Advance Aquaculture Technology
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Lecture 58
Mitigation and Adaptive Strategies

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Hello, everyone. Welcome to the third lecture material of the module 12 environmental considerations of aquaculture. My name is Professor Gourav Dhar Bhowmick, I am from agriculture and food engineering department of IIT, Kharagpur.

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In this lecture material we will be discussing about mainly the different mitigation techniques and different adaptation strategies that we can follow. The same material we will be discussing for the next two lecture also, where we will be elaborately discussing about different climatological conditions which are affecting the aquaculture process aquaculture system.

And how this system how this sector is actually is adapting, what are the way by which it can adapt to these changes in the climate, climatic condition and also what are the different mitigating techniques that we can follow and that will be discussed in details in the next two lectures as well.

So, the concepts that I will be covering in this particular lecture are the impact of climate change on aquatic animal health, introduction to mitigation and adaptation strategies mitigation of climate change impacts on the aquaculture.

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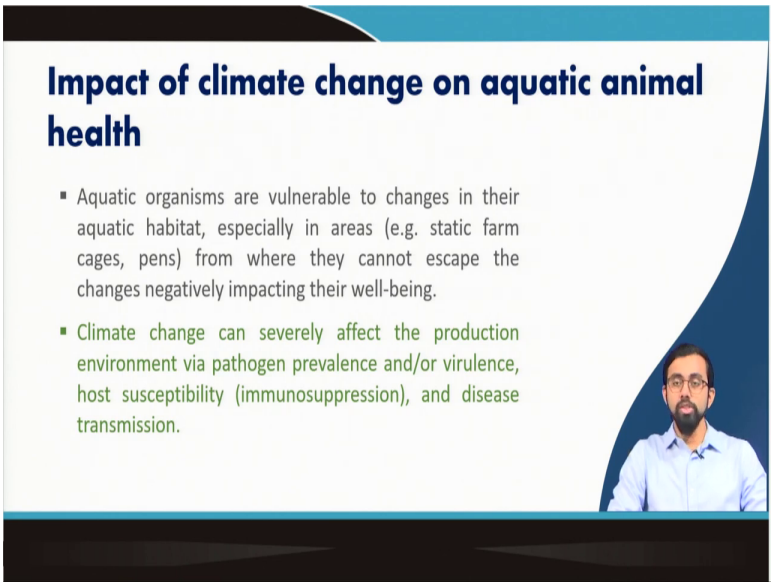

So, to start with, you know this is not something very new to you, I can I am hundred percent sure, because, that how the climate change like, remember, we discussed in the last two lecture also, how different climatological factors are actually affecting the aquaculture sector like how they can affect the health how they can affect the habitat and how they can affect the overall behavior analysis, behavioral changes, it was already discussed in last two lecture material and here also, we will be discussing in details.

And the more in depth discussion on the aquatic animal health will also be done in this lecture. So, mainly, we will be discussing about the how these different the changes in this climatic condition how it can help to spread different kinds of pathogens for this aquatic microorganisms. They not only enhance the pathogenic prevalence in that, any sector like whether it be farm whether it be say like aquaculture in a surface water bodies.

So, how it is affecting this aquatic bodies, aquatic animals, like prevailing this pathogens, they are virulence and the host susceptibility and the disease transmission, these are the factors that are severely affected by the climate change. Especially this when the climatic condition is not up to the mark or not up to the same standard that those aquatic animal are actually well habituated with.

So, what will happen like especially, when it is in a very static sector that you are in a static medium by at which you are growing your aquatic animals, they will be in maximum danger, they will be in most vulnerable situations, because they cannot escape that situation, they cannot escape that particular land or particular pond or farm or something. So, for them this climatic change, these changes in the climate are actually having very drastic effect in their well being.

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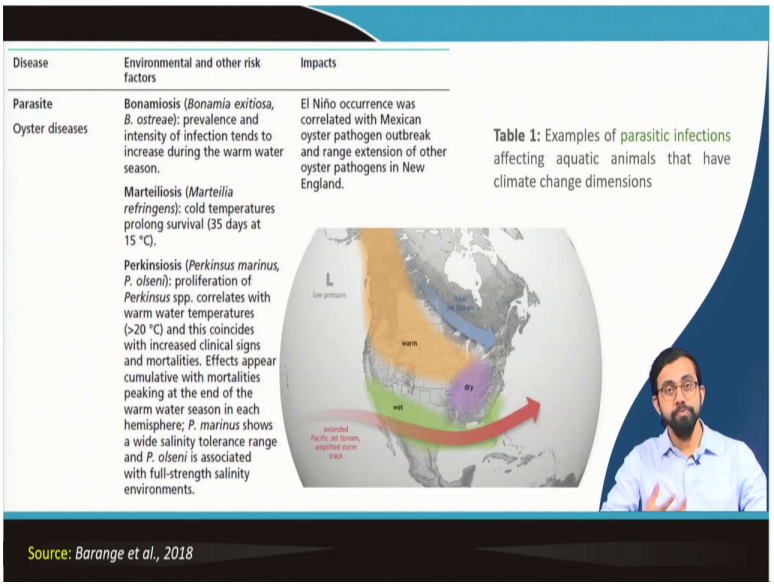

So, we will have to think about different strategies and different mitigation techniques or adaptive strategies for to get rid of this. To start with we will first discuss about the different examples of different microbiological infections like it can be parasitic, it can be viral, it can be bacteriological. I will be discussing in coming slides.

So, in this particular slides, I have discussed about I have given some examples of parasitic infections, which are affecting the aquatic animals because of the climatic change climate change dimensions. Do you have any idea about what is El Nino or La Nina? These are two actually two different climatic conditions. Two different kinds of event it is named as an El Nino and La Nina.

