E-CONTENT PREPARED BY

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E-Content prepared for students of

M.Sc.(Semester-III) in Conservation Biology

Name of Course:
Quantification Techniques

Topic of the E-Content:
Biological sampling and census techniques

Wildlife Sampling

See the photograph very carefully, you can locate a box with white dot in between the two wolves. That is a camera trap, and this photograph has been taken by another camera trap installed just at the opposite end! This is an example of wildlife population sampling in high Himalaya, at 5000m altitude in Trans-Himalayan cold desert of Gangotri National Park. The reason of showing this picture has several points, the photograph itself is showing that wildlife usually resides in harsh and tough geographical and climatic conditions, often they are hard to detect and many times we can’t cover the entire range of their habitats. So, what should we do if we want scientific information about their existence? The answer is – sampling and in case of wildlife (animal and plants), this is called wildlife sampling

Wildlife Sampling

- Wildlife conservation and management was built on natural history observations and conclusions from associations with environmental factors rather than experimental tests of hypotheses
- Wildlife biologist confronts uncontrollable natural variations that may bias the results and conclusions

Conventional laboratory experiments are not possible in wildlife science, particularly when sampling of wild animals in their habitat is concern. Wildlife sampling consists observation of fauna and/or flora in natural condition. The term natural condition implies that the condition is not controlled by anyone. And this very factor influences the results of analysis. For example, think about the previous photograph, if there was such a heavy snowfall that the camera lenses got covered, no detection was possible, but only the tracks or pugmarks of the wolves would be visible. In that case we could confirm the presence of the species but we cannot count how many of them were present.

Need of Study Design

- Investigation in natural environments over large geographic area
- Difficult to observe and accurately count or estimate the abundance of target organism
- Spatial and temporal variation of associated biotic, abiotic and anthropogenic factors
- Rigorous scientific investigation in wildlife science is challenging and requires careful design

This slide shows what are the requirements for study or sampling designs, in most of the cases, particularly for vertebrates and trees, you have to cover a large area for sampling, without a proper design, coverage of the area would be impossible if the resources such as money and manpower are limited. As detecting wildlife is challenging, we need to plan how to execute the sampling. Spatial variation means the changes in the habitats of different locations, temporal variations means changes that we experience due to change in time, such as seasonal changes, day and night time differences, morning and evening time are most active period for wild animals, afternoon is for resting etc. Biotic factors denote the habitat composition which consists of living things, abiotic denotes all physical, chemical, geological and climatic properties of the habitat, anthropogenic factors are impacts caused by human on the wildlife and their habitats. The last point summarizes what is meant till now.

Descriptive vs Experimental Research

Descriptive Research

- Broad Objectives
- Lead to formulate a general research hypothesis or conceptual model

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Examination of the validity of this hypothesis or model– **Experimental Research**

In the previous slide, we discussed why we require study design for sampling, in this slide, we will discuss the broader aspect of sampling that is research. Now, research can be of two types, one is descriptive or hypothetical, where a concept is generated. For example, Albert Einstein formulated the hypothesis in the form of the famous equation $E=MC^2$ then another part is the experimental research which were carried out by several scientists who developed the atom bomb. Similarly, many hypothesis can be developed in wildlife science observing the trends and patterns and their validity can be tested in field.

Sequential events in scientific research

- 1- Research problem identification
- 2- Literature Review
- 3- Identification of broad research objectives
- 4- Reconnaissance survey
- 5- Exploratory data analysis
- 6-Research hypothesis or conceptual model formulation
- **7- Design the research or sampling design**
- 8- Data collection according to the research design
- 9- Data analysis
- 10- Result interpretation and draw inferences
- 11- Speculate on results and formulate new hypotheses
- 12- Repeat the process with new hypotheses

These are the 12 essential steps involved in a scientific research, research starts with identification of problems or question. Again remember the first photograph of wolves, where we or the managers have no idea about the population size of wolves in the valley. Then the second step is to search for previous works which have been carried out on same or similar species in similar habitats and to learn what are the techniques they adopted, what are the challenges they faced and what were their findings. This review helps us to formulate our own research objectives. For this particular example, the objective may be stated like this-"to estimate the abundance of wolves in Gangotri valley". After setting the objectives, we have to visit the habitat, we have to talk to the locals to know the whereabouts of the wolves. This is called reconnaissance survey. The data gathered in reconnaissance survey can be analysed with simple means and the results help us to formulate our hypothesis. In this example, suppose, the initial survey data shows that all the respondents indicated that wolves are found only in the Northern part of the valley and they avoid the habitats near the concrete road. Now our job is to test these findings. Here, at this point of the research process, the necessity of sampling designs comes in. Rest of the processes you will know later on.

Sampling and Estimation

***Sampling*: The act, process, or technique of selecting a representative part of a population for the purpose of determining the characteristics of the whole population.**

***Estimation*: The process by which sample data are used to indicate the value of an unknown quantity in a population. Results of estimation can be expressed as a single value, known as a point estimate; or a range of values, known as a confidence interval.**

This is the definition of sampling. We select a representative part of a large population to know the features of the entire population. To know the features we need to calculate or quantify certain aspects (parameters) that we are investigating. This process is called estimation. In case of our example, from the sampled observations, we will calculate the abundance of wolves in Gangotri valley. Now, if we are sure that we have counted all the individuals then our result will be a single number (say 50 individuals). But in general, due to various factors as discussed earlier, we can’t assume 100% detection for wild animals. In that case we need to report the range of our estimations like 40 to 60 individuals. To find this range, all the statistical terms such as mean, standard error, confidence intervals are required. These you may know or will learn soon in your statistics class.

PURPOSES OF SAMPLING

- ESTIMATE ATTRIBUTES (PARAMETERS)
  - Abundance/ density
  - Survival
  - Home range size
- ALLOW LEGITIMATE EXTRAPOLATION FROM DATA TO POPULATIONS
- PROVIDE MEASURES OF STATISTICAL RELIABILITY

These are the three major purposes of sampling, to calculate or estimate features, to extrapolate the inference for the entire population and to give statistically reliable answers.

SAMPLING NEEDS TO BE

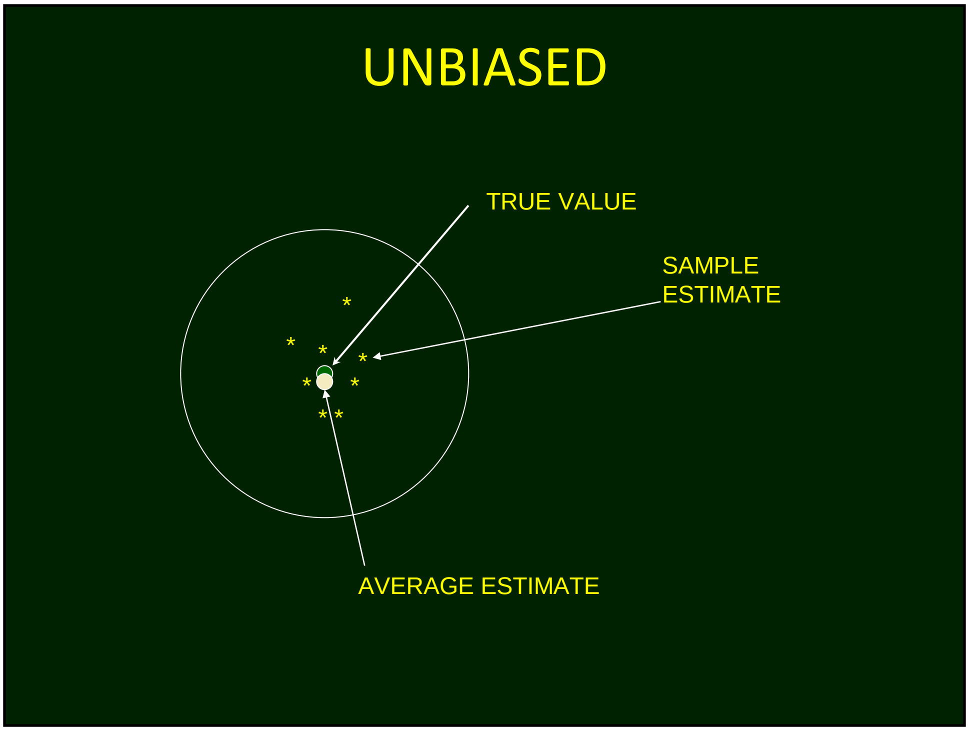
- ACCURATE– LEADING TO UNBIASED ESTIMATES
- REPEATABLE– ESTIMATES LEAD TO SIMILAR ANSWERS
- EFFICIENT– DO NOT WASTE RESOURCES

These three are the most important characters of a robust sampling design, accurate estimations, repeatability that means, the process can be repeated by others in similar conditions and efficiency to handle the available resources (money, manpower etc.) to complete the sampling process.

