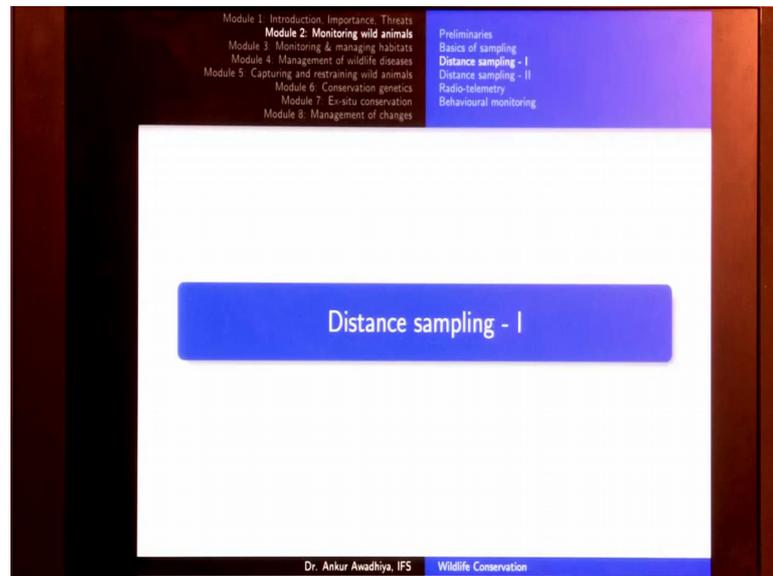


**Wildlife Conservation**  
**Dr. Ankur Awadhiya**  
**Department of Biotechnology**  
**Indian Institute of Technology, Kanpur**

**Lecture – 07**  
**Distance Sampling – I**

[FL] In today's class we will have a look at Distance Sampling.

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This is a sampling procedure that we normally use for counting of wild life. So, in case of directly getting into distance sampling let us build up the concepts step by step.

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### Measuring animal density through complete census

Density of animals can be calculated as:

$$D = \frac{N}{A}$$

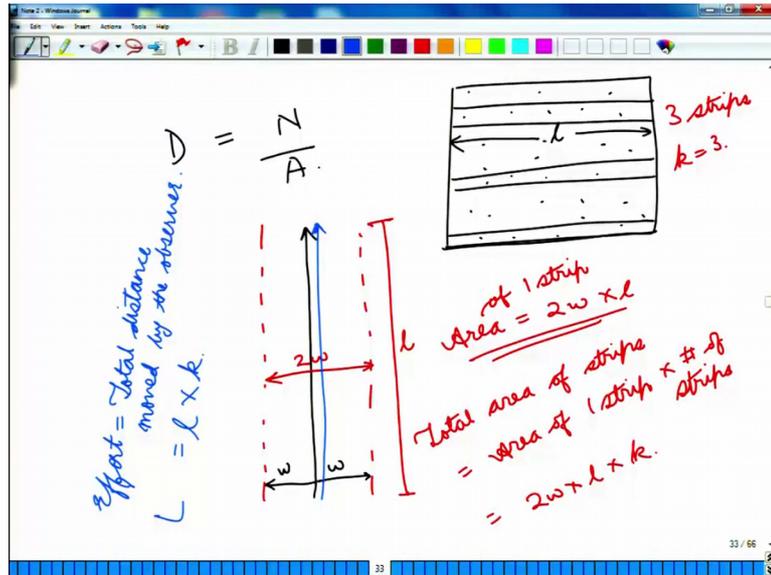
where  
 $D$  is the density of animals  
 $N$  is the count of animals as found through census, and  
 $A$  is the area of the region under study

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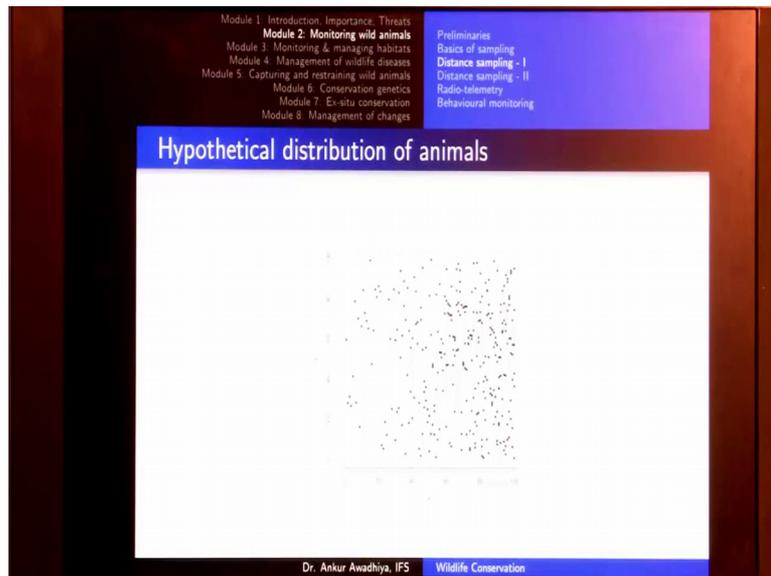


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Now, if we consider a forest then the density of animals  $D$  or the density is the number of animals divided by the total area of the forest or the total area of the region under study.

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So, now let us consider this forest in which these dots represent the animals. Now these animals are concentrated to 1 side and are sparsely on the other side probably because, say this second side is having a high mounted and this side is having more of grasslands. So, this area is providing more food to the animals.

Now in this hypothetical situation if we counted each and every animal in this forest and we divided it by the total area of the forest. So, in this case total area is 100 meters by 100 meters, which becomes 1 hectare.

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### Measuring animal through complete census

To illustrate, let us consider the animals represented as dots. The area under study is 100 m × 100 m, or 1 hectare.  
If we counted all the animals, and found the total number as  $N = 205$ , then knowing  $A = 1 \text{ Ha}$ , we shall calculate density as

$$D = \frac{205}{1} = 205 \text{ animals per hectare}$$

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And suppose we found that there were 205 animals in the complete forest. So, 205 animals divided by 1 hectare gives us a value of 205 animals per hectare. So, this is our normal formula which is  $D$  is equal to  $N$  by  $A$ , but then doing a complete census in most cases is difficult.