If you do not know you can Google it and it is this this El Nino is something which is drastically changing the whole weather pattern or the whole climatic condition of the earth right now. Just

to start with just to give you one example like just to give you some brief about what is El Nino, El Nino it means little boy it is a Spanish word.

So, what does it mean what happen this Pacific region if you see this figure in the Pacific region in the western side of the USA, there normally what happened in a specific time of the year the hot air water it will move from one place to another the hot water it tends to move towards the more western side and towards the east side of the this Asia. So, it moves towards that and the cold water what is actually in general they come in place of this cold in this hot water bodies in the western side of the USA that is a general phenomenon.

Because of the climatic because of the change because of the global warming and change in different reason, this is not happening this effect is how to say it is changed it is not the same way it used to be even like 50 years back also.

The hot water that it is supposed to go towards more towards the western side it is not happening what happened instead the hot water that that hot water it is keep on accumulating in that specific zone only which can cause a very huge amount of cyclonic and typhoon events and very high amount of precipitation in the southern part of the America whereas the Pacific part of the America like Pacific West part of America, they will be warm and dry and they will there is facing severe drought situations. This is because of the El Nino this is related to this event called El Nino.

The same way there is another term called a La Nina, La Nina is like it is a Spanish word it is also it means the little girl to the best of my knowledge little boy and little girl. So, this La Nina event when it happens why I am giving you this extra information, it will help you understand the factor much nicer way that what is actually happening in our earth and how this changes in the oceanic behavior is actually affecting the landmass as well.

Though we can think like why do we have to worry about because whatever is happening in the ocean, it keeps it will be in the ocean only no it will have a very drastic effect on the environmental situation and the I mean like the climatic situation of your region as well. So, this is just one example.

In case of La Nina what happen, in that case hot water it will go towards the west, but the amount will of the hot water is much higher, which is moving towards the west and which can cause just the opposite effect in US condition if I say only about the condition which will prevail in the US.

In case of La Nina in a southern part of the US will be in drought condition and the west Pacific west part will be affected with the huge amount of rainfall, this is a very sudden changes in the climate which are not there even few years back few decades back also and this events this anomalies climatic this climate anomalies are keep on increasing year by year by another.

So, because of that, it has a drastic impact on the aquaculture as well, in order to start with before just to give you some example about how these climates, climatic conditions are affecting aquaculture, we will be discussing for the next two three slides that how it can affect.

Like I am giving one example to start with, like the oyster disease parasitic infection in case of oyster diseases, this Bonamiosis or Marteiliosis is or say like Parkinsiosis these are the different diseases or environmental risk factors that the oysters are actually facing, because of the event like El Nino, because what happened this El Nino which is occurred in the, it is actually very much correlated with this Mexican oyster pathogen outbreak and its range extend up to the western pathogens in the New England region as well.

So, that is why this specific event El Nino is not only affecting the landmass, but also landmass and the land like a species, but it is also affecting the aquatic species present there, because of the changes in the temperature changes in the this overall climatic behavior.

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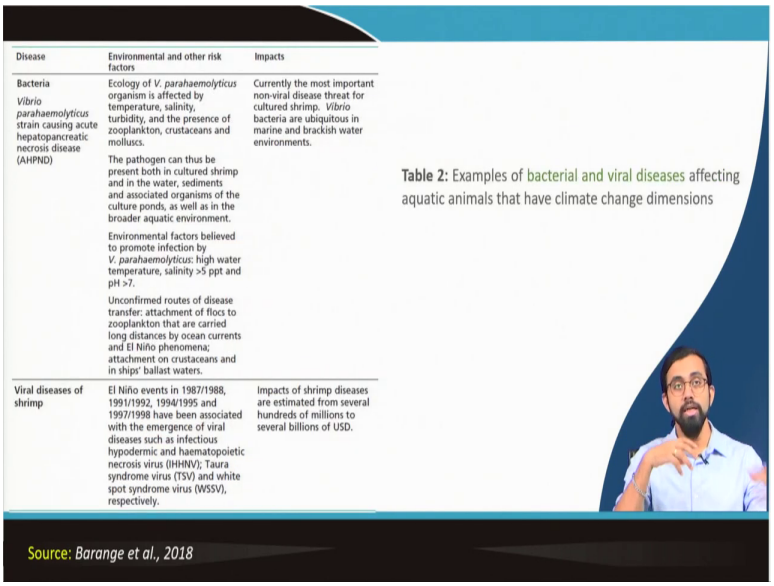

The same way there are earlier example was about the parasitic infection like different kind of parasitic infection, we can discuss about the different bacterial load, in case of like, different types of streams, the culture streams, they are actually very much threatened with this Vibrio species of this bacteria and this Vibrio species they are very much, they started growing, I mean like they started affecting our culture farm affecting our typhoid farms in the way the streams are normally being cultured.

And this is considered as the reason of changes in the climatic situations like because of the climatic changes, the temperature, salinity, turbidity and the presence of zooplankton, crustaceans and mollusks are also changed and all these factors are actually affecting and causing this kind of bacterial pathogenic infection or like the disease outbreak in stream species.

Same way the viral diseases in El Nino event that happened in 1987, 88, 91, 92, 94, 95 and 97, 98, it is very much the experts say that it is very much associated with the emergence of different viral diseases like TSVs, TSV white spot syndrome disease like WSSV and all (()) (11:11) and they are the loss are in the range of millions to several billions of USD because of this climatic event.

So, you can understand like how our activities I will definitely say it is our activities, because of our anthropogenic activity only the chain the earth is experiencing in this improper situation and

this abnormalities in the anomalous is in the climate a condition. So, this is not only this is not only affecting the whole like ourselves, but also is affecting land animals aquatic animal, the whole ecosystem.