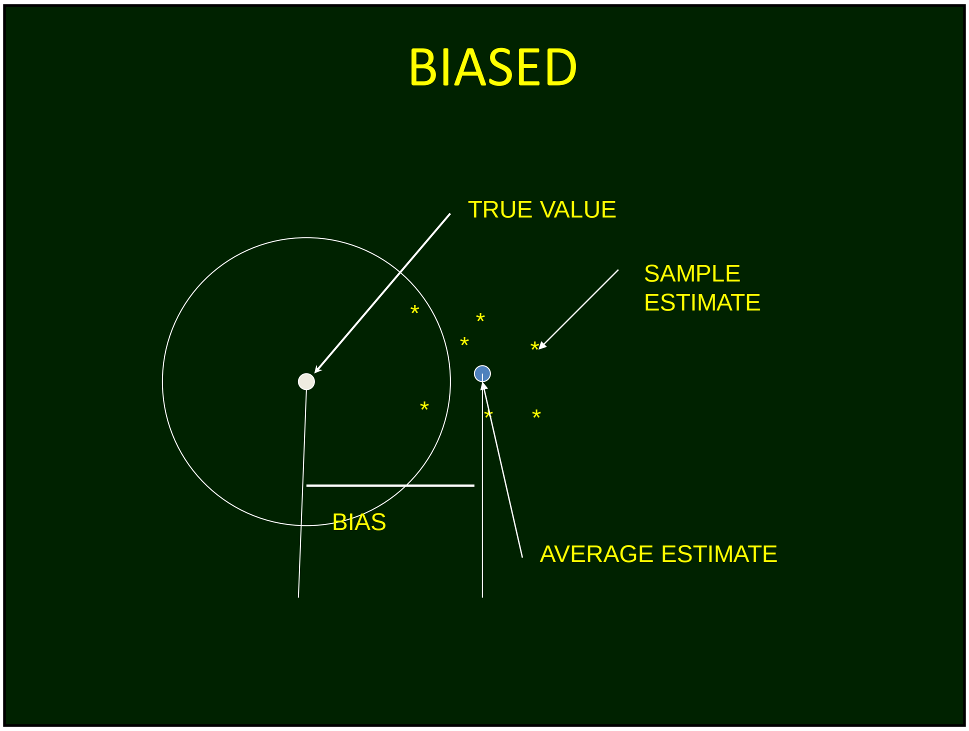
BIAS

- HOW GOOD "ON AVERAGE" AN ESTIMATE IS
- CANNOT TELL FROM A SINGLE SAMPLE
- DEPENDS ON SAMPLING DESIGN, ESTIMATOR, AND ASSUMPTIONS

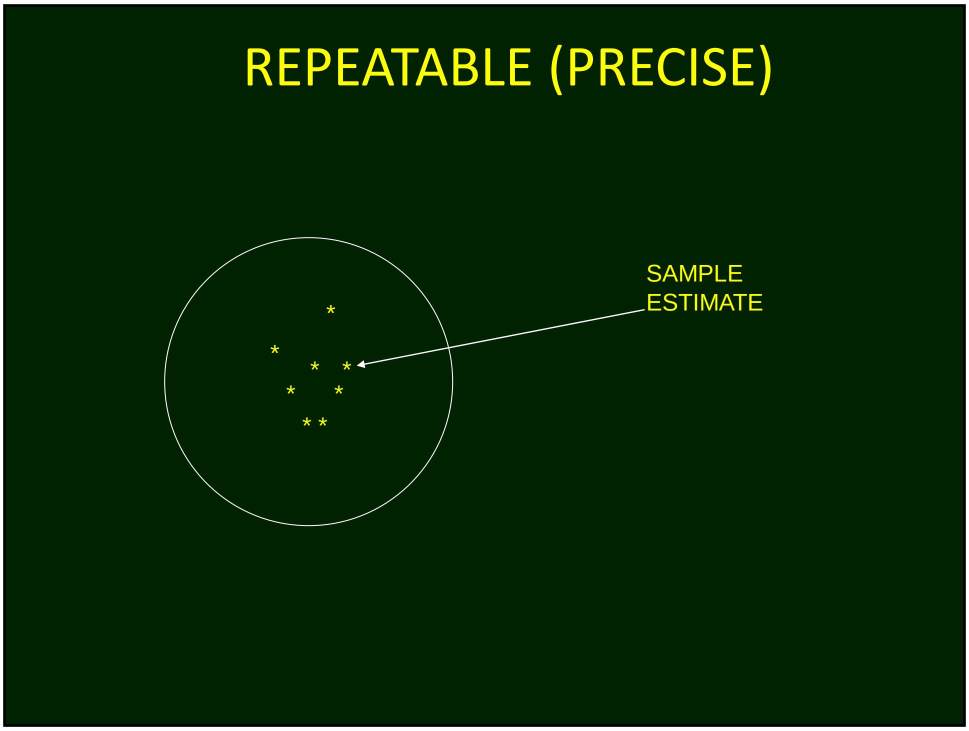
This is a very important term, whenever you do sampling you need to sort a strategy to keep the bias minimal. To understand bias you can think about the meaning of the word itself. Suppose in your examination, if I give full marks to any single individual and give pass marks to all others, where everyone copied from the same book, my evaluations would be regarded as a bias one. Similarly, in our wolf example, if we sample only the Northern part of the valley and never goes to the other parts, our estimation will give us biased results. In a nutshell, bias is the deviation of your estimation from the accurate or the true value of the sampled parameter. We must deploy the best possible sampling design and most appropriate analytical procedure to keep the bias low.



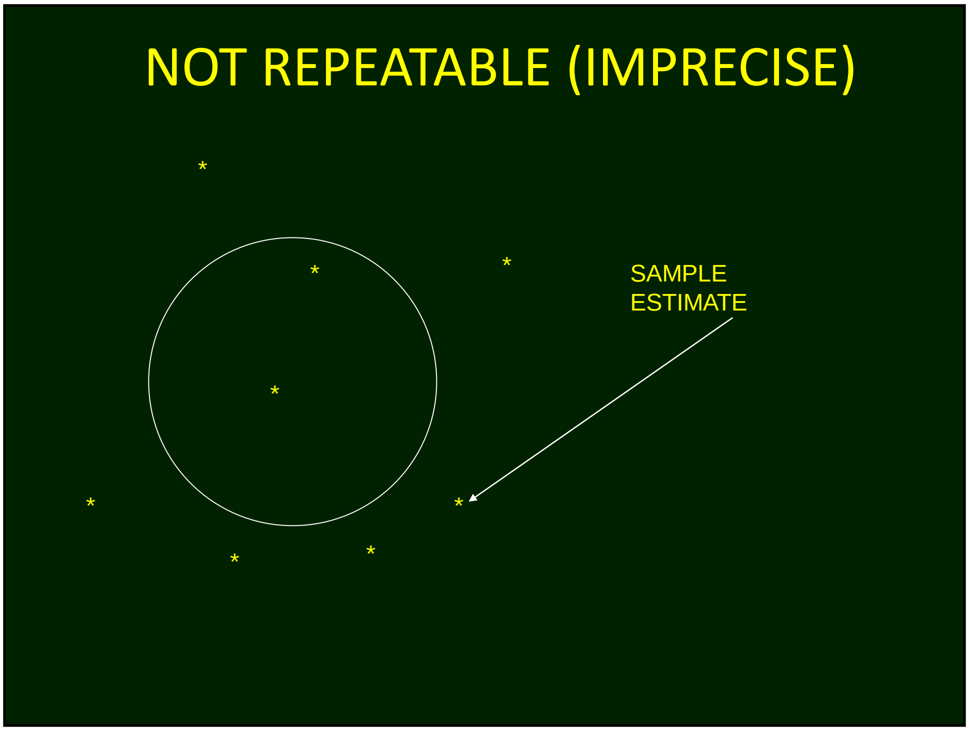
This is the representation of sample estimates in a bull's eye. The small blue circle at the centre is the true value of the parameter that we are estimating, we may or may not have a prior knowledge of this value. The yellow stars are denoting sample estimates in different occasions. The small white circle at the centre denotes the average value of all the small yellow stars or the sample estimates. In this particular slide, the average estimate and the true value are quite similar, that is called unbiased estimation.