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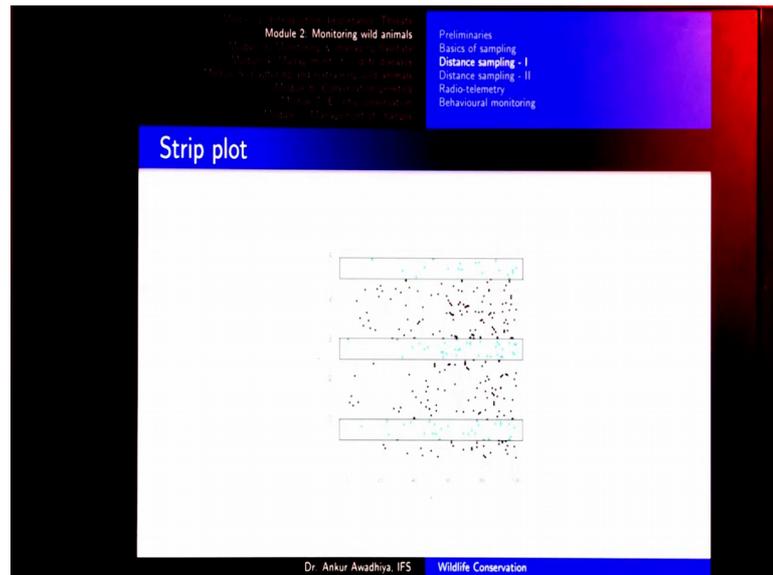
### But complete census is difficult. Can we use sampling?

Yes, plot sampling can be used with strip or circular plots. In plot sampling, we count the animals in an area that is a fraction of the total region of interest, and use that value to estimate the actual animal density in the region of interest.

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So, can we make use of some sampling procedure in place of getting the complete census. So, in the case of a sampling procedure we would not be using the complete number of animals that are there in the forest. So, we will not be counting the whole of these number of animals, but will be dividing this area into small plots and then we will be using the number of animals in those plots to get an estimate.

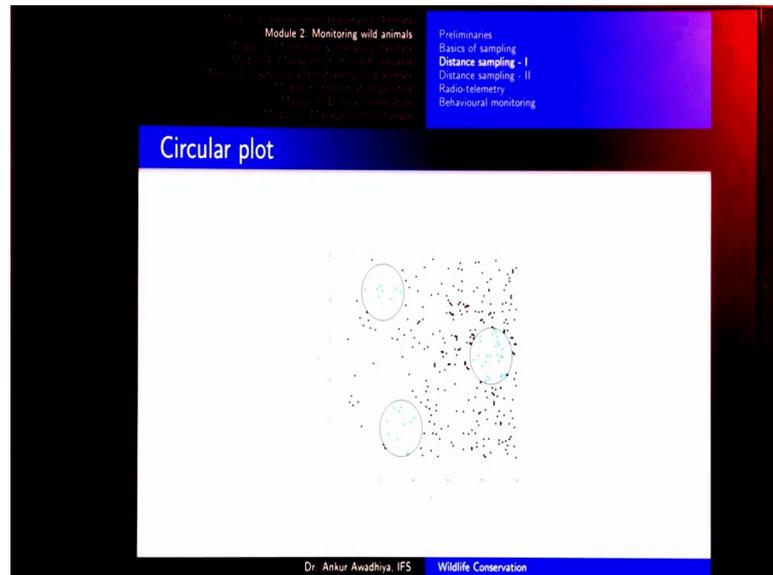
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So, in this case we can make use of a strip plot. So, in the case of a strip plot we have taken these 3 strips and in all of these 3 strips we count the number of animals that are here, we count the number of animals that are here and we count the number of animals that are here. We divide this figure of the total number of animals divided by the area of the strip plots.

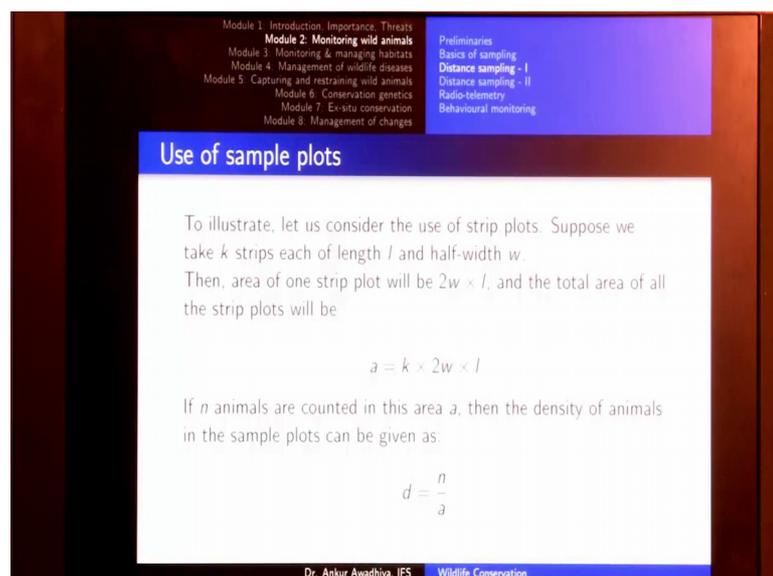
So, the area of this strip plus the area of this strip plus the area of this strip; so, we will get an estimate of the density and then we would say there that the density of our animals in this strips is the same as the density of the animals in the complete forest. So, by multiplying this density by the area of the forest we would be getting an estimate of the number of animals in the forest.

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Similarly, we could make use of circular plots and so in this case we have these 3 circular plots and we perform the same procedure, we count the number of animals in all of these 3 plots divided by, we take the sum of animals in these 3 plots divided by the sum of these 3 areas to get a density. And, then we say that the density of our sample is the same as the density of the population multiply that with the area of the forest to get the number of animals in the forest.

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So, how would that look? So, to illustrate let us go with our strip plot example. So, in this case we had our forest and we had divided it into strips and we had taken 3 strips like this. Now and we had animals both inside and outside the strip and we had only counted the animals that were inside the strip. Now, let us say that each of these strips was of length  $l$ . So, how do we take a strip?

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So, how do we make a strip plot? So, in a very simple example let us take the stick I hold it like this and then I start walking; what I am interested in is noting the number of pellets of animals that are there on the ground or say noting the number of some particular plant species that is there on the ground.

So, in that case when I am walking on a straight line then this is the half width on my left, this is the half width on my right and  $l$  is the distance that I am moving and I will only be considering the any samples that are just below just within this length of the rod. So, when I am moving I am creating a strip through my movement. So, when I am walking on a straight line like this I have a half width  $w$  on my right side and a half width  $w$  on my left side and by walking this distance I am creating a strip that has a total width of  $2w$  and a total length of  $l$ .

So, the area of 1 strip is twice  $w$  into  $l$  because it is the width into length the area of a rectangle. Now, in place of taking these rods I could also use a computer and say that when I am walking on this line take this much distance to the right and take this much

distance to the left and can always make use of a laser rangefinder to check if I have seen any animal whether that animal falls within my chosen width half width of  $w$  or whether it is outside of that distance. So, the use of a rod is not always essential, but it is to simplify this concept and it is used in cases when we are doing a pellet count or when we are doing a hub count.

Now, this is the area of one trip. So, this is area of trip. Now suppose I took  $k$  number of steps. So, in our example we had 3 strips. So,  $k$  is equal to 3. So, the total area of strips is the area of 1 strip multiplied by the number of strips. So, in this case it becomes  $2w$  into  $l$  into  $k$ . Now coming back to the slides, so here we have it the total area of all the strips is  $k$  into  $2w$  into  $l$ . Now, in our strip method suppose we counted  $n$  number of animals in this area small  $a$  then the density of animals is the number of animals divided by  $a$ . So, it becomes  $n$  divided by  $k \times 2w \times l$ .