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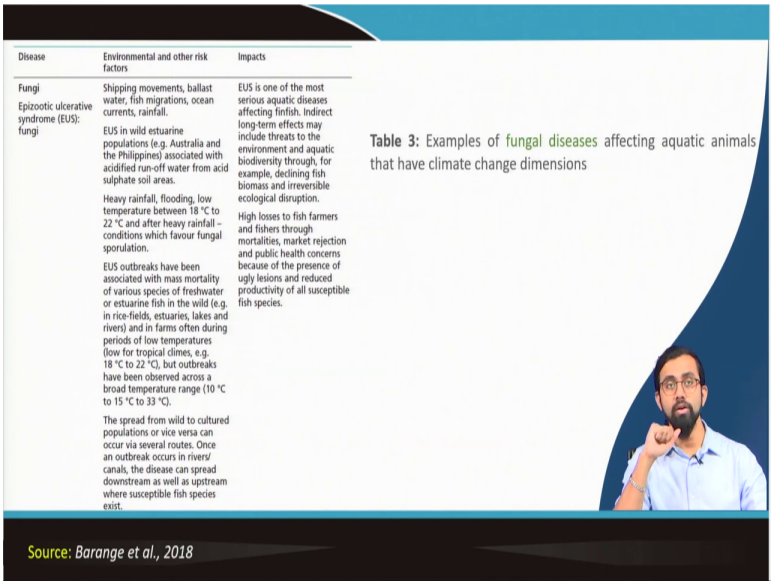

Fungal diseases are also getting outbreak like this in this because of this events and one specific type of this disease called this Epizootic Ulcerative syndromes or EUS we call in short. So, it is actually considered to be the reason behind the ballast water movement the shipping movements the fish migrations and the ocean current and the rainfall. You know what is shipping movement you know what is the fish migration ocean current and also the rainfall maybe you do not know about what is ballast water, ballast water is sometimes just to give you one example suppose you have a oil tanker.

So, in your oil tanker from oil tanker it is like say when it comes from the oil mine to your port. So, it in when it comes with the load of oils and in the port it will void itself so after then what will happen it is structured the ships are structured in such a way that it can carry up to that load of oil and that particular amount of weight, but when it will disperse when you will the containers and the these tankers they unload themselves like at the end they will be very light in a weight.

So, because of that there is there will be changes in different factors the and drag forces (())(13:21) that is a different thing anyway the ship movement will be affected. So, because of that what we do we put instead of oil we simply replace it with the water we fill up the water of this tankers and from that region and then we go to the then that ships again going back to the oil mine and then they get rid of all the water and then they fill up with the oil.

Now, the thing is what do you think these waters are pure water freshwater no, this is the water which they can collect it from the near coastal region only when they are collecting this water from the near coastal regions what will happen it is very much reach in different faunas and flora and faunas.

So, once they are very much reach in this flora and faunas this which is like specific to that specific place, now it is moving say like hundreds of kilometers away and go to the oil mine then it will replace this water with the oil again and this water will come in contact with the that following water body right now.

And because of that what will happen those flora and fauna which is very much specific to that core that coastal region it will be replaced to that it will not be replaced it will come and it will enjoy a new environment but it will definitely not enjoy because the thing is like for them that environment that ecosystem is not built for them. Or suppose whatever you are carrying it from the coastal regions, maybe they are they are being considered as a predator for in the nearby water vicinity where you are discharging them.

So, anyway in the both way it is not good, for in the both way for both of the cultures, both of the species that was there in like, set a site A and site B, for both of them, it is a very, very much change, it is like the whole ecosystem can get collapsed, because of these changes in the because of this different movement of the species because of this ballast water.

So, now I think you I hope you will understand you understand, like, what is why this is something like not to be practiced and if you are practicing, you have to make sure that the water that you are carrying, it is like, free of any restricted migratory species, restricted species to be migrated. So, there are a lot of practices, lot of discussions, lot of expert's opinion are there it is

floating in the air, but still there are a lot of work to be done in this particular sector. Anyway, so this EUS, this type of fungal diseases are prevalent because of these activities.

And it is like very, it is a one of the most serious aquatic disease which affects the finfish, and it has a indirect long term effect, like, it can threat the environment in the aquatic biodiversity and also it can decline the fish biomass and also irreversible ecological disruption can also happen. So, all these things are there, all these factors are there, which has to be properly taken care of otherwise, they will be a destruction in the whole ecosystem.

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So, now we know about all this factors. Now, let us discuss about the mitigation and adaptation technologies, strategies that is there, majorly, the climate change related risks to aquaculture, food security and the water supply and the economic development will continue to increase unless until we really restrict our global warming limit up to 1 point 5 degrees Celsius.

So, and because of that, both the agriculture sector like as well as the capture, as well as the culture fisheries, as well as the communities, those are involved, they are required to mitigate and adapt to the changing climate situation by developing or using the advanced technologies and resources.

This mitigation and the adaptive adaptation, it together, it can help prepare the eco farming community population and the ecosystem to build resilience and effectively cope with the climatic situation on the climate changes in the climatic conditions.

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So, to start with the mitigation to what do I mean by the mitigation to mitigation, it is like normally, we focus on reducing or reversing the rate of climate change, which is very hard to do, but it is possible, it is a collective effort of us definitely can do a major change. Mainly the aquaculture producers, as well as the stakeholders can play a substantial role in mitigating the climate change effect.

First of all, they can minimize the emission of greenhouse gas, they can start utilizing the environmental friendly practices and the technologies which is available and which is like experts are already provided, and it is already there in the pen and paper, but you just need to follow it and you just need to replicate it and make it introduce it to your new to your farm design.

