Wildlife Ecology
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Lecture - 31
Optimum yield problem

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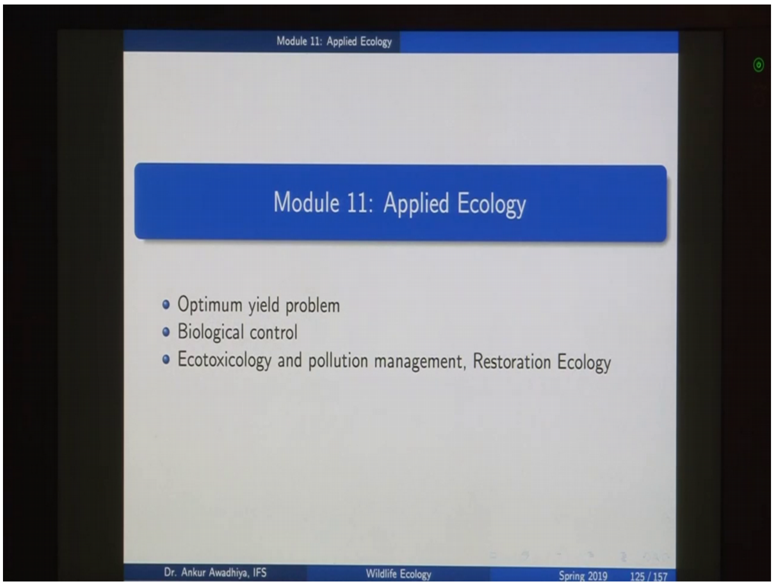

[FL]. Today, we begin a new module and this module is Applied Ecology or the application of the ecological principles or whatever we have learned so far to the problems of humanity. In this module, we will have three lectures. The first one is the Optimum yield problem. The optimum yield problem has to do with sustainable harvest of resources.

So, if you talk about any resource to be it a forest, be it say fishery resources or say whales that are there in the oceans and we are trying to harvest these resources. So, what is the level at which this harvest will be maximum and this harvest will be sustainable. That is if you have say 1000 fishes and if you are only taking out just 1 fish. So, this is going to remain sustainable for a very long period of time, but then this is probably not the most economically efficient option.

So, we need to ask whether we can take out say 5 fishes or 10 fishes or 20 fishes or say 200 fishes. So, what is the upper level or the upper limit at which we can take out these resources, we can harvest these resources and still be able to maintain our sustainability.

so that we can continue our operations year after year. So, that is the optimum yield problem. The second lecture will deal with Biological control. So, biological control is aimed at using different predators or say different diseases of different parasites or pests so that we are able to control the populations of pests. So, we suffered from a number of pests and especially we have a number of insects that eat away our crops and one option is to use pesticides or insecticides.

But as we have seen that a number of those insecticides or the pesticides are chemical compounds and even at very low doses they are also harmful to a number of other organisms. Besides they tend to accumulate in the bodies of different organism. So, we have this phenomenon of bioaccumulation. At the same time, they also tend to magnify as we move up in the food webs. So, there is the phenomena of bio magnification. So, biological control says or ask this question is there a way in which we can get rid of these insecticides and pesticides and maybe make use of some biological entities to control different pests.

Now, the third lecture we will deal with ecotoxicology and pollution management and it will also cover restoration ecology. Now, ecotoxicology is the study of the toxins that are there in the environment or in the ecosystem. So, it has your ecosystem plus toxicology. So, here you have the word toxic which is the poisons and here you have logy which is the study.

So, eco toxicology is the study of different harmful chemicals that are there in the ecosystems and we will move on. And we will have a look at pollution management; how can we take care of different pollutants and also we will have a look at restoration ecology. So, some parts of it have already been dealt with in the previous lectures, but then, in this lecture we will look at it in more detail. So, let us begin with the optimum yield problem.

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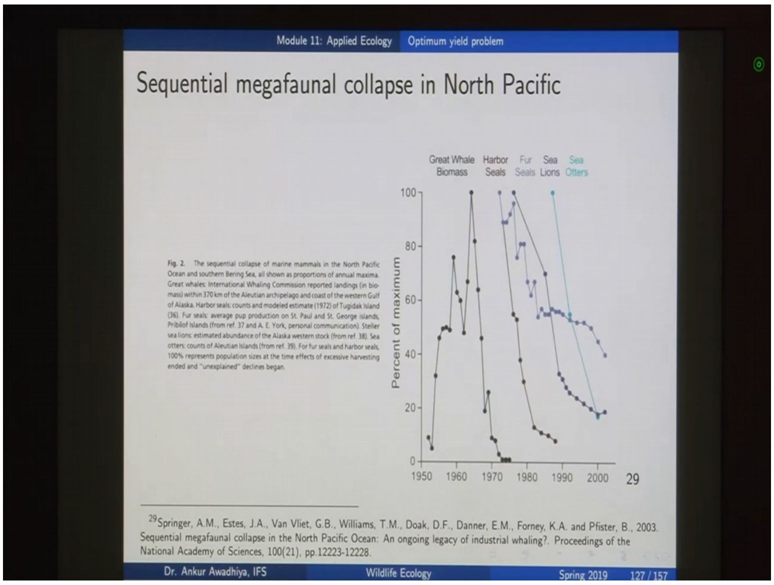

Now, if you look at this particular graph, this is telling you the collapse of a number of megafauna. Now, mega is large for nice animals. So, we are talking about the sequential collapse or loss of different large sized animals in the North Pacific Ocean. So, on the x-axis, here we have the years.

So, it starts from 1950 and ends at 2000 and on the y-axis, we see the percentage of the maximum population that was present or the percentage of the maximum yield that was taken out. So, it says the sequential collapse of marine mammals in the North Pacific Ocean and Southern Baring Sea, all shown as proportion of annual maxima. Great whales International Whaling Commission reported landings.

So, in the case of your great whales it is the biomass that was reported in the landing that is this much amount of biomass was taken away from the oceans and brought to the ports; 370 kilometres of Aleutian archipelago and coast of western Gulf of Alaska Harbour Seals. So, this organism so, it includes the counts and the model estimate of this particular Island and then in the case of the third organism; you have the Fur seals and the sea lions. In the case of sea lions, it is an estimated abundance. So, in these organisms we are talking about how the population decline. In this organism, we are talking about the amount that was taken out of the oceans.

Now, we will remember that when we were talking about the abundance, we talked about two concepts and the first one was an absolute abundance; in the second one was a relative abundance.

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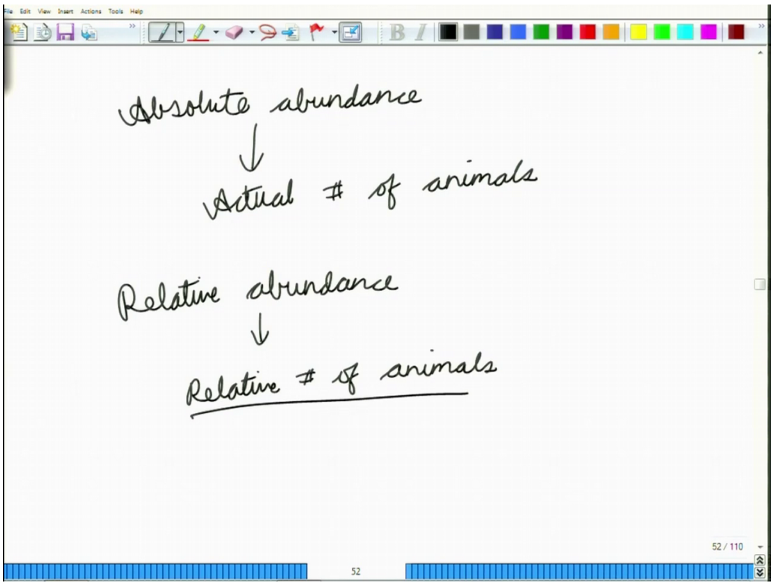

So, when we talk about the absolute abundance, we are talking about the actual number of animals that are present and when we are talking about a relative abundance, here we are talking about the relative number of animals. So, for instance you went into the forest and you saw say 10 tigers. So, that is the absolute abundance of tigers that are there in your forest because you have counted each and every tiger. However, if you go to the forest now and you saw say 5 tigers in one day and then, you go to the same forest after a year and you are able to see say 3 tigers in 1 day.

So, and these are the our average majors that as in the first case you are going into the forest again and again and on an average you are able to see 5 tigers every day. In the other case, you went into the forest and you are able to see on an average 3 tigers every day. So, we will see that the population has come down. So, there is a decline in the relative abundance and when we were talking about the relative abundance we also talked about the method of removal.

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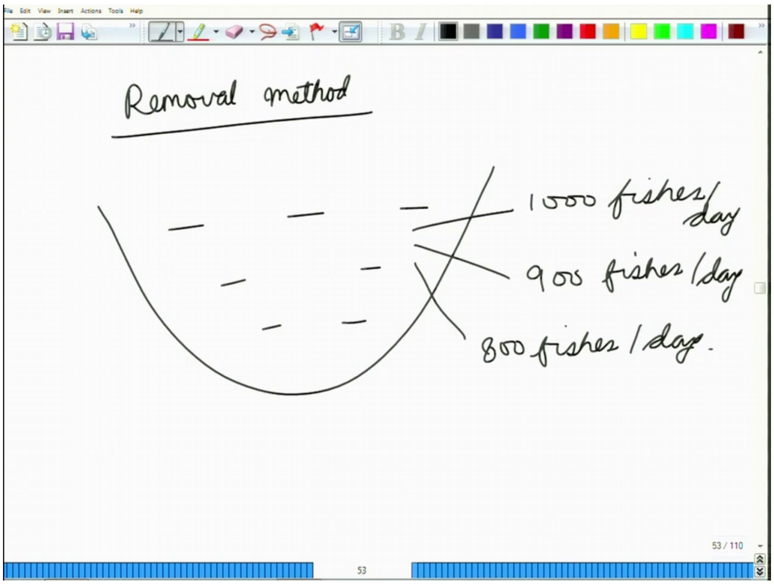

So, in the case of the removal method, we said that if you have a forest in which or say if you are having a lake in which you have 1000 fishes and then you are doing some amount of fishing and so, you are able to remove 1000 fishes every day. Now, after the while the fishes will decline in their population and then, after a while you will be able to remove only 900 fishes per day. Then, after a while you will be only able to remove say 800 fishes per day.

Now just by removing these organisms, just by hunting these animals, just by pooching these animals, we are reducing the population and the amount of animals that we are able to remove in per unit time gives us a good estimate of the number of animals that will be there in this particular lake. Because if you are or efforts are the same, we are putting in the same amount of time, we are putting you we are using the same resources and we are able to catch a lesser number of fishes. So, the only argument can be that your total number of fishes in the lake has gone down.

Now, similarly when we are talking about this graph, this is talking about the removal of animals. So, we are talking about the removal of the great whales from the oceans and in these cases we are talking about either the absolute estimates or the modelled absolute estimates.

Now, here we can observe that in the 1950's when we started collecting the data and in this period, the number of whales that was removed every year it was increasing every year apart from a few years here, when there was some moratorium and then, it peaked in around 1968 and then it started to decline. In the case of harbor seals, this population has continued to decline. In the case of fur seals, the population has continued to decline. In the case of sea lions, the population has continued to decline. In the case of sea otters, the population has continued to decline and we call it a sequential collapse. Because when this population of the great whales was going down, at that time the sea otters were roughly maintaining their population.

So, they were not undergoing a population collapse. So, after great whales started collapsing, the harbour seal's is started collapsing, after that the fur seals started collapsing. Now the question is why is this so? Why are we saying this sequential collapse?