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### Use of sample plots

We estimate that the density of animals in our region of interest is the same as the density of animals discerned from the sample plots:

$$\hat{D} = d = \frac{n}{a}$$

Now, the estimate of total animals in the area of interest  $A$  will be

$$\hat{N} = \hat{D} \times A = \frac{n}{k \times 2w \times l} \times A = \frac{nA}{2wL}$$

where  $L$  is the total length traversed, also called effort:

$$\text{Effort. } L = k \times l$$

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Now, when we are doing a strip plot we say that this density  $d$  which is  $n$  by  $a$  is the same as the density of the animals in the whole of the forest which we represented as capital  $D$  with the hat. So, capital  $D$  with a hat is the estimate of the density of animals in the whole forest, now just, because it is an estimate we put a hat on top of capital  $D$ , because it is representing the whole of the forest and this small  $d$  is because it is representing the strip plots. So, once we take this assumption that the density of animals

in the forest is the same as the density of animals in our strips then we can use this formula to find out the total number of animals in the forest.

So, total number of animals would be given by the density of animals multiplied by the area of the forest. So, capital A is the complete area of the forest now because we took this assumption that  $\hat{D}$  is equal to small d which is  $n$  by  $a$ . So, we have  $n$  by  $a$  as in the previous slide we had seen that  $a$  is  $k$  which is the number of strips multiplied by twice of half width multiplied by  $l$ ; so,  $k$  into  $2w$  into  $l$ . So, we put that here  $k$  into  $2w$  into  $l$  multiplied that with the area of the forest  $A$  to get this formula  $n$  small  $n$  capital  $A$  divided by  $2wl$  here this capital  $L$  is small  $k$  into small  $l$ .

So, small  $l$  was the length of 1 strip  $k$  is the total length that I have moved. So, now coming back to the board when I had moved this distance of small  $l$  the effort that I have put because I am not moving in the whole of the area I am only moving in a straight line. So, this line is of length  $l$ . So, when we say effort is the total distance moved by the observer.

So, total distance moved in this case is the length of 1 strip multiplied by the number of strips that we had; so,  $l$  into  $k$  which is also given by capital  $L$ . So, now, coming to the slides here we have small  $k$  that is the number of strips multiplied by the length of the strip is capital  $L$ . So,  $nA$  divided by  $2w$  capital  $L$  which is the estimate of the number of animals in the whole of the forest and capital  $L$  is the effort which is  $k$  into  $l$  now this much portion is simple.

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### Why do we use hats in $\hat{N}$ and $\hat{D}$ ?

We use hats to differentiate the quantities that are estimated from quantities that are measured or counted.

Thus, while  $N$  would represent the actual count of animals as found in a census,  $\hat{N}$  represents the total count of animals as was estimated through our sampling exercise.

Similarly, while  $D$  would represent the actual density of animals as found using a census count with the total area of the region of interest,  $\hat{D}$  represents the estimate of density of animals as found through a sampling exercise.

While  $N$  and  $D$  are the accurate values,  $\hat{N}$  and  $\hat{D}$ , being estimates, may or may not be accurate.

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And we use hats in capital N hat and capital D hat because both of these are estimates.

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$n$  → Actually observed.  
 $d$  → Actually calculated.  
 $d = \frac{n}{a}$   
 $\hat{D} = d$   
 $\hat{N} = \hat{D} \times A$

So, when we wrote small n coming back to the board when we wrote small n. So, small n is the number of animals that we actually observed when we wrote d that is the density of the animals that was actually calculated why we say actually because, d is n by small a we have actually observed the number of animals n and we have we know precisely what the value of a is. But, when we say that the density of animals in the whole of the forest is equal to this small d is something that we know for 100 percent sure, but capital D we

do not know that that whether it is 100 percent equal to small  $d$  or whether there is a small fluctuation.

So, we make this estimate to say that capital  $D$  is the same as small  $d$ . So, just because this is an estimate we put a hat on top of it similarly when we calculate the number of animals in the whole of the forest we put a hat here because this again is an estimate because it makes use of  $d$  into a and  $d$  here is an estimate. So, when we have this estimate capital  $A$  is something that we know 100 percent sure, but  $D$  hat is something that we do not know, this is again an estimate. So, estimate multiplied by some value will again be an estimate.

So, this much is simple. So, it is very easy to calculate the density of animals in a forest just by taking some plots and then we count the number of animals in those plots divide that by the area of those plots to get a density of animals in the plot and then we say that the density of animals in the forest is the same as the density of animals in our sample plots. So, we get density of animals in the forest multiply that with the area of the forest and to get the total number of animals in the forest, but then distance sampling is different from these simple plot samplings, because of this assumption.

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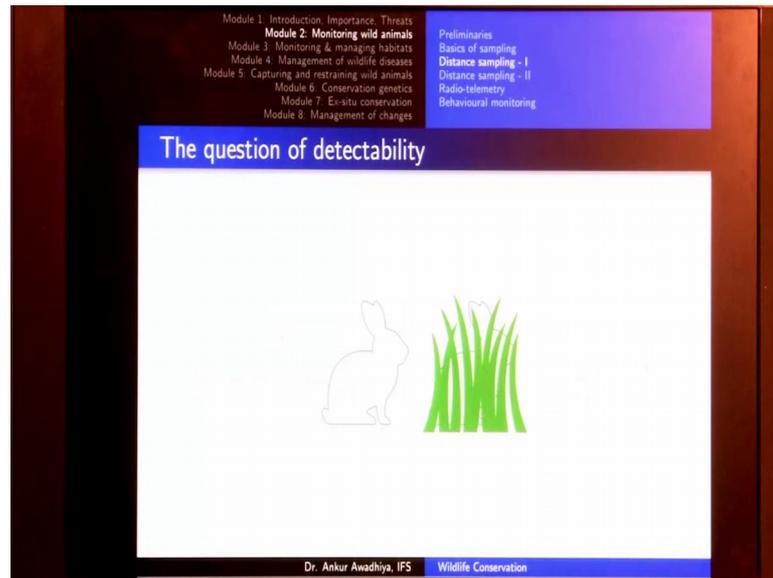
### How is distance sampling different from plot sampling?

Plot sampling assumes that all the animals in the sample plots are detected and counted. This may or may not be a correct assumption, as shown in figure on the next slide.

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Plot sampling assumes that all the animals in the sample plots are detected and counted which may or may not be a correct thing in the case of a forest.

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Because to illustrate let us take the example of this rabbit, now if this rabbit is out there on the ground will be able to see it, but if this rabbit is in a in a patch of grass it might be occluded.

