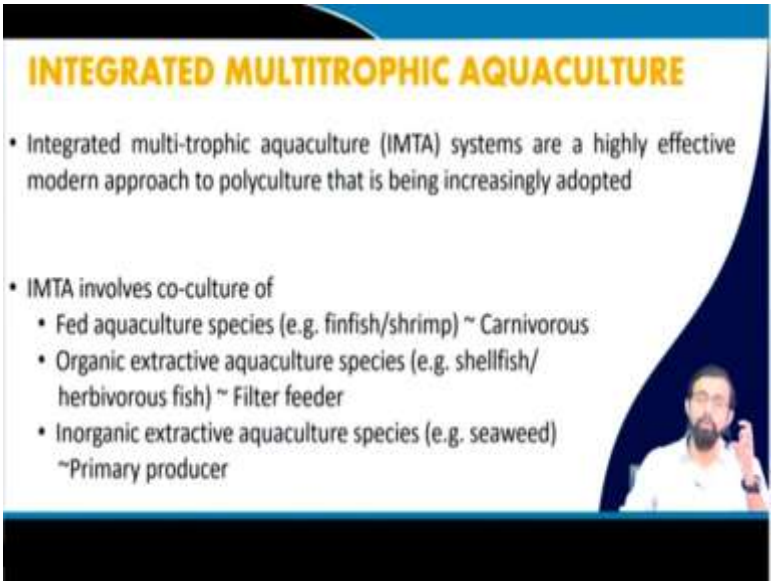

So, what is integrated multi-trophic aquaculture or IMTA? IMTA it is a system which is a highly effective modern approach of polyculture that is being increasingly adopted nowadays. In case of IMTA, unlike unless like unlike polyculture, which is which is actually a type of polyculture as well. But in this particular case, we target all the trophic level. All the trophic level means? First of all, the feed aquaculture species like fin fishes or shrimp are the carnivores. Who like the species who fed by only aquaculture species; they fed only other aquaculture species or like say zooplankton or say small fishes et-cetera.

Organic extractive aquaculture species like shellfish, shellfish and herbivorous fish; they normally are the filter feeder. They are organ, they they extract the organics, organic whichever the very small zooplankton and phytoplanktons available in the water; they kind of filter feed, they have this mechanism in inbuilt their body in their body. They another one is inorganic extractive aquaculture species like the seaweed and they are the primary producer. So, if you see there is like if you go ahead with the culturing of seaweed, any kind of shellfish and the shrimp, or any kind of finfish together. What will happen?

First of all, the seaweed will act as a primary producer. Second thing, the herbivorous fish or the shellfish, they will consume this, this this primary producers; they will they will be called for a Filter feeder and all. Or they are then they are can be fed by, they can be fed to the carnivorous animals, carnivorous aquatic species that is available. So, in the same go, you can have this culture

of culture of finfish, shellfish and the seaweed in the same go. So, this is called the IMTA integrated multi-trophic aquaculture.

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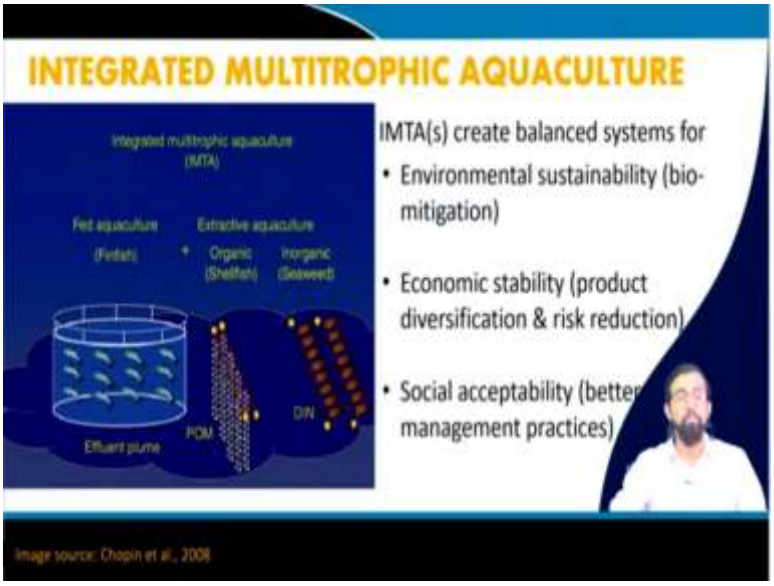

If you see in this particular picture the fed aquaculture with the finfish, you see the the extra. Here the fed aquaculture plus the extractive aquaculture is done in the same go; where the organic and the organic matter is consumed by the shellfish; and inorganic matter is consumed by the seaweed. So, the same go you have this organic and inorganic consumers; you have this finfish we are consuming; the all your this all the available the other fishes, other aquatic species that is available.

