Wildlife Conservation
Dr. Ankur Awadhiya
Department of Biotechnology
Indian Institute of Technology, Kanpur

Lecture - 28
Population viability analysis

[FL] In today's class we will have a look at Population Viability Analysis or an analysis of the viability of a population.

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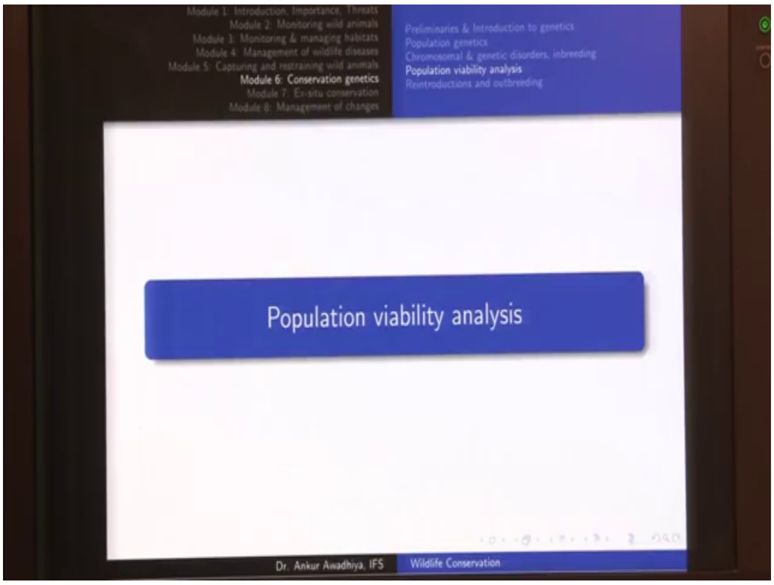

Now, population has we have seen before is a collection of individuals of the same species that are residing in the same area that are interbreeding amongst each other and that are separated from any other such similar group of species.

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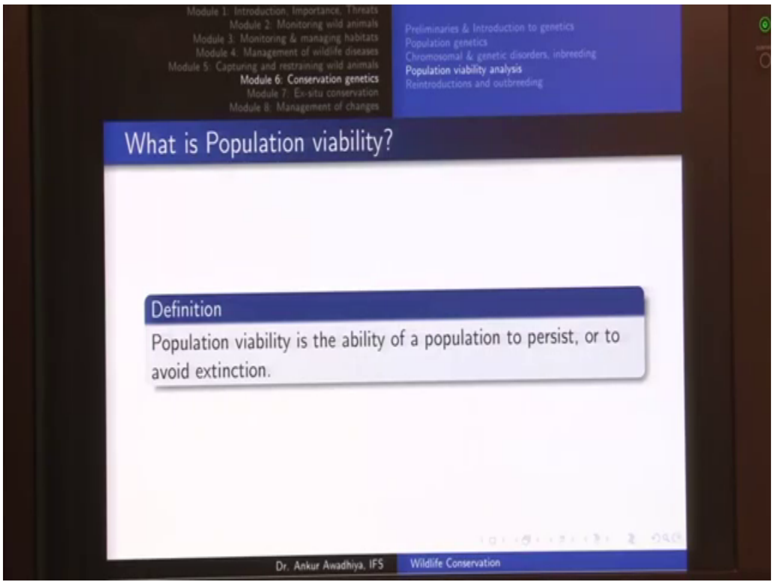

So, let us begin with population viability. So, when you say population viability what do you mean population viability is the ability of a population to persist how to avoid extinction. Now, what we are asking here is that suppose you have see around 10 tigers and (Refer Time: 00:54) tiger reserve. So, if we have these 10 tigers when these 10 tigers be able to persist for a long period of time will they be able to avoid extension or when they will go extent in short while. So, population viability analysis is an analysis of the viability of the population, so an analysis of whether or not this population will be able to persist or not.

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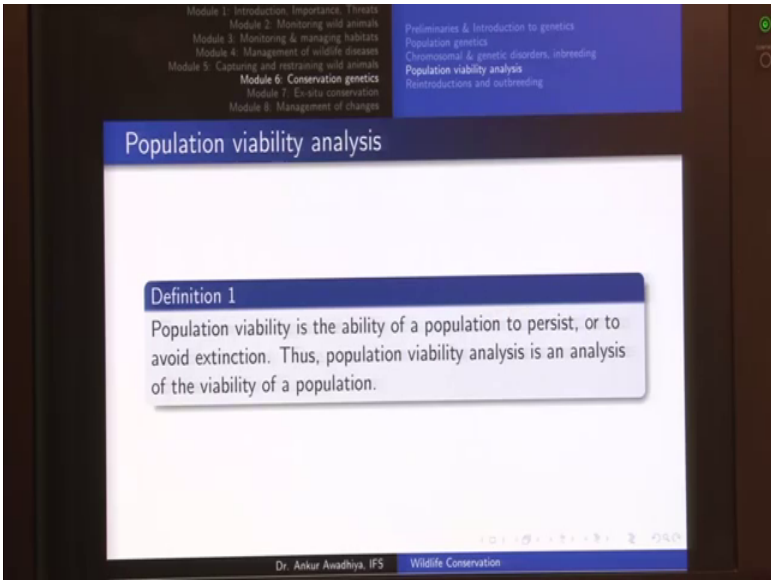

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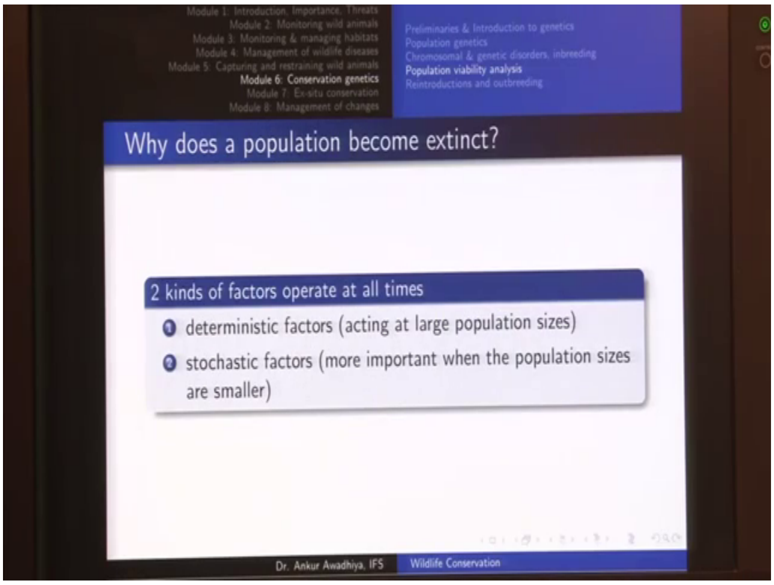

Now, why do you need to perform such an analysis? So, we have seen before that populations can become extinct because there are two factors operating at all times that could lead to the extension. These are deterministic factors and stochastic factors; deterministic factors that act at large population sizes and stochastic factors that up chance factors acting at smaller population sizes.

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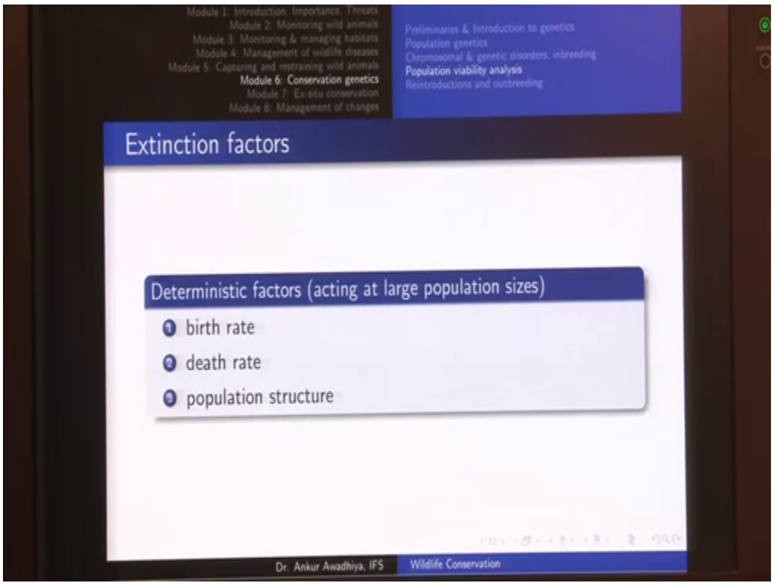

Now, to recap we have these 3 deterministic factors birth rate, death rate and the population structure. So, if your death rate is greater than birth rate than the population might become extent or if the population has comprising only of very old individuals and then also it may be moving towards an extension.

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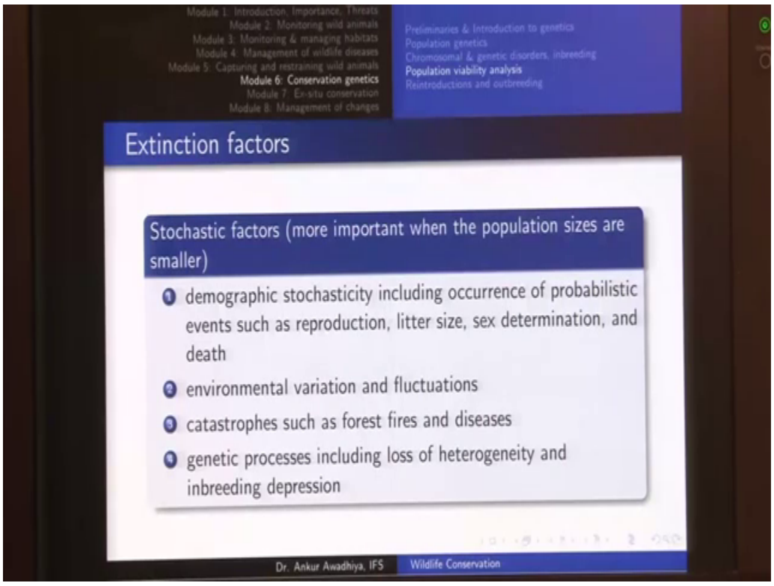

Whereas, in the case of stochastic factors or chance factors we saw that we have demographic stochasticity factors including the occurrence probabilistic events such as reproduction, litter size, sex, determination and death. So, this means that probably that even if you have a very small death rate we could have a situation in all the adults died off in certain time period or probably all the breeding individuals at a very small litter size or probably all the off springs that were bond happened to be believe. So, these are as stochastic factors that would be that would be working in the population sizes or smaller otherwise they would get averaged out and so, we would not be able to see this stochasticity.

The 2nd are environmental variations and fluctuations so, things such as temperatures of a droughts. The 3rd is catastrophes such as forest fires in diseases. Then genetic processes including loss of heterogeneity and inbreeding depression that could also be acting at very small population sizes because, all the individuals are now genetically related to each other.

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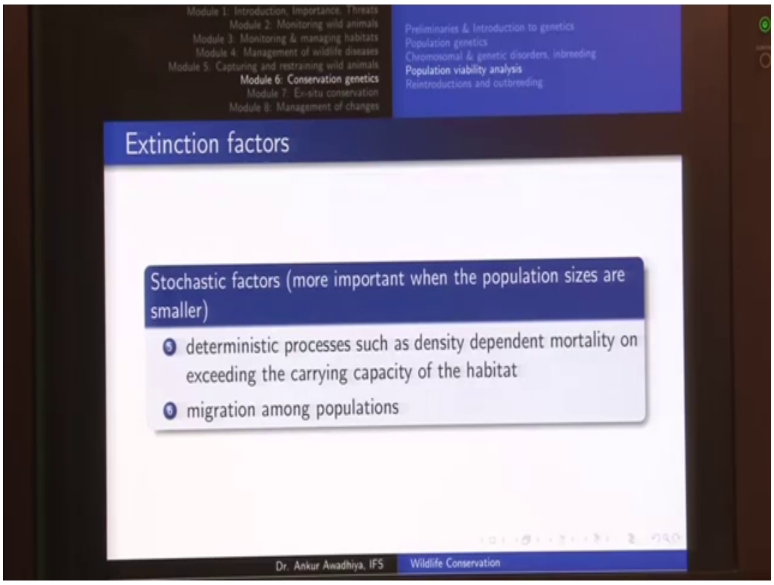

Or we could have some deterministic processes such as density dependent mortality on exceeding the carrying capacity of the habitat. So, if you have a habitat in which we have very small carrying capacity. So, carrying capacity will tell us the number of individuals that this habitat would be able to sustain. So, for instance if you have a tiger reserve and this tiger reserve is all full of say trees and only full of say wetlands, but it does not have any grasses. So, they would be a very less number of herbivores that this tiger reserve would be able to sustain and a less number of herbivores would mean less repopulation. We should also tell us that this tiger reserve would be able to sustain a very less number of tigers.

On the other hand if he tried to increase the carrying capacity of the habitat probably by say cutting of a few trees and converting some areas into grasslands, maybe also by training of some amount of the wetlands and converting those also in to grasslands in those cases the carrying capacity of the habitat would increase. So, it would be able to sustain more number of a herbivores and also more number of carnivores such as the tigers. And the last is migration amongst population, so, if there is a very small population and there are a few individuals that migrate out then whatever remains might not be able to sustain the though population and its own place.