So, we might miss out this rabbit and this is something that we need to put into our computations to get the correct figures because in the case of forest there are a number of situations in which we miss out the animals, any animal that is behind a tree will be missed out any animal that is not moving is just camouflaged inside say some bushes will be missed out, any animal that gets into the grasses will be missed out and this is something that we need to compensate for in our computations.

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The slide features a table of contents in the top left corner, a title bar, a main text area, and a footer. The table of contents lists modules 1 through 8, with 'Module 2: Monitoring wild animals' highlighted. The title bar reads 'Distance sampling'. The main text explains that distance sampling accounts for non-detection by considering that not all animals in a transect are detected and aims to estimate the number of missed animals for a better count or density estimate. The footer identifies the speaker as Dr. Ankur Awadhya, IFS, and the topic as Wildlife Conservation.

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## Distance sampling

Distance sampling takes this factor of non-detection into account by considering that not all animals in the transect are detected. Then it tries to estimate the number of animals that were missed in the counting exercise to get a better estimate of animal count or density.

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So, distance sampling takes this factor of non detection into account by considering that not all the animals in the transit are detected, now what is our transect. So, when we move this path we call it a transect. So, transect is a path on which we are moving in the forest to get our data.

So, distance sampling coming back to the sides. So, distance sampling takes the factor of non detection into account by considering that not all the animals in the transect are detected then it tries to estimate the number of animals that we missed out in the counting exercise.

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### Distance sampling

The estimate is given as:

$$\hat{n} = \frac{n}{\hat{p}}$$

where  
 $\hat{n}$  is the corrected estimate of animal numbers,  
 $n$  is the uncorrected estimate of animal numbers as found in the sample plot by considering that all the animals in the plot have been detected, and  
 $\hat{p}$  is the estimate of the probability of detection of animals.

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So, this estimate is given as  $\hat{n}$  is equal to  $n$  divided by  $\hat{p}$  now  $n$  is the number of animals that we counted, but our probability of detection is not 100 percent because we have missed out some animals. So, when we divide  $n$  by the probability of detection we get another estimate which is small  $\hat{n}$ . So, small  $\hat{n}$  is  $n$  divided by  $\hat{p}$  where  $\hat{p}$  is the probability of detection.

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### The question of detectability

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What we want to say in this case is that, when we moved on these transects, when we took out these strip lots there were some animals that we missed out.

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The slide is titled "Distance sampling" and is part of a presentation on "Wildlife Conservation" by Dr. Ankur Awadhya, IFS. The slide content is as follows:

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Distance sampling

For instance, suppose  $\hat{p}$  is estimated to be 0.75. This means that only 3 out of 4 animals will probably be detected. Thus, if 30 animals were detected in plot sampling, there were actually 40 animals in the transect area, considering the estimated probability of detection. We can write this as:

$$\hat{n} = \frac{n}{\hat{p}} = \frac{30}{0.75} = 40$$

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And suppose out of every 4 animals we were only able to see 3 animals and we missed out 1 animal. So, in that case our probability of detection that is  $\hat{p}$  is given by the number of animals detected divided by the number of animals actually present.

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The whiteboard shows the following handwritten derivation:

$$\hat{p} = \frac{\# \text{ animals detected}}{\# \text{ animals actually present}}$$
$$= \frac{3}{4} = 0.75$$
$$\frac{\# \text{ animals detected} = 30}{\# \text{ animals present} = x} = \hat{p} = 0.75$$
$$\Rightarrow \frac{30}{x} = 0.75$$
$$\Rightarrow x = \frac{30}{0.75} = \frac{30}{3/4} = 40.$$

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So, suppose we detected 3 animals when we had 4 animals actually there. So, we will have a  $\hat{p}$  is equal to 3 by 4 or 0.75. Now suppose we have this data of  $\hat{p}$  we know that our  $\hat{p}$  is 0.75 then we did another exercise and we directed 30 animals. So, we will have number of animals detected as 30, number of animals present is  $x$ , which we do

not know and this ratio number of animals detected by the number of animals actually present is  $\hat{p}$  and we have somehow computed this  $\hat{p}$  to be 0.75.

So, in this case we have  $30 \times x = 0.75$  or  $x = 30 \div 0.75 = 30 \times \frac{4}{3} = 40$ . So, once we know our value of  $\hat{p}$  and once we know the number of animals that we actually counted which is small  $n$  we can estimate the number of animals that would actually been there.

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### Distance sampling

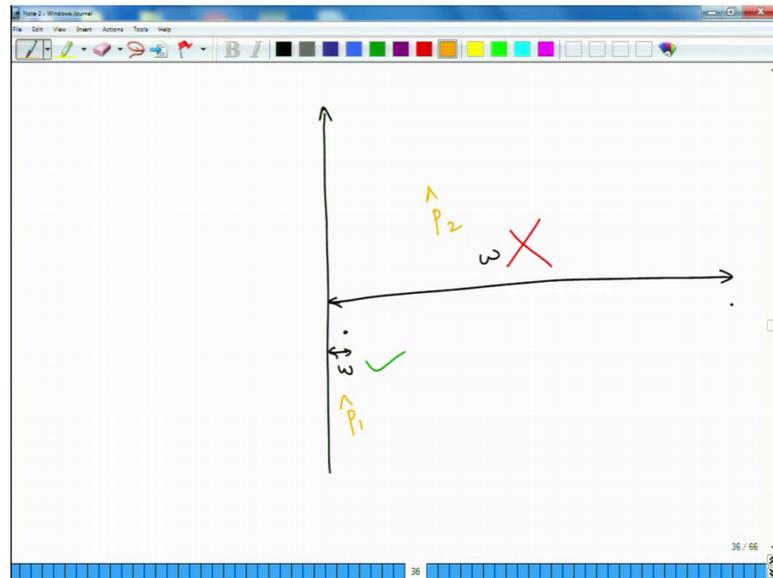
There is one other prominent distinction between plot sampling and distance sampling: the width of the strips. Since plot sampling assumes that all the animals inside the strip get detected and counted, the width of the strips must invariably be small so that this assumption remains valid. This is because the probability of detection of animals goes on decreasing with distance from the transect line. For the plot sampling assumption of full detectability to hold true, the distance from the transect line, therefore, cannot be large.

On the other hand, since distance sampling assumes that not all animals will be detected, the strips can be much wider. For every width of the strip, there will be some  $\hat{p}$ , which can be estimated.

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Now, another distinction between plot sampling and distance sampling is that of the assumption, in the case of plot sampling because, we said that we have detected each and every animal. So, our strips cannot be very wide because when the strips are wide enough. So, suppose

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We are moving in the forest and if there is an animal here it will be easier to do to detect this animal as compared to an animal that was at a far off distance. So, when we say that our assumption is that we are detecting each and every animal this the width or the half width of the strip cannot be very large. So, this  $w$  would be acceptable, but this  $w$  will not be acceptable in the case of a strip plot, but in the case of a distance sampling experiment because we are assuming that we are not detecting each and every animal. So, in this case we will be having certain value of  $p$  hat let us call it  $p$  hat 1 in this case we will be having a certain value of  $p$  hat which is  $p$  hat 2.