In mitigation, it is actually a long term solution for climate change and it has to be implemented simultaneously with the adaptation strategies for better and more effective outcomes. So, only

mitigation will not do the job, you have to adapt with the change in situation as well. So, both are equally important.

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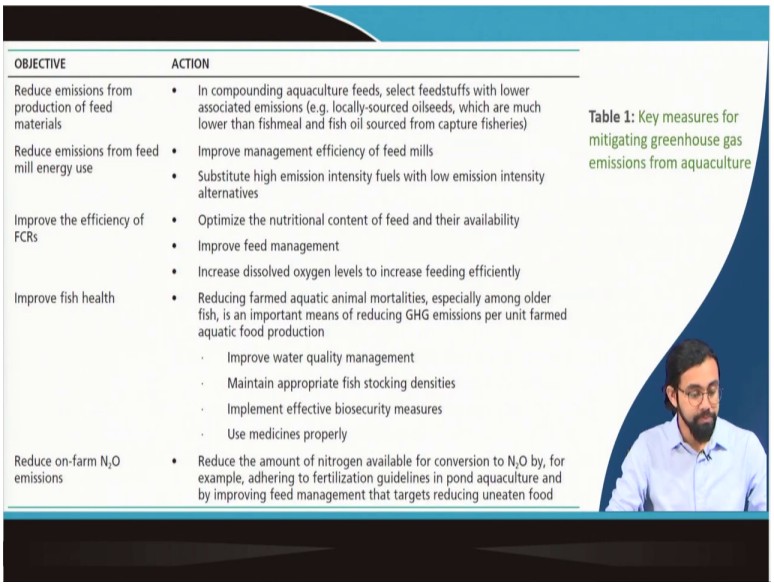

So, what are the measures or what are the processes or like how we can, you can reduce the or mitigate the greenhouse gas emissions from aquaculture. To start with, suppose, in order to reduce the emission from reproduction of the feed materials, what you can do, you can compound this aquaculture feed and select the feeds with lower associated emissions, like, locally sourced oil seeds instead of fishmeal or fish oil, which is sourced from the capture fisheries which definitely cause certain it has also its carbon footprint.

I hope you guys know what is carbon footprint? Any product that is developed we can call it a green product, sustainable product it is not it does not matter that at that particular moment, you are using some sustainable technology and you are considering you are claiming it to be organic or claiming it to be carbon neutral.

No, suppose just to give you example, we say like electro most of the electric car and electric vehicles are very much good for the environment, it is only good at the moment when you start utilizing the energy source from the renewable energy like if you are harvesting the energy for that particularly EV car and EV cell from the renewable energy then you may call it somehow carbon neutral. Still the construction material is whichever is involved to harvest that renewable energy, it also has some carbon footprint, because in order to manufacture those, you need to involve some amount of energy.

So, you have to go up to the source for each and every instruments or each and every chemicals or whatever you have used, you have to go up to the source and you have to understand that what is its carbon footprint.

Then only you accumulatively come and go to and at the end, you will do this lifecycle analysis and at the end you will say, so, my product is carbon neutral, because whatever the key raw materials that I have used, they whatever the carbon footprint they are having that can be surplus that can be neutralized by the material that I have developed, this way we can call it carbon this way we can call it carbon neutral technology, so, sustainable technologies. So, but this carbon neutrality and carbon footprint is very important for you to understand.

So, this is the reason why we can go it is better to replace the fish oil fish meal with the locally sourced oil seeds because this fish meal for to capture this fish to prepare this fish meal and fish oil you have to go to the open sea for capture fisheries it will cost a lot of transportation the oil and involve people's involvement and all these things, it has a huge carbon footprint.

So, in order to reduce that carbon footprint or greenhouse gas emissions, what you can do you can start go with a locally produced material, it can reduce the emission from the feed meal energy just like you can improve the management efficiency of the feed meals, you can substitute the high emission intensity fuels with the low emission intensity alternatives, you can improve the food conversion ratio by optimizing the nutrition content you know how to do that we have already discussed you can improve the Feed Management Technology increase the dissolved oxygen level.

So, to increase the feeding efficiency you can improve the fish health, the better the fish the health of the fish and the better it will the more amount of food it will consume and the more amount of biomass conversion it will do from the feed.

So, how we can reduce how we can improve the fish health you have to improve the water quality management practice maintaining a proper fish stocking density it cannot be much higher implement efficient biosecurity measures and use the medicines properly and try to quarantine the fishes which are already in danger and so that it and treat it very cautiously so, that it will not

go and damage your whole farm and also it will reduce your overall strategy overall, economic return as well.

So, these are the practice that you should follow you should have to reduce on from nitrous oxide emissions like you can reduce the amount of nitrogen available in for this conversion of this nitrous oxide to by like just an example you can add into the fertilization guidelines by provided by the local authorizing body for pond aquaculture and improve the feed management that targets the reducing the uneaten fish food because this uneaten food is actually converted into the waste materials. So, if you reduce this uneaten food consumption, you can definitely increase the productivity and also it you can definitely work on the environmental cleanliness.