So, by this way you can have a cumulative production, you have a; it can grow multiple, multi it can grow very high; it can it can multiply your economic return from your farm as well. So, in general, IMTA it creates a balanced system for environmental sustainability or the bio mitigation. It improves the economic stability product diversification and the risk reduction definitely. It also have the very high social acceptability; because better management practices are being performed in case of IMTA.

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What are the criteria for selection of species? Definitely species with the complementary roles. You have to target the complementary roles like one species has should not have any direct competition with other species. So, you have three different species which are complementary to each other, plus they can fed by fed to trophic level, so that is also good. So, in that case, you are actually artificially building an ecosystem; they are building a food chain there. That food chain if you successfully optimally cultured them, it can grow very high; or it can give you a very high economic return from each trophic of from each trophic level.

The adaptability of the species to the habitat, it is very important; you need to know that it is not only that the trophic level does matter. You have to know that if this species is actually be culturable in that particular habitat or not that you have to understand. The culture technology and the site environmental condition, you have to be precise about it; like what are the technologies that you will be using and how you can optimally enhance the production performance of the of your system by choosing proper selection proper species as for your cultures, for your culture tank or culture form.

Ability to provide both efficient and continuous bio mitigation definitely; so as you have to have this bio mitigation techniques. You see the carbons or the organic fed is the feeder is there; inorganic feeder is there. What is happening for because of the presence of them, like giving you one example. Because of the presence of seaweed, carbon dioxide reduction is happening. It can

consume huge amount of carbon dioxide; it can act as kind of oxygens supply, dissolved oxygen supply the oxygen to the aquatic species is present there. So, it can enrich the ecosystem of the nearby vicinity.

Other than that, though the shellfish they are consuming all the organic; that means they are filter feeders; so they consume the zooplankton, phytoplankton like this, which can and which are having very high carbonaceous body in self. So, they will consume it and they will use it in their body. In the same go, finfish they will consume this shellfish and the and the shellfish; and they can consume they they if the other fishes and all. And they will they are in the highest chain of the higher side of the trophic level.

Market demand for the species, definitely it is very important in the commercialization potential. How how much it is like what is the possibility of commercialization of the species that you are targeting in your system is also another important thing to worry about.

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What are the subsystems of IMTA inorganic extractive subsystems, where aquatic plants have a high assimilative capacity we know? So, the more inorganic extractive subsystems as I example, as I gave the already already I gave the example of seaweed. So, seaweed has a very high assimilative capacity; so, it will consume huge amount of nutrients present in the in that aquatic body, not only that it consumed the carbon dioxide. So, it assimilates a lot of obnoxious and nuisance creating products elements from the environment.

The plant bio-filters can thus thus greatly reduce the overall environmental impact of fish culture; and it can stabilize the culture environment. Farming of the species that are low in the food chain and that extract their nourishment from the water involves relatively low input. So, why because of they can extract the nourishment from the water itself; so you have do not have to worry about the feed or the their the feed requirement or the nourishment requirements and all. Because they are they grew by them, they grow by themselves.

So, they do not need any additional monitoring or additional involvement, human involvement for their for them to grow. So, most suitable in the highest productivity as a seaweeds; so definitely seaweed has tremendous market and tremendous opportunity in Indian context as of now. Maybe I will I will devote complete lecture in the later lectures in a later say later you will find it. So, in the seaweed I will completely devote one lecture series just to let you guys know what what is the importance of seaweed at this moment in Indian context.

And the government of India is also putting a lot of effort on it. And we are also doing a lot of research on this field, like how we can introduce the seaweed in Indian context, and because India has a vast coastal line. So, if we can introduce if we can really properly utilize this vast coastal line, we can we can develop; we can very much improve our GDP by only culturing this kind of aquatic species.

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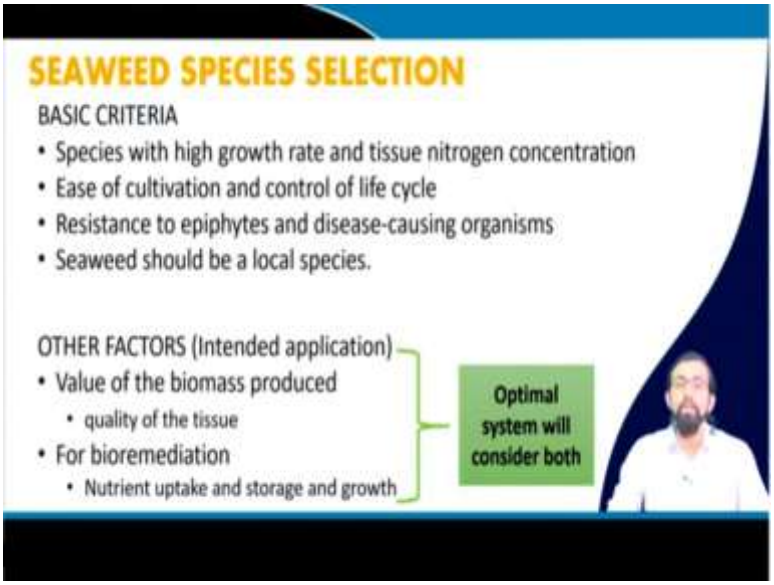