Now, because in both the these situations we are saying that we are not detecting each and every animal and there is some  $p$  hat involved we can take any width of the strip as much as we want. So, basically this assumption is crucial in the case of forest because like when you are moving in a forest and when you see an animal at a great distance, so whether you include it into your sample or not. So, when you see an elephant that is say 800 or even a 800 meters or even say a kilometer away from you, you cannot include incorporate that into a strip plot, but you can always incorporate that as a data point in the case of your distance sampling and we can always compute  $p$  hat and use that in the figures.

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### Distance sampling formula derivation

For plot sampling, we had estimated the number of animals as:

$$\hat{N} = \hat{D} \times A$$

$$\Rightarrow \hat{N} = \frac{n}{k \times 2w \times l} \times A$$

$$\Rightarrow \hat{N} = \frac{nA}{2wL}$$

where  $L$  is the total length traversed, also called effort

$$L = k \times l$$

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So, now coming back to the distance sampling formula we had estimated for the plot sampling that  $\hat{N}$  is  $\hat{D}$  into  $A$  and we had taken out this formula as we had seen in the previous slide in the case of distance sampling.

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### Distance sampling formula derivation

For the corresponding equation for distance sampling, we replace  $D$  with  $\hat{D} = \frac{\hat{n}}{\hat{p}}$ , or  $n$  with  $\hat{n} = \frac{n}{\hat{p}}$  to get:

$$\hat{N} = \frac{nA}{2wL\hat{p}}$$

All that remains now to use this equation is an estimate of  $\hat{p}$ .

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We replace  $n$  with  $\hat{n}$  or  $n$  by  $\hat{p}$ . So, in the case of this in the earlier slide we had this formula  $nA$  by  $2wL$  and in this case it will become  $\hat{n}A$  by  $2wL\hat{p}$ . So, in place of  $n$  we have replaced it by  $\hat{n}$  or  $\hat{p}$ . So, now all that remains is to estimate the value of  $\hat{p}$ . So, how do we estimate the  $\hat{p}$ .

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The slide is titled "Estimation of  $\hat{p}$ ". It contains the following text and table:

To estimate  $\hat{p}$ , we begin by tabulating the number of animals observed at different distances from the transect line.

Table: Table of the number of animals detected at different distances from the transect line

Distance from transect line (m)	Number of animals observed
0 - 10	35
10 - 20	35
20 - 30	22
...	...
60 - 70	1

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Footer: Dr. Ankur Awadhya, IFS | Wildlife Conservation

So, to estimate  $\hat{p}$  what we do is when we are walking on a transect line and we are seeing animals we find out the distance of these animals from us and then we group it into a number of categories. So, suppose we saw 35 animals at a distance of 0 to 10 meters. We saw 35 animals at a distance of 10 to 20 meters.

Then at 20 to 30 meters we saw only 22 animals at 60 to 70 meters we saw only 1 animal. Now our assumption was that the density of animals throughout the forest is constant. So, essentially we should be seeing equal number of animals between our distance of 0 to 10 and our distance of 60 to 70, but this is not happening in the case of actual detection of animals. So, we plot these animals as a chart.

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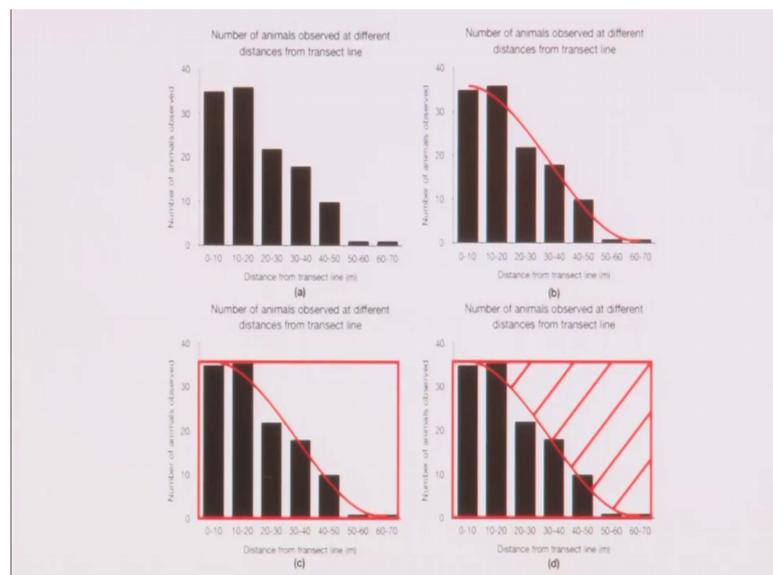
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### Estimation of $\hat{p}$

Next, we plot these distances in a bar chart, with the distances from the transect line on the x-axis, and the number of detected animals on the y-axis.

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So, what we have done in this plot is that we have noted out our distances from the transect line on the x axis and the number of animals that we have detected at different distances on the y axis. So, from 0 to 10 meters we saw 35 animals from 10 to 20 we again saw 35 animals and at a large distance we saw only 1 animal.

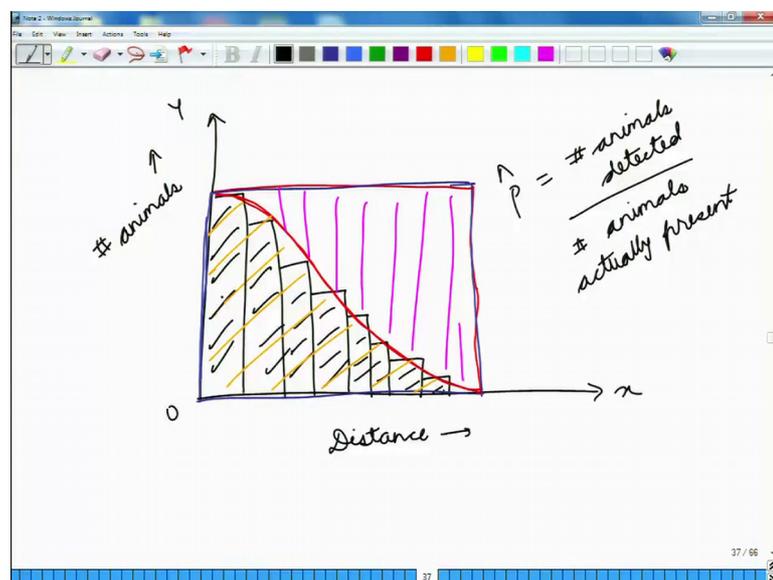
So, this is our bar diagram that we got from a at. Now this bar diagram can then be converted into a curve by taking the midpoints and then drawing a curve that goes through all the midpoints of all the bars. So, this red line detects our curve. Now our

assumption was that the density of animals throughout the forest is constant. So, the number of animals that we have detected here should be the same of the number of animals that we have that should be at this distance as well.