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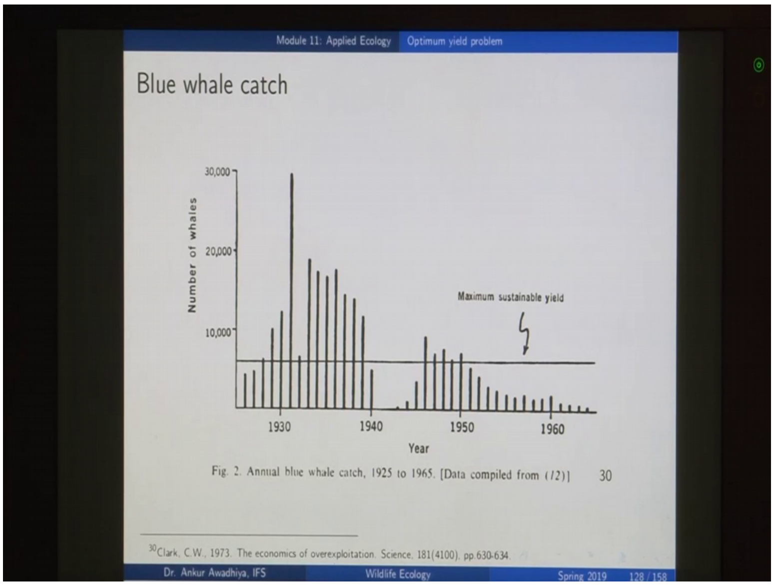

Now, if you look at any particular species such as if you look; have a look at the blue whale catch. So, here we will see a very similar trend. So, the trend increases and then it starts to decline. Now here are a few years during the Second World War, when a lot of commercial whaling was not possible. But then, we can see that overall this curve moves like this and then it declines and then it goes on declining. So, essentially this is giving us an indication that the total number of animals that are there in the ocean, they are reducing because our caching effort has not gone down. It has either gone up or it has remained steady and even then the population is declining.

Now, why would you have a situation in which the population is declining?

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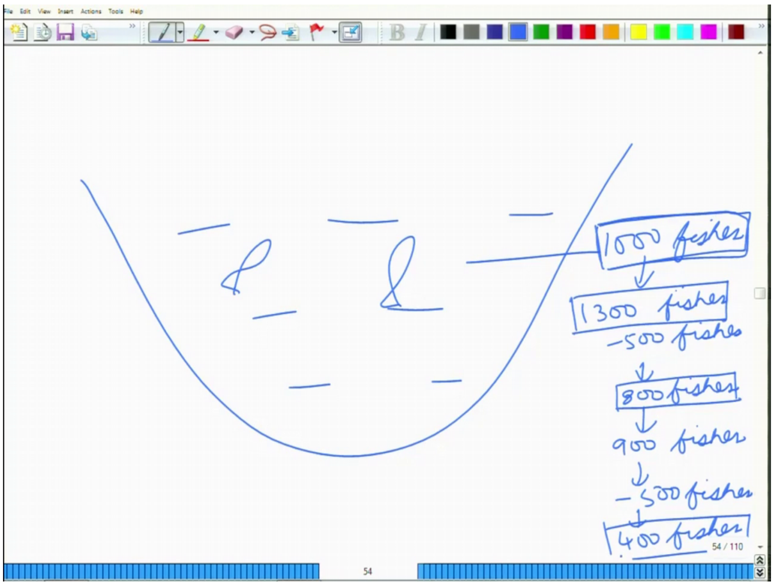

So, suppose you have this lake and in this lake, you have say 1000 fishes so, you have a total of 1000 fishes. And in a year this fish population because these fishes are breeding so, this population increases from 1000 to say 1300. Now, if this population increases from 1000 to 1300 and if we remove 300 fishes by fishing, then the population again becomes 1000. Now, in the next year, it will again increase to 1300. So, we can again remove 300 fishes. So, this is something that we can continue again and again and again.

But then, if we are removing at a rate that is greater than this particular rate. So, in case of 300 fishes, let us say we are removing 500 fishes; so you remove 500 fishes. So, now you are left with only 800 fishes. Now, your 1000 fishes after giving birth to the next generation produce 1300 fishes. So, now if you are only left with 800 adults, the population will grow at a slower rate because we have lesser number of parents. So, you will have lesser number of progeny. So, probably these 800 fishes will only increase to say 900 fishes.

Now, with this 900 fishes, if you again remove 500 fishes, you will be left with just 400 fishes and the lesser this number becomes, the lesser will be the growth of the population. So, we are moving from 1000 fishes to 1300 fishes when there was no fishing. But then from 1300, we went down to 800 from there we went down to 400 and so on. So, in this case because we are removing the fishes at a rate that is greater than the rate at which they can replenish their own population. So, the population is declining and is exactly what we are seeing here.

Now, in this case; in the case of the blue whales, the sustainable catch had to be somewhere near this line. So, this is somewhere around 7000 whales that is what we could have removed every year, but in place of removing 7000 whales, we actually removed as much as 30000 whales in a year.

So, when you are taking out a very big chunk of the population, so whatever remains, will not be able to replenish the population. And then, what happens when you are when this catch reduces because people still want whales, this is the level at which you were still having a nice demand, but then at this level your demand has remain the same, but the supply has gone or has shrunk considerably.

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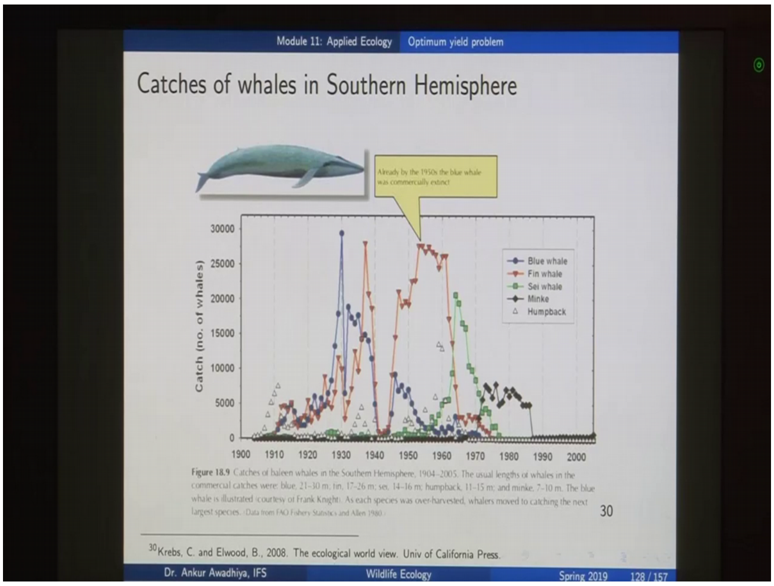

So, what do people do? Then they just shift to another species. So, if you look at different caches of different whales. So, here we can see that as in the previous curve, we started with the blue whales and then the population started to decline. Now, when we were there in this declining population so, people were not getting enough number of whales. So, what did they do? They started hunting some other whale. So, after this blue whale started declining, this; we can see that this second curve which is people shift to which is this Sei and which to decline, then they move to a fourth whale which is the minke whale.

Now in this case we can see that there is a sequential collapse of different species of whales because you started with the whale that you wanted the most. Now you did an unsustainable harvest, its population declined so, you moved to the second best whale. When the population of the second best whale also started to decline, then you went for a third best whale, then a fourth best whale and then, this thing will continue. And after a while we will have a situation in which you will hardly have any whales left in the oceans. So, the population will be so less that it will become commercially unsustainable to harvest the whales.

For instance, here we can see that already by the 1950's, the blue whale was commercially extinct. So, by the 1950's the catch was so less that now it was very difficult for somebody to make a living out of catching the blue whales. So, they had to shift to another whale. Now, we come to this question how do we determine; what is the level at which we should do this catching because we cannot just say that ok, we are not going to catch any whales because people are having requirements. There are some people who want to eat these whales, there are people who want to use the body parts for something maybe a traditional medicine. So, there will be a some demand that will always be there.

Now, to match that demand, we will have to take out some resources because after all if you are doing any activity, there will be some negative impact on the environment. Now our aim is to have this activity at least till that level that it is at least sustainable for the long period. So, how do we compute that? So, we start with the population equation.

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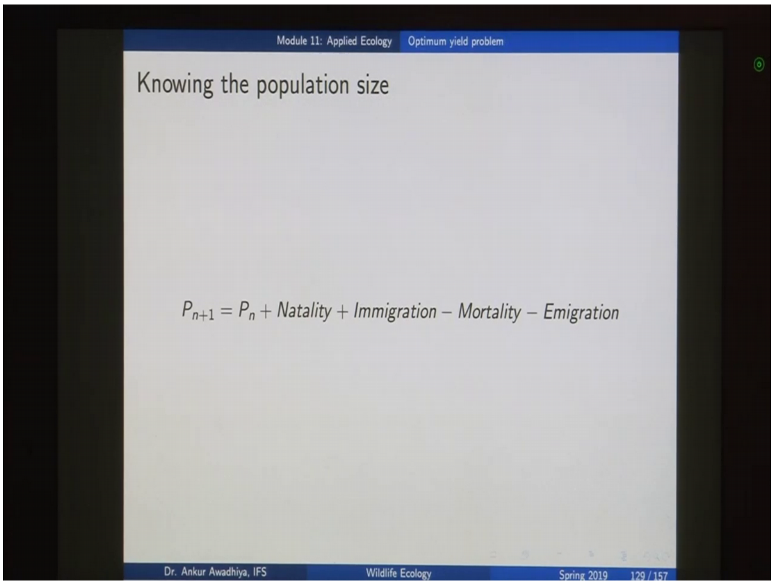

So, we had seen that if you have the population in the nth generation as P n, the population in the next generation will be P n plus 1. And that will be given by the population in that nth generation plus birth which is natality plus immigration that is animals that are coming from outside minus mortality which is the death and minus the emigration.

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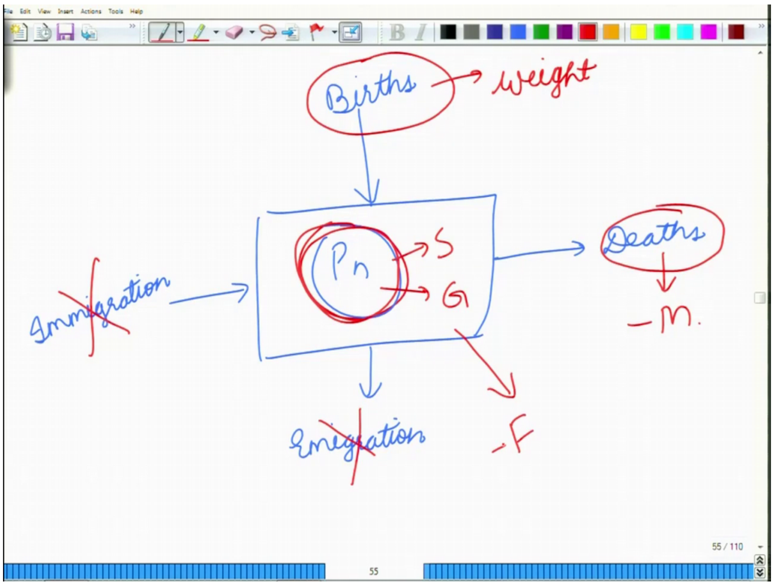

So, what we were saying here is that if you have any population. So, this is P n. So, there are two things that are adding more individuals into this population. You will have births so, if you have births, then the population increases. If you have emigration, so animals are coming from outside so, here also the population will increase. And then, there are two things that are taking individuals out of this population will have deaths which will reduce the number of individuals that are there in the population and you also have emigration, which is the moment of animals outside of this population.