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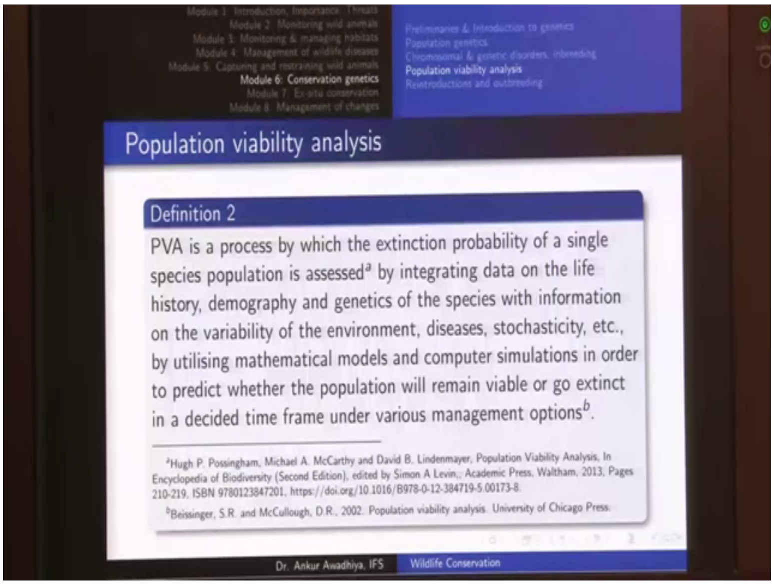

Another definition of population viability analysis is that it is a process by which the extinction probability of a certain species of a population is assessed by integrating data on the life history, demography, genetics of the species with information on the variability of environment, diseases, stochasticity, etcetera. By utilizing mathematical modules and computer simulations in order to predict whether the population will remain viable or go extinct in a decided time frame under various management options.

Essentially what this is trying to say is that we know what is the demography of the population, how many males and females are there, what is there age classification? You also know the life history of the population that is how long does an individual survive at what age do the individuals become productive, what is the little size you also know the genetics of the species, what is the level of homogeneity or heterozygosity that is present in that species.

We can also make some guess about the variability in the environment by looking at past data. So, for instance if we say that every 3rd year we get a draught, so we can make use of this information we can also look at the diseases that are prevalent there and how frequent do we get an outbreak of diseases, we can look at some other stochasticities.

And when we have all these information we can put these information into a mathematical model or a computer simulation. So, when all of these data are being fit into a computer simulation then we can use the simulation to predict whether this population will remain viable or go extinct in a decided time frame. So, essentially we could say that we have looking at population viability for see the next 100 years or say for the next 1000 years and with all these initial conditions will our population able to survive or not under various management options.

So, various management options could include harvest of some individuals or say supplementation of some individuals. Harvest means that we are killing of some individuals and then removing them for the from the population also our population does not go very close to the carrying capacity. Supplementation is a process in which we are bringing in individuals from some other area into our population so as to bring about a genetic rescue or to increase the population size. So, given all of these conditions we can use a mathematical model or computer simulation to predict what is going to happen and this prediction will be very important for our management interventions.

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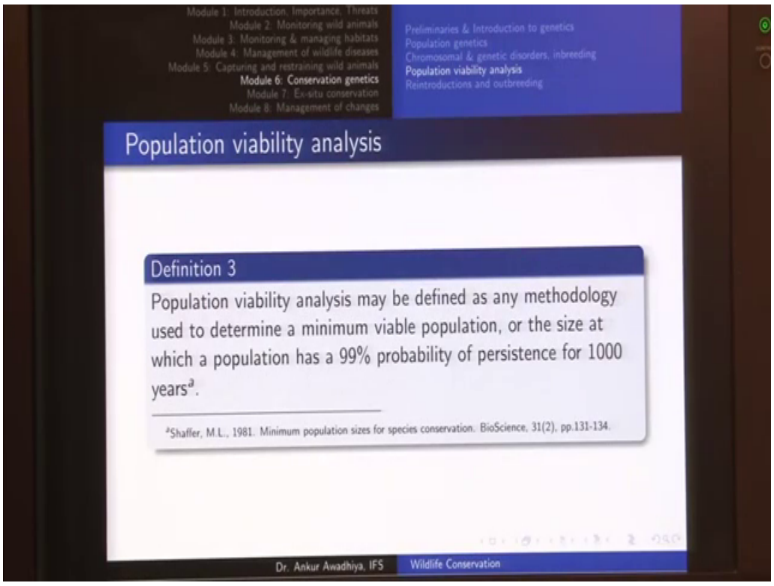

The 3rd definition says that population viability analysis may be defined as any methodology that is used to determine a minimum viable population or the size at which the population has a 99 percent probability of persistence for 1000 years. Now, in this case we are turning our earlier definition upside down we are saying that we are we will not start by saying that we have this much size of the population.

But, we are going to back calculate that if we have a time frame of 1000 years if we have are the survival probability of 99 percent. And given all of our other inputs that is the life history, the stochasticity, the rates at which the environment fluctuates and so on we will use all of this information to back calculate the minimum viable population that needs to be there in an (Refer Time: 08:03).So, essentially we could go or with this and both the ways.

So, in our previous definition, so in this definition what we could do is that we can start with say 4 individuals and with 4 individuals for the next 1000 years what is the extinction probability? If the extension probability is less than one percent or the survival probabilities more than 99 percent then we would say that that 4 individuals are enough.

But, then if the probability of survival for the next 1000 years is say 80 percent then in place of 4 individual we will go for 5 individuals, then this 6 individuals and so on. So, as to determine the minimum viable population that is needed to get to are decided outputs of 99 probability for 1000 years. And we look at it in more details when we going to the computer simulation in a short while.

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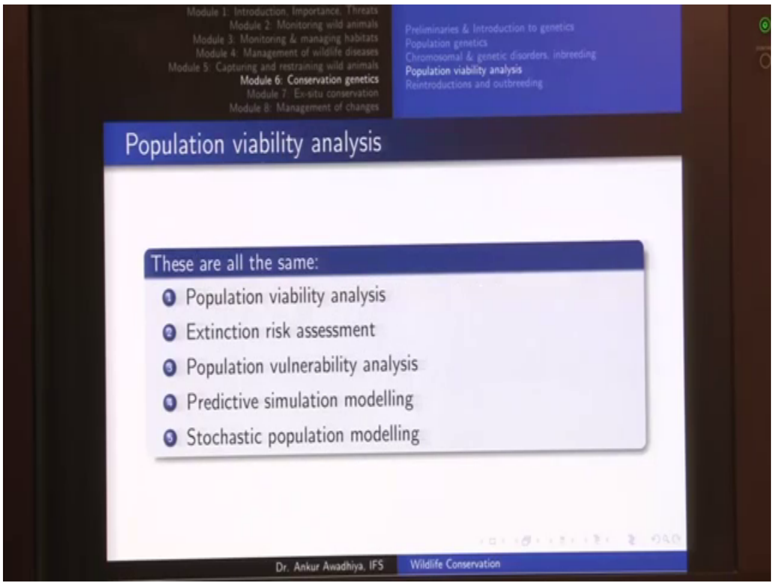

Now, population viability analysis also goes by a number of other terms such as extinction risk assessment. So, in this case we are trying to emphasize that we want to know what is the probability of the population getting extinct in a decided time frame? So, it is in extinction risk assessment it is also a population vulnerability analysis. Why that a vulnerability analysis?

Because we can thinker with our stochastic variables to see whether our population is more vulnerable to extinction because of poaching or our population is more vulnerable to extinction because it is reaching the carrying capacity or say our population is more vulnerable to extinction because of say in breeding depression. So, we can play with all of our parameters to understand which parameter is making our population most vulnerable to extinction. So, this is also another way in which this analysis can be used.

Next is predictive simulation modeling, so in this case we are doing a simulation and modeling to predict the future of the population. And next is this stochastic population modeling because we are using stochastic phenomena to model our population to understand how this population will behave in the next few years.

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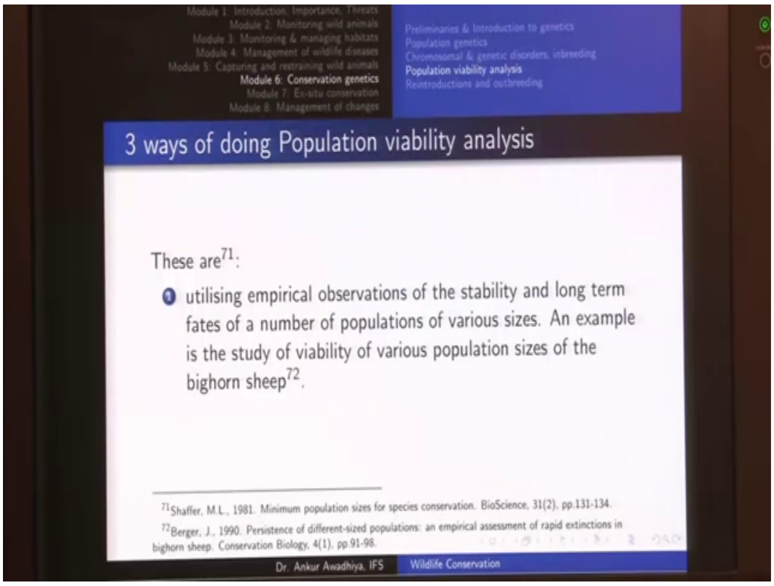

And there are 3 ways of doing population viability analysis; the first one is to use empirical observation. The empirical observation means that we are referring to the field observation. So, field observation of the stability and long term fates of a number of population of various sizes an example is this study of viability of various population sizes of the bighorn sheep. So, what we are saying here in the case of empirical observations is that we have a number of case studies from the field and in these case studies they are looking at a number of populations.

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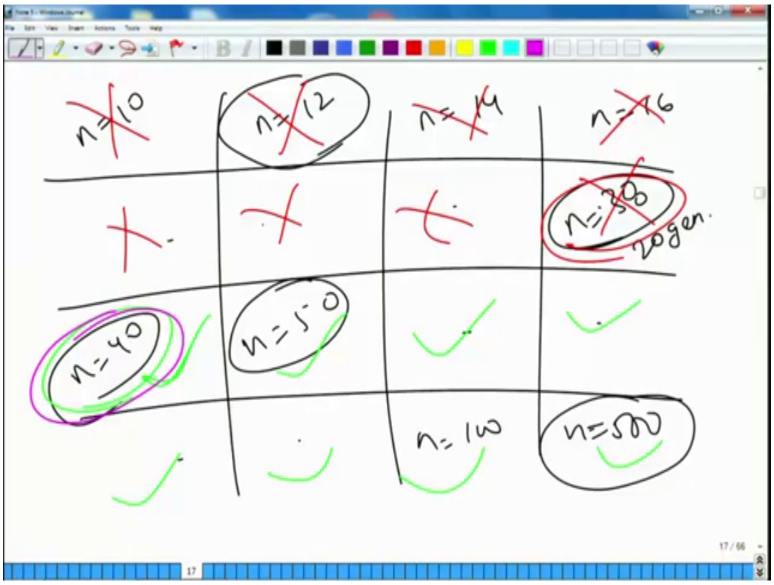

So, the first population is started with 10 individuals. There was some of the population that started with 12 individuals, 14, 16 and so on. See n is equal to 50, n is equal to n is equal to 100, n is equal to 500. Now, we have all of these case studies that we have been observing out there in the field.

Now, what were the results of these cases? So, in this instance there was a population of 12 individuals that was say deciding in one mountain top and this mountain top population was separated from all of the other populations. So, we started observing these populations and we saw that after 3-4 generation this population went into an extinction, because of say inbreeding. Then we also looked at some other populations we look at a population at 40 sizes.

So, we had 40 individuals on top of a mountain and this population was also separated from all the other surrounding population and we that say this population in able to survive for say 20 generations and even up to up to 20 generation this population surviving. And same in the case of the 50 individual population or 500 individual population so, we would say and say in the case of 38 individual population this population survive for say 20 generations and after that this population became extinct.

So, by using all of these empirical observations we would say that 10, 12, 14, 16 anything up to 38 dies off in 20 generations, but anything that is 40 or more it is survives. So, this survives, this survives, this survives, this survives and all of these survive.

So, in this case we would say that are minimum viable population is 40, because if we have 40 individuals then our population will survive for a very long period more than 20 generation or say more than 100 years more than or 1000 years. So, this is one way in which we are just making use of field information or empirical information to understand the viability of different populations sizes so, this is the 1st approach.