So, we take a straight line from the, from the top of the first curve till the end point and then we draw this rectangle. Now in this rectangle the number of animals that were actually present is given by the area of the rectangle because we have this number of animals or the density of animals and which is constant at all the distances.

So, if we take the area of this rectangle it will be proportional to the total number of animals that were actually present in the forest; however, when we did our experiment we only saw these animals which is the area of the curve that is below this line. So, this is the number of animals are detected and this total is the number of animals that were present and if you look at this hashed portion this is the number of animals that were not detected.

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So, what we saw in our curve is that we have animals that we have plotted as these bar charts and then we used this bar chart to create a curve which is this red curve of which is a scooped out data line of the number of animals actually seen, now the total number of animals that were there in the forest is given by or is proportional to the area of this rectangle whereas, the number of animals that we actually saw in the forest is given by

the area of this figure under the curve and the number of animals that we missed out is given by this area.

Now, going back to the equation of  $\hat{p}$  is the number of animals detected divided by the number of animals actually present. So, when we use this formula we get  $\hat{p}$  as the area under the curve given by these yellow lines divided by the total area of the rectangle.

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### Estimation of $\hat{p}$

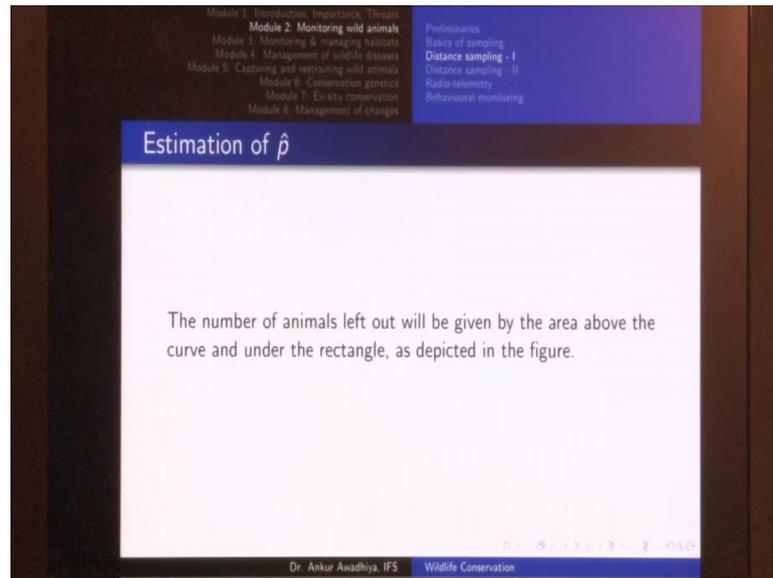
The total number of animals in the strip of width 70 m will be given by the area under the rectangle. On the other hand, the actual number of animals detected in the strip of width 70 m is given by the area under the fitted curve. The ratio of these areas will give the probability of detection:

$$\hat{p} = \frac{\text{Area under the fitted curve}}{\text{Area under the rectangle}}$$

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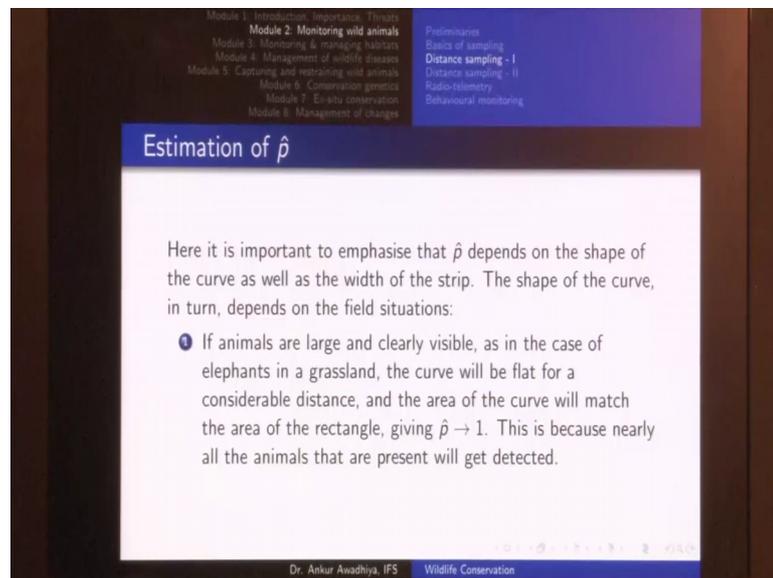
So, coming to the slides we have  $\hat{p}$  is the area under the fitted curve divided by area under the rectangle. So, this is one way in which we can estimate  $\hat{p}$ .

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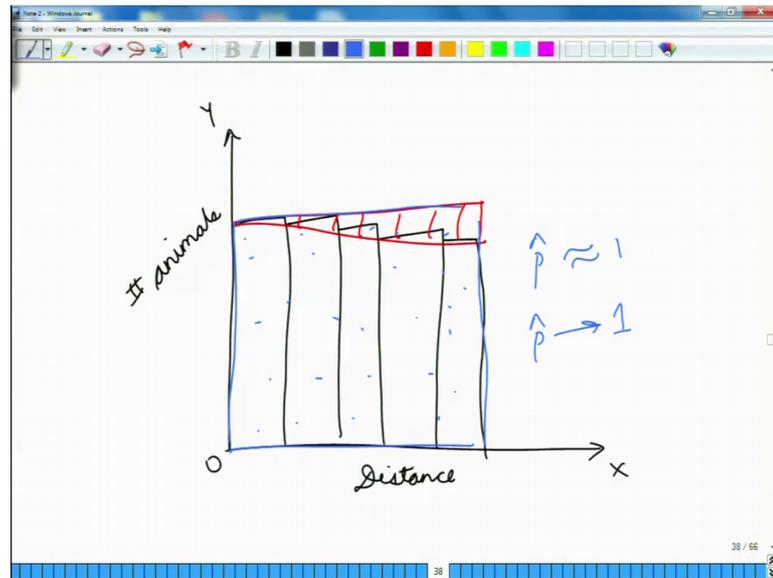
And the number of animals that is left out is given by the area in the hashed lines in red in this figure.

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Now, when we are estimating  $\hat{p}$  it will depend on a number of field situations. So, if the animals are large and clearly visible as in the case of elephants in a grassland the curve will be flat for a considerable distance and the curve will match the area of the rectangle giving  $\hat{p}$  close to 1 what we mean in this case is that when we are plotting distance versus number of animals.