So, if you do these computations, if you have this population Pn, you figure out the number of births the number of deaths, the number of animals coming in and the number of animals going out, you can figure out the population which is there in the next generation which is P n plus 1. Now, in our case we are not just interested in knowing the number of animals, but we are interested in knowing the weight of the stock; the tons of whales that we are removing from the oceans.

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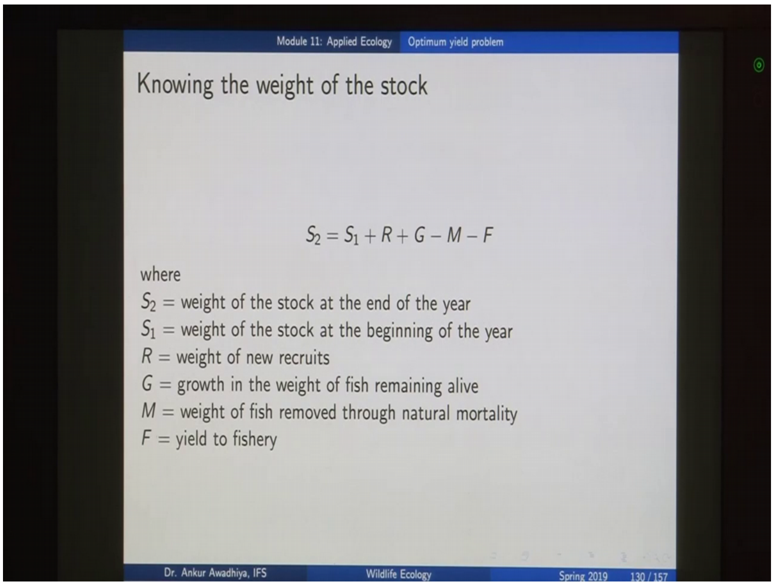

Now, in this case the equation becomes slightly more involved. Now, here we say that if the weight of the stock at the beginning of any year. So, let us say that our year is from January to December. So, in January of 2019, let us say that the total biomass of all the whales that was there; that are there in the oceans is S 1. Now, if we look at the biomass that is available at the end of the year that is in December 2019, it will be given by S 2. Now, what is causing this change, if there is any change, what will be the reasons that will cause this change?

So, the first thing will be recruitment. Now, recruitment in this case refers to not just the births, but also the weight of all the animals that have been incorporated because of these births. Even in the case of Pn, we have shifted it to S, where S is representing the total biomass that is available. So, you have S2 is equal to S1 plus R because there are some animals that are born and these animals are also gaining some weight.

Now, this would also in include plus G, now G is the growth of the individuals that are already born before the start of January 2019. But then, through this period through the through is complete year from January to December, the organisms that are already there in the population, they will also grow in size. Because earlier you have a calf and now that calf is moving to a sub adult; sub adult is turning into an adult and so on.

So, even in the case of this P n, there will be some amount of growth which is given by capital G. Now, there will also be some losses and the losses will be in terms of the mortality. So, if there is any death of these individuals and because of death some individuals are getting removed from the system. So, we will also remove that weight. So, in the case of these deaths, we are taking a minus M which is a minus mortality.

Now, in this case because we are considering all the animals which are there in the ocean or say all the fishes that are there in a lake. So, in this case we are not considering any immigration or emigration. So, both of these parts are not there, but then there is one other part that is leading to the loss of animals and which is the removal because of fishing so, which is minus F. So, this minus F is telling us the yield or the number of animals that we or the weight of the animals that we have removed in the complete year 2019.

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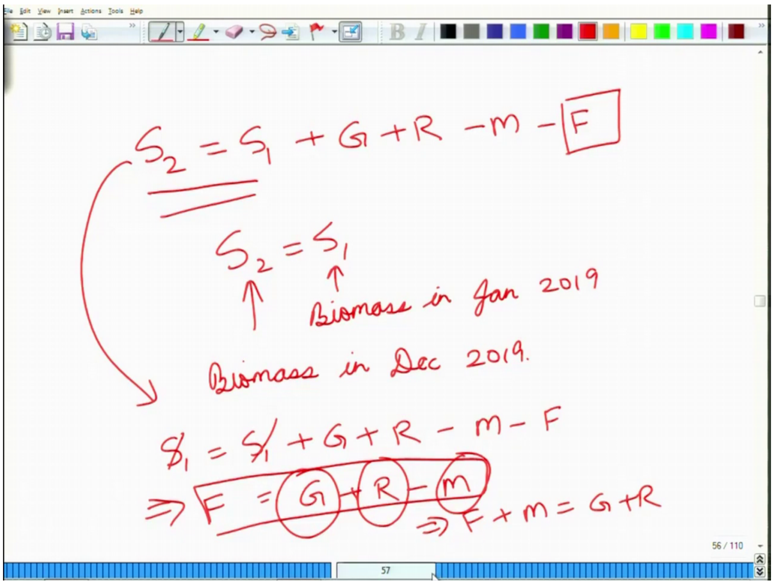

So, we can say that S2 which is the total biomass at the end of the year is S1 plus growth plus recruitment minus mortality and minus the amount that is taken out because of fishing. Now, if we see that we want to maintain a constant stock. So, for a constant stock that is we want that even in December 2019, we should be having the same biomass as was there in the, in January 2019; so there should not be any change. So, if there is no change, we will say that S2 is equal to S1. So, S2 is the biomass in December 2019 and S1 has the biomass in January 2019.

So, throughout this year, there has been some growth, there has been some recruitment, there has been mortality and we are trying to compute the amount of F that can be there. So, we want to have the maximum amount of yield because of fishery and still we want to maintain that S 2 should be equal to S 1. Now, if that be the case, we will have the equation S 2 is equal to S1. So, S1 is equal to S1 plus growth plus recruitment minus mortality minus fishing.

So, S1 and S1 cancel out. So, here we will have the yield or the total biomass of the animals that we can remove throughout the year will be given by the growth in the population that is the growth in the biomass of all the animals that are already there plus recruitment which is the new animals that have been born and they are also growing minus the number of animals that are dying out naturally or we can say that F plus M is equal to G plus R. So, essentially this is the equation that we can make use of if you want to calculate the total amount of biomass that we can remove sustainably. So, F plus M is equal to G plus R Now, so far so good, but then how do we compute what is the value of G; what is the value of R; what is the value of M. So, that is something that needs to be computed. Now, let us look at one simplification.

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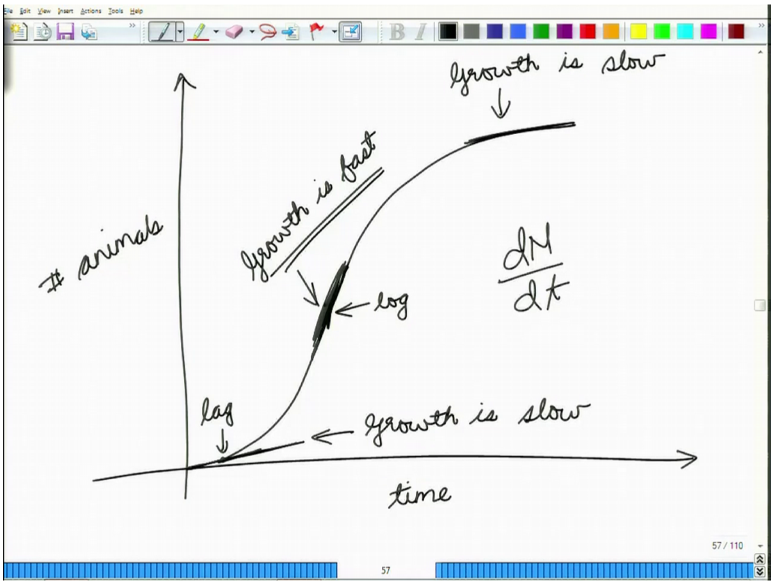

Now, that simplification as if we do not consider the growth of animals and if we just consider the number of animals and if we see that every animal has an equal mass. So, in that case the we can make use of the sigmoidal curve. So, here you have the number of animals versus time. So, we had seen it earlier in population ecology. So, when you have a very small population, it grows at a very slow phase; so here we have the lag phase. Then, at this in this part you have a logarithmic phase. So, we call it a log phase and then here we are reaching a steady phase.

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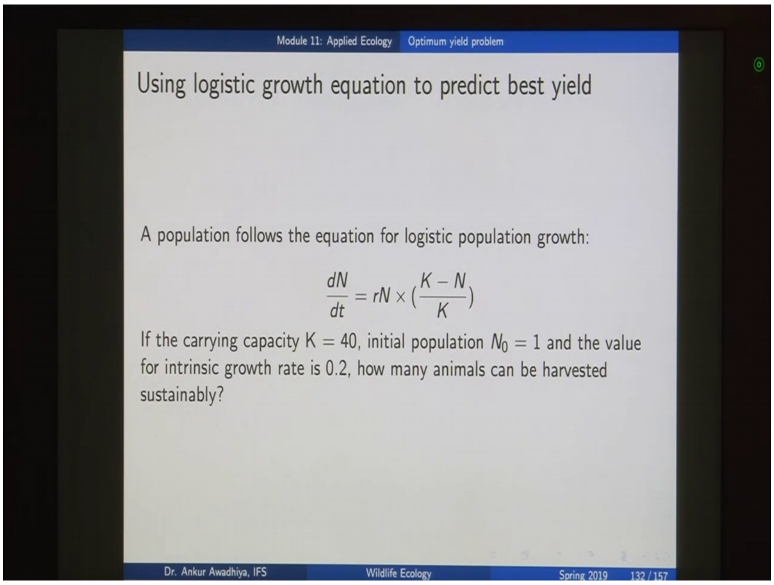

And we are also seen the equation or the logistic growth equation which was d N by d t is equal to r into N into K minus N by K, where K is the carrying capacity; N is the number of animals that we have and r is the growth rate. Now, if we take the simple example and if we say that we are only interested in the number of animals that we can remove. So, the question will be if the carrying capacity is say 40 and the initial population has 1 and the value for the intrinsic growth rate is 0.2; how many animals can be harvested sustainably or at least when should be remove the animals?

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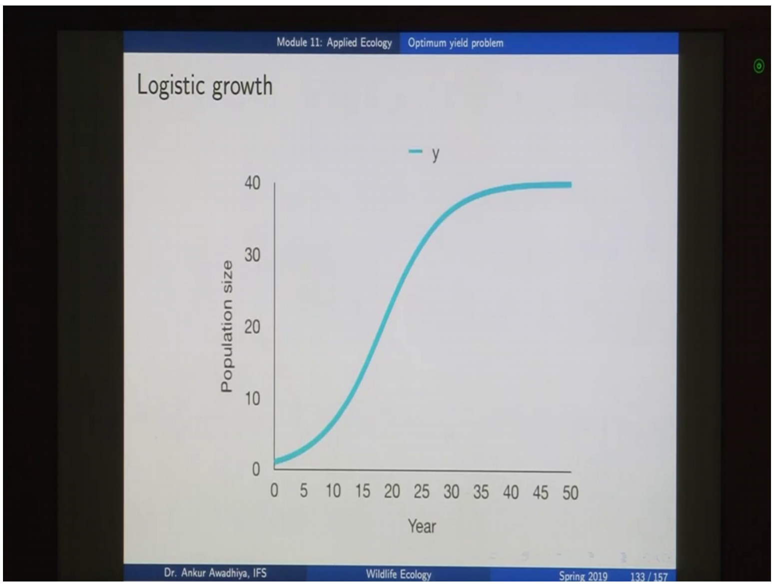

So, if we plot this equation, this is what we get. So, if K is equal to 40. So, this curve will becomes stable or say parallel to the x-axis near the value of 40 and we are seeing this growth phase. Now, if you want to take out the maximum number of animals, so in that case you would want to take out the animals in a phase where there is the maximum amount of growth.