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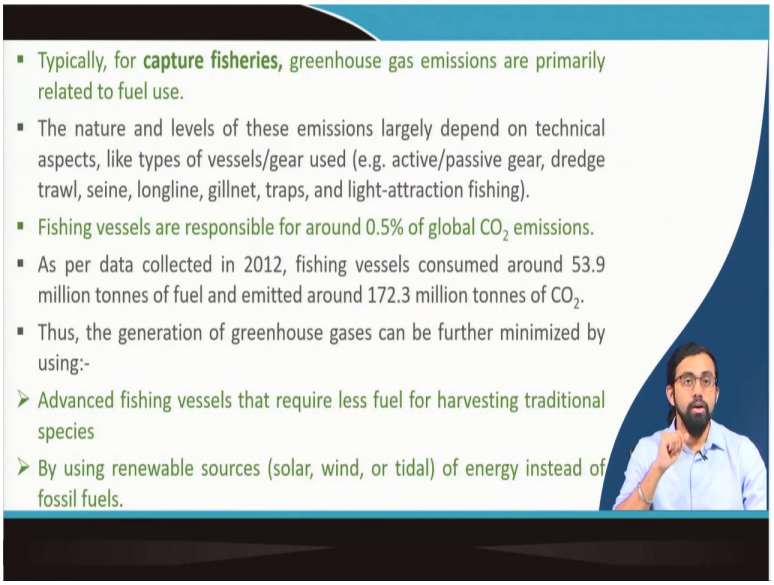

So, typically, for capture fisheries, the greenhouse gas emission is actually mainly related to the primary fuel uses like I mean like the fuel that they use for the transportation it can be it is depending upon the type of the vessel or the gear they are using and majorly it is majorly depends on this kind of technical aspects only. And they are actually responsible for almost 0.5% of the global carbon dioxide emissions.

Can you imagine this fishing vessels, it is captured fishery still in this particular in this era also, we are talking about this where there are like very much advanced technologies already available

just because of the lack of initiation, initiation from our side we are losing we are actually generating these much of greenhouse gases.

This generation of these greenhouse gases can be further minimized by advanced fishing vessels that require less fuel for harvesting the traditional species by using the renewable sources of energy like instead of fossil fuels like solar, wind or tidal can be used.

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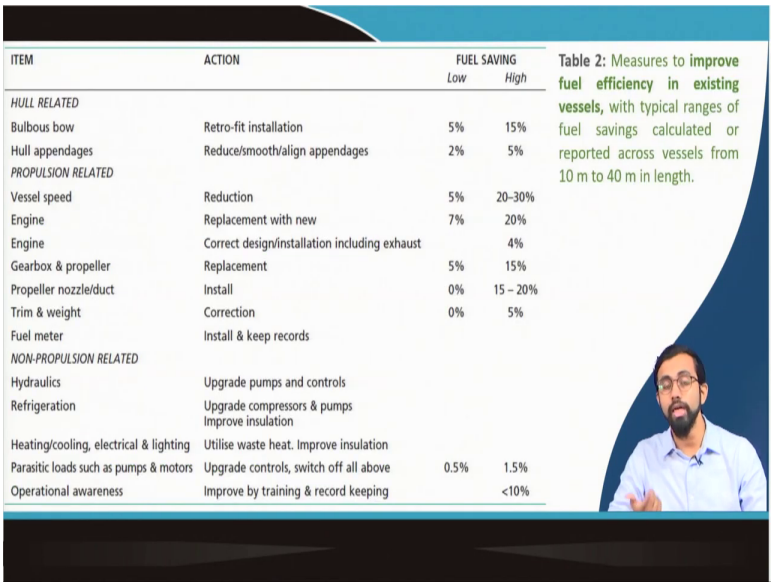
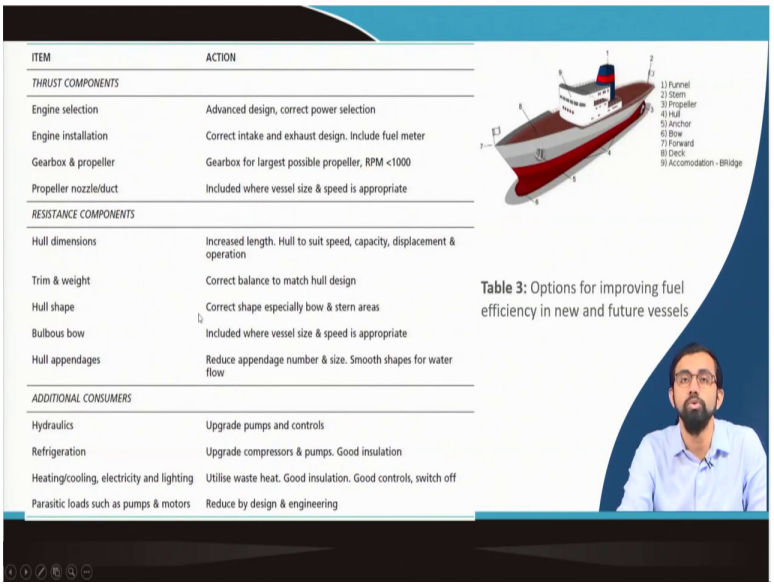


ITEM	ACTION	FUEL SAVING Low	High
HULL RELATED			
Bulbous bow	Retro-fit installation	5%	15%
Hull appendages	Reduce/smooth/align appendages	2%	5%
PROPULSION RELATED			
Vessel speed	Reduction	5%	20–30%
Engine	Replacement with new	7%	20%
Engine	Correct design/installation including exhaust		4%
Gearbox & propeller	Replacement	5%	15%
Propeller nozzle/duct	Install	0%	15 – 20%
Trim & weight	Correction	0%	5%
Fuel meter	Install & keep records		
NON-PROPULSION RELATED			
Hydraulics	Upgrade pumps and controls		
Refrigeration	Upgrade compressors & pumps Improve insulation		
Heating/cooling, electrical & lighting	Utilise waste heat. Improve insulation		
Parasitic loads such as pumps & motors	Upgrade controls, switch off all above	0.5%	1.5%
Operational awareness	Improve by training & record keeping		<10%

Table 2: Measures to **improve fuel efficiency in existing vessels,** with typical ranges of fuel savings calculated or reported across vessels from 10 m to 40 m in length.