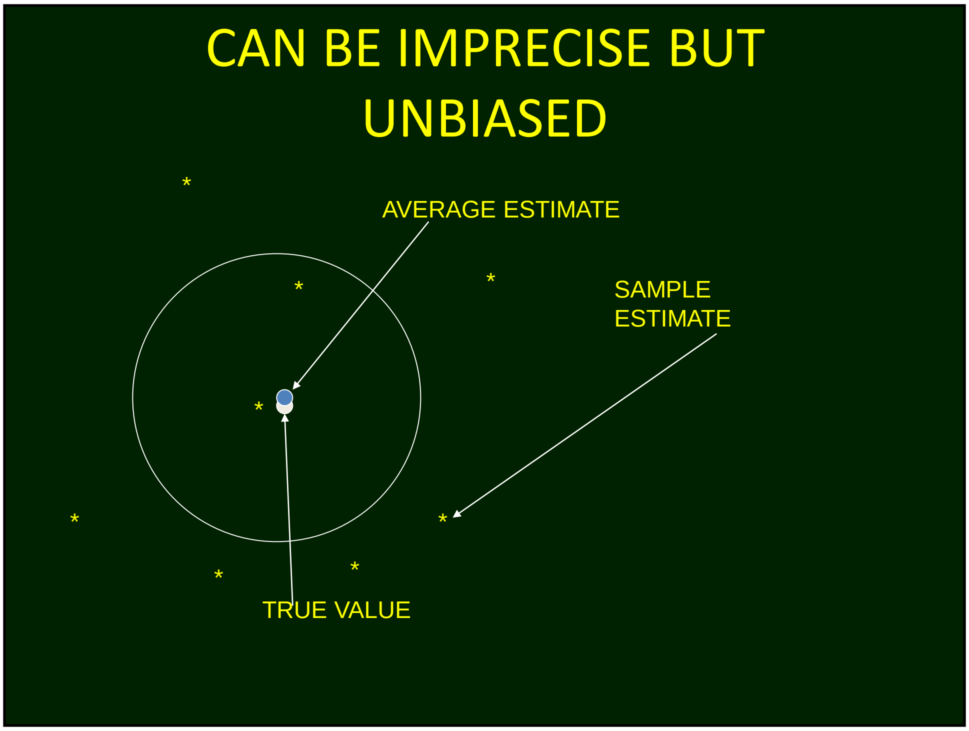
Here the average estimate differs from the true value and the difference is the amount of bias in the estimation



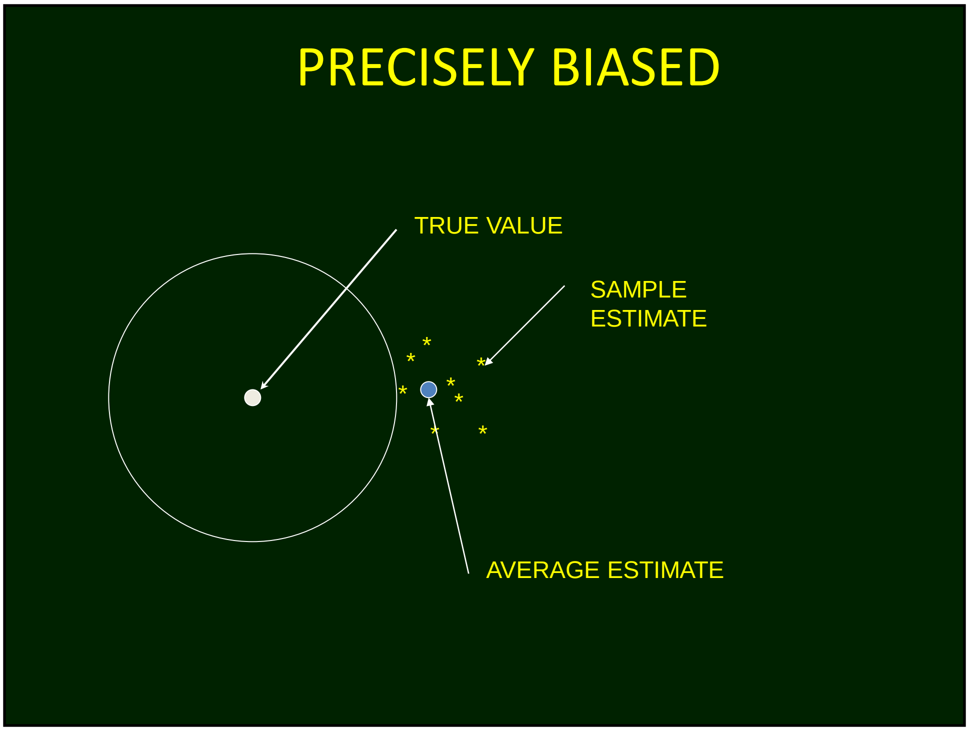
Here all the sample estimates are very nearly placed to each other, that means the differences among each sample estimate is not large. At each repeat the sampling procedure yielded similar results. This is called precision. As the results did not vary much in each repeat, this sampling procedure can be regarded as repeatable.



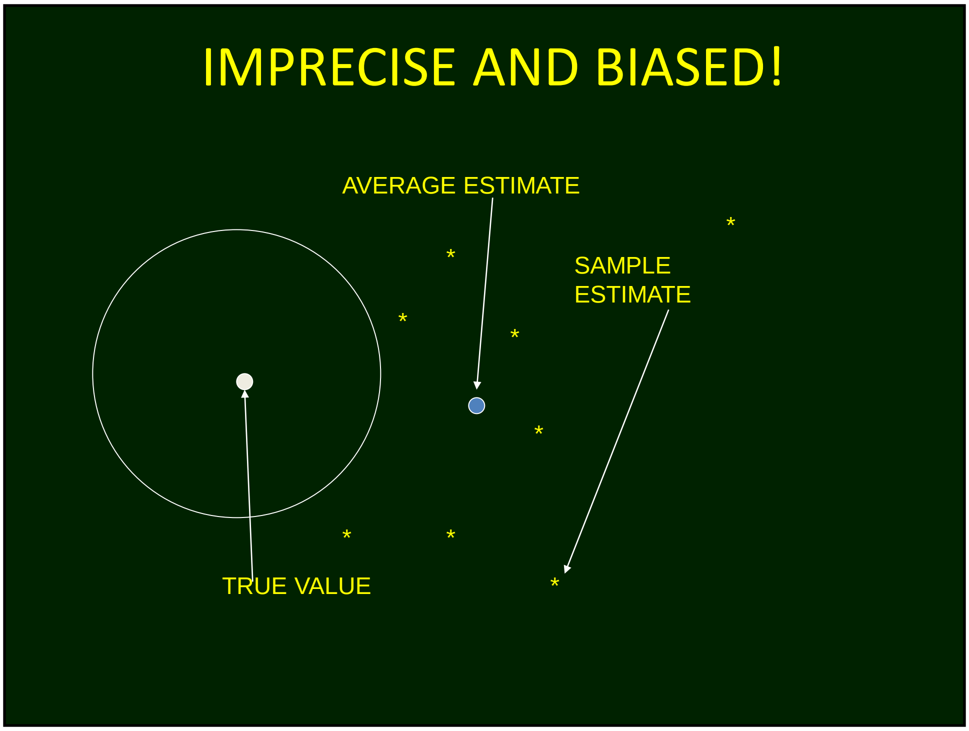
This is just the opposite case….