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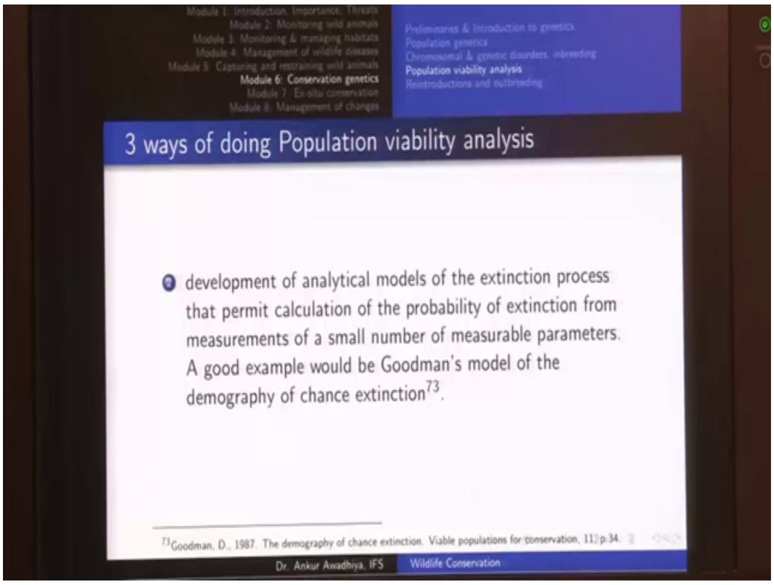

The 2nd approach is the development of analytical models of the extinction process that permit calculation of the probability of extinction from measurements of a small number of measurable parameters. So, an example is Goodman's model of the demography of chance extinction.

So, what you doing in this method of population viability analysis is that we are developing an extinction model, in analytical model or a mathematical model of the extinction process. So, we are doing some amounts of computations to develop a model which is a mathematical model and once you have this model. So, this model will be using a number of inputs. So, this is our model and in this model we are providing a number of inputs.

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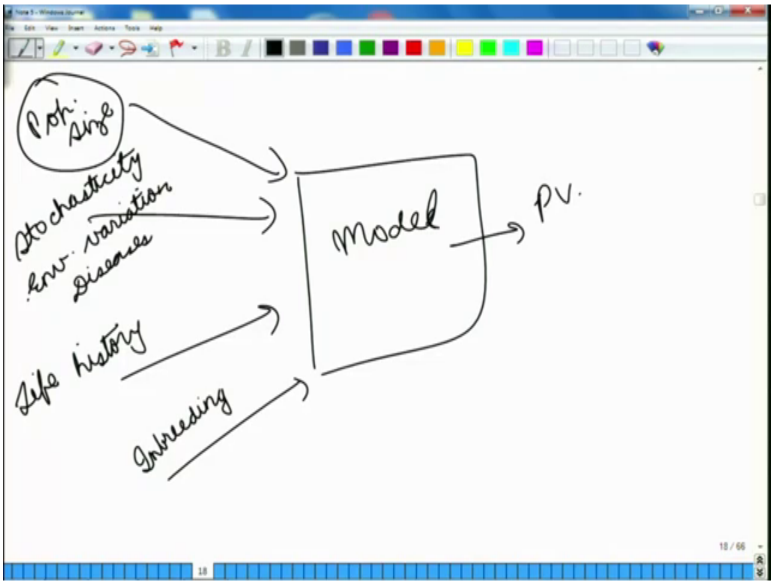

These inputs could be say population size or the stochasticity or this stochasticity would include environmental variation or say diseases. Then we could also include things such as the life history of the population which tells us the area at which at which individuals become reproductive, the litter size and so on or we could also include things such as the amount of inbreeding that is there in the population so, all of these are different inputs.

Now, we put all these inputs in a mathematical model and we understand the population viability for this population size of n for n number of years or 40 number of years which could be 100 years of 1000 years. So, in this second method we have development of analytical models of the extinction process that permits the calculation of population viability of the extinction possibility.

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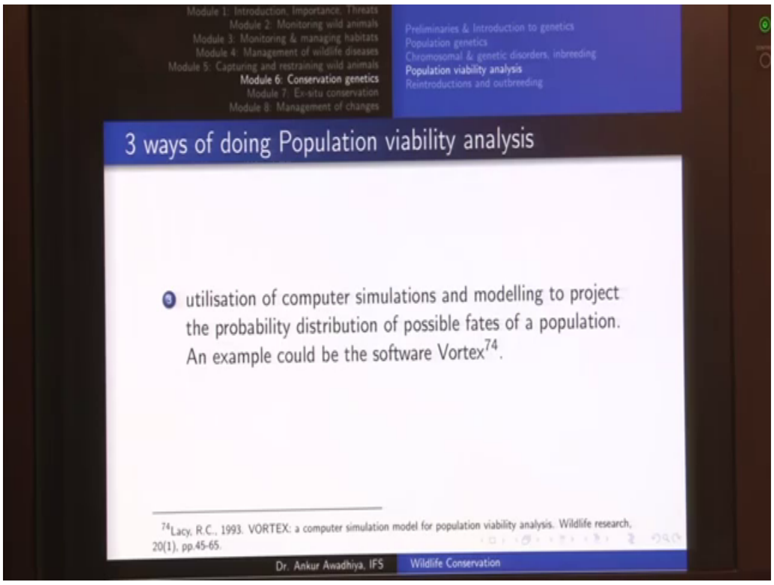

But these days because we have quite a good amount of computing power there this is our 3rd method that we use most often. So, this is utilization of computers simulations and modeling to project the probability distribution of possible fates of a population an example is the software vertex. So, what we are doing here is that we are using a computer to do a brute force analysis.

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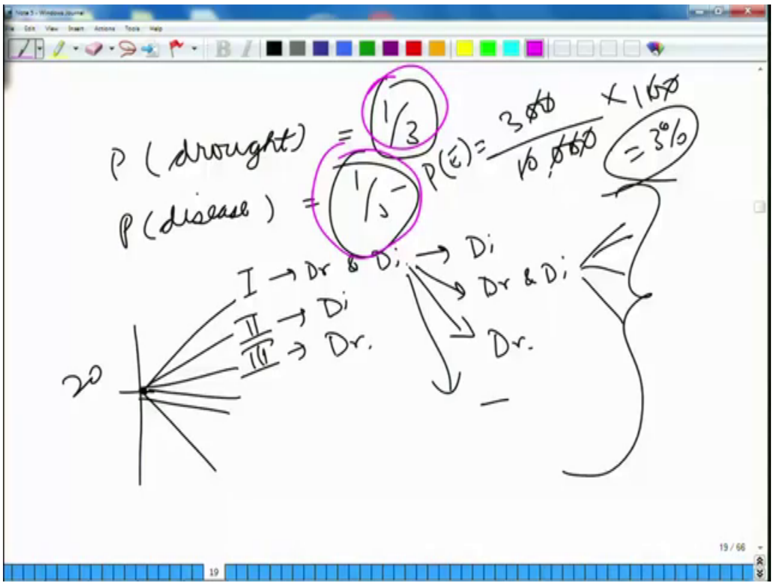

So, in this case what we are doing is that suppose we have the probability of drought is say 1 in every 3 years and the probability of a disease is say 1 in every 5 years. So, what we are doing here is that we are asking our computer to start with our population size say 20 individuals and then it will go with the number of simulations so, it will go with a number of simulations.

Now, they would be one simulation that would say that in the Ist year we have a draught and a disease, then there is another simulation that says that we begin only with the disease, there is a IIIrd simulation that says we begin only with the draught. Now, in this simulation a draught and a disease here is followed by only a disease here or we could have another year both draught and disease or we could have a IIIrd year that has only a draught or we can have a forth here that does not have any of these so, it is a blank year.

And then each of these would then again be 4th draught. So, once we are using such a method we have a computer simulation and modeling to project the probability distribution of possible fates. So, probability distribution of possible fates would mean that once we have done all of these simulations we would say that we have say done 10,000 simulations. And out of these 10,000 simulations we observe that in 300 the population went to an extinction. So, then we would say that the probability of extinction is given by 300 by 10,000 into 100 which is 3 percent.

So, this is a 3 percent possibility of extinction under these circumstances of every third year being a drought out the or probability of disease being 1 and 5. So, here we are doing a probability distribution of the possible fates of a population and an example is a software vertex that we will look into any short while, but before we do that what does this model require.

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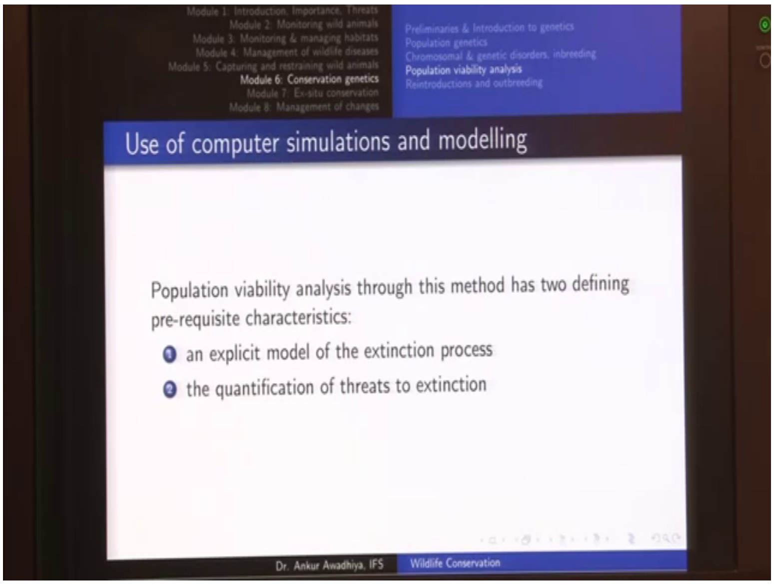

So, population viability analysis through this method has two defining prerequisite characteristics, one is an explicit model of the extinction process. So, basically earlier when we saw that we used a mathematical model or an analytical model such an explicit model of extinction process is also required for the computer simulation to begin with. And also it requires a quantification of the threats to extinction that is we require a quantification of all of these probabilities.

So, the probability of draught, probability of a diseases or say probability of a flood or probability of extinct of temperatures all of these we will also need to be quantified. So, quantified means that we cannot just say that we will have a draught some time we will have to put a figure regarding how many years will we get a draught.

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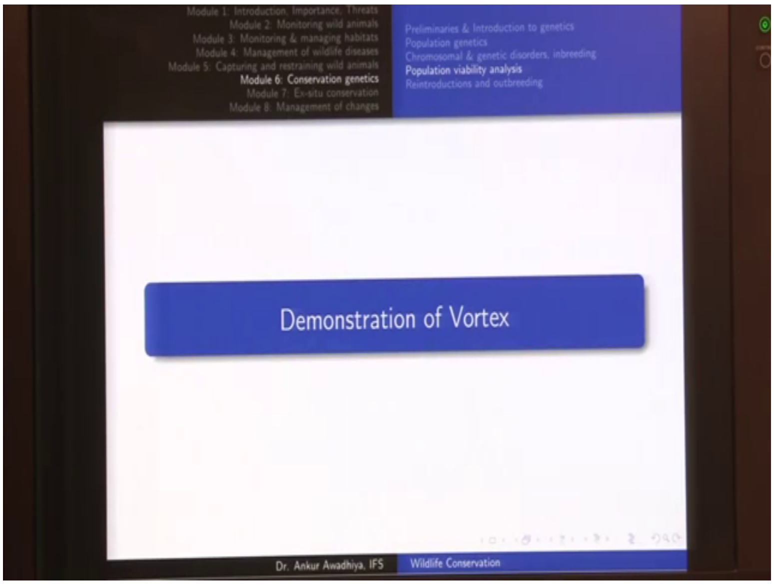

So, now we will go into a demonstration of the vortex software. So, let us now, have a look at a demonstration of the vortex software and here we are using the eddy software which is an educational lite version of the same software.

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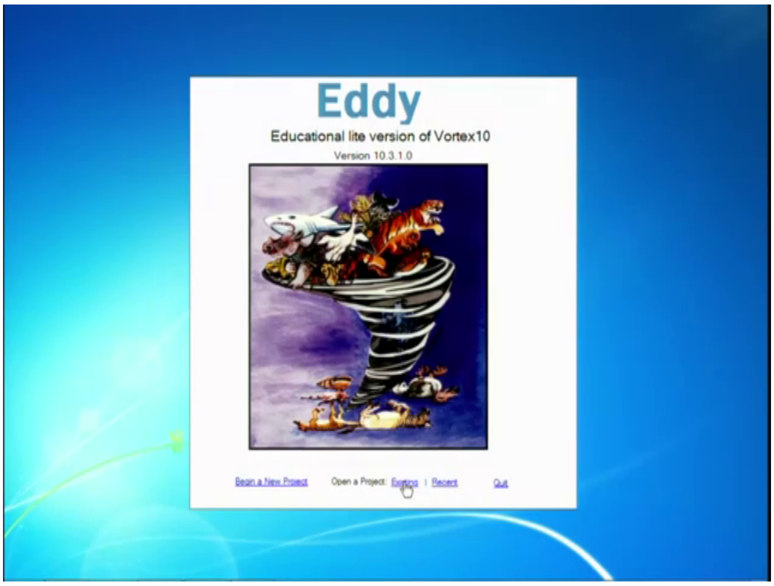

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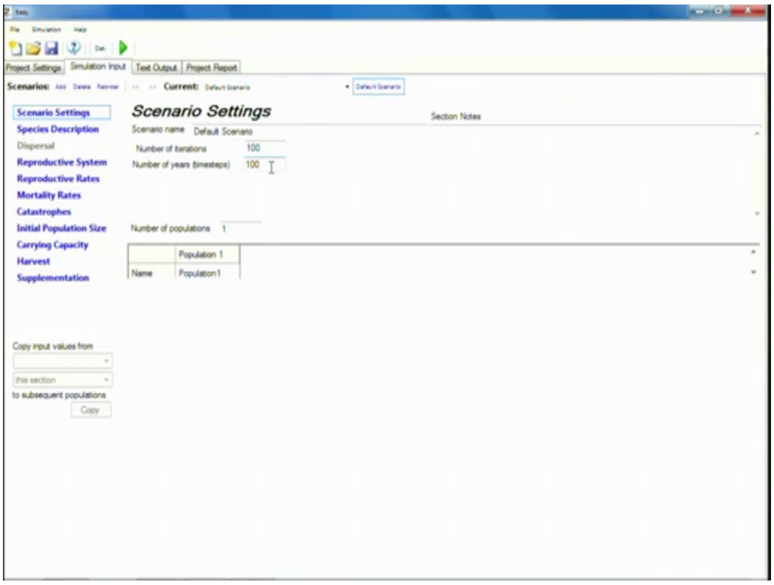

So, we open our project. Now, we have name this as a project tiger, and here we are required to give all different side sorts of input that we just discussed. So, essentially we are putting number of iterations. So, basically how many number of cases do we want to see, do you want to see a 100 cases, do you want to see 100 cases or 10,000 cases or so on. And then how many years are we do we require the simulation to run. So, do we want to see the extinction probability in the next 100 years or say the next 1000 years and so on? In this case you are only dealing with one population, so we are not dealing with any migration immigration and emigration.