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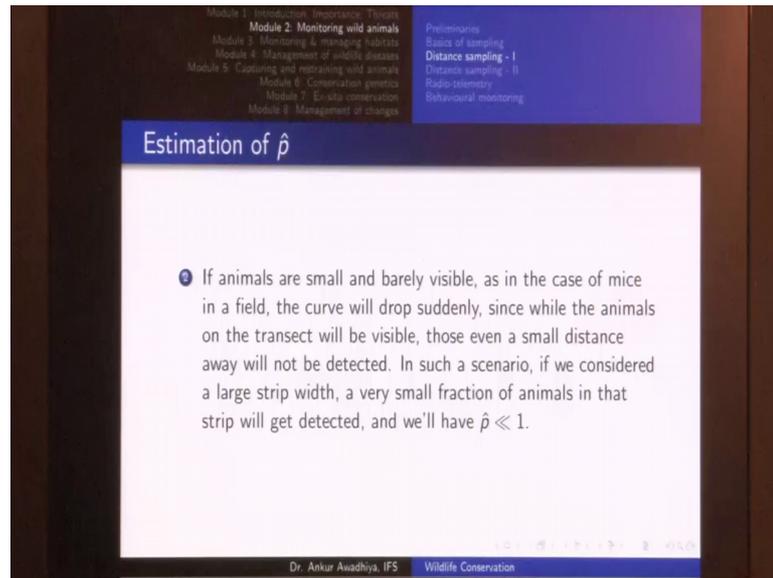


So, we are considering a situation in which we have grasslands for a very large distance and we have large sized animals like the elephants. Now, even if you have an elephant at a distance and you have short grasses there you will be able to see the elephant and basically because we have a flat terrain we are able to see it for a very large distance.

So, the density of elephants that we find at every distance would be nearly the same. So, essentially our curve would be close to this even if we are missing out some elephants at a distance the total number of animals that we are missing out this much is very small as compared to the area of the complete rectangle.

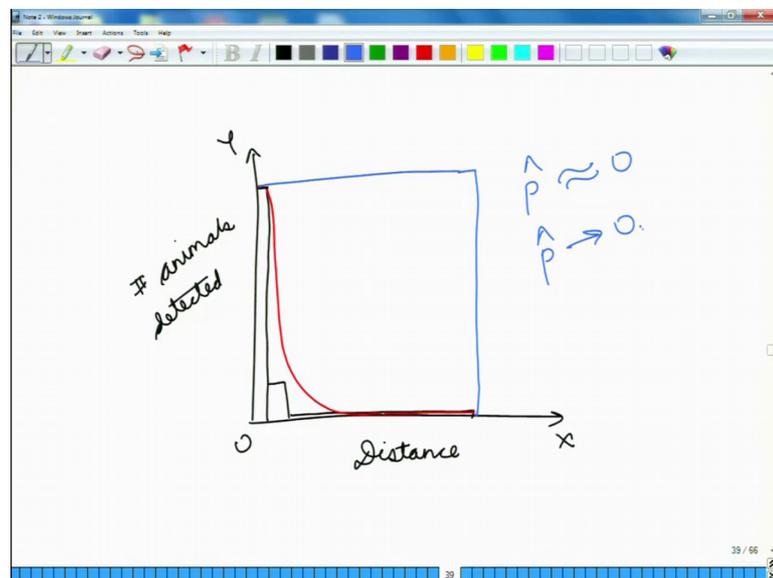
So, in this case we will be having  $\hat{p}$  is close to 1 or  $\hat{p}$  is tending towards 1. On the other hand if you have a situation in which the animals are barely visible. So, consider that you are moving in a grassland and the animal you are interested in is say a mouse that has found in that grasslands.

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Now when you are walking on your transect if the mouse is there on the transect itself you will be able to see it but as soon as your mouse gets into the grasslands you will not be able to see it. So, essentially when we draw the curve it will be like this.

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So, you have distance and the number of animals detected. So, at a very close distance at a distance of 0 when your animal is actually on your path you are able to see that animal, but as soon as you this animal has moved away from you it has gone into a bush into a,

bush of grasslands. So, as soon as this animal enters into the grass it will be occluded you will not be able to detect it.

So, coming back to the board your detection it might be a bit of detection when it is just entering to the grass, but then it will become close to 0. Now, when you draw your curve it will be something like this and when you take the area under the curve and divide it by the area under the rectangle you will have a  $\hat{p}$  that is very close to 0 or a  $\hat{p}$  that is tending towards 0. Similarly,  $\hat{p}$  would also depend on a number of other factors.

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### What does $\hat{p}$ depend on?

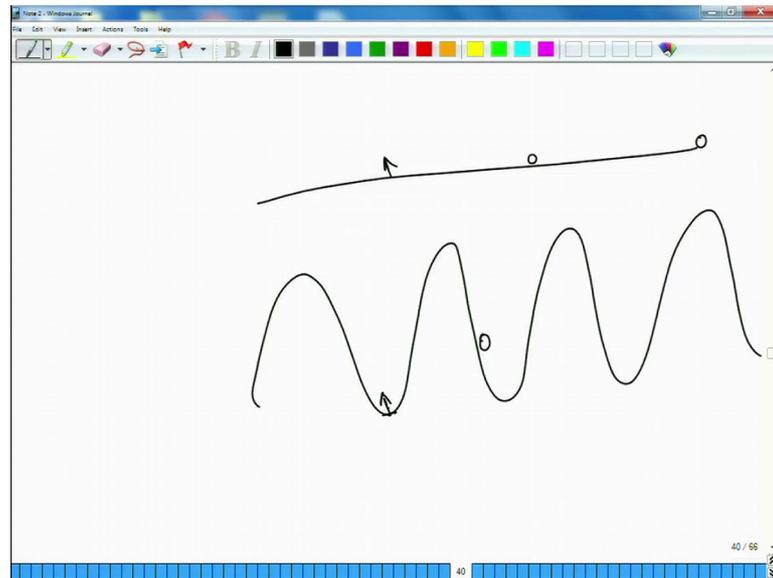
Under field conditions,  $\hat{p}$  is often an extremely tricky quantity to estimate, since it is affected by several factors, many of which may not even be under our control. Some factors influencing  $\hat{p}$  are listed below:

- 1. **The characteristics of the terrain:** Flat, clear terrains are easier to work with, since they provide little scope for animals to hide while providing the observer a large field of view. On the other hand, animals may not be seen in tall grasslands, thick bushes or undulating terrains. Thus, the terrain may have a large bearing on the value of  $\hat{p}$ .

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So, coming back to the slides  $\hat{p}$  would depend on the characteristics of the terrain, if your terrain is flat, so you are able to see for a very long distance you will be having a greater probability of detection as compared to an area which is having an undulating topography.

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So, if this is my area I am walking on a transect that goes like this. So, any animal which is here will not be seen whereas, if I am walking on a flat line this is my transect any animal at a very large distance also will I will be able to see that animal. It also depends on the nature of the transect exercise.