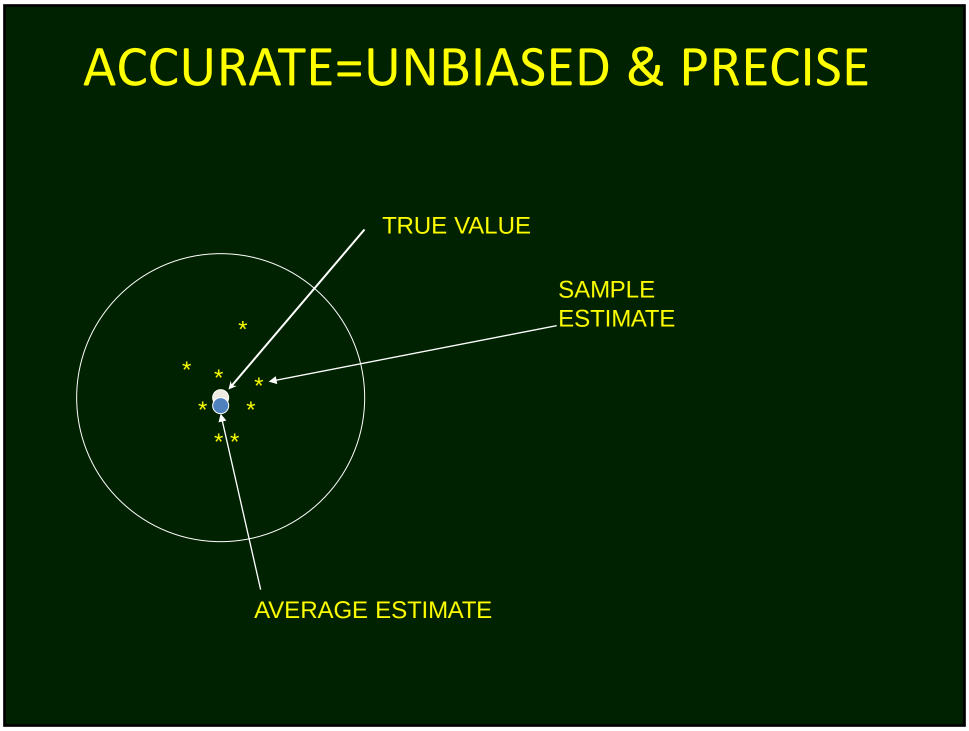
This may be unbiased but not desirable as this process cannot be repeated as there is huge variations among the sample estimates.



This is biased but the process is repeatable. In a bull's eye, this can happen when a champion shooter uses a faulty pistol. All of his or her attempts failed to hit the bull's eye because the aim of the pistol was not straight, if that can be corrected, the bull's eye can be hit. Similarly if we can correct the fault in our sampling process (may be human, mechanical or design error), we can achieve the true value.



This is the most avoidable situation, but unfortunately, in wildlife this is the most common case.



Our aim should be to achieve this and how that can be achieved, that will be discussed…

HOW DO WE MAKE ESTIMATES ACCURATE ?

- KEEP BIAS LOW
  - SAMPLE TO ADEQUATELY REPRESENT POPULATION
  - ACCOUNT FOR DETECTION
- KEEP VARIANCE LOW
  - REPLICATION (ADEQUATE SAMPLE SIZE)
  - STRATIFICATION, RECORDING OF COVARIATES, BLOCKING

To keep the bias low, good coverage of the study area or the study population is required, account for detection will be explained later in classes of transect and point count. What is variance you may know, if not please read the statistics book that SMS sir has provided. Replication, stratification all these are different aspects of sampling design. Replications means repeats, may be on same sampling unit (pseudo replication) or on other sampling unit (replication). Stratification is division of the study are according to habitat differences (our college can be stratified into grassland, building, forest and barren land). Covariates are parameters associated with the sampled parameter. For example, in the wolf abundance estimation, we can collect data on habitat, disturbance, prey availability etc. as covariates along with the count of wolf individuals. Blocking is one kind of stratification

HOW DO WE MAKE ESTIMATES ACCURATE ?

Replication

Definition: selection of multiple sampling units from a sampled Population

Needed to assess the sampling variation associated with parameter Estimates

Pseudo-replication: Sub sampling of primary sampling units, and treating the subsamples as if they are independently collected

Examples:

- Recording the weights of 3 independently sampled animals Vs recording the weight of 1 animal on 3 different occasions
- Splitting a transect into two and treating them as separate transects
- Treating individuals in a cluster as independent

Differences between Replication and Pseudo-replication is a must for your examination, please read carefully and ask question if not understood

HOW DO WE MAKE ESTIMATES ACCURATE ?

Control of variation

Results in more precise parameter estimates, and more powerful statistical tests

Methods of controlling variation:
- increase sample size
- use of stratification or blocking
- use of auxiliary covariates to eliminate nuisance sample-to-sample variation

GENERAL APPROACH OF SAMPLING

Purpose: obtain sampling units from a population to estimate population parameters

Since entire area of interest/ population cannot be surveyed, select a sample of areas, based on which inferences can be made to the entire area of interest/ population

Samples are collected in such a way that what is observed in the sample represents what is not observed

This is a summary of what you read till now.

INITIAL STEP: ASSESSING RESOURCES, CONSTRAINTS

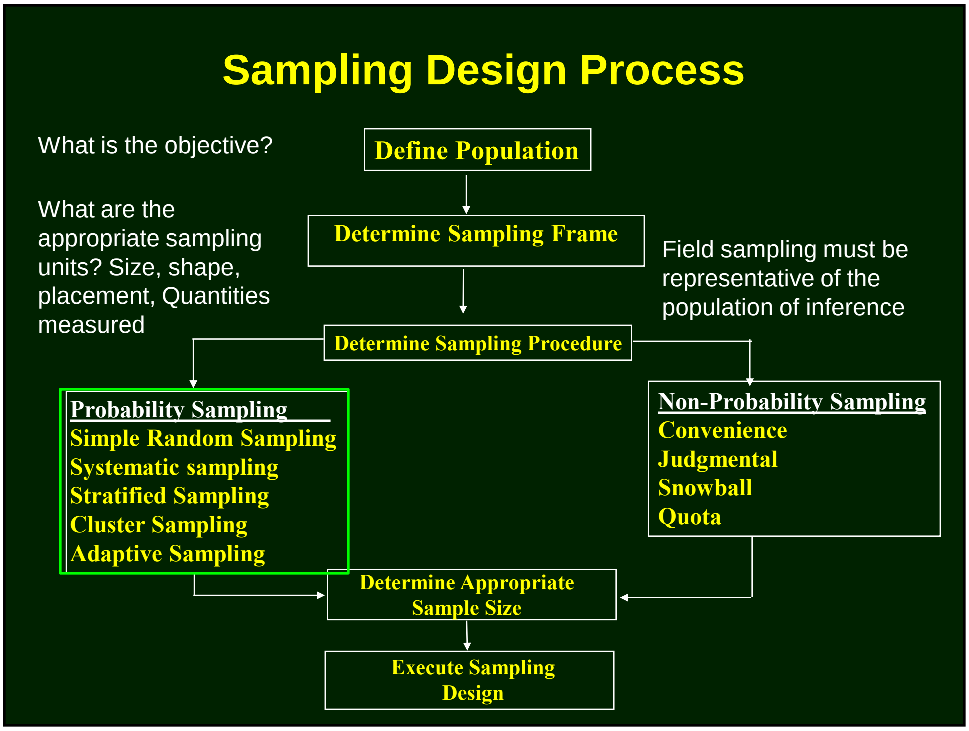
1. **Material resources:** money, equipment, vehicles, logistics

2. **Human resources:** numbers, field skills, technical skills

3. **Logistical constraints:** accessibility, weather

4. **Social constraints:** social factors, cultural aspects

Give an example how social factors can be constraints to sampling??



Sampling Design Process
What is the objective?
Define Population
What are the appropriate sampling units? Size, shape, placement, Quantities measured
Determine Sampling Frame
Field sampling must be representative of the population of inference
Determine Sampling Procedure
Probability Sampling
Simple Random Sampling
Systematic sampling
Stratified Sampling
Cluster Sampling
Adaptive Sampling
Non-Probability Sampling
Convenience
Judgmental
Snowball
Quota
Determine Appropriate Sample Size
Execute Sampling Design

Selecting a Sampling Design

- **Probability sampling - equal chance of being included in the sample (random)**
  - simple random sampling
  - systematic sampling
  - stratified sampling
  - cluster sampling
- **Non-probability sampling - - unequal chance of being included in the sample (non-random)**
  - convenience sampling
  - judgement sampling
  - snowball sampling
  - quota sampling

Non-Probability Sampling

- **Subjective procedure in which the probability of selection for some population units are <u>zero</u> or <u>unknown</u> before drawing the sample.**
- **information is obtained from a non-representative sample of the population**
- **Sampling error can not be computed**
- **Survey results cannot be projected to the population**

Types of Non-Probability Sampling

- ***Convenience Sampling***
  - A researcher's convenience forms the basis for selecting a sample.
    - people in my classes
    - Mall intercepts
    - People with some specific characteristic (e.g. bald)
- ***Judgment Sampling***
  - A researcher exerts some effort in selecting a sample that seems to be most appropriate for the study.