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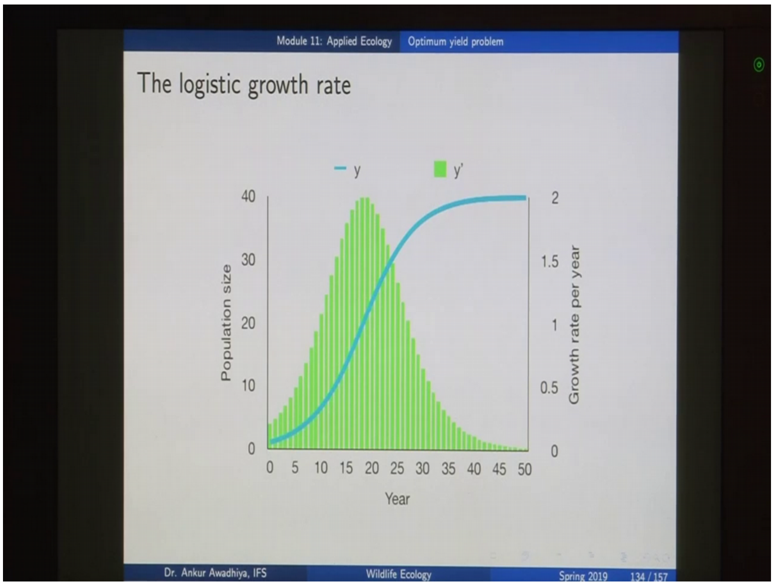

So, we can figure out the rate of change in this curve by plotting dN by dt. Now, in this case what we are saying is in this phase, the growth is slow. Now, the growth is slow in this case because you have very few number of animals. Again, at this stage, the growth is slow. Why is the growth rate slow here? Because the population is already very close to the carrying capacity, in this stage the growth is very fast because this is the logarithmic phase.

Now, if you have the maximum growth that is going on at this stage, then probably it makes much sense to remove the animals when your population is in this stage because when that is the case, so you will be able to extract the maximum amount of biomass or the maximum number of animals per unit year.

Now, if we plot this d N by d t, it will come up like this. So, this green curve is showing us d N by d t and of course, these are in different scale. So, this one is the population size and this is the growth rate per year. Now, when the curve; if you look at this portion. So, this portion has a very low growth rate. This portion has a high growth rate and this portion again has a very low growth rate. So, because it has flattened out so, here again the growth rate reduces. So, the growth rate increases and then, it reaches a peak and then it decreases.

Now, when you have this peak; so, at this peak, you have the maximum growth rate in this population. You are having maximum number of animals that are added into this population. So, probably if you can maintain your population at this point. So, you will have the maximum growth rate and you can take out these many number of animals every year.

So, for this particular question, if we do the analysis, we will have that the maximum growth rate is 2 per year and so, if your population is somewhere here you will be able to remove 2 animals every year. And this is when we are only considering that though that the number of animals has to be removed and every animal is having an equal weight. Now, in this equation, if we put in the weights of different animals so, we can get to a the computation of the yield.

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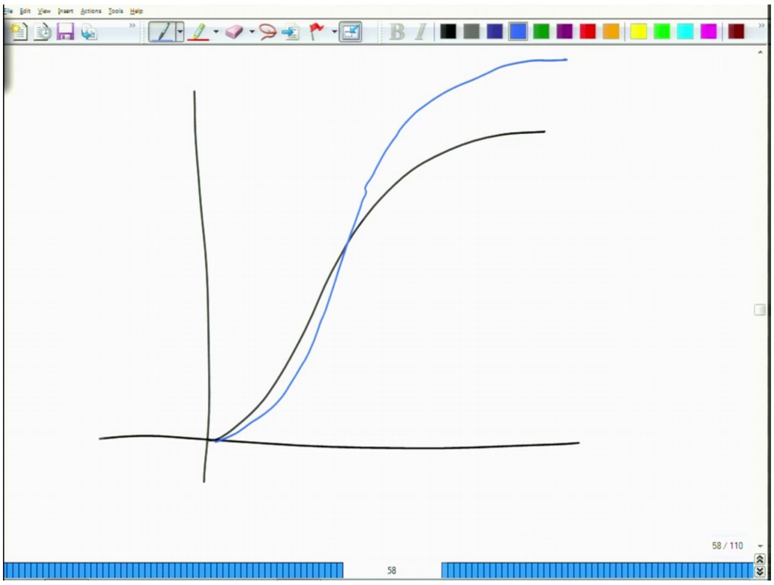

So, in this; in that case when you are having this growth curve so, probably when you are have reached this ad this section. So, you have a more number of adult animals. So, probably the growth rate will move something like this and you will have a curve that goes something like this; so again it can be computed by these methods.

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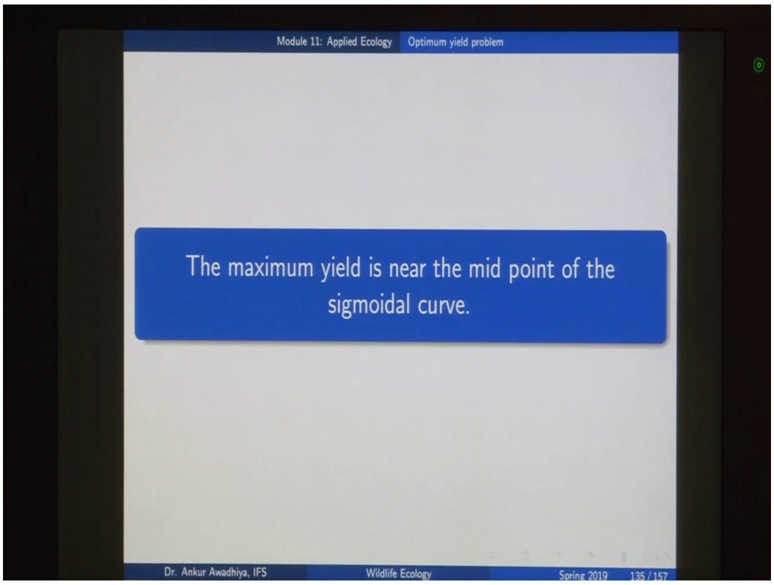

So, we can say that the maximum yield is near the midpoint of the sigmoidal curve, but then can we take out these many number of animals that is the next question. So, this is what we are getting by doing our computations that the maximum yield is 2 per year. So, we can take out 2 animals every year, but then can be infield in practice, can we take out these 2 animals, now that is the next question or is there something else that we have to be cautious about.

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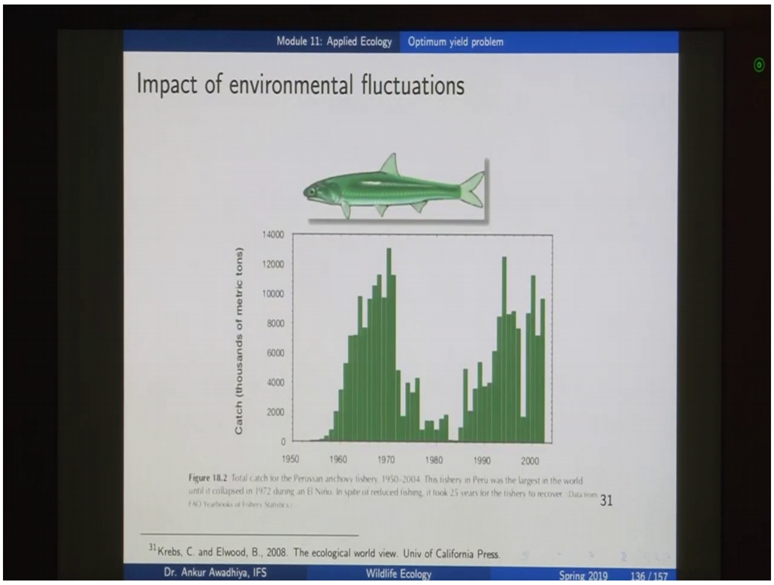

So, let us look at the impact of environmental fluctuations because so far we in the case of the sigmoidal curve, we were expecting that there is no environmental fluctuation.

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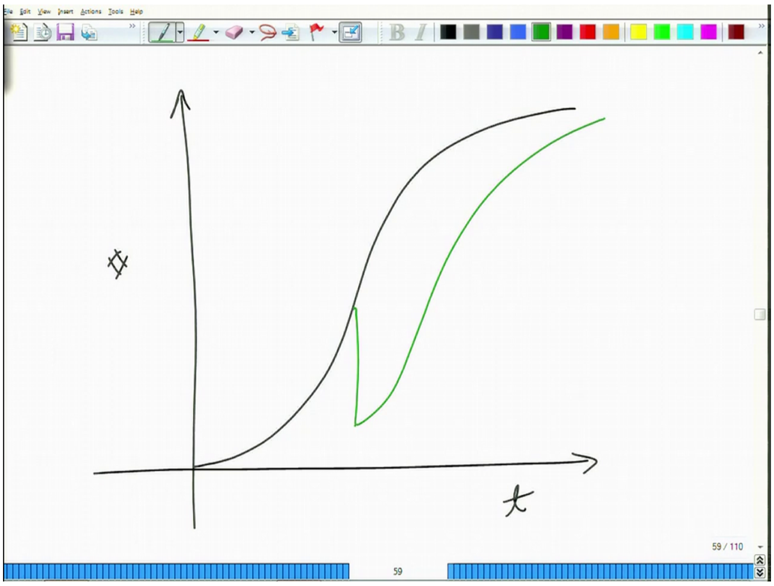

Or you have this population that has been put into an environment, where the only thing that it can do is to grow, is to reproduce and there are no external impacts. Because it is also possible that when you have reach this stage, probably there was a huge poaching because of which the numbers go down and then, they will have to again start that is also possible. But then, we are not considering those circumstances when we are doing our computations of the growth rate.

Now, in this is an example of the impact of environmental fluctuations. So, in the country of Peru, we have these anchovies. So, anchovies are fishes that were in huge demand and this is how you the catch varied versus way versus different years. So, here we have a catch that has been increasing and then in 1972, it crashed. Now, why did this population crash? The crash was attributed to a phenomenon that is known as El-Nino and I will come to it in a short while. So, this population crashed and once this population crashed, it took roughly 25 years to again reach to the maximum values.

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Now, in all the earlier curves, we were seeing that the catch had been increasing and then, you start having lesser and lesser number of animals and so, it gradually decreases in the case of animals such as the whales. Now, in the case of the anchovies, the population crashed here. So, it went right from this point to a very low value and then, it had to again start with another sigmoidal curve and it took a very long period of time as much as 25 years to again come to the peak value.

So, this is what we are seeing here the population has crashed and then, it again starts to grow and then, now these periods we can neglect these 3 years because in this case what we are seeing is that the population is crash, but still because people are very used to having a large quantity of fish. So, they are overfishing. So, this is not an example of an sustainable harvest, but then when the population has crashed, then it again starts increasing with a very slow rate and it takes roughly 25 years. Now, the first question is why can a population crash like this?