ITEM	ACTION
THRUST COMPONENTS	
Engine selection	Advanced design, correct power selection
Engine installation	Correct intake and exhaust design. Include fuel meter
Gearbox & propeller	Gearbox for largest possible propeller, RPM <1000
Propeller nozzle/duct	Included where vessel size & speed is appropriate
RESISTANCE COMPONENTS	
Hull dimensions	Increased length. Hull to suit speed, capacity, displacement & operation
Trim & weight	Correct balance to match hull design
Hull shape	Correct shape especially bow & stern areas
Bulbous bow	Included where vessel size & speed is appropriate
Hull appendages	Reduce appendage number & size. Smooth shapes for water flow
ADDITIONAL CONSUMERS	
Hydraulics	Upgrade pumps and controls
Refrigeration	Upgrade compressors & pumps. Good insulation
Heating/cooling, electricity and lighting	Utilise waste heat. Good insulation. Good controls, switch off
Parasitic loads such as pumps & motors	Reduce by design & engineering

Table 3: Options for improving fuel efficiency in new and future vessels

There are other measures also that can also be done to improve the fuel efficiency in the existing vessels like the hull related I think you know what is hull the structure the main the bottom structure that is there in the ship.

Let me show you the with the figure if you see this figure of a ship, in general any ship or any vessel in this aquatic vessels if you see the number 4 if you see the number 4 in the bottom that is called the hull.

And this number 1 this is the funnel and there is this 2 this stern in the backside of it which is like stern and then it has his propeller just below the stern we have this propeller, we have this anchors to stuck to the seafloor, we have this bow in if you see number 6 in the front there is like one extension that is called bow and this is the forward in the upper deck extension that is called forward and the deck and the accommodation the bridges.

So, this is the how these vessels are actually vessels looks like in any ship. So, this hull this is the bottom this hull what happens sometimes this what are the measures that we can do we can do this we can retrofit installation of the Bulbous Bow.

And what is Bulbous Bow this you see the bow number 6 which is in the extension of this bottom this hull part of this call this is the Bow what this bow is doing in general when the suppose there is a ship there is like typical rerik (()) (27:00) structure it will go cutting the water waves.

So, what will happen because of the generation of the wave it will go up and down then it will lose it because of this wave because there will be an additional wave that it will generate from its the front part of its hull and because of that what will happen there is a chances of high drag into your vessel and this drag value will be very high and also because of that the motion of the ship will be very unstable.

That is why people started introducing these bows and especially if you have this Bulbous say this Bulbous Bow that we call when we retrofitted in this kind of structures, what will happen this Bulbous Bow they because of their specific design, it will kind nullify this generation of the wave or it will create the wave which will just, just like the opposite to the sinusoidal curve.

Suppose your bow is generating like say 0 degree to 90 then again 180 like this and because of the Bulbous Bow it will go from the other way around it will from 0 to negative side then 90 to 180 because of this the opposite sinusoidal curve that it is generating, it will nullified the wave pattern around.

So, in general it will reduce the drag and reduce the it will increase the stability of the ship because of the reduction in the drag and the increase in the stability of the ship it will consume less amount of fuel you understand why we why the ships they provide this Bulbous Bow that is there in front of the ships. So, this is the reason.

Hull appendages the hull should be as smooth as aligned as possible it should not have the edges because if there is edges what will happen it will cause the resistance the water will stuck and it will restrict the how to say it is the velocity of your fishing vessel. So, it will restrict because of this restriction that it is if the resistance that it is getting from this extra appendages from your hull. So, you should avoid it, it should be as smooth as possible the bottom structure.

Proportionate and vessel speed you have to reduce you have to do. So, all this changes in the hull related items it can save the fuel 5 percent to as high as 15 percent is Bulbous Bow was (()) (29:22). In case of hull appendages 2 percent to 5 percent if you properly maintain the speed, it can go 5 to even 20 to 30 percent of the fuel saving is possible.

Engine replacement with the new definitely it will the moment it will start you have to change it according to your shelf life, according to the manufacturer's guide, the gearbox propeller nozzles trim and weight the fuel meter it all these things really does matter how you are maintaining your fishing vessels or how you are maintaining, just to increase the capacity of increase the fuel efficiency and because of that, by means of this you can save the climate change because by

events of this you can save the greenhouse gas emission and obviously it is good for you for your business as well.

There are other activities as well like the thrust component like the engine selection, you have to go for a very proper powered I mean like correct power adaptation is, selection power selection is very much important with very much advanced design that is available in the market.

The engine installation properly proper intake and exhaust lines is important including the fuel meter gearbox the it should be largest possible propeller and with the RPM of less than 1000 and propeller nozzle or duct included where vessel size and speed is appropriate.

What are the resistance component like the hull dimension increased length and what will happen it will give the hull to switch proper speed capacity and replacement and operation, trim you have to currently balance to match the hull design you have to correct the shape especially for bow in the bow and the stern areas to maintain the hull shape for in proper way.

You have to include where the vessel size and the speed is appropriate this Bulbous Bow should be included the hull appendages should be reduced as I discussed because to smooth shape will give you the proper water flow proper velocity it will not provide any restriction or any resistance.

You have to improve its hydraulics upgrading the pumps and control how to increase the recreation upgrading the compressors and pumps and the good insulation of your recreation unit heating and cooling and electricity lighting utilize the waste heat and the good insulation and good control and properly time to time switch off you have to if you have a parasitic load such as pumps and motors, you have to reduce by designing and engineering properly.

So, all these factors always implement installations if you do, you can definitely improve the overall fuel consumptions the you can improve the overall greenhouse emissions by all the other means by the carbon footprint that I discussed.