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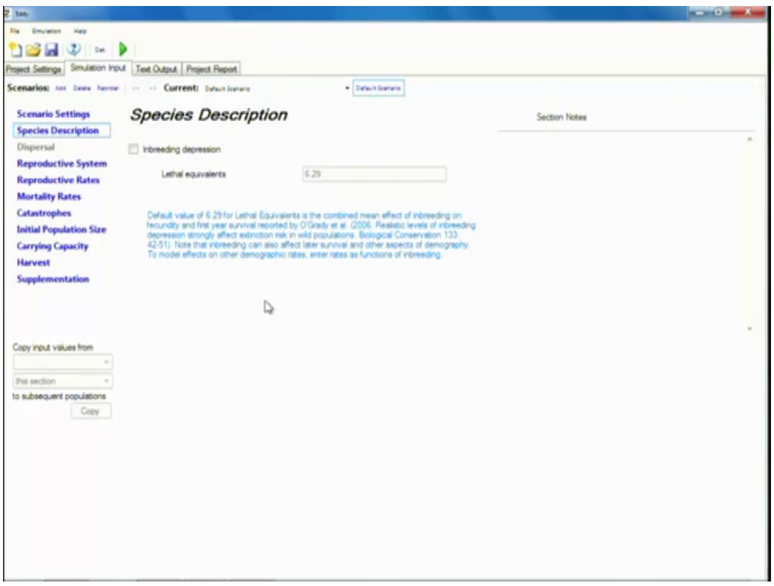

Then we could also include things like inbreeding depression and the lethal equivalents, but for simplicity we will ignored this for the time being.

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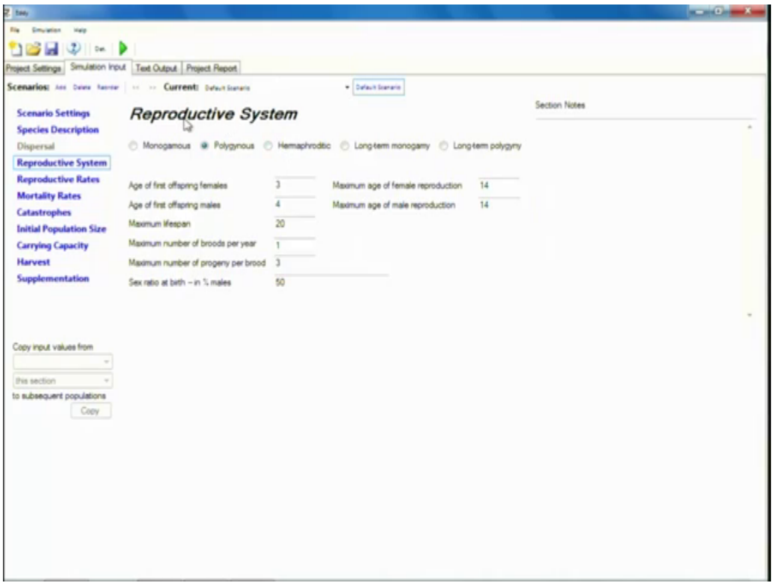

Now, in the case of reproductive system we are saying that a tiger is a polygynous individual. So, essentially one male tiger can made with any number of females. Then we are putting in all the life history. So, for the females the age of first off spring is the age of sexual maturity that is 3 years, for the males the sexual maturity is 4 years the maximum lifespan.

Now, in the zoo conditions we have seen tigers growing living for as many as 26 years, but in the forest areas in the national scenarios we will put it as 20 years. Now, maximum number of broods per year is 1 maximum number of progeny per brood is how many individuals are born in a later let us call it 3; sex ratio of birth let us see that 50 percent of the individuals that are born a brood or males maximum is a female reproduction and male reproduction we keep it at 14.

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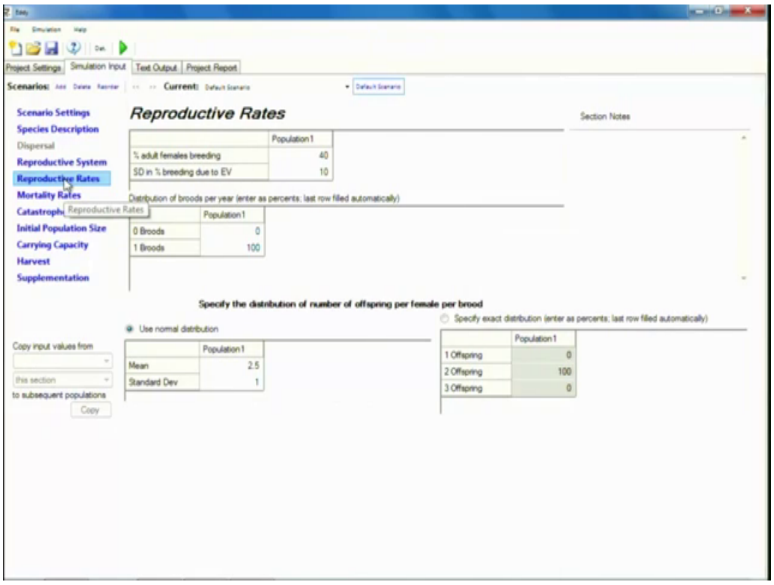

Next we go to the reproductive rates; now, this is asking is percentage of adult females that are breeding. So, if we have 10 adult females do all of them breed at the same time. Now, it is observed that in the case of tigers if there is female that has given one letter the cub remains with the mother for around 3 years. So, in that case let us put this as 40 percent and then distribution of broods per year. So, we will say that let 0 broods 0, 1 broods is 100 so, these are things that we can play with.

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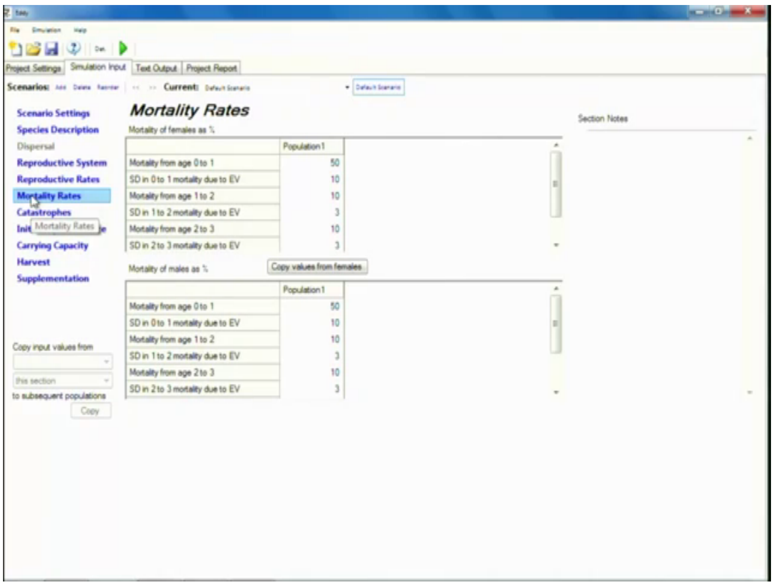

Next we are putting it in the mortality rates. So, in the case of females and in the case of males as well, so we are saying that mortality from age 0 to 1 is 50 percent. So, here we are talking about the infant mortality rate. Let us put it 50 percent and then if there is a tigress of age 1 then in the next one year there is only 10 percent mortality and so on so, we can put all of these figures.

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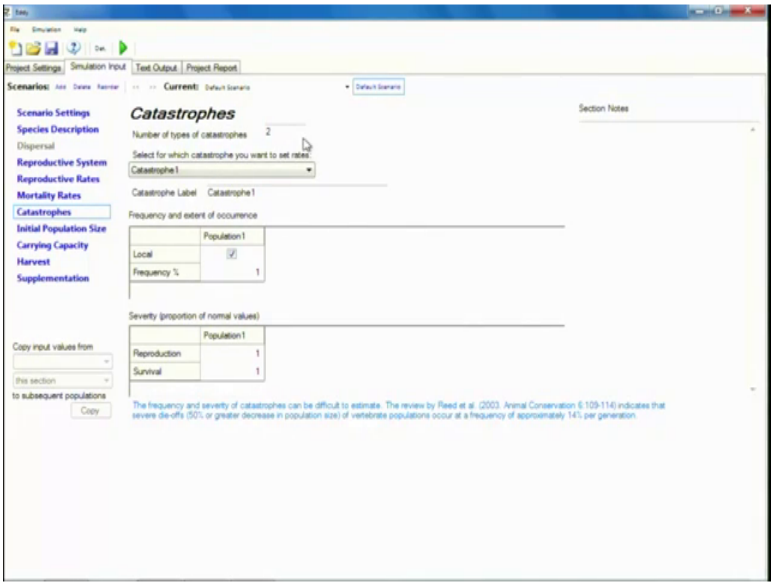

Next we are putting in catastrophes and we are saying here that we are going to have 2 number of catastrophes 2 types of catastrophes and then we can also put in their frequencies.

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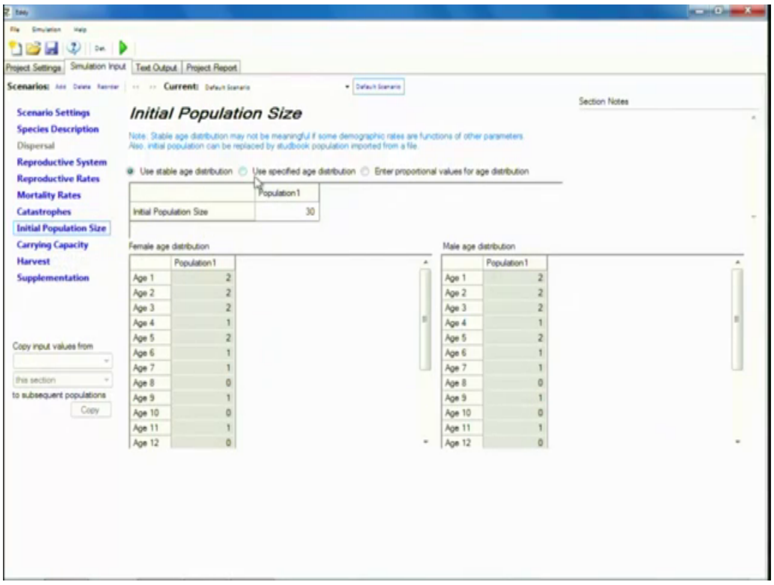

The next talks about the population size so, let us begin with a population size of 30 and here we are having a female distribution and the male distribution when we are having 30 individuals. So, we can either use a stable age distribution in which the software computes it automatically or we can put calculator any of these values by ourselves. So, we can see in place of two individuals here we have 3 individuals and in case of say at age 7 we do not have any individual so, we can play with all these parameters.

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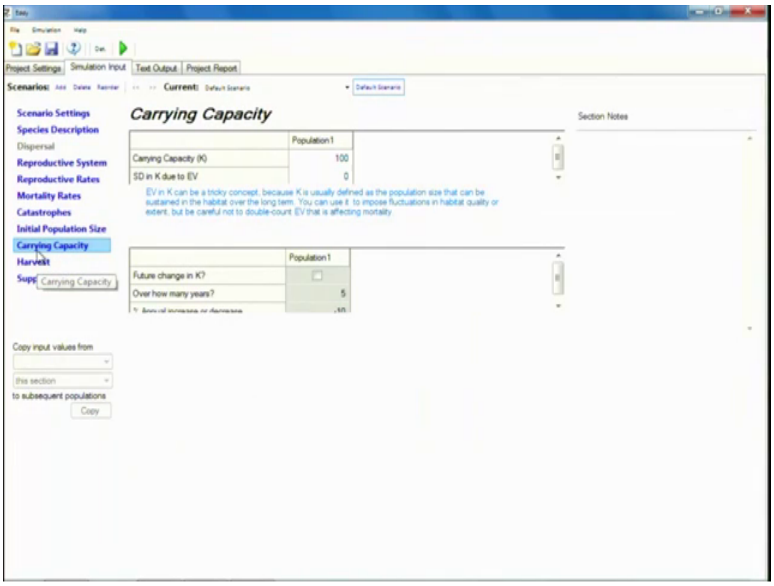

Next we have the carrying capacity so, this has go to deal with our age are density dependent mortality. So, let us say that the carrying capacity of the environment is 100 individuals so, it can support 100 tigers.