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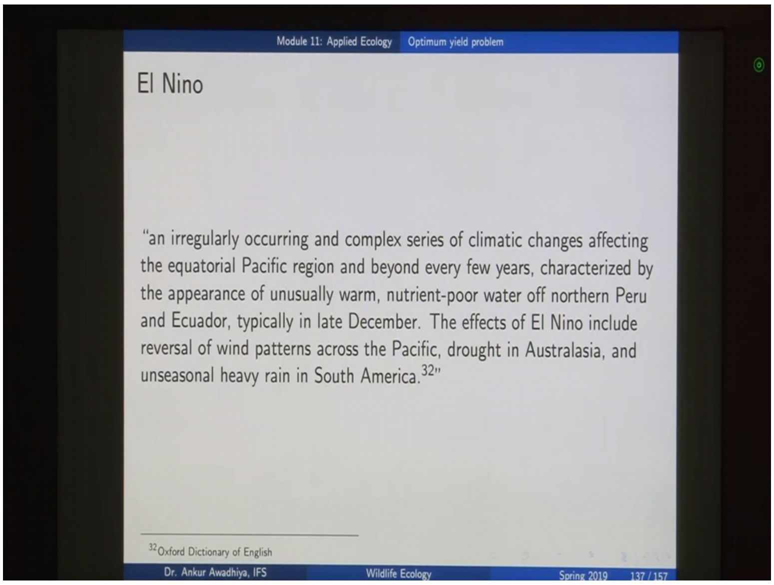

So, when it was attributed to El Nino; what is El Nino? El Nino is "an irregularly occurring and complex series of chemical changes of climatic changes affecting the equatorial Pacific region and beyond every few years and it is characterized by the appearance of unusually warm, nutrient-poor water off the northern Peru and Ecuador, typically in late December.

So, it is also called as the Child in Spanish because it comes very close to the Christmas time and the effects of El Nino include reversal of wind patterns across the Pacific, drought in Australasia, and unseasonal heavy rain in South America." So, this is a regular climatic phenomenon and what happens in this climatic phenomena is that you have warm waters that develop in the coast of Peru.

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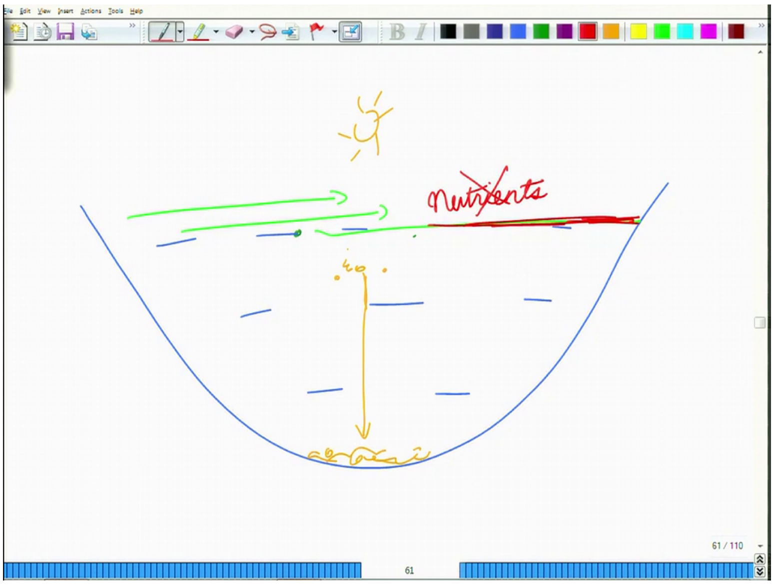

Now, we have seen earlier in the case of a energetics that if you have a water body. So, in this water body the photosynthesis occurs in the very top layer and for this photosynthesis, you require sunlight and you require the planktons plus you require the nutrients. So, nutrients are very important and we also saw in the case of primary production that most of the waters are nutrient poor.

Now, why are the of the waters nutrient poor because once you have these phytoplankton's that have come up. So, after a while they will start dying. When they start dying, so all their bodies they will come up and they will accumulate in the bottom of the water body and that will also take all the nutrients along with it downwards.

Now, what is the way in which we can have nutrients back up into the system, if there is say some amount of water moment that goes like this. So, you will have a system probably you have a system in which you have winds that are blowing in this direction. So, that is taking the top layer of the water away because of which you are having this upwelling and the upwelling is bringing cold in nutrient rich water to the top layer and once you have lots of nutrients here, you will have a plentiful growth of the phytoplanktons and these phytoplanktons will then serve as food for the fishes.

Now, in the case of these El Nino years what happens is that you do not have these vents; probably their direction changes and once that happens, you have the wind direction that is moving like this. So, it is bringing all the warm water to this area. So, let us represent it by warm water. So, this is the warm water that has now accumulated near Peru.

Now, if you have warm waters here. So, the cold water that was nutrient rich is not able to reach to the top and so, the nutrients that were there downwards, they are not able to reach to the top. So, it is characterized by warm water and it is characterized by nutrient poor water because of which you do not have a lot of planktonic growth in this area.

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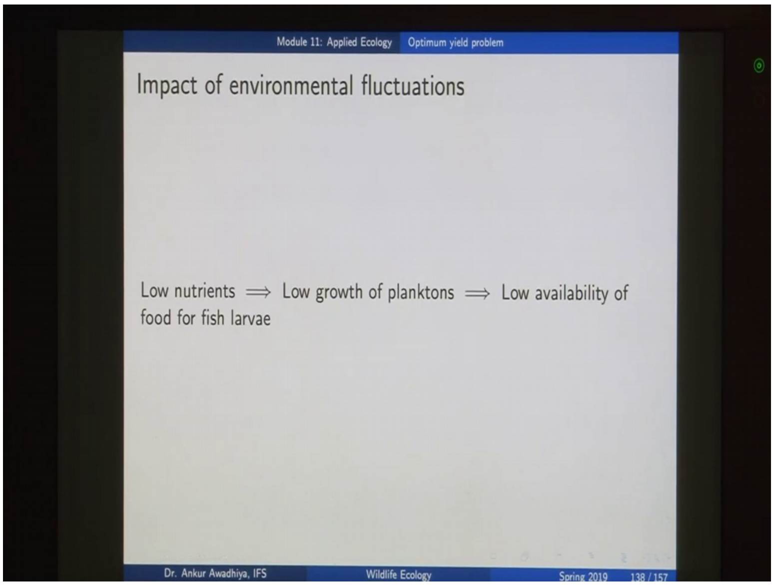

Now, if you have low nutrients and you have low growth of planktons, it also means that you have a low availability of food for the fish larvae.

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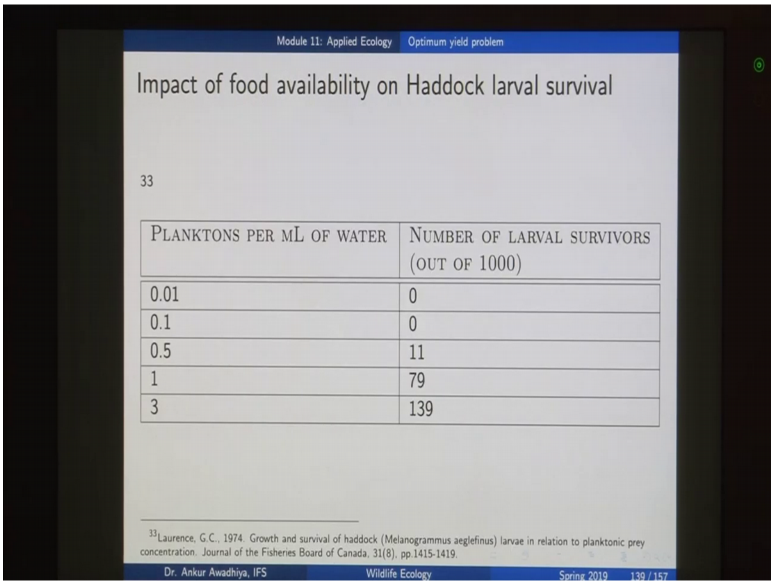

Now, there were some experiments that were done that if you take the larvae of Haddock. So, this is another phase this is not anchovy, but the experiments were done on Haddock. Now, in the case of Haddock, if you take the eggs and you let the larvae come out and you give them planktons at different amounts. So, different quantum of planktons are given. So, planktons per ml of water is 0.01, 0.1, 0.5, 1 and 3 and there are 1000 eggs and we are looking at the long term survival of these eggs.

If you have very less amount of planktons, all the larvae that come up they die because of a lack of food. If you have 0.1 planktons per ml of water again 0 larvae are able to survive. If you have 0.5 planktons per ml, you have 11 larvae that are able to survive. With 1 plankton per ml, you have 79 larvae that are able to survive. With 3 planktons per ml, 139 larvae are able to survive.

So, here we are seeing that if you are having more amount of food for the planktons, the number of survivors increases or conversely if you are having a less amount of food that is available to the larvae, there will be very less survival of fishes and this is probably what we saw there.

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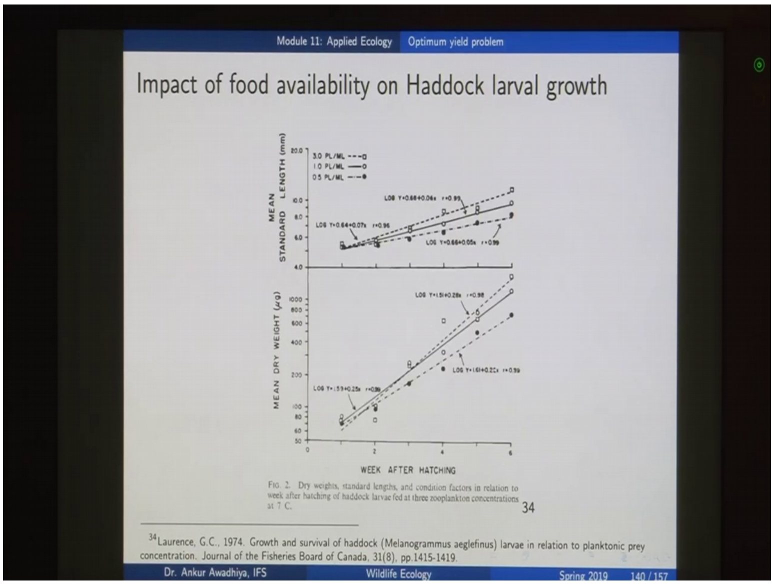

Also the larvae that are able to survive. So, in this case the experiment was only done up till three planktons per ml of water, probably you can also go with go with even higher amounts of food for these fishes. But it was also seen that if we look at the length of the larvae or the weight of the larvae that also show the very direct correlation with the amount of food that is available. So, if you have 3 planktons per ml, so that is this squarish graph. So, this is the; this top curve that is coming up, then 1 plankton per ml is the middle curve; 0.5 planktons per ml is the bottom curve.

So, if you give the larvae more amount of food, they are able to survive better plus they are able to grow faster, they are able to reach longer lengths now, in the case of El Nino because we had waters that were warm and nutrient poor. So, we did not have ample amount of planktons because of which the fish population crashed and once the fish population crash you did not have enough number of recruitments. So, the total number of fishes that could be captured or that could be harvested also dropped instantaneously which is why we are seeing a crash in the population.

Now, even when we were having this crash and this population had crashed like this, even then we were taking out a very huge amount of fishes from the waters and once that happened the largest sized fishes which were mostly the adults, they were still being taken out and once that happened, you had very few number of adults. So, that were left the larvae that were there were not able to survive because they were not having enough amount of food. They were not able to grow, they were not able to convert into adults and so, the population took a very long period of time.