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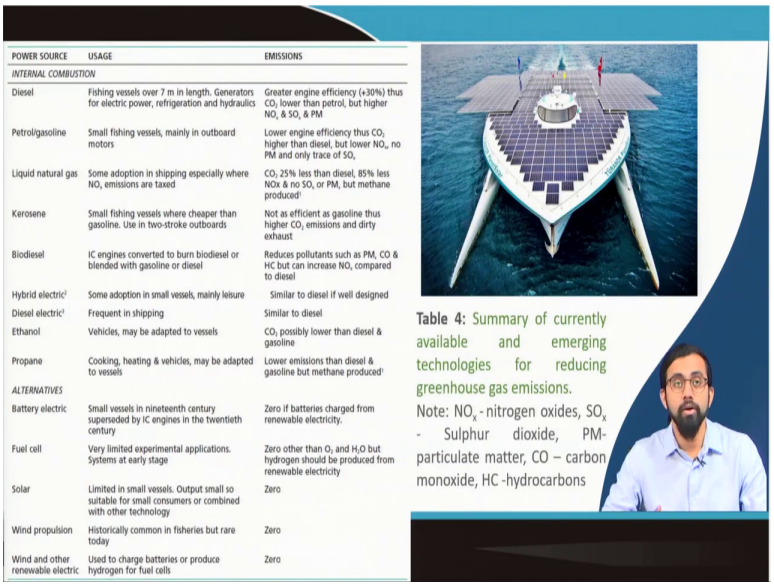

POWER SOURCE	USAGE	EMISSIONS
INTERNAL COMBUSTION		
Diesel	Fishing vessels over 7 m in length. Generators for electric power, refrigeration and hydraulics	Greater engine efficiency (+30%) thus CO_2 lower than petrol, but higher NO, & SO, & PM
Petrol/gasoline	Small fishing vessels, mainly in outboard motors	Lower engine efficiency thus CO_2 higher than diesel, but lower NO_x, no PM and only trace of SO,
Liquid natural gas	Some adoption in shipping especially where NO, emissions are taxed	CO_2 25% less than diesel, 85% less NOx & no SO, or PM, but methane produced[1]
Kerosene	Small fishing vessels where cheaper than gasoline. Use in two-stroke outboards	Not as efficient as gasoline thus higher CO_2 emissions and dirty exhaust
Biodiesel	IC engines converted to burn biodiesel or blended with gasoline or diesel	Reduces pollutants such as PM, CO & HC but can increase NO, compared to diesel
Hybrid electric[2]	Some adoption in small vessels, mainly leisure	Similar to diesel if well designed
Diesel electric[3]	Frequent in shipping	Similar to diesel
Ethanol	Vehicles, may be adapted to vessels	CO_2 possibly lower than diesel & gasoline
Propane	Cooking, heating & vehicles, may be adapted to vessels	Lower emissions than diesel & gasoline but methane produced[1]
ALTERNATIVES		
Battery electric	Small vessels in nineteenth century superseded by IC engines in the twentieth century	Zero if batteries charged from renewable electricity.
Fuel cell	Very limited experimental applications. Systems at early stage	Zero other than O_2 and H_2O but hydrogen should be produced from renewable electricity
Solar	Limited in small vessels. Output small so suitable for small consumers or combined with other technology	Zero
Wind propulsion	Historically common in fisheries but rare today	Zero
Wind and other renewable electric	Used to charge batteries or produce hydrogen for fuel cells	Zero

Table 4: Summary of currently available and emerging technologies for reducing greenhouse gas emissions.
Note: NO_x - nitrogen oxides, SO_x - Sulphur dioxide, PM- particulate matter, CO – carbon monoxide, HC -hydrocarbons

So, what are the currently available and what are the emerging technologies available for reducing the greenhouse gas emission so currently available technologies we have this diesel we normally it is we use it for inefficient vessels over 7 meter in length and it generates for generators for the electric power and recreations and the hydraulics it has a greater engine efficiency but it emmits huge amount of nitrogen NO_x, SO_x and particulate matters.

Whereas petrol or gasoline it is used for the small fishing tank mainly in outboard motors it has a lower engine efficiency but carbon dioxide emission is higher than diesel, but it has a very low NO_x and low particulate matter and only a stress amount of SO_x is emitted.

Liquid natural gas it is a sometimes people use it in the shipping vessels especially where the NO_x emissions are taxed. So, carbon dioxide emission is almost 25 percent less than diesel 85 percent less in case of inverse emissions, no SO_x emissions and particulate matter. But methane production is there and is produced when you use the liquid nitrogen natural gas kerosene it is the notorious one it has it is not efficient as efficient as gasoline but very high carbon dioxide emission and dirty exhaust.

Biodiesel IC engines converted to bond this biodiesel and blended with the gasoline and diesel sometimes it can reduce the pollutants like particulate matter, carbon monoxide hydrocarbons

but can increase the NO_x compared to diesel there it is possible just remind this is not biodiesel it is completely pure.

Hybrid electric or the diesel electric they are similar to diesel engine diesel engine based internal combustion diesel based diesel fuel based internal combustion engines whereas ethanol propanol are also being used now it is. What are the alternatives, better alternatives go for battery electric. Small vessels of they can you can use the battery electric and if it is only the emission is 0 if the batteries are charged from renewable electricity still I would not say it is 0 it is near to 0 because of its carbon footprint.

Fuel cell based it is a very advanced technology if you remember in the sixth module we have discussed about sixth I think or seventh or eighth model I do not know in twelth that we have discussed like what are the different biochemical systems how they can be used to generate electricity out of the waste materials. And this electricity can be transferred to your ship.

Solar energy, wind propulsion, wind and other renewable energies like the tidal energies that also can be used in your shipping vessels, which can be which will be considered as a very, which will definitely reduce the overall greenhouse emission gas emissions you will see this is a example of a solar powered steamers, how it looks like it definitely it is a completely solar powered steamers.