Types of Non-Probability Sampling

- ***Snowball Sampling***
  - Selection of additional respondents is based on referrals from the initial respondents.
    - friends of friends
  - Used to sample from low incidence or rare populations.
- ***Quota Sampling***
  - The population is divided into cells on the basis of relevant control characteristics.
  - A quota of sample units is established for each cell.
    - 50 women, 50 men
  - A convenience sample is drawn for each cell until the quota is met.

  (similar to stratified sampling)

Probability Sampling

Simple random sampling (SRS)
n units are selected in a way that every unit has the same probability *n/N of being selected*

Sampling typically without replacement, can also do random sampling with replacement

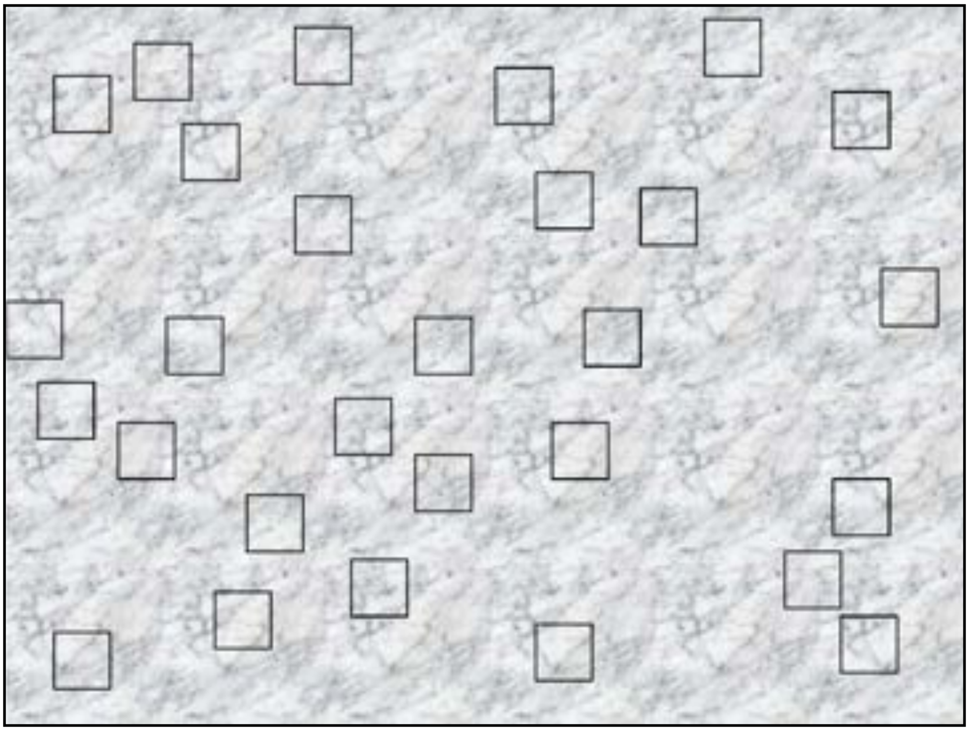
Simple to implement and derive estimates of mean and variance, but precision can be ‘improved’…

May not provide good coverage of area of interest

How to sample randomly?

Objective: To select n units out of N such that each ${}_N C_n$ has an equal chance of being selected

Procedure: Use a table of random numbers, a computer random number generator, or a mechanical device to select the sample



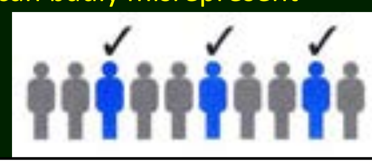
Systematic (or uniform) sampling

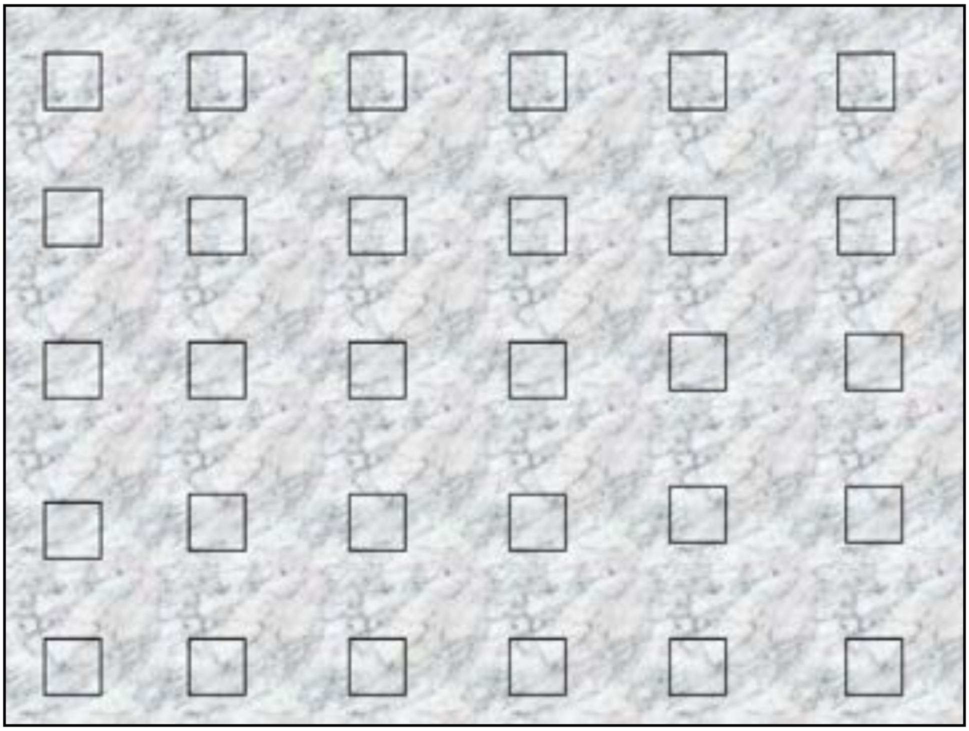
Randomized selection of a first sampling unit, and systematic (nonrandom) selection of sampling units thereafter

Equivalent to SRS if the ordering of individuals is independent of the attribute being measure
e.g.: - Survey of roadside vegetation, with samples every 10th km

Can provide much better sample coverage than a simple random sample

However, if there are systematic but undetected patterns in the population units, a systematic sample can badly misrepresent variation in the data





Stratified random sampling

Takes advantage of population structure to improve estimator precision

Stratify the population into groups of similar units
-population variation primarily reflects variation between groups

Requires some prior knowledge of variation in abundance
e.g. - Divide study area into strata according to vegetation types, use Simple Random or Systematic Sampling WITHIN strata

- Stratification by age or sex

Stratified random sampling

Useful if variable of interest is expected to vary across DISCRETE groups/ areas

Mean should be same/ similar to SRS, but variance estimates MUCH LESS, if large part of population variance is indeed between strata

Allocation of sample sizes

-Proportional allocation (by stratum size)

- Optimal allocation to minimize variance, given differences in stratum sizes, within-stratum variances, and per unit costs