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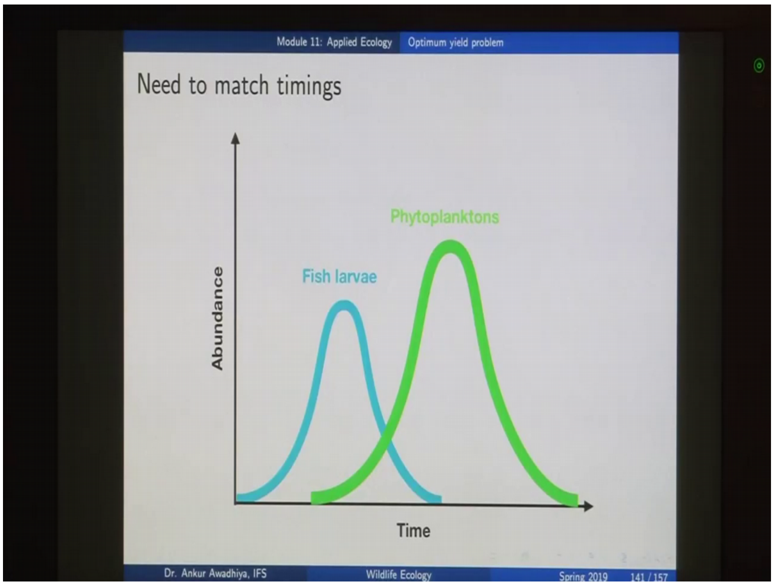

So, in the case of fishes not only do we have to take into account, the growth of the fishes, but we also have to take into account when do we have these planktons. So, there is a need to match these timings.

If you have these fish larvae and they come up at a time when you have an abundant amount of phytoplanktons. So, in that time they will be able to survive better they will be able to grow better, but if both of these curves are not matching. So, in that case you will have a severe mortality of the fishes, which brings us to this hypothesis that is known as the match mismatch hypothesis.

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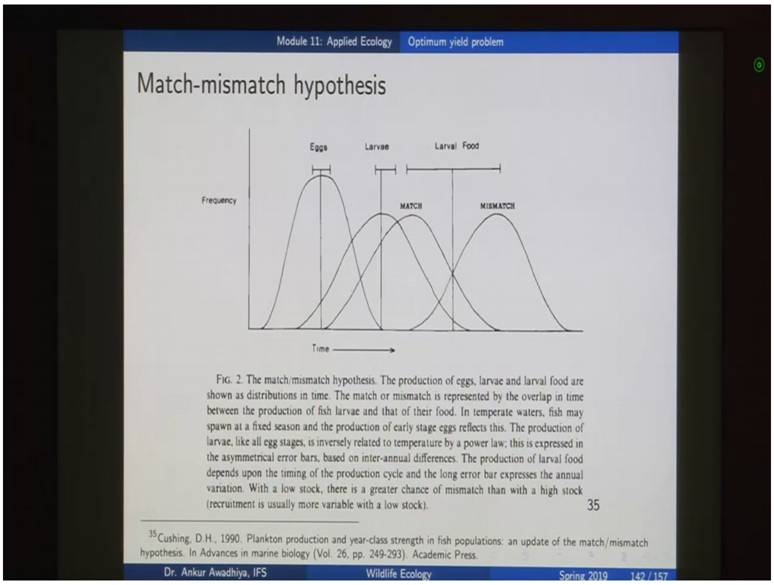

Now, on the x-axis here we have the time, on the y axis we are seeing the frequencies of different events. Now, if you look at the laying of eggs, different fishes do not lay eggs right at the same time, but there is some difference. So, there would be some fishes that startling eggs early. They would be with maximum number of fishes that lay egg at this point of time and there will be some fishes that will lay eggs at a later point of time. Now, why is that so, again because of variation that we see in different populations and also take into account the food availability at different time points.

So, suppose if we consider these fishes that are laying eggs earlier and if you are getting your planktonic growth at this point of time. So, probably all these larvae will die out, but then suppose there was a year in which this plankton growth occurred before this. So, all these larvae will be able to survive. So, nature has built in this mechanism so that at least some of the organisms are able to survive at all times. So, here we are looking at the variations in the timing of laying of the eggs.

Now, similarly when you look at the timing when the larvae are formed; so, these eggs will give out larvae at a at an earlier time these eggs will give out larvae at a later time. So, probably this is the curve where we are seeing the larvae and again, the peak of this curve will vary with time. So, you can have this peak that probably comes say in December or you can have this peak that comes in around 15th of November or it can come around 15 of December or it can come around 1st of December. So, you will have some variation in their time at which you will have this peak.

And here we are looking at the larval food. Now, the larval food can come at this time period or it can come at this time period. So, if it comes early so, there is a good match. So, this is your larval population, this is the food population. So, probably these larvae are not able to get enough amount of food, but then the maximum amount of larvae right from this point to this point will be able to get a plentiful supply of food. But then, if the growth of the planktons comes up here and there is a mismatch. So, from here to this point the larvae will not be able to get any food and only these larvae will be able to get the food.

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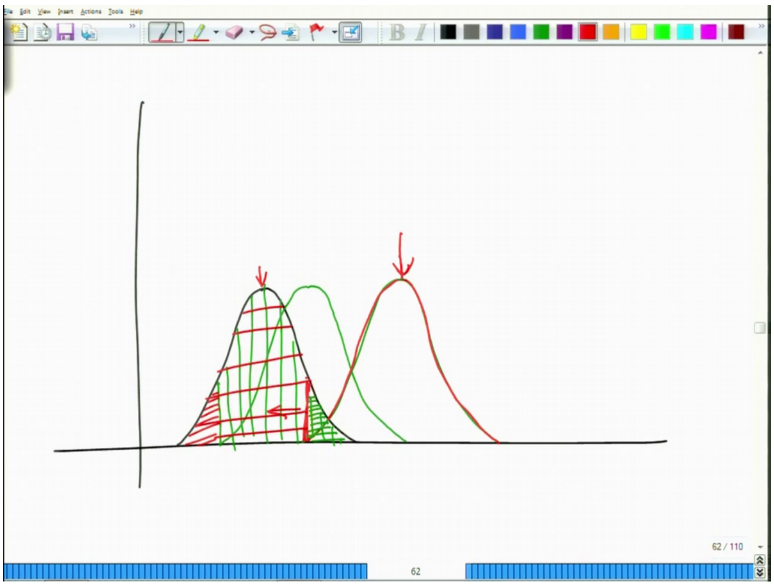

So, what we are referring to here is, suppose this is the curve of the larval of the larvae. Now, there are two instances the first instance is that you get of in the planktonic growth very early or the second instance is that you can have a planktonic growth after a while. Now, if the planktonic growth occurs early, so these larvae do not have access to the food in the early stages of their life. But all these larvae that are coming up later on they will have access to enough amounts of food. So, in this case they will be a bumper growth because most of the larvae are able to get sufficient amounts of food.

But then if the growth of the plankton is delayed so, there is a mismatch between this curve and this curve. So, in that case only these larvae are able to get some food from the very beginning and we will see survival only in this particular portion of larvae and rest all that is everything to the left of this line it will die off. So, probably all these larvae will die off, if the growth of the planktons comes up later and that is also one reason because of which you can have a crash of the populations.

So, again we talked about coevolution, coevolution is when you have two species that are evolving at the same time. Now, in this case the egg ling has to be matched in timing with the growth of the planktons so that the larvae as soon as they are able to come out of the eggs, they have a sufficient amount of food, but then if there is a mismatch and this mismatch is because of an environmental variation and the fishes do not know that this environmental variation is going to come in this particular year. So, there can be a mismatch and which can lead to a severe population crash.

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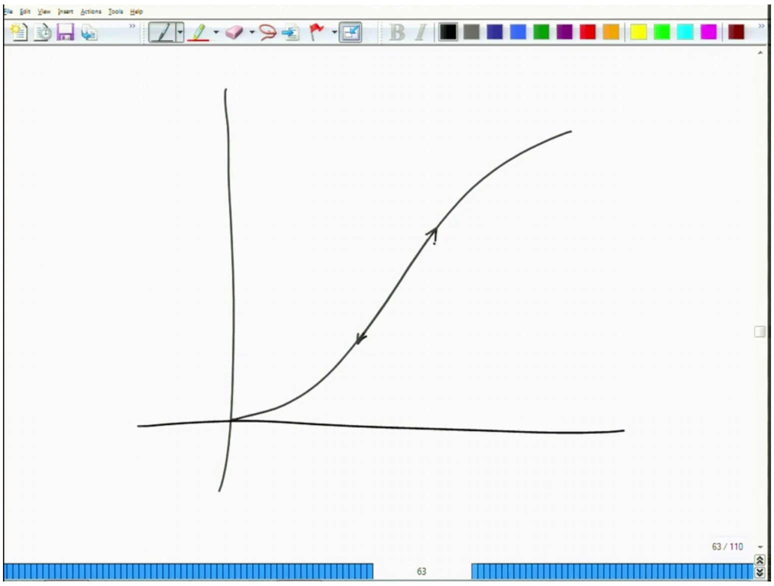

So, when we were talking about the removal of fishes in the log phase, we need to take into account that this log phase might not come at the same time always because there are also environmental variations. Now, apart from the ecological variation variability's that we need to take into account such as this match mismatch hypothesis; the other things that we need to take into account are things like tragedy of the commons.

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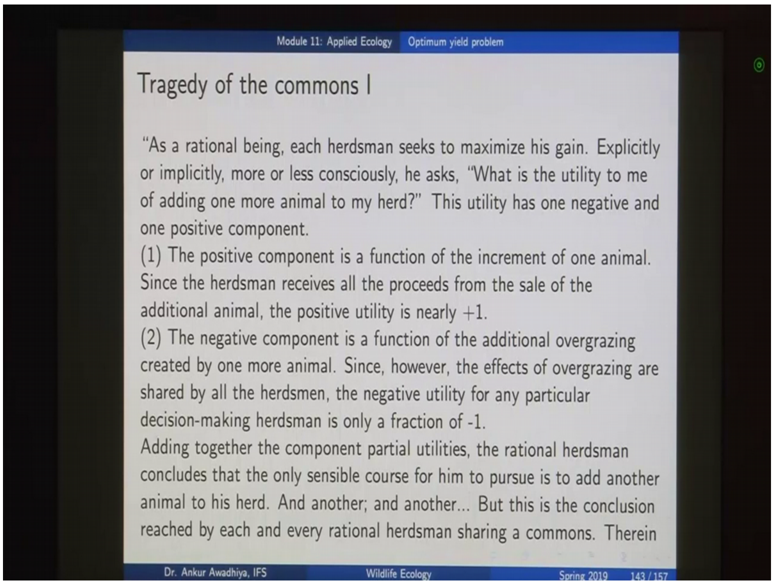

Now, tragedy of the commons is a concept that was given by Garret Hardin and this is an example that he has given in his paper.