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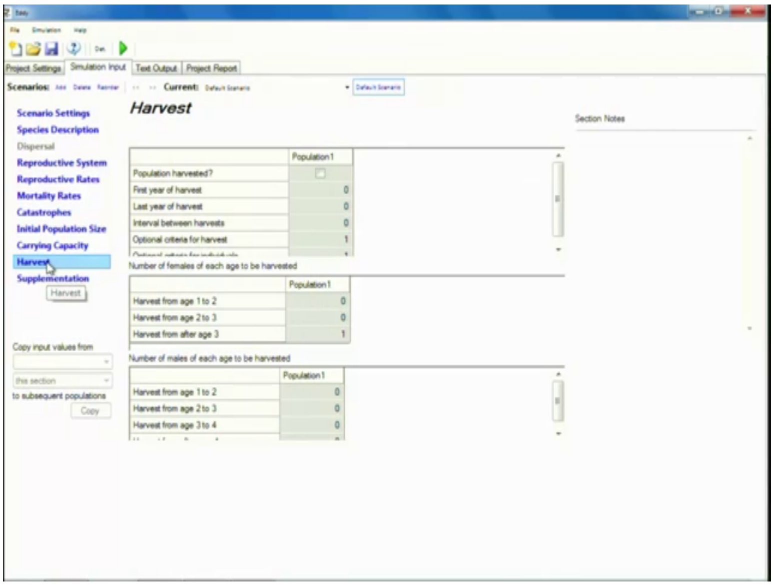

Harvest is talking about the number of tigers that has been removed say by poaching or by culling. So, poaching could be say illegal poaching and which is hunters are getting insides and killing tigers for their skin or say for their bones or we could even go for culling of tigers. So, if there is a huge amount of inbreeding depression then we could go for a departmental culling now, departmental culling is not done in India, so we will we will ignore this.

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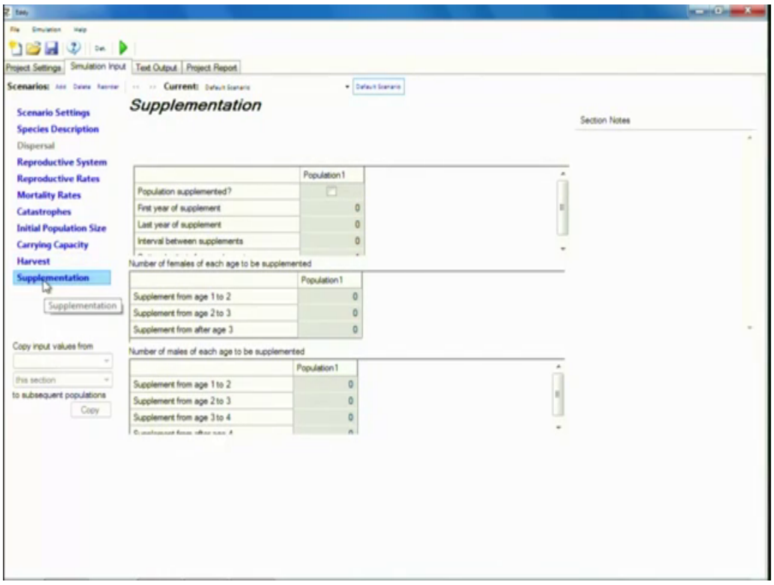

And supplementation is talking about how many individuals you are bringing in from some other population to supplement this population so, we will ignore this for the time being. So, let us see that if you have 30 individual population how does the simulation look like so, let us run the simulation.

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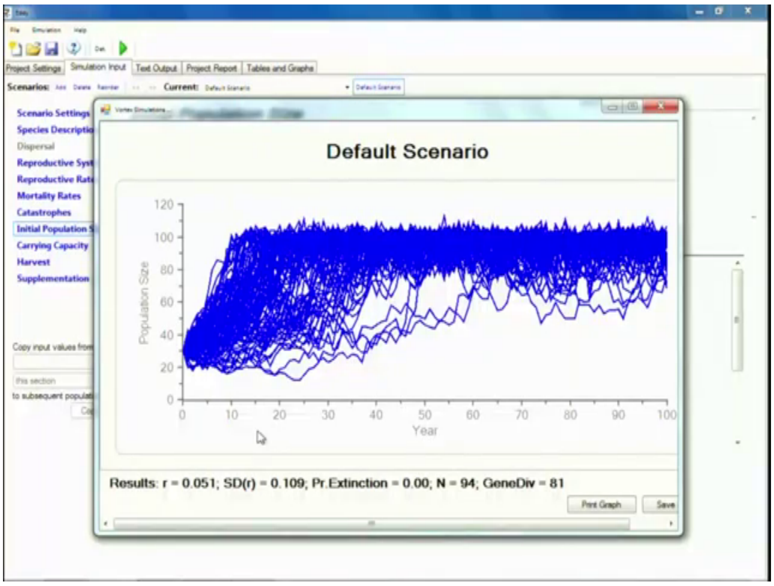

So, what we saw is that up till the age of up till this 100 years and we have run 100 number of simulations. Now, in these 100 number of simulation you are saying that the probability of extinction is 0 percent because, there was no scenario in which any of these populations came to a decline. But in the case of this particular simulation we see that the population size decrease from 20 to say close to around 6. But then it was able to recover after this, but then it is also possible that it could have gone down. Next let us begin with an initial population size of say 4.

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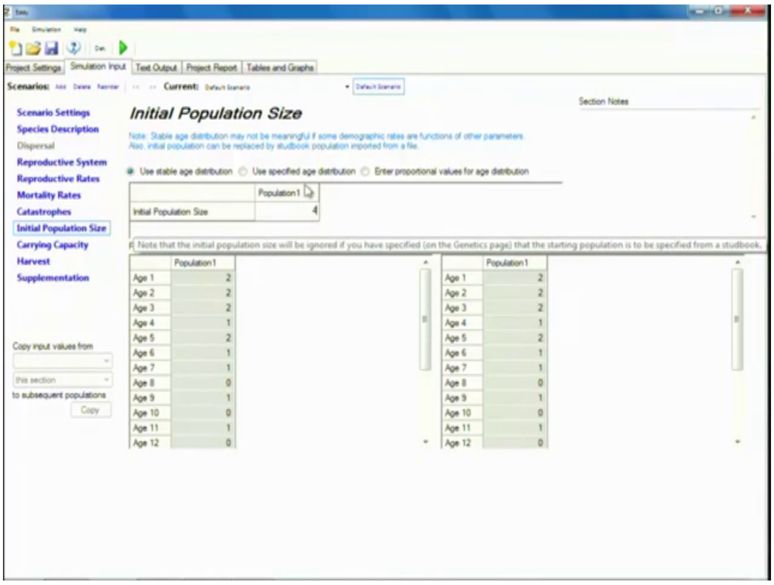

So, we have or let us take the extreme case we are starting only with 2 individuals.

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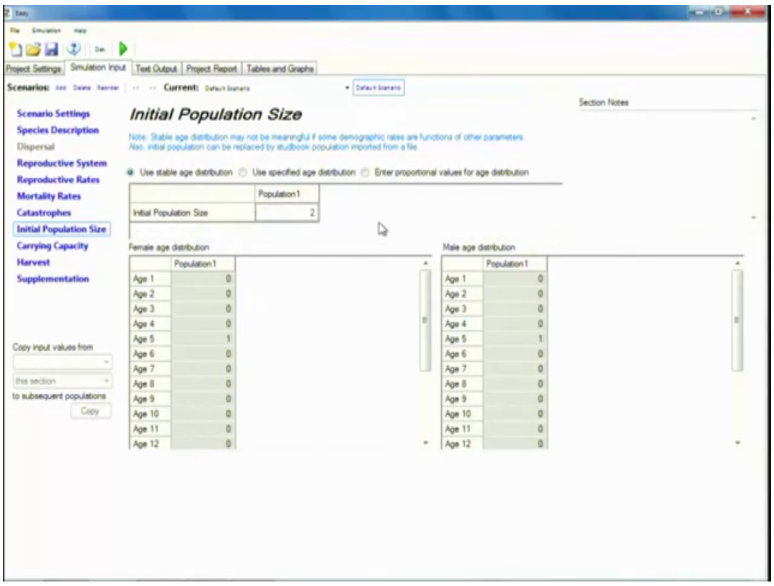

Now, in these 2 individuals we are having the female of age 5 and we are having a male of age 5. So, now, let us run the simulation again, with only two individuals. Now, what we are observing here is that there is an 82 percent probability of extinction because of all the 100 simulations that we run 82 were touching this line of 0. So, one it has raised to a population size of 0, so the population become extinct. Let us now, increase the population size so, in case of having 2 individuals, let us begin with 4 individuals.

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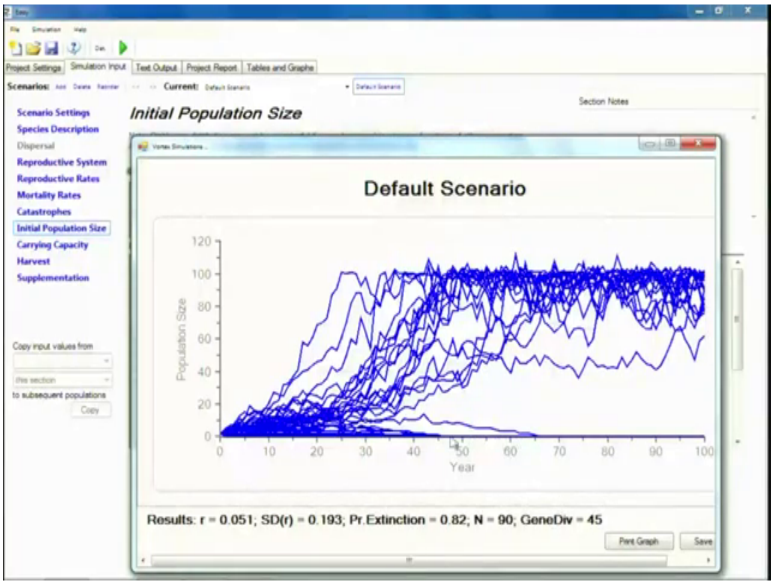

Now, with 4 individuals; now, we are automatically saying that we have an individual of age 2 and age 8 both for males and females, but then we can also change this.

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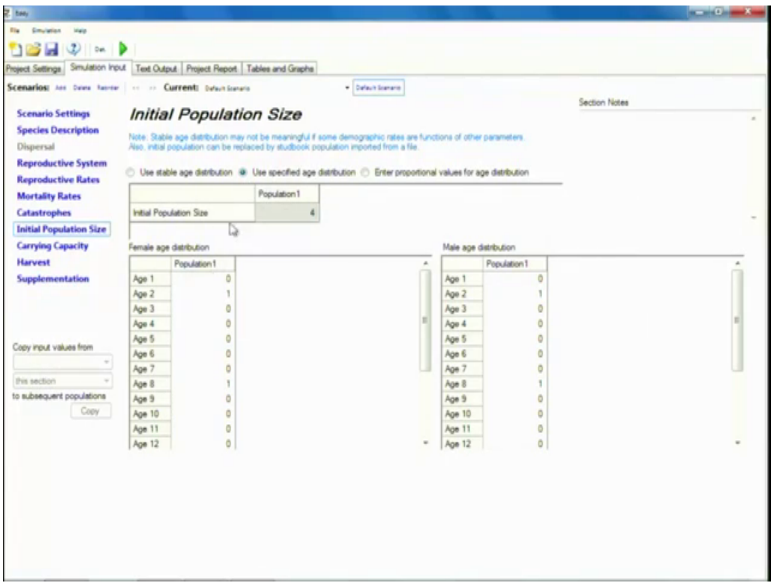

So, let us say that in place of having each 2 individual, let us have a female of age 4 and the female of age 8. Now, let us run the simulation again.

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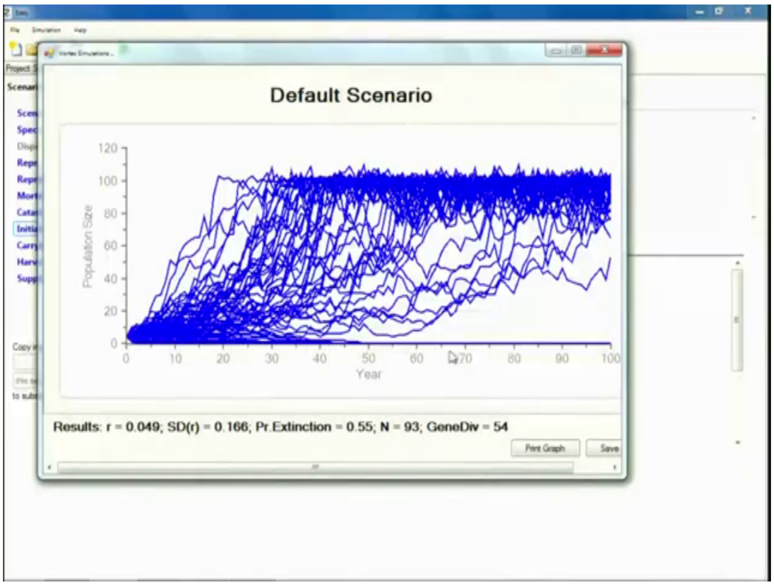

Now, from in 82 percent probability of extinction not the probability of extinction is come down to 55 percent. So, it tells us that only 55 out of these 100 simulations does 0 (Refer Time: 25:32) able to reach the canning capacity or somewhere in between. Now, let us increase our population size, let us begin with 6 individuals.