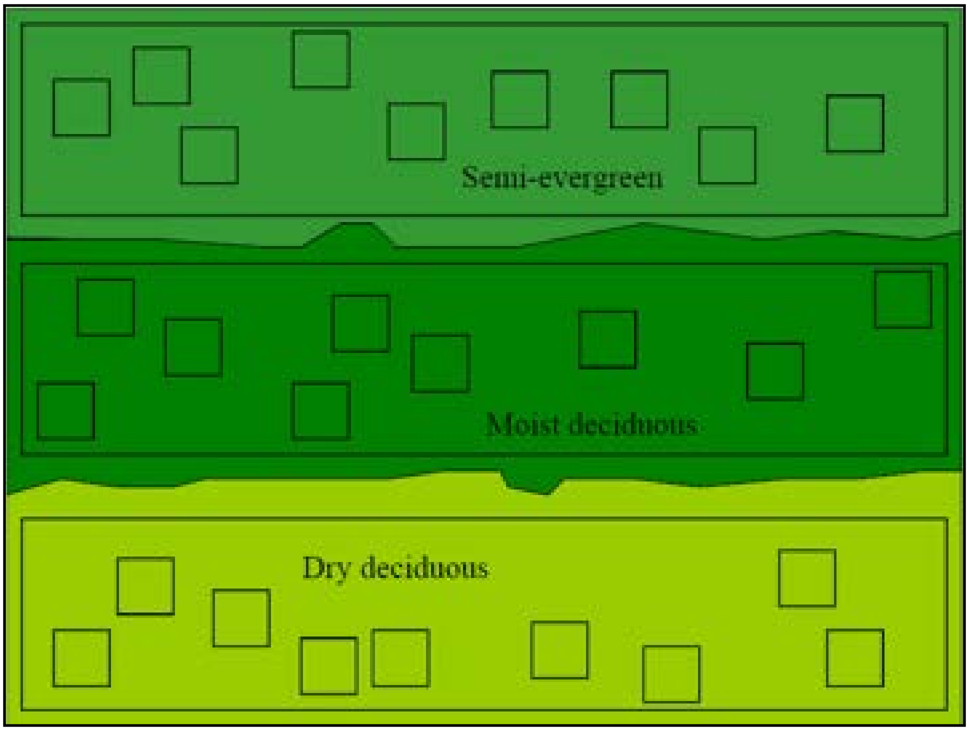
Stratified random sampling

- **Direct Proportional Stratified Sampling**
  - The sample size in each stratum is proportional to the stratum size in the population
- **Disproportional Stratified Sampling**
  - The sample size in each stratum is NOT proportional to the stratum size in the population
  - Used if

  1) some strata are too small

  2) some strata are more important than others

  3) some strata are more diversified than others


Semi-evergreen
Moist deciduous
Dry deciduous

Cluster sampling

Takes advantage of population structure to improve estimator precision

Clustering divides the population into groups of dissimilar units

- population variation primarily reflects within-group variation

Requires some prior knowledge of variation in abundance

e.g. Divide study area into clusters along the density gradient, such as transects radiating away from a river. Select a simple random sample of clusters—

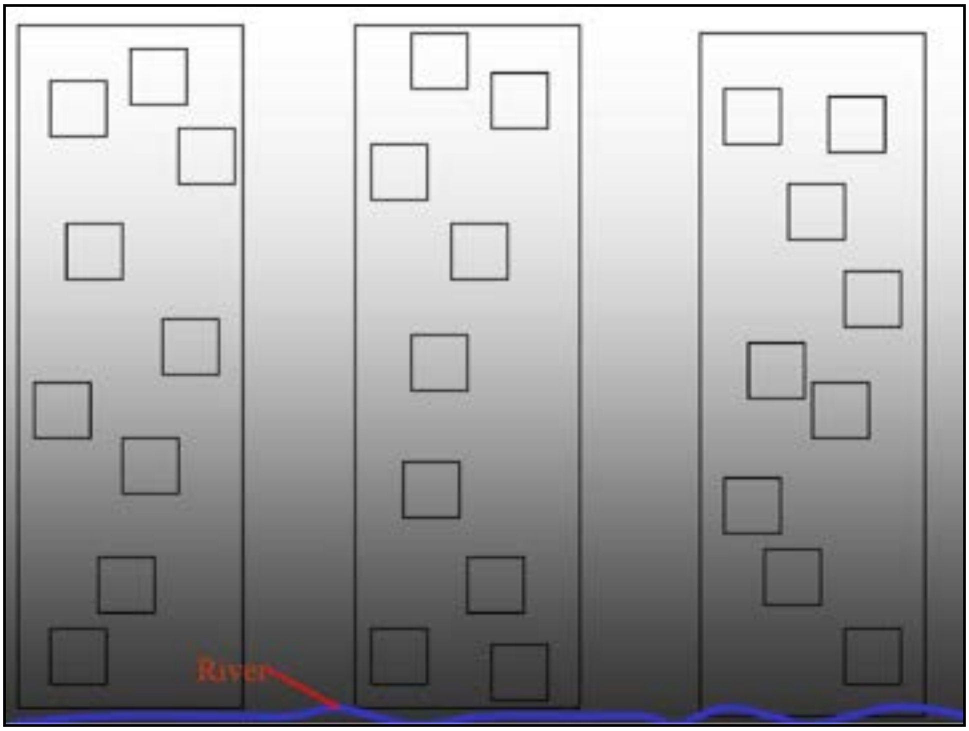
every unit in a selected cluster is included in the sample

Cluster sampling

Mean should be same/ similar to SRS, but variance estimates MUCH LESS, if large part of population variance is indeed within clusters

Only a limited number of clusters need be sampled to obtain estimates of population parameters

Clustering is beneficial if within-cluster variation is large relative to among-cluster variation


River

When to use stratified sampling

- **If primary research objective is to compare groups**
- **Using stratified sampling may reduce sampling errors**

When to use cluster sampling

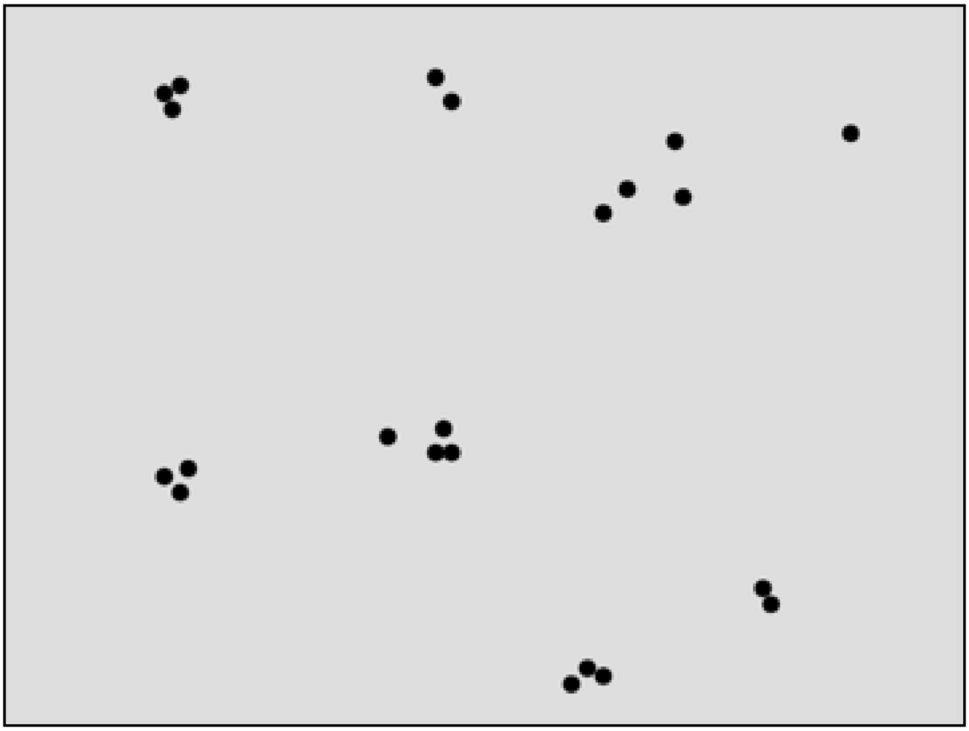
- **If there are substantial fixed costs associated with each data collection location**
- **When there is a list of clusters but not of individual population members**