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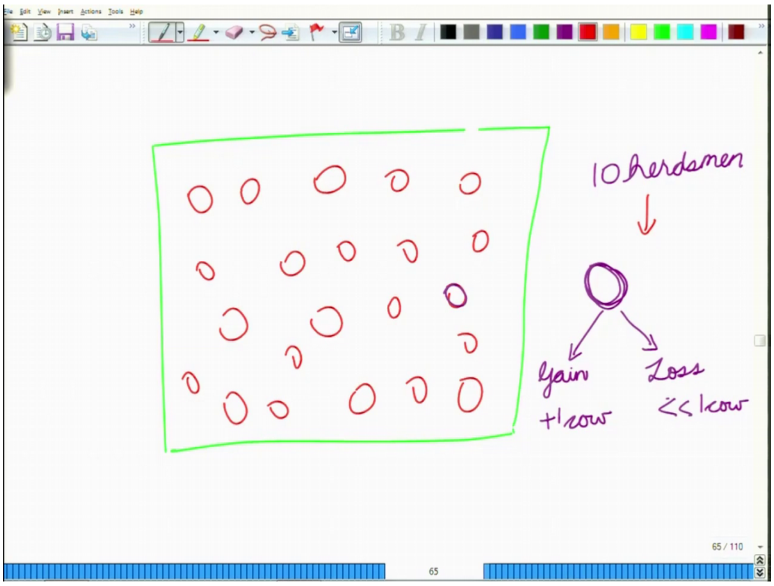

So, this example talks about an area, where you have a piece of grassland and on this grassland, you have say 10 herdsmen that are having their cows or their cattle and they are grazing their cattle onto this particular land. Now, the example of the tragedy of the commons is an example of how if everybody is acting rationally; rationally by their own thinking, it can lead to a situation and which becomes irrational for the whole of the community. So, the example says that if we have say this nine cattle that are there in grazing on this farm and if you look at the point of view of any single herdsmen. So, let us talk about this particular herdsmen and this particular herdsmen has see this cow that is grazing in this grassland.

Now, should this herdsmen have only 1 cow or maybe he should have 2 cows. Now, if you think from the point of view of this herdsmen, if he in place of having just 1 cow, if he increases his number of cows by 1. So, he will be able to gain the benefits that are coming from 1 extra cow that he is owning. But then if you have an extra cow which you are putting into this grassland so, that will be putting some more amount of pressure on this grassland because the grasses will not be sufficient for maybe 10 cows.

So, but in that case the loss that will be suffered by this particular herdsmen that will not be equal to 1. So, if we the gain is plus 1 cow and all the benefits that he will be gaining out of that cow; whereas, the loss is very much less than the value of 1 cow that he will be gaining because not only his cow will be getting less amount of grass, but everybody's cow will be getting less amount of grass. So, from the point of view of any particular individual, the most rational thing is that by looking at the cost benefit analysis he or she should have 1 more cow for himself or herself. But then if everybody tries to increase the populations of their cows, the grassland will not be sufficient for all the cows.

So, if in place of 9 cows, if we have more number of cows so, every cow is now getting less amount of grass and the productivity of every cow will decline. And at the same time you will over exploit your grassland to such an extent that they will not be any grassland left. So, if we go with his words- "As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks, "What is the utility to me of adding one more animal to my herd?" The utility has one negative and one positive component.

The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly plus 1. Because he is owning this animal and so, all the proceeds of this animal will come to this particular herdsman. On the other hand, the negative component is a function of the additional over grazing created by one more animal. Since, however, the effects of over grazing are shared by all the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of minus 1. So, it is not completely minus 1. It is only a small fraction because it is shared by a number of herdsmen and we see a very common phenomenon everywhere.

If you look at an industry so, the industry is giving out pollutants. Now, if the industry is manufacturing something, the profits of that industry go to the person who is owning the industry, but the losses that are being given out in the form of pollutants, they are being shared by the whole of the society. So, from the point of view of every industrialist, he or she would want to have as many industries as possible.

Even if it gives out pollution from the point of view of society, we should have less number of industries or maybe less polluting industries, but because every industrialist would want to have more and more industries. So, even though every industrialist is thinking rationally from his point of view and at it becomes a decision which is irrational for the whole of the community.

So, now in this case because the positive utility is plus 1, the negative is only a fraction of minus 1. So, added together the component partial utilities the rational herdsman concludes that the only sensible course for him to persuade is to add another animal to his herd and after one he will add another and another, but this is the conclusion reach by each and every rational herdsmen sharing a commons and therein is the tragedy.

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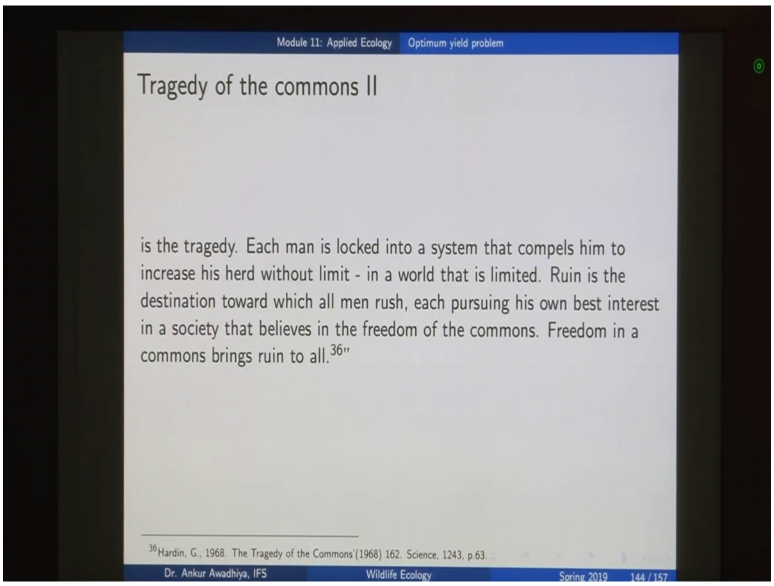

Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination towards which all men rush, each pursuing his own best interest in a society and believes in the freedom of the commons. Freedom in a commons bring ruin to all.” And we sits see the same situation in the case of fishing.

So, every fisherman wants to increase the share of his or her own catch because if the number of fishes in the ocean or the number of fishes in any water bodies if body effect goes down. So, in that case the negative consequences will be shared by all the fishermen that are there in this area, but the positives will only come to the particular fisherman who is doing the over catching.

So, it becomes a very rational decision for him and it becomes a negative decision for the whole of the society and then, in certain cases the convents also feel compelled to keep this process on and on. So, this is an example it is known as Ludwig’s ratchet.

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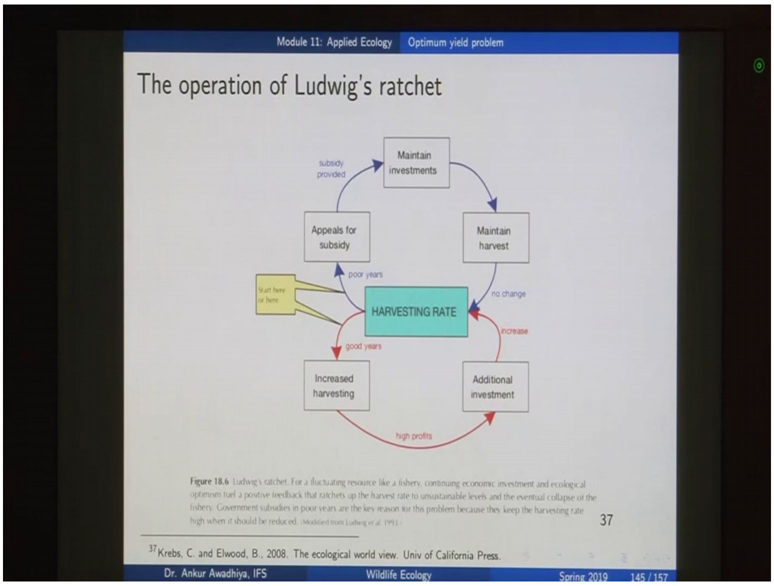

Now, a ratchet is a device that can move only in one direction and in this case we are talking about a situation in which everybody is compelled to do an over fishing. Now, let us look at this ratchet. Now, suppose this is the current harvesting rate and suppose you have a good year.

So, in the good year there is a very good match between the larval outcomes and a very good match with the amount of phytoplanktons that you have. So, you have larvae that are able to survive very well, they are able to grow very fast and so, you are having more number of animals or more amount of biomass that can be harvested. So, the because it is a good harvest. So, the amount that you can harvest will be greater than the current harvesting rate and so, everybody would want to have an increased amount of harvesting.

So, probably if you were having one 1 boat, probably you would want to go for two boats because there are more number of animals that you can catch. So, why not take them out? And then, because of this increased harvesting, there is higher amount of profits; higher amount of profits brings in additional investment. So, from 2 boats you see take 3 boats, 4 boats and then when you have these increased number of boats. So, if you were having only 1 boat you could only harvest say 1000 fishes in a day. If you are having 4 boats now, you can harvest 4000 fishes per day. So, the harvesting rate increases.

Probably if you have another good year from you are able to harvest even more number of animals, you get even more profits, you invest even more into your resources and in place of having 4 boats now you have 10 boats. Now, because you have 10 boats, you harvest again the harvesting rate again increases, but then after a while you will have a situation where the number of larvae that are there it would reduce because it is not a good year anymore.

Now, if it is a poor year. So, as a fisherman you would tell the government that see I am having 10 boats and we do not have so many amount of fishes. So, I will be ruined in a short while. So, I need to have access to some subsidy. So, this is what we are seeing in the case of farmers; this is what we are seeing in the case of fishermen; this is what we are seeing in the case of even the industrialists, whenever there is a lean time people tend to ask for subsidies. Now, consider a situation that would have happened in the normal case in an ecosystem.

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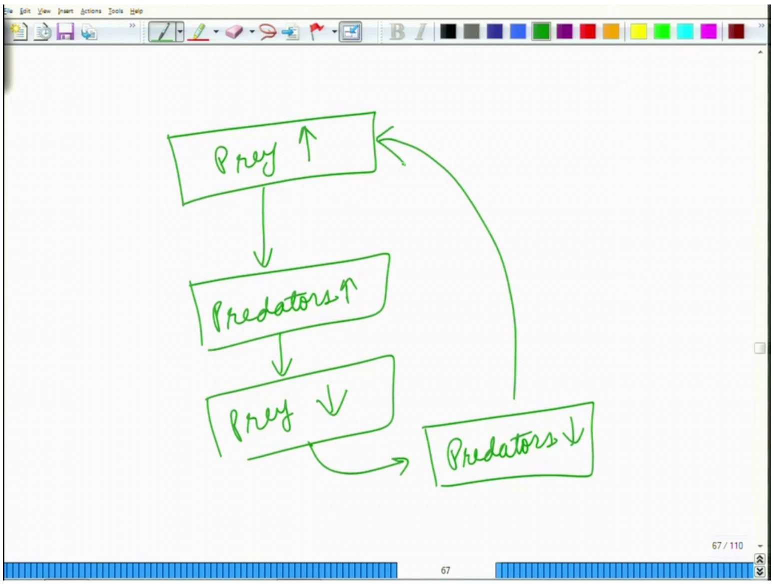

So, in an ecosystem say that if you have an ecosystem in which you have prey and you have the predators. Now, if the prey number increases; now prey number increasing is the same as your good news here or the good amount of harvest year. So, if you have more amount of more number of prey that would lead to more number of predators. So, the number of predators also increases.

In this case the number of predators increasing is the same as the additional investment, you are having more number of boats. Now, when you have more number of predators, they would be taking out more and more number of prey. They would be feeding on more and more number of prey so, this is what we are showing here. So, you have more number of prey day of prey. So, you increase the number of predators which now increases the harvesting rate of the prey.

But then, because you have this system in nature, the number of prey would then go down because you are taking out the prey in a number that is greater than their growth rate of the population. So, once that happens, the prey number would reduce. Now when there is a reduction in the prey number that is similar to a poor year. Now, in the poor year because you have less number of prey that would lead to a decrease in the number of predators.