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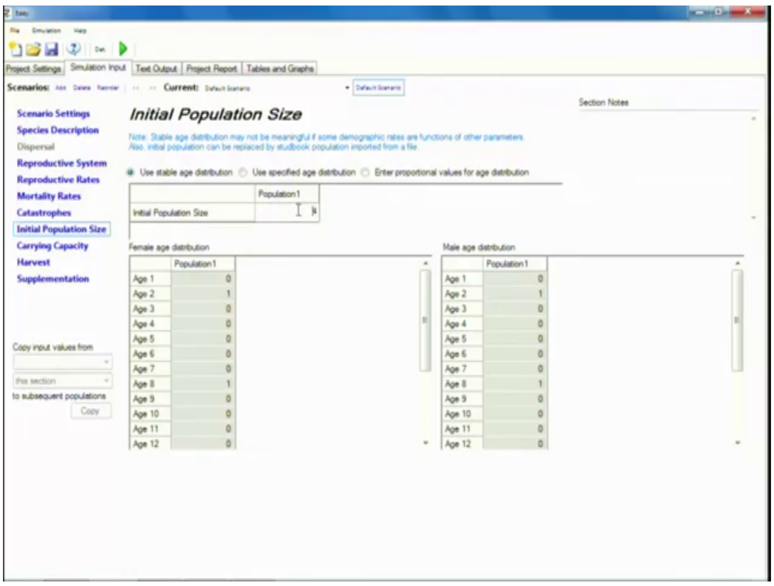

Now, when we begin with 6 individuals, here again we are seeing extinctions.

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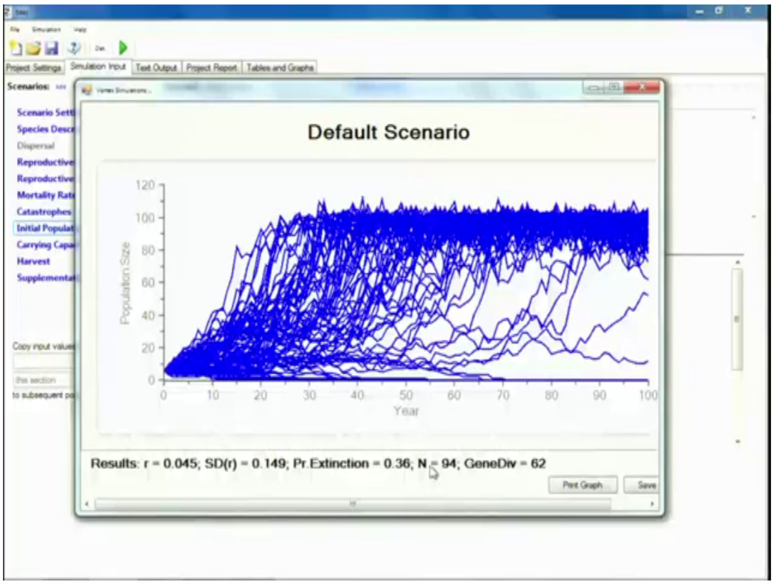

So, now, the probability of extinction has come down to 36 percent. Now, we can just go on playing with these figures. So, let us begin with our population size of 8.

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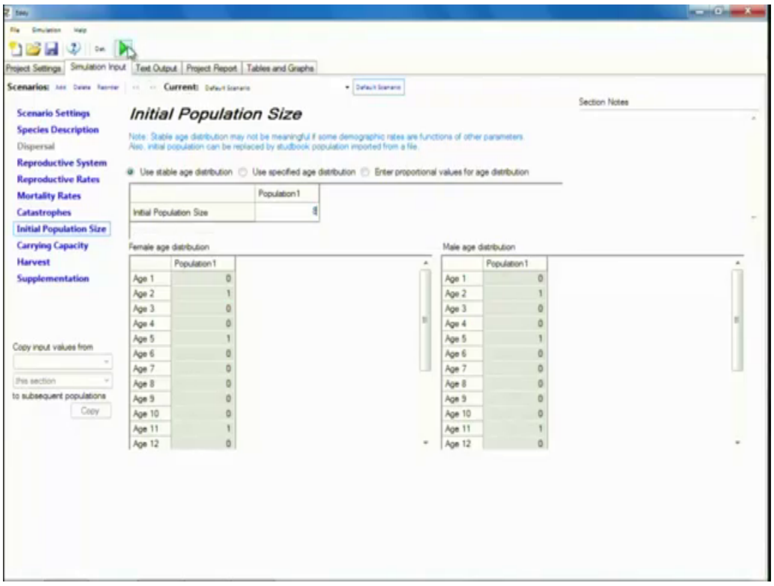

Now, more and more population or more and more simulation are able to avoid extinction. So, from 36 percent it has come down to 27 percent.

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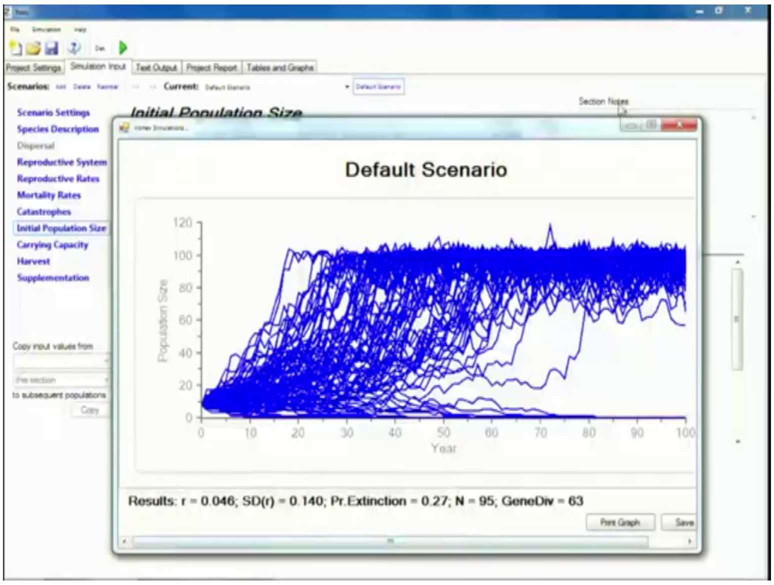

So, what we are trying to do here is that we are trying to understand the minimum viable population size.

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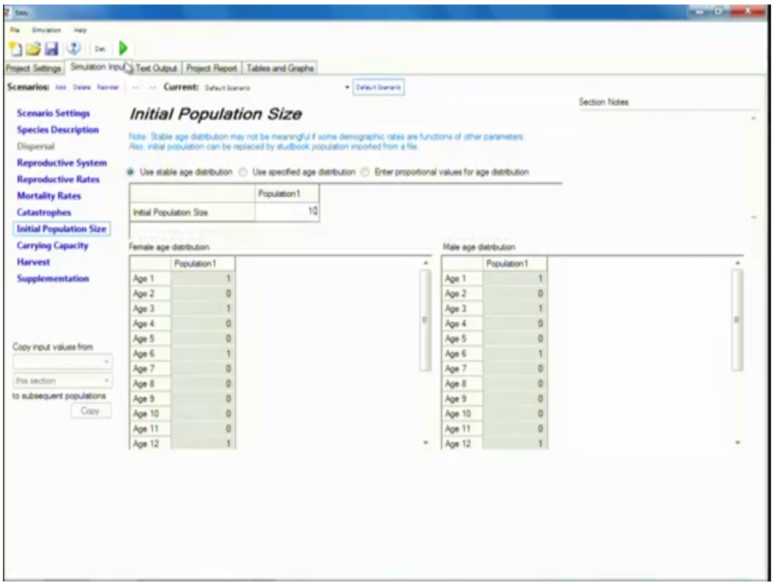

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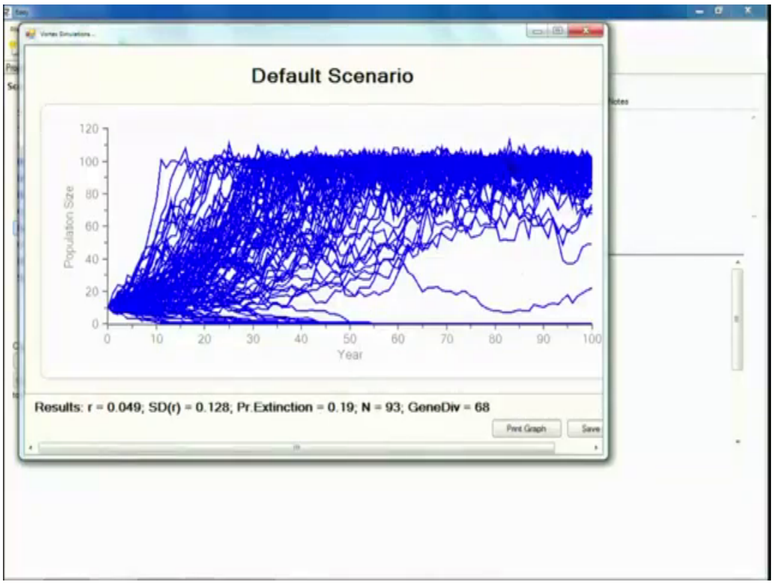

Here also we are seeing extinction s, we will see that this is also not a viable population, but then the extinction probability is now only 19 percent.

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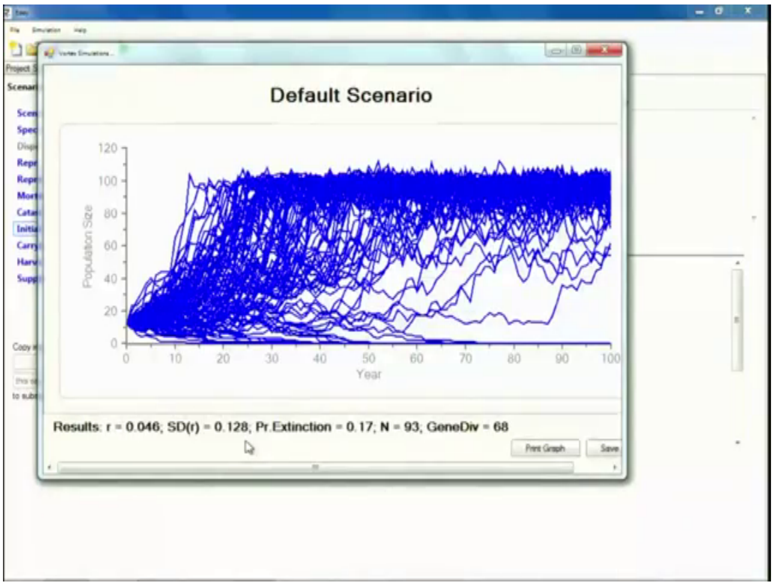

Now, with 12 individuals as are starting we have a extinction probability of 17 percent, that is increase it even further we have brought it down to 12 percent.

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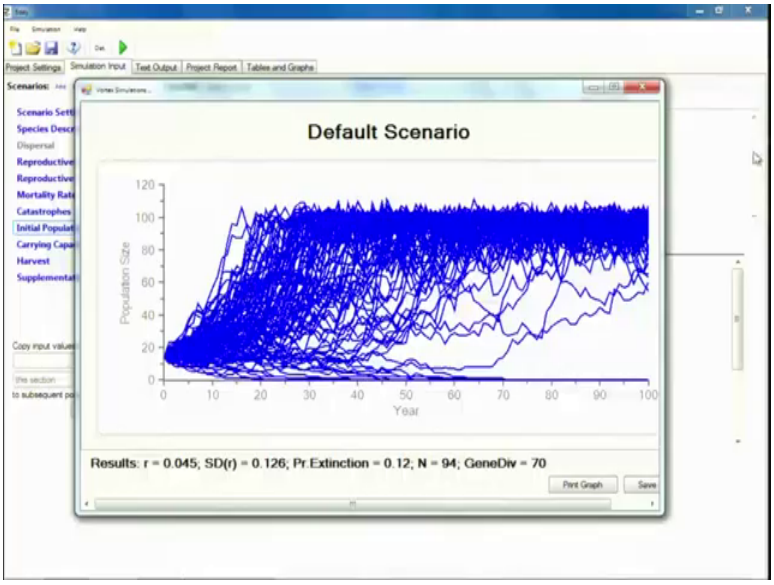

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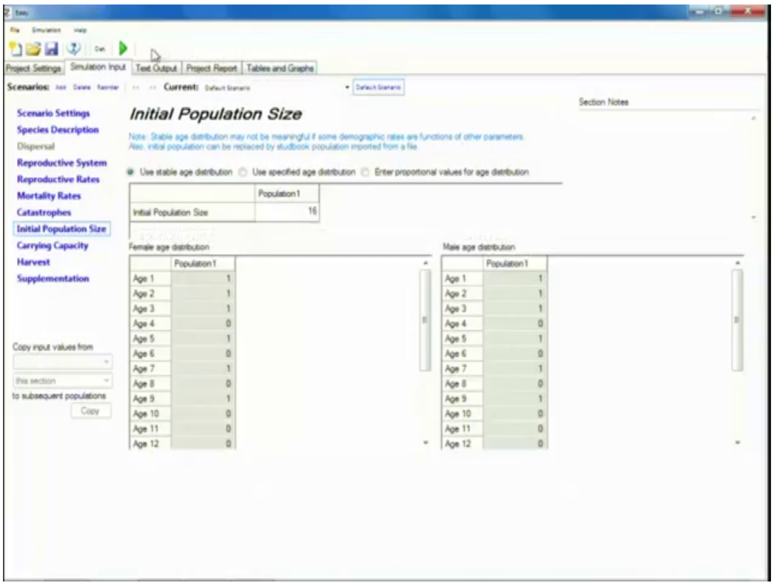

Let us, let us talk about a cut off, let us say that if it is less than 5 percent then we will say that our population will be say minimum viable population.