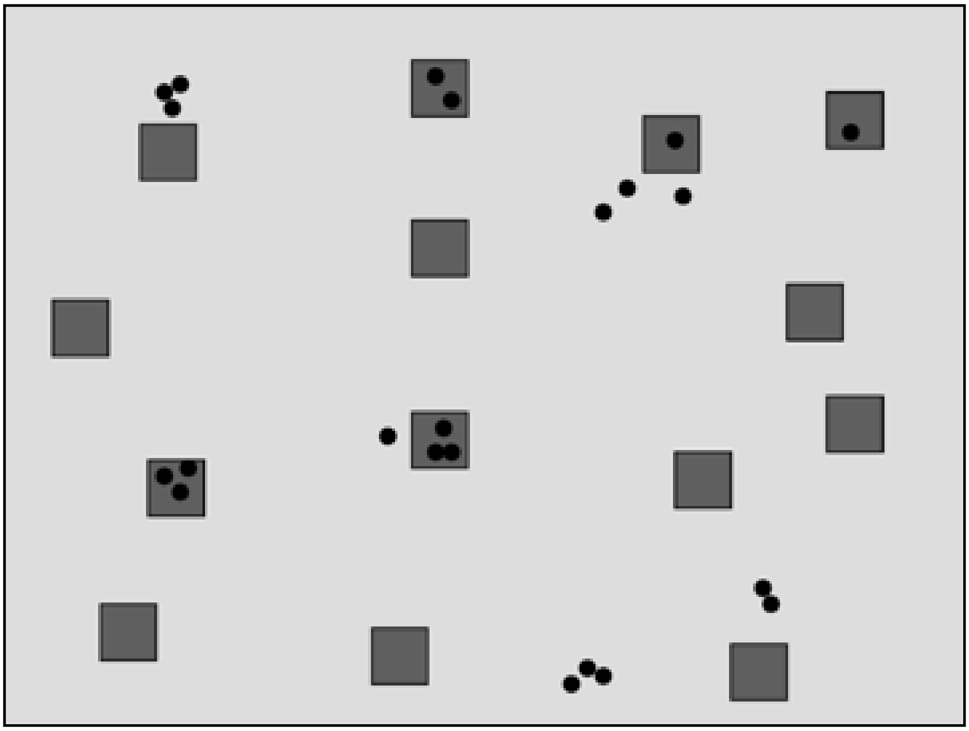
Adaptive sampling

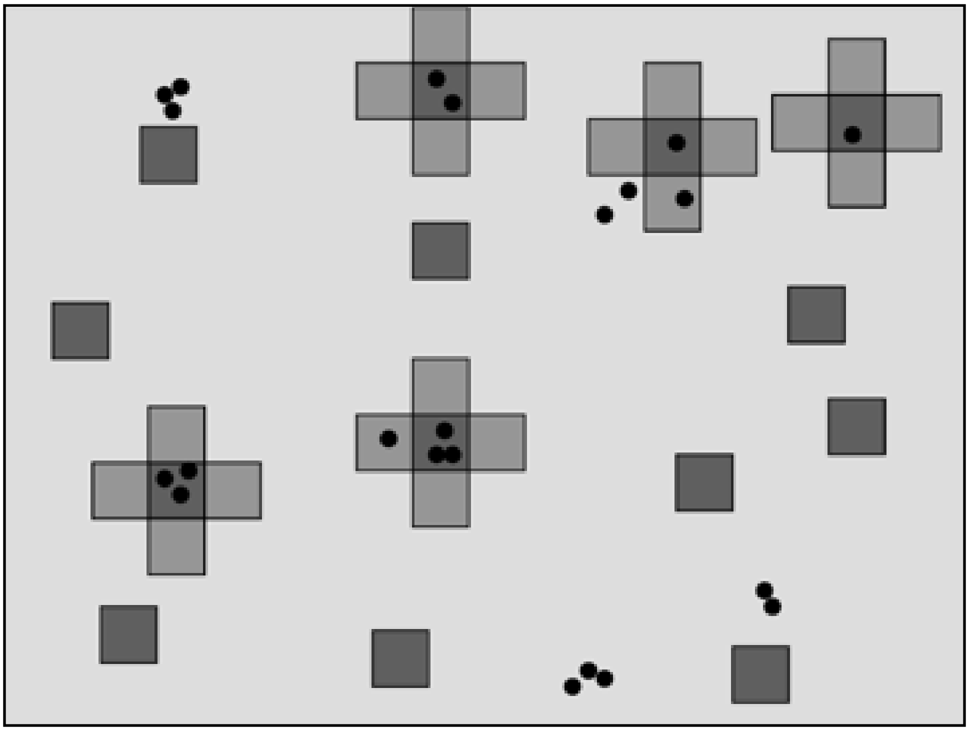
Basic idea:
-Start with an initial sample coverage (e.g., systematic sampling design)

- Based on results, increase sample coverage wherever animals were found in the initial sample

Advantageous when animals have a patchy distribution







Probability Vs. Non-Probability Sampling

- **Non-probability sampling is less time consuming and less expensive.**
- **The probability of selecting one element over another is not known and therefore the estimates cannot be projected to the population with any specified level of confidence.**
- **Quantitative generalizations about population can only be done under probability sampling.**

Take Home Message

- Even when all the options exist, it is often unclear which sampling method should be used.
- Test different options, using hypothetical data if necessary.
- Choose the most cost-effective approach; that is, choose the sampling method that delivers the greatest precision for the least cost.