Seaweed species selection: the species of with a high growth rate and the tissue nitrogen concentration will be the best to choose. The ease of cultivation and the control of lifecycle is another important criteria. Resistance to the epiphytes and disease causing microorganisms; and the seaweed should be of local species. So, if we can, if we want the moment we want to have proper consideration for the type of seaweed that you need to culture, or type of seaweed that you need to check. So, you need to worry about these basic criteria's and all.

Other factors, other internet applications the value of the biomass produced, which is definitely the quality of the tissue that it involves. And the for bioremediation, nutrient uptake, storage and growth. So, optimal system for optimal system will be considering the both; so that what does that mean? First of all, the biomass that you are getting out of culturing this kind of seaweeds and all. What we are going to do with it? It has a lot of economic benefits; it can be used for production of agar, production of alginate and all.

Not only that, there are various other chemicals that it can produce that it can, we can harvest out of it; and we can segregate out of it; and we can, we can use it for byproducts recovery for personal care products, pharmaceuticals, et-cetera et-cetera. Other than that, it is a very good food products nowadays as a very good sea source or a seafood source. Other than that, at the end, if you do not have a very good quality seaweed and all; at the end, what you can do? You can simply dry it and use it for fertilizer.

You do not know how big of a change that you can get in your if you are doing land based agriculture; and if you are using the seaweed based extract or seaweed based fertilizer for your culture land or for your farm. It will drastically improve the quality of the soil; it will drastically improve the quality of the production of your yield or production of the yield of your target crop species.

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Organic extractive sub-system: The filter feeders like the bivalves, they reduce the nutrient loadings by filtering and assimilating the particulate waste. As I already discussed, they use the filter feeding mechanism. And there are literature's which shows the 95 percent of the particles released from the aquaculture systems like a fish farms and the closed air recirculation systems are 20 micron diameter; and they they will settle in the bottom of the pond. So, if that can be utilized, so filter feeders are selective in extracting particles. That particles that this small particles can be utilized properly by introducing the filter feeders like bivalves and all.

It can reduce the economy, it can reduce the environmental impact of the system overall pond. Also it will increase the economic benefit like anything. The particle size of wastes from IMTA should be known for selecting a suitable bivalve species. So, based on the particle size of the waste that is present in your IMTA; based on that you can choose your bivalve species and so that that bivalve can easily assimilate or you can easily utilize the particle that is being released from the aquaculture; and they can utilize it and because of that we can have additional benefit out of it.

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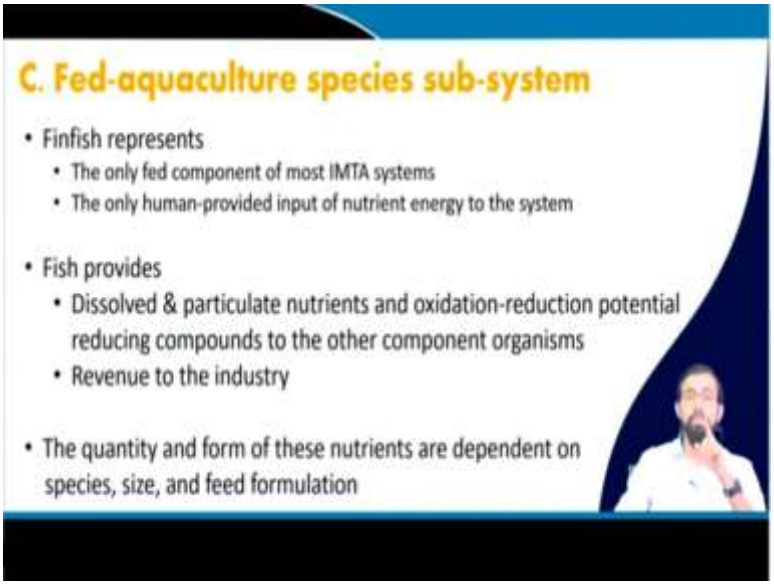

Fed aquaculture species sub-system, where the finfish represents the only fed component of most IMTA systems. The only human provided input of nutrient energy to the systems; this species it provides the dissolved and the particulate nutrient and oxidation reduction potential reducing compounds to the other component organisms.