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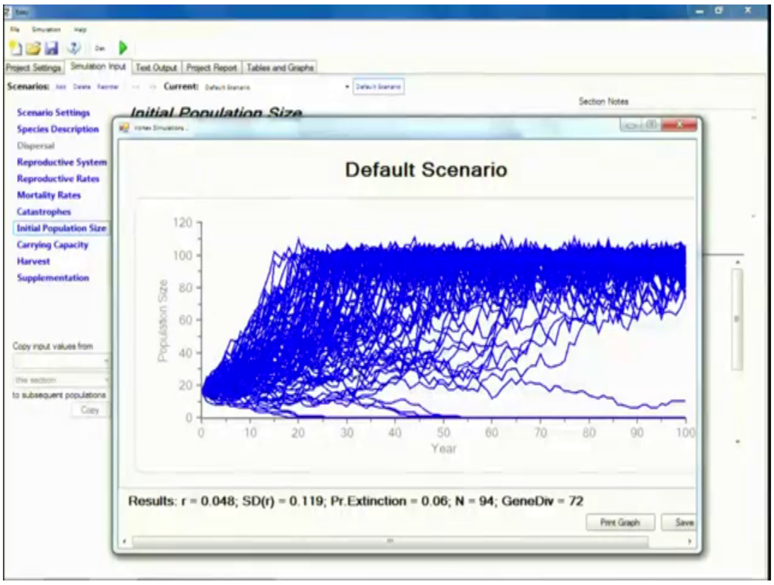

Because, even if you have a very low probability of extinction even if it is 1 percent it is possible that our population will go extinct after sometime s, here they are very close to our cut off of 5 percent s, we are at 6 percent.

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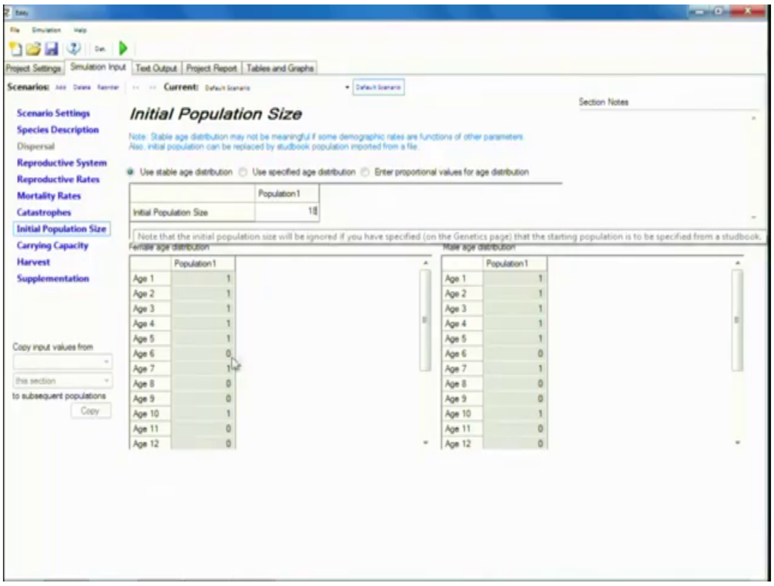

Let us put at 18 individuals, run it again, here we have these 5 percent.

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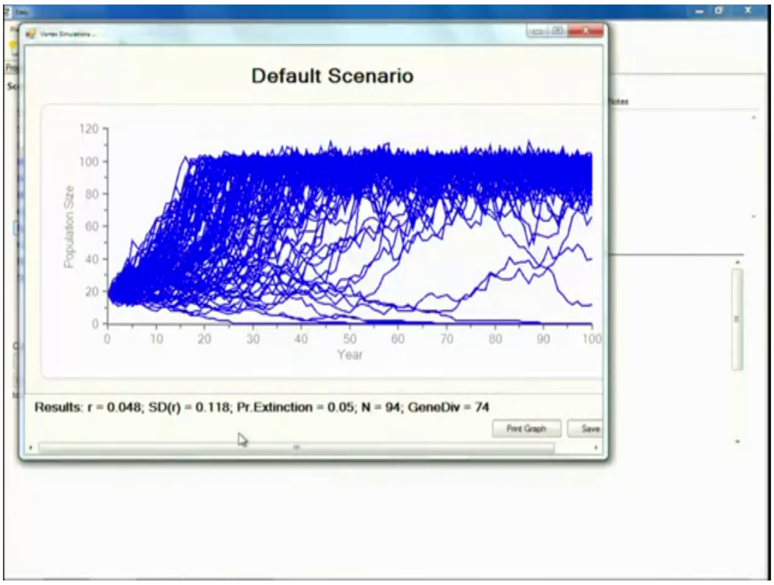

So, in this case once we have decided on our cutoff we said that we that if our probability of extinction is less than 5 percent less than or equal to 5 percent then we will say that this will be a minimum viable population. So, by this way we have come to the conclusion that 18 individuals is something that will provide us the minimum viable population. And then we can also include thinks like harvest. So, in the case of harvest we can say how many individuals are getting pulled out? So, let us say that let us use our default values and then the simulation again.

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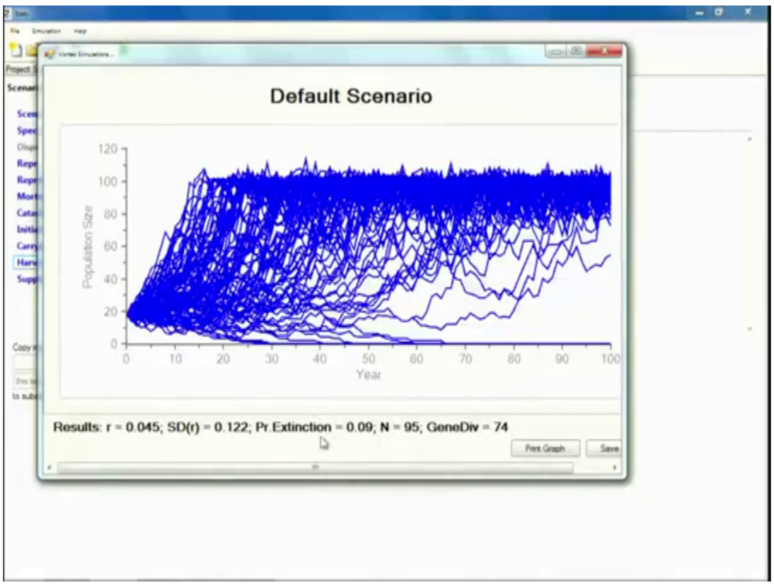

So, we are harvesting some individuals, but not to a very large extent and a probability of extinction has gone up it has gone to 9 percent. So, we would say that a population has seems to be a minimum viable population or let us say that we increase it further.

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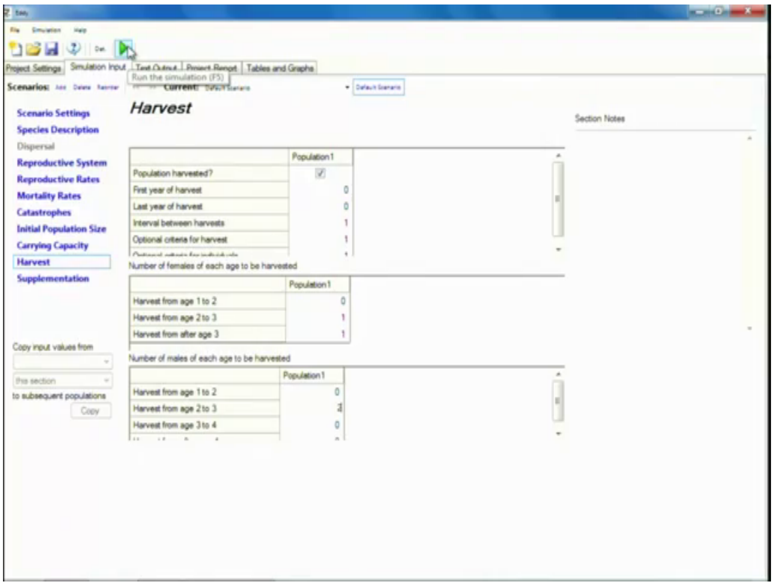

1 and number of females of each age is to be harvested let us say 1 here and number of males here is let us say 2. So, now, we are intensifying the level of poaching that is there in the population so, it is till 9 percent.

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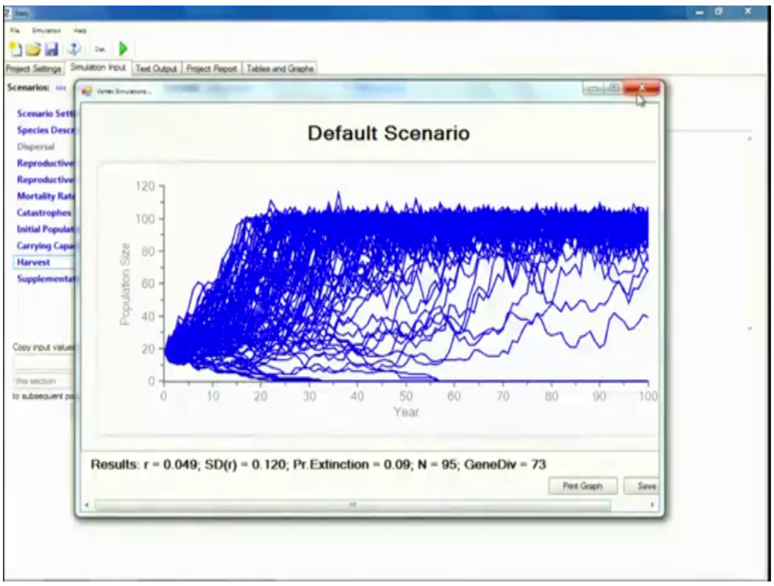

So, basically we can play with such parameters and once we go on running these simulation we will get an idea of how all of these things whether our poaching or also supplementation are going to help us or are going to leave this population to extension. So, this is the demonstration of the vertex software.

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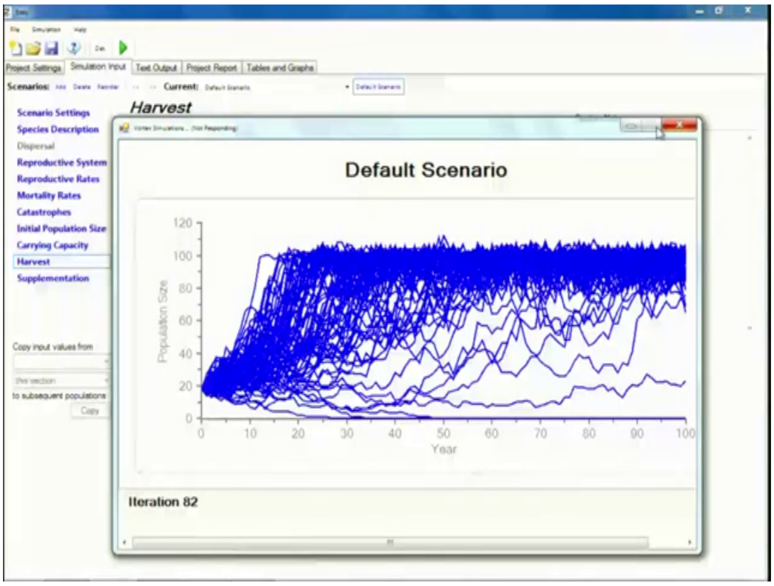

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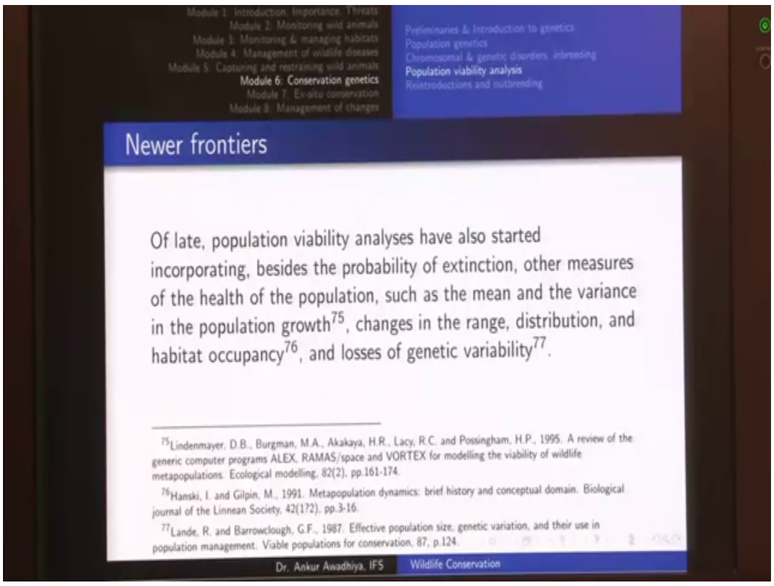

Now, apart from just using softwares and simulations for understanding of just the population viability, these days population viability analysis is also being used for other things besides extinction, such as the measure of the health of the population. Such as the mean and variance in the population growth changes in the range distribution inhabited occupancy and losses of genetic variability. So, when we look an our simulation we saw that our last column was the amount of genetic heterozygocity that was present in the population. So, (Refer Time: 30:13) these can also be understood by using methods that are very similar to our population viability analysis.