Because the predators now do not have access to enough amount of food and when your predators do not have access to enough amount of food, they will not grow at that faster rate. Their population will come down, there will be mortality because of mortality when you have a reduced number of predators, the number of prey would then increase and then, we will have this cycle that goes on again and again.

Now, in the case of our human systems, we are not allowing this number to go down. So, if your investment increased in a good year, it should decrease in a bad year, but then the investment does not decrease because you apply for a subsidy and once you get the your subsidy, you are able to maintain your investments.

So, even in very bad years you are able to maintain 10 boats and once you have your 10 boats, you will again be doing more and more amount of harvest, but then you do not have enough number of fishes out there to harvest. So, what will happen? You will push the fish population towards a crash. So, this is known as Ludwig's ratchet because this only tends to increase the rate of harvest. Even in a good year, it tends to increase; in a bad year also, it tends to increase or at least keep it at the same rate.

Now, some people would argue that this is the situation, but then we need to have more and more amount of fishes. So, is there any way out can we look at it ecologically.

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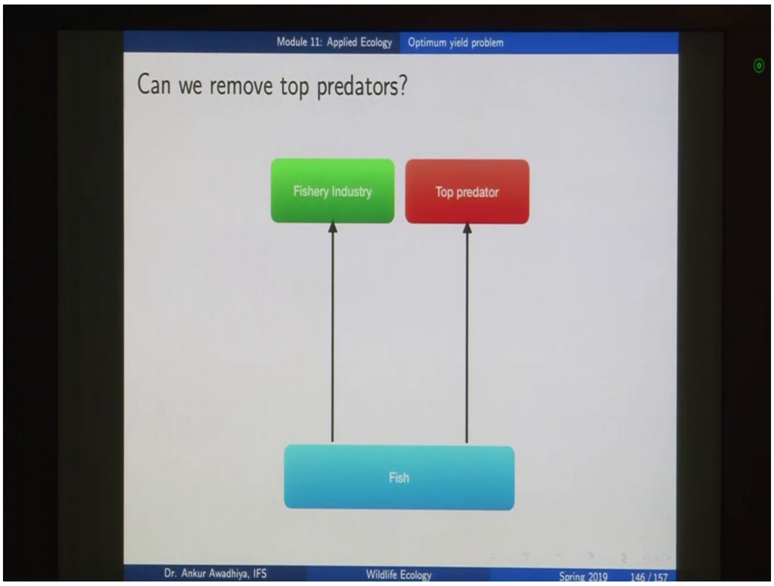

And then, some people have come up with this sort of a solution. So, you have some fishes that are there in your oceans you are taking it out in the form of the fishing industry and there are some top predators that are also fishing. Let us say that you have some big fishes that are eating up the small fishes. So, why not kill all these big fishes; why not kill all the sharks; why not kill all the whales because if you are able to remove the whales from the system, your number of fish fishes would increase and so, you will be able to get more amount of fishes for your industry and that looks like a very logical argument. Ok, you remove the top predators; if you remove say the tigers that are there in a forest the your chital population will go up.

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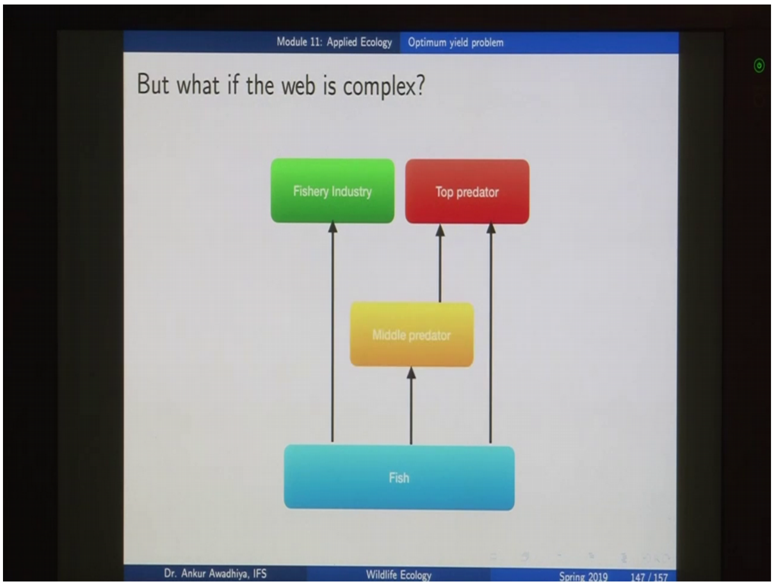

But then we have seen in the case of a number of eco systems that are systems are not simple they are complicated. Suppose this top predator also feeds on a middle predator what will happen now? If you remove this top predator, the middle predator will increase in its numbers. Once your middle predator increases in number, the fish population will go down, because it is not so having a much greater amount of predation pressure. And this is something that we have seen in the case of trophic cascades; so, if you remove your top predator the middle predator increases, the next one goes down after that one will increase and so on.

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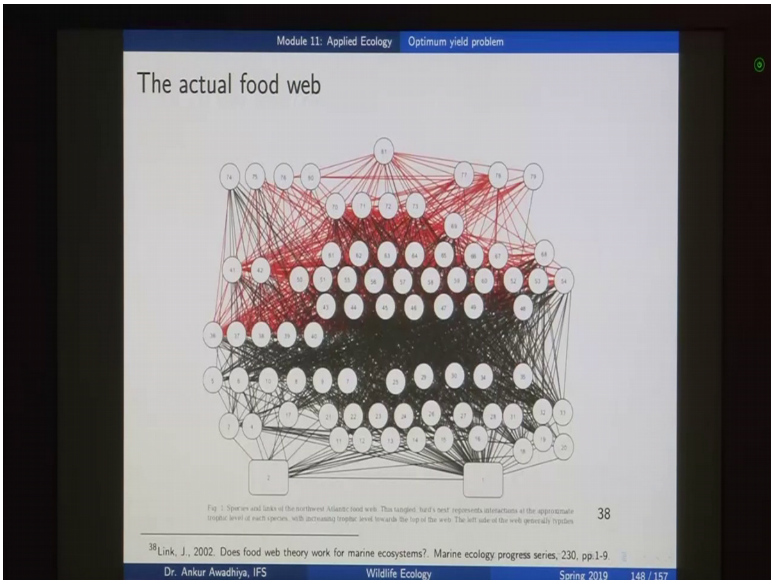

And if you look at a number of our food webs, this is what is the situation. The actual food webs are so complicated that you cannot have such a simple solution. What about the impacts of sizing.

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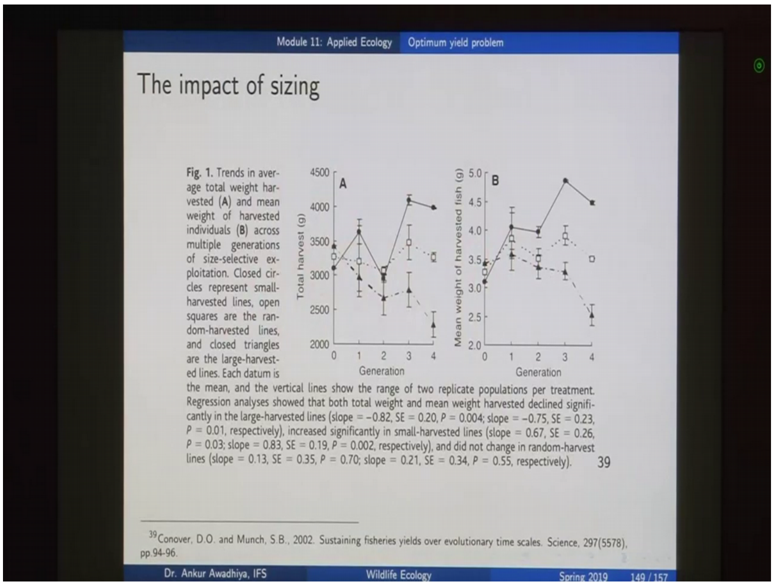

So, somebody would say that we should only remove those fishes that are large in size and for those fishes that are small in size. So, we if there are any young ones, if there are small size fishes, we should not take them out that looks like a logical argument that only of the daddle fishes are big sized fishes, if we remove only the adults so, the young ones will be able to grow. So, this was an experiment that was done and we looked at four different stages or four different generations of fish and so, there were fishes that were kept in a tank and then these fishes were harvested using one of the three ways.

In the first way, you removed all the smaller fishes. So, if you remove the smaller fishes the bigger fishes are able to survive and so, their genes are able to be passed to the next generation and in this four generations you see fishes that are larger in size from what you had started in. On the other hand, if you have the fishing in the normal logical way that you are only removing the last size individuals.

So, only the small individuals are able to survive. Because the larger ones have been removed from the system and so, the population tends to become smaller and smaller and then, this is the impact of the random fishing. If you have a random fishing it more or less remains parallel. So, your total harvest remains the same, but if you go for a size based selection, if you remove the smaller fishes you have you have the harvest that goes on increasing every year.

If you remove only the larger fishes the your harvest goes on decreasing every year and that is the same with the total harvest as well as the mean weight of the harvested fishes. So, now, this is something that we need to take care. So, there is now very simple answer to managing of these sustainable resources.

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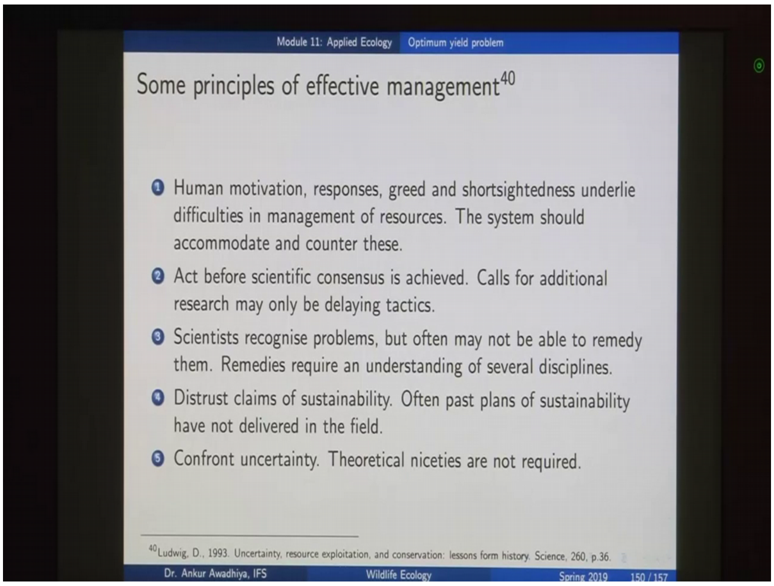

But the only thing that we can say is that whatever system you are proposing, you need your system need to take into account the human motivation, responses, greed and short sightedness that is bound to be there; no matter what is the system that you are proposing. You need to act before a scientific consensus achieved call for additional re research may only be delaying tactics.

So, if you are seeing that your population is decreasing, you will have to act you cannot just wait for more and more scientific findings. Because scientists can recognize the problems, but they often may not be able to remedy them because remedy requires an understanding of several disciplines; even when we are talking about the sustainable harvest of a natural resource, we need to take into account psychology, we need to take into account, economics, finance and a number of other things.

Distressed claims of sustainability, often past plants of sustainability have not delivered in the field. So, this is not a new field and we have seen that so many populations have already crashed. So, we need to distressed any claims of sustainability, we always have to be on the lookout for newer methods and you need to confront uncertainty. Theoretical niceties are not required and you have to take different steps once you a come face to face with any problem.

So, this is the in short what we know about the sustainable harvest of resources. So, that is all for today.

Thank you for your attention. [FL].