So, this finfish is actually not only helping getting rid of not only say suppose if this is a carnivorous one; it is utilizing the other fishes or not, does not matter. And if you want to have it optimally run, so you can even supply some additional sources of nutrients, additional feed to the system as well for survival survival of finfish.

It can reduce the particulate nutrients and that can it can it can utilize it; so and also the oxidation reduction potential reducing components. So, because of that, that place is well equipped, well how to say it would be like well dwelling in nature for other component organisms to survive; and also the revenue to the industry definitely. It is the maximum revenue generating part this finfish; because it has a very high market value.

Although this is also based on the fact it I am not, I cannot be guarantee about this (dis), this particular statement. Because if there are possibility of having some kind of exotic seaweeds which has a very high value, then even the finfish, the normal finfishes that is available in the market. The quality and the form of the nutrients, these are depending on the species, size and the feed formulation; so, definitely based on that we go ahead with this.

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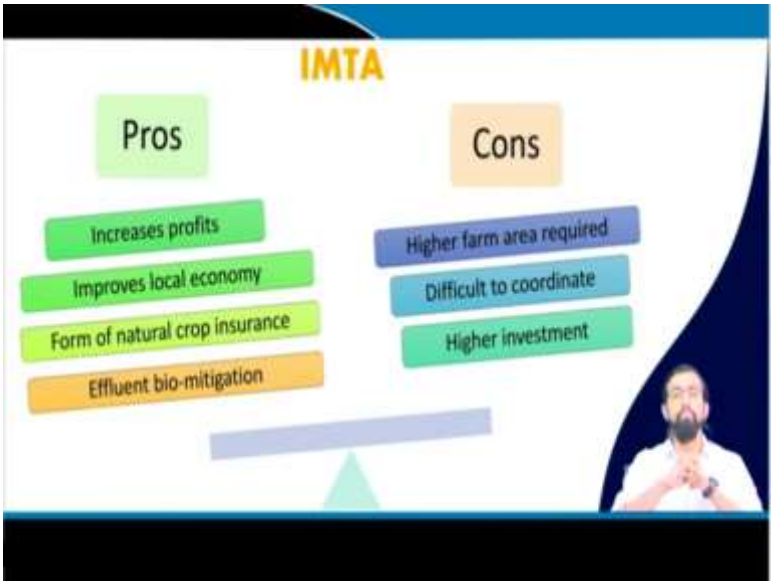

So, what is the what are the pros and cons of IMTA? From all our discussions that we have, you guys have already have a better idea about what are the pros and cons of this IMTA system. So, first of all, it increase the profits, it improves the local economy, it improves the local economy; it form the natural crop insurance. There it can if it can mitigate the bio effluent bio-mitigation can also be happening. Effluent bio-mitigation means is the waste worst treatment that can also be possible in the system itself.

The cons part of it the higher farm area is required, difficult to coordinate, higher investment definitely. So, definitely at the beginning you have a very high investment related to this kind of this kind of aquaculture systems. But, once you have it has a very low payback period, based on your design and all, you can design it. If you design it optimally, it has a very low payback period within a year or two or three year, you will get all your money back. All the investment back, and you will start getting a huge amount of revenue out of it. So that is possible.

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So, let us come down to the conclusion. So, sustainable aquaculture farming systems are now gaining the prominence nowadays considering the environmental impacts of the aquaculture. So, this is very important why? This is one of the major reason why I thought of delivering this particular course to all of you. So, too so for you guys to remember that aquaculture in general the aquaculture practice has a huge environmental impact negatively in general. If you cannot do it sustainably, if you cannot do it environmentally benign way; so that can cause additional load to the climate, additional load to the earth's ecosystem.

Why not why to do that? Where there is a possibility there is a scientific explorations already available to eradicate these kind of issues. Why not we go for this kind of easy solutions, this kind of scientific advancement; we can we can in we can intake this kind of animals. We can utilize those advancement and we can go ahead with the for increase the production capacity. We can increase the final product value and all, without compromising with the environment. That is what our targets should be in.

Because that is why I choose of I think of I thought of actually delivering this course in NPTEL; so for all of you, for you, it will be the one one of a kind subject and that will be delivered. That is actually been delivering right now; so, you need to remember these things. So, two main types of sustainable aquaculture farming systems were discussed polyculture and IMTA. And coastal and mariculture, algal culture, macroalgae or seaweed culture, and pearl culture will be discussed in the next constitutive class.

So, that is all that we want to discuss in this particular lecture. So, these are the references that I think you should you can pause the video and you can check this. You can check these details and it will be very much helpful for you to remember. You can go ahead with this paper and you can get the details about this discussion that we have in further. So, that is it for this lecture. See you, see you soon. Thank you.