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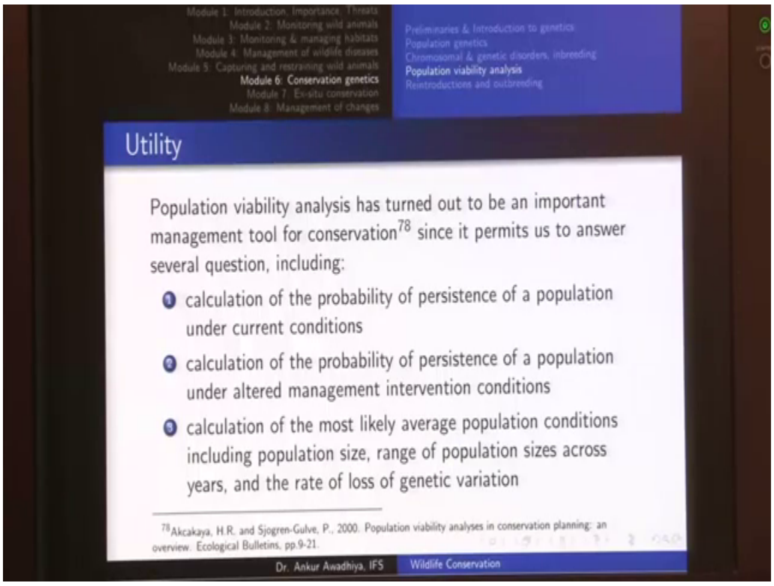

The utility of such an exercise is that it is an important management tool for conservation, because we can compute a number of parameters and you can answer a number of questions which is calculation of the probability of persistence of a population under current conditions. So, for instance, if you have a tiger reserve and if you want to say that only this small size tiger reserve is not going to be sufficient for the population because the carrying capacity is less. So, you can use these simulations to come out with a minimum area that would require for your tiger reserve.

Similarly, calculation of the probability of persistence of a population under altered management intervention conditions. So, alter management intervention conditions would include say increase of the size of the tiger reserve. So, you can also include in an increase canning capacity and then redo the calculation to see if it increases the probability of persistence of the population.

Also calculation of the most likely average population conditions including population size, range of population size is across years and of loss of genetic variation. So, when we are doing the simulations we can ask the computer that at every iteration it should give us the population size. The range of population size is and also the rate of loss of genetic variation we can even look at them such as the numbers of males and the number of females that would be there under different conditions.

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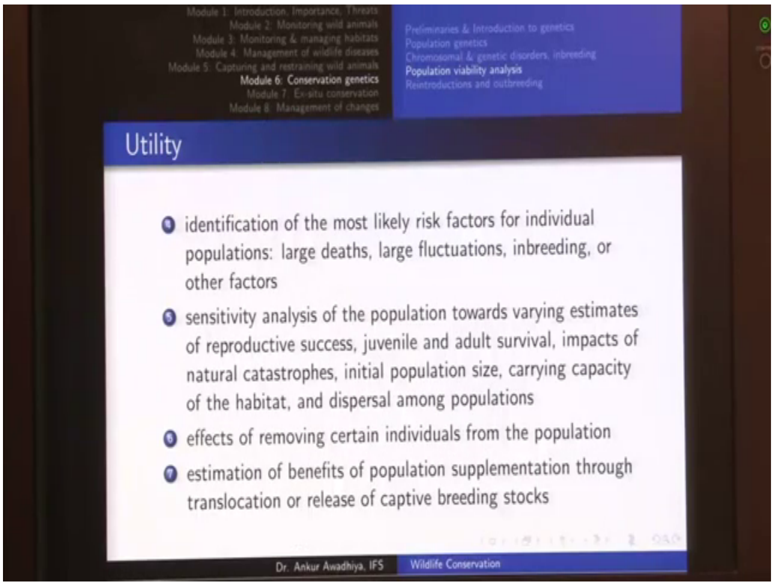

So, that for example, if there is a poaching and poaching is mostly done for males because they are offer larger size and also because they come out of the reserve area when they are dispersing. So, in those situations males are preferentially removed from the system we can use such an analysis to ask this question that how would the sex ratio change with time also identification of the most likely risk factors for individual populations. So, as at large deaths large number of fluctuations in breeding or other factors, so essentially, we are looking at the vulnerability of the population because of all of these different risk factors.

Then sensitivity analysis of the population towards varying estimates of reproductive success juvenile and adult survival, impacts of natural catastrophes, initial population size carrying capacity and dispersal among populations. So, in this what we are doing that we are asking that if we get this population more protection so that there is a better juvenile and adult survival rate how is that going to affect the population. So, is protection more important for our population or say reducing the impacts of natural catastrophes is more important?

So, if our area is suffering from drought do we an it is also suffering from poaching, do we give more attention to poaching or do we give more attention to construction of more water (Refer Time: 33:09) in this area, I thinks that could be asked using this same technique. Also effects of removing certain individuals from the population that is here we are asking what is the impact of poaching of culling of the population of different ages and different sexes?

And estimation of the benefits of population supplementation through transportation or release of captive breeding stocks. So, if we are doing any supplementation should we are bringing in tigers from some other reserve into our reserve. So, how is that going to help our reserve is something that we can ask with this simulation.

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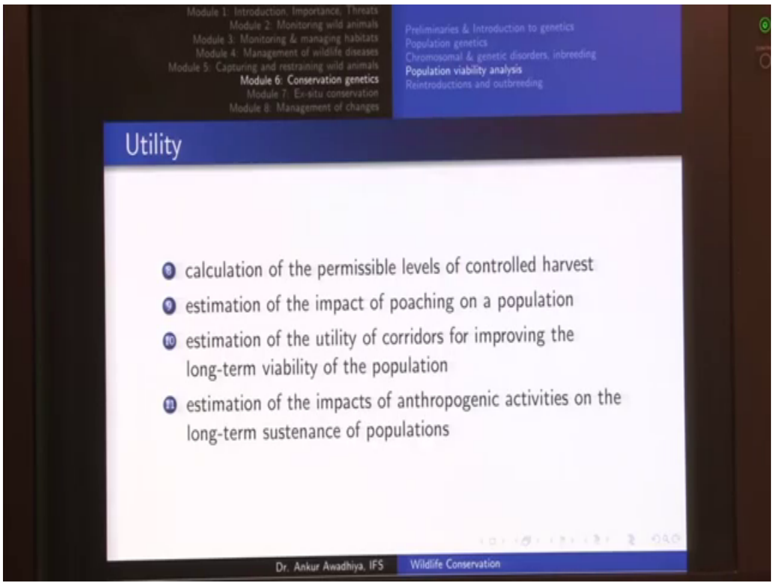

Now, others include calculation of the permissible levels of controlled harvest. So, this is more full in the case of African countries that have a legalize hunting. So, we can use these sorts of simulations to ask the questions regarding how many individuals can be permit to be hunted every year. We can calculate that and then use that as a management decision; also estimation of the impact of poaching of on a population, estimation of the utility of corridors for improving the long term liability of the population.

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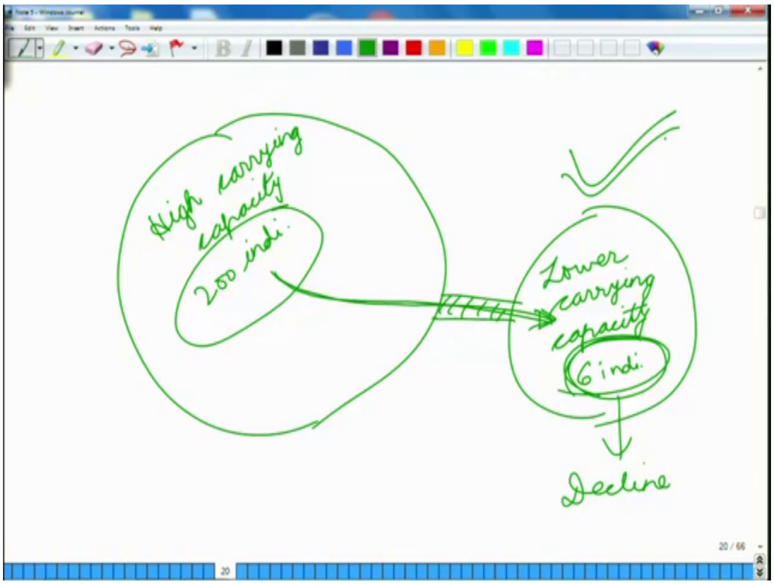

Now, what we are doing here is that suppose we have a larger size forest and you have a smaller size forest. In this smaller size forest we have a lower carrying capacity. Now, because of this lower carrying capacity suppose this forest can only support its 6 individuals. Now, 6 individuals is very less and so this population will go towards a decline. And in a in a few generations we would have a situation in which this population become extinct. However, nearby we also have a larger forest with high carrying capacity.

So, suppose this has a carrying capacity for say 200 individuals. Now, if we constructed a corridor between both of these s o, we connected both of these forest with a small (Refer Time: 35:19) of forest. So, in that case these individuals when they are the spacing out they could even dispersion to this area. And in that case these 6 individuals would have resulted in a decline of this population because of say in breeding. But, because we are having a continuous influx of individual from the larger forest this population would be able to survive this population would they survive for a very long period.

So, this is what we are asking here estimation of the utility of corridors for improving the long term viability of our population. So, in place of going on with more and more supplementation if we had corridor with that help us more then what are other intervention would have helped us. Also estimation of the impacts of anthropogenic activities on the long term sustenance of populations, now these anthropogenic activities include not just poaching, but also things like habitat loss and habitat degradation and also habitat fragmentation.

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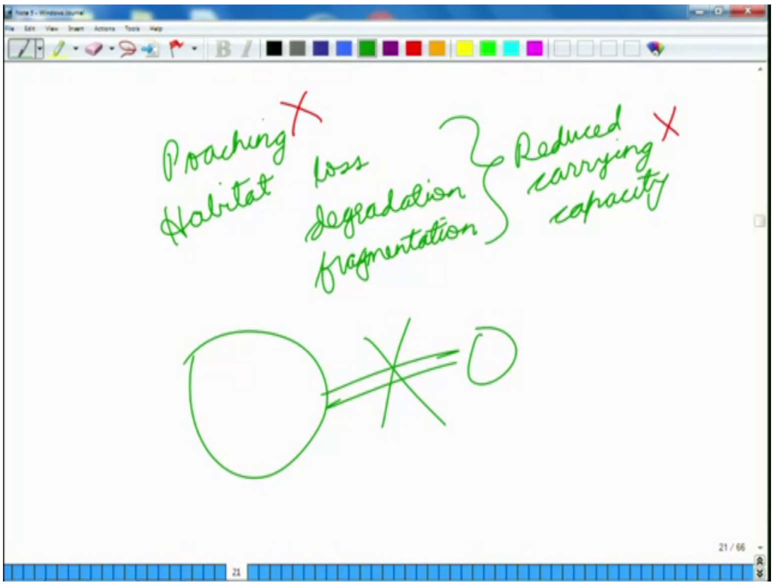

So, in all these situations we are getting to a situation in which the habitat has reduced carrying capacity. So, not only are we removing are individuals from the population, but we are also reducing the carrying capacity of the pop of the habitat. So, this is what we are asking here; estimation of the impacts of anthropogenic activities on the long term system of populations.

Also thinks such as if you already have a corridor somewhere and if this corridor is taken off because this land the small patch has been diverted for agriculture what would be the impact of that on the population. So, things such as these can also be asked in the case of population viability analysis.

So, in this lecture we had a look at the concept of population viability analysis and how we can use 3 different methods; the empirical method that uses field observation datas, the mathematical method and also the simulation method. And we also worked with our software called vortex eddy is lightweight version of vortex, but then we had a glimpse of how we input all of our different input parameters such as life history and starting population size number of (Refer Time: 37:52) and so of and so on.

And how this software runs are n number of simulation save 100 simulation for a time period of the 100 years to give us an extinction probability for each of these initial conditions. And we can use all of these to estimate not only the minimum populations viable population size that should be there, but also the impacts of various interventions to help our management decision making. So that is all for today.

Thank you for your attention [FL].