So, basically when you are walking this transect you can either walk on foot or you can take a vehicle. When you are walking when you are moving on this transect in a vehicle which we call as a vehicular transect you are at a much elevated height. So, from that elevated height you will be able to see for a much larger distance as compared to when you are walking on by yourself on foot.

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### What does $\hat{p}$ depend on?

- 1 **The nature of the transect exercise:** Vehicular transects may result in larger number of detections than walking transects, not only because they provide a higher vantage point of observation, but also because the animals, habituated to vehicles by their park experiences, often feel more comfortable and do not run away.
- 2 **The nature of the transect:** Transects on areas that are more frequented by animals will have larger detection probabilities. Examples include some trails and roads.

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Also in the case of a forest when you are moving in a vehicle the animals are much more comfortable because like in most of our tiger reserves we have. So, many tourists that are that are already moving in the park areas. So, the animals are habituated to the sight of a vehicle moving because that vehicle does not do any harm to them, but the animals are not habituated to the to the situation of finding a human being on foot. So, the animals might be startled now this can have a good impact on our probability of detection or it can have a bad impact, a good impact because even animal is standing somewhere in the forest it is difficult to detect that animal mostly because most of the animals are actually camouflaged they are already camouflaged.

So, camouflaging is consider the case of a tiger, a tiger has stripes it moves in the grasses. So, it blends with the grasses and so, you are not able to see that animal. If you see any animal say chital. So, chital is normally found in areas that has brown colored soil. So, when you have a chital in the foreground brown colored soil in the background you do not see the chital because chital already has a brown color. So, brown and brown mixes well, but when this animal is moving you can very easily say that yeah there is an there is a chital that is moving.

So, just because of its movement you are able to detect. Now, in the case of a vehicular transect because the animals are comfortable they will just be doing their own activities. So, if they are grazing on the grasses they will be grazing on the grasses they will not be

running, but when you are moving into that area the animal will run when you are moving on foot.

So, when you when you are moving on foot, you will be able to detect that animal in a much greater probability as compared to when you are moving in a vehicle just considering the movement aspect, but then a typically it is observed that in the forest the detection of the animal of the human being is much greater. So, basically when you are moving in the forest the animal will see you much before you will see the animal.

So, with your at a distance from the animal and if that the animal has detected you and it has run away then you have already missed that animal. So, the  $\hat{p}$  will depend a lot on the nature of the transect exercise there will be some things that will help you there will be some things that will not be helping you and these aspects will have to be put into your computations. The nature of the transect, so, transects on areas that are more frequented by animals will have larger detection probabilities. So, for instance there are some animals that prefer walking on the roads. So, if you are walking on the roads you will have a much greater detection of animals just because you have the animals that are concentrated there.

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### What does $\hat{p}$ depend on?

- 1 **Local traditions:** In areas where locals feed animals, the animals might come closer to the observer, facilitating their detection.
- 2 **The characteristics of the animals:** Some animals are bold; they approach the observer. Some animals are shy; they avoid the observer. Some animals may have a keen sense of sight, sound or smell; others may not. The characteristics of the animals under observation have a large bearing on the value of  $\hat{p}$ .

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$\hat{p}$  also depends on the local traditions. So, if there are some areas in which the locals regularly feed animals and if you are walking in those areas then the animals are already habituated to the sight and smell of a human being. So, they will come to closer to you

and so they will facilitate their detection. It will also depend on the characteristics of the animals, some animals that are shy might freeze and if they freeze on seeing you will not be able to detect them, but on the other hand if there are some animals that are shy and they run away you will be able to detect them.

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### What does $\hat{p}$ depend on?

- 1. **The colour of the dress worn by the observer:** Bright colours will make the observer easily detectable by the animals. While some shy animals might move away (facilitating their detection due to movement) or freeze (hampering their detection due to absence of movement), some other bold animals might approach the observer (facilitating their detection).
- 2. **The perfume worn by the observer:** Since many animals have a keen sense of smell, perfume will affect the detectability of the observer, resulting in similar effects as listed above.
- 3. **The food eaten by the observer:** Many foods leave a trace scent, which might be sensed by the animals, affecting  $\hat{p}$ .

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Similarly, the color of dress that is worn by you when you are doing a transect exercise the perfume that has worn by you the food that is eaten by you because it will have some smell and it will also impact the animals because, they will be able to detect you and then depending on the nature of the animals they might even just freeze at that location or they might start running away which will impact the detection probability.

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### What does $\hat{p}$ depend on?

- 1. **The mental state and fatigue of the observer:** Under conditions of mental stress or fatigue, an observer might not take note of all the animals, affecting the estimate of detectability of the animals.
- 2. **The size of the observer group:** When there are more observers, there are more number of eyes that could facilitate the detection of animals. On the other hand, if the group members talk, the sound could signal the animals, affecting their detectability, besides hampering the concentration of the observers.

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$\hat{p}$  also depends on the mental state and fatigue of the observer and on the size of the observer group because typically we have seen in the forest that whenever these exercises are carried out in the beginning the people are extremely excited to see the animals and note down the results. So, even small movements are noticed by the people, but after a while when people get fatigued their mental state also becomes dull and they do not take note of all the animals.

Similarly, the size of the observer group, if you have a larger group you have more number of eyes that are looking out for the animals which should increase your detection probability, but typically what we have seen is that in a larger group people start chatting and this sound also alerts the animals. So, this again might be having a positive or a negative impact.

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### What does $\hat{p}$ depend on?

- 1. **The direction of wind:** When wind blows from the observer(s) towards the animals, human scent quickly reaches the animals. On the other hand, when wind blows from the animals towards the observer(s), then the human scent does not reach the animals fast. Animals react to scent; hence the direction of wind may also affect the  $\hat{p}$ .
- 2. **The weather on the day of observation:** Overcast skies will give very different results from clear skies, since weather impacts the activity of animals. When animals are more active and keep moving, they are easily detected.

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Next is the direction of the wind, if the wind is moving from the animal towards you the animal will not be able to detect you through the smell, but if the wind is moving from you towards the animal then the animal will be able to detect (Refer Time: 33:24) from your smell at a very large distance. So, that will also impact the  $\hat{p}$ . It also depends on the weather on the day of the observation because animals will typically be showing very different characteristics on different days of observation; so, for instance if you are looking out for snakes in a cold season and you have sun outside.

So, the animal will typically be found basking on the rocks or probably even basking on the trail whereas, if you are looking out for the snakes on an overcast day then probably the animal would be hiding somewhere. So, the nature and behavior of the animal also depends a lot on the weather on the day of observation. So, typically it is easy to say that we can estimate  $\hat{p}$ , but  $\hat{p}$  because it depends on.

So, many factors it becomes difficult to estimate and so has to be computed using numerical methods for each and every exercise. So, essentially we do not have a value of  $\hat{p}$  that we can just put up in our equations to get the number of animals that should be there. It will have to be computed again and again for every exercise and we will look at it in greater detail in the next lecture so.

Thank you for your attention, jai hind.