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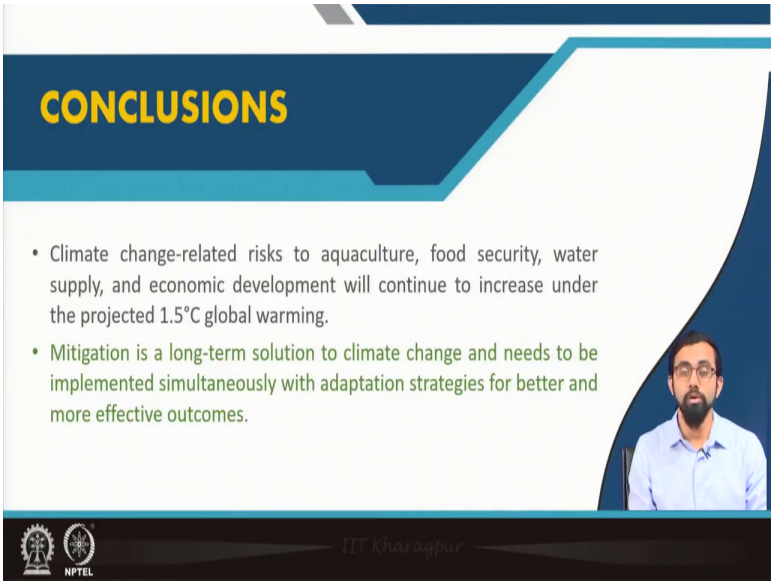

So, in conclusion, there are different climate change related risk are there in aquaculture and food security in the water supply and the overall economic development and what are the mitigation techniques that we can follow, we discussed in details it will be followed by coming lecture materials as well.

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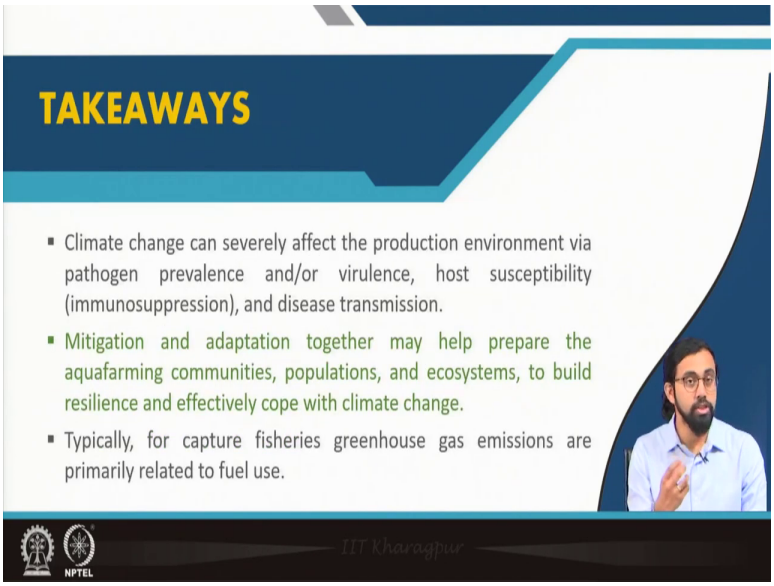

And I hope you in the coming lecture, you will get to know more about the what are the different other adaptive strategies that we need to follow other than the mitigation techniques that we are discussing right now.

We discussed about that these things to be go along like the mitigation technique as well as adaptation strategies has to go along in order to prepare your eco farming communities population in the ecosystem to build the resilience and effectively cope with the greenhouse the climate changes.

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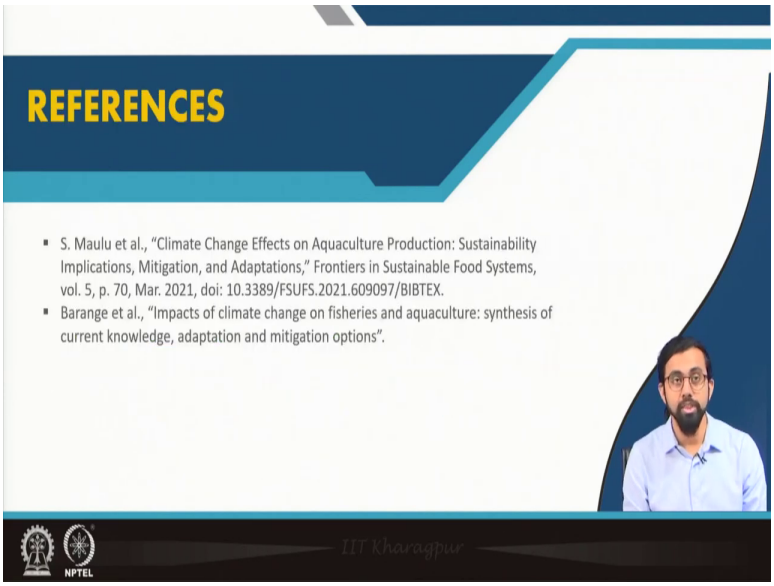

These are the references that you can follow to gain more knowledge about it. I hope this lecture, from this lecture material you are very much enlightened with the very important factors the physics behind all these things and you got to know that how we can effectively eliminate how we can take the different mitigation technologies are already available, which can be replaced or the retrofitted on a existing ones so, to reduce the greenhouse emission to so to, somehow reduce the climate change anomalies and all these factors.

I hope you are very much benefited with this lecture we will continue in the coming two lectures as well about this different climate change effects in the aquaculture and what are these mitigation and adaptive strategies. Thank you so much. See you in the next lecture video.