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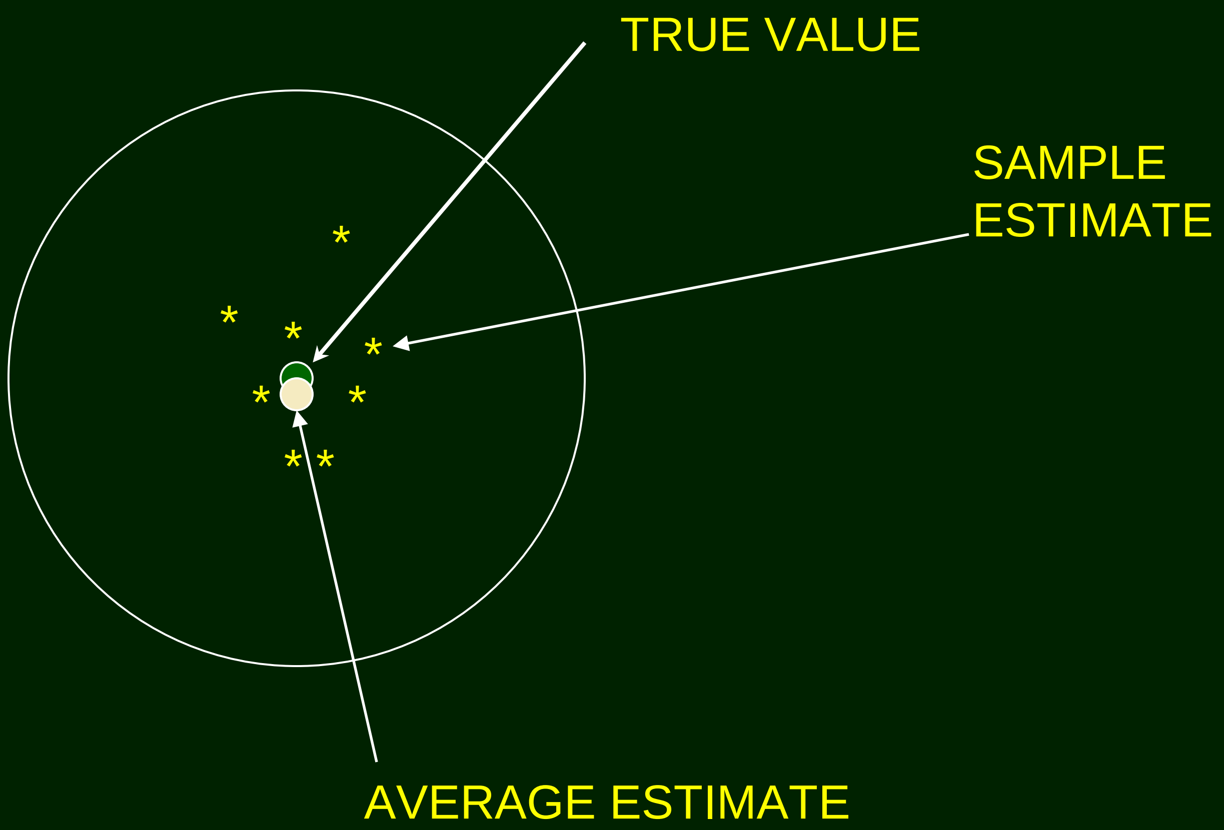
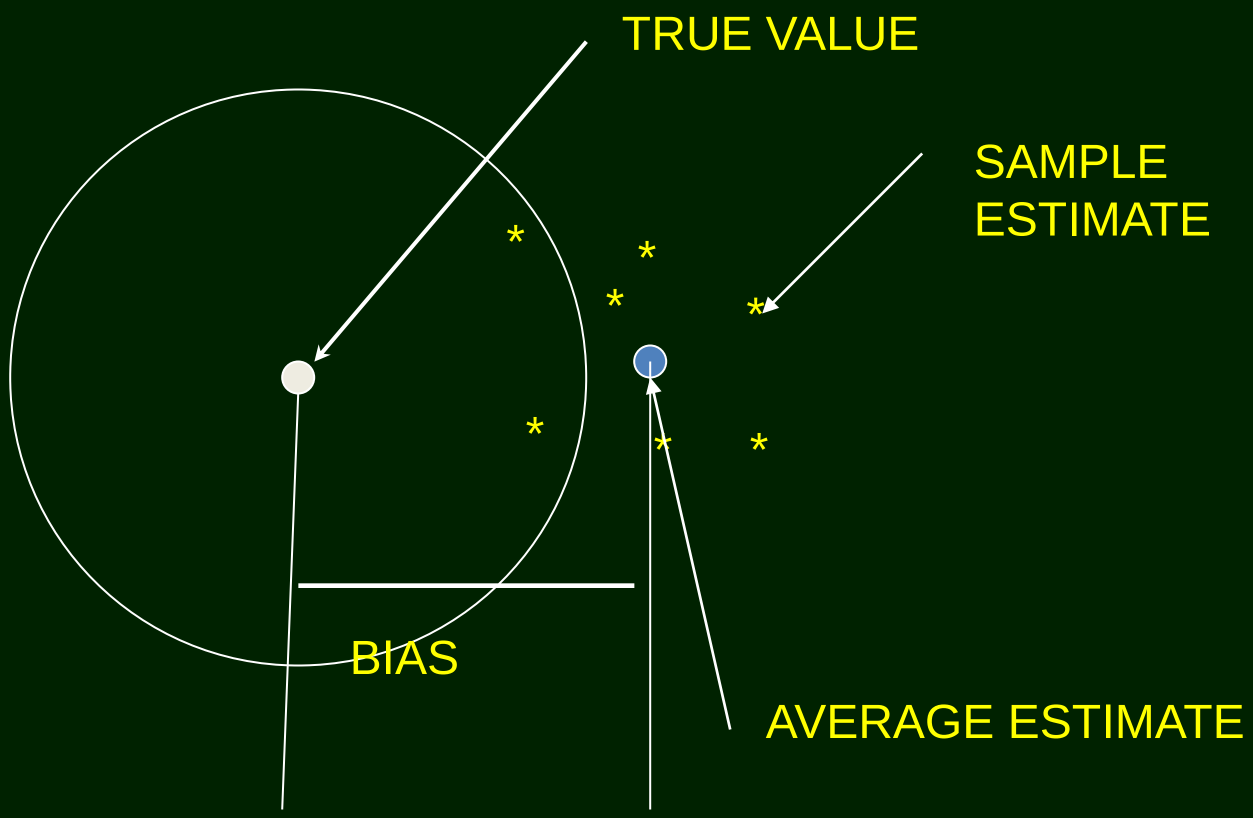
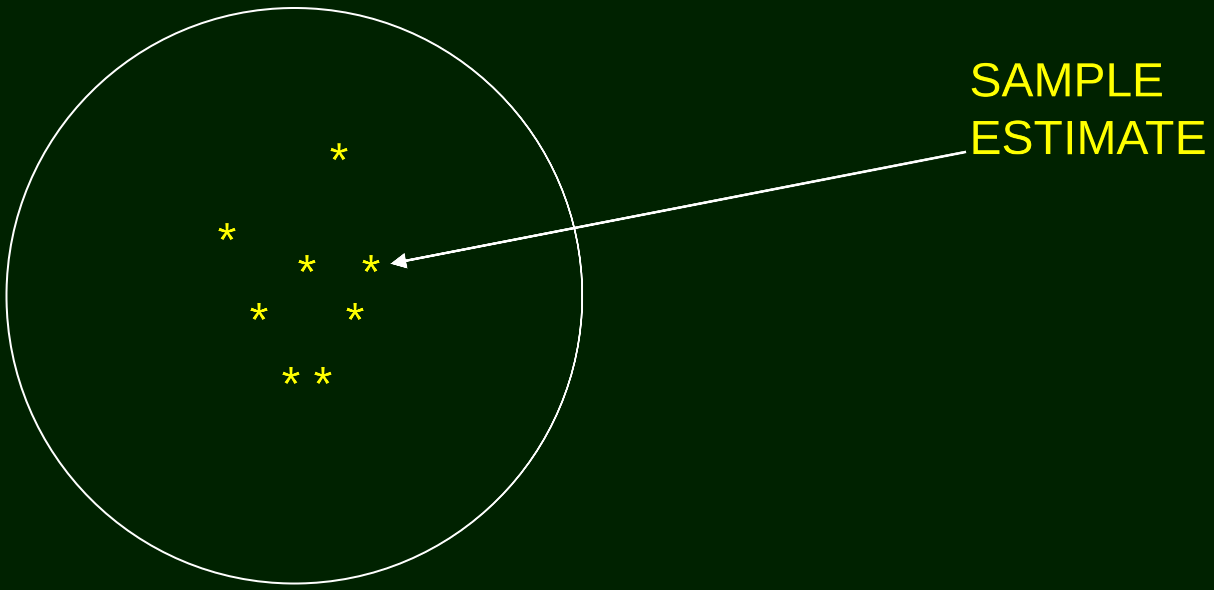
UNBIASED



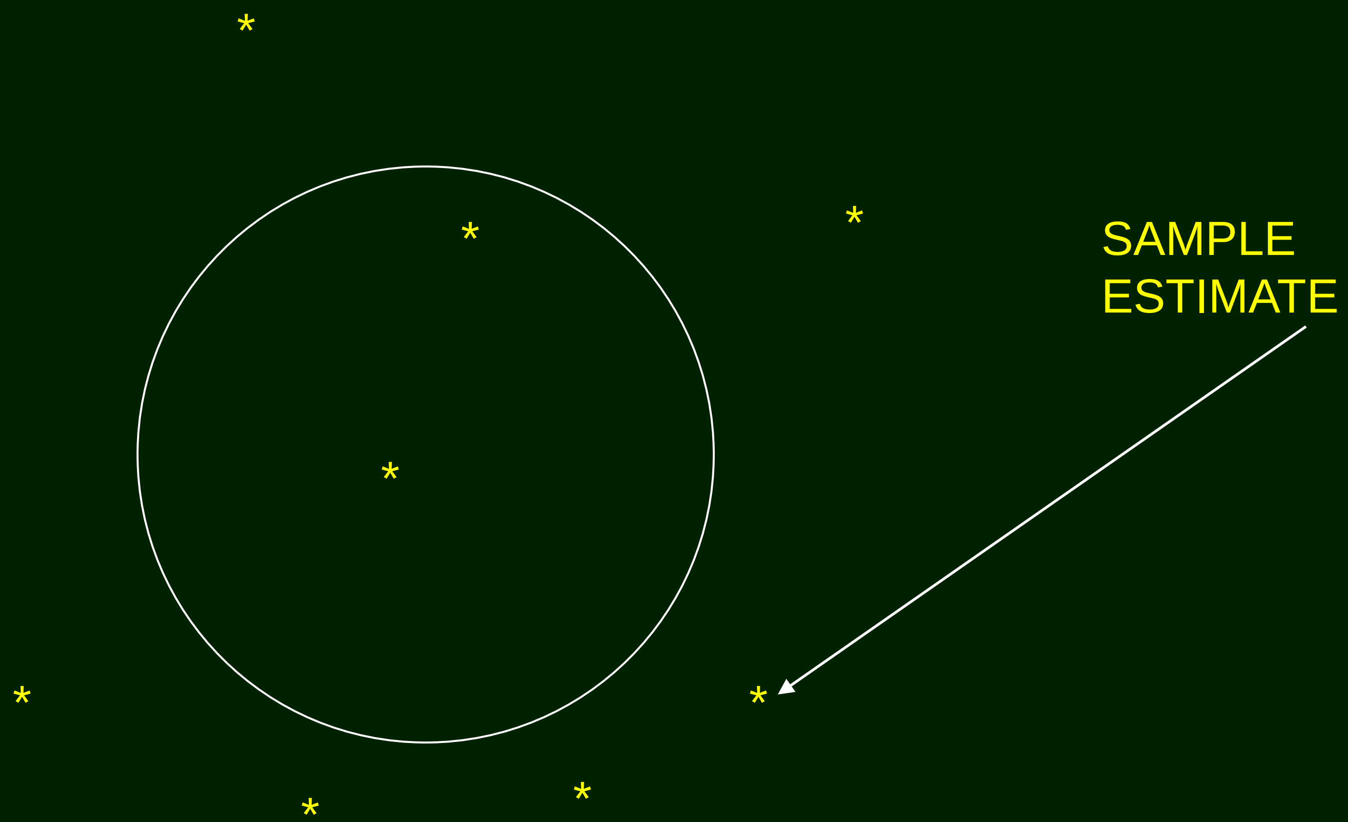
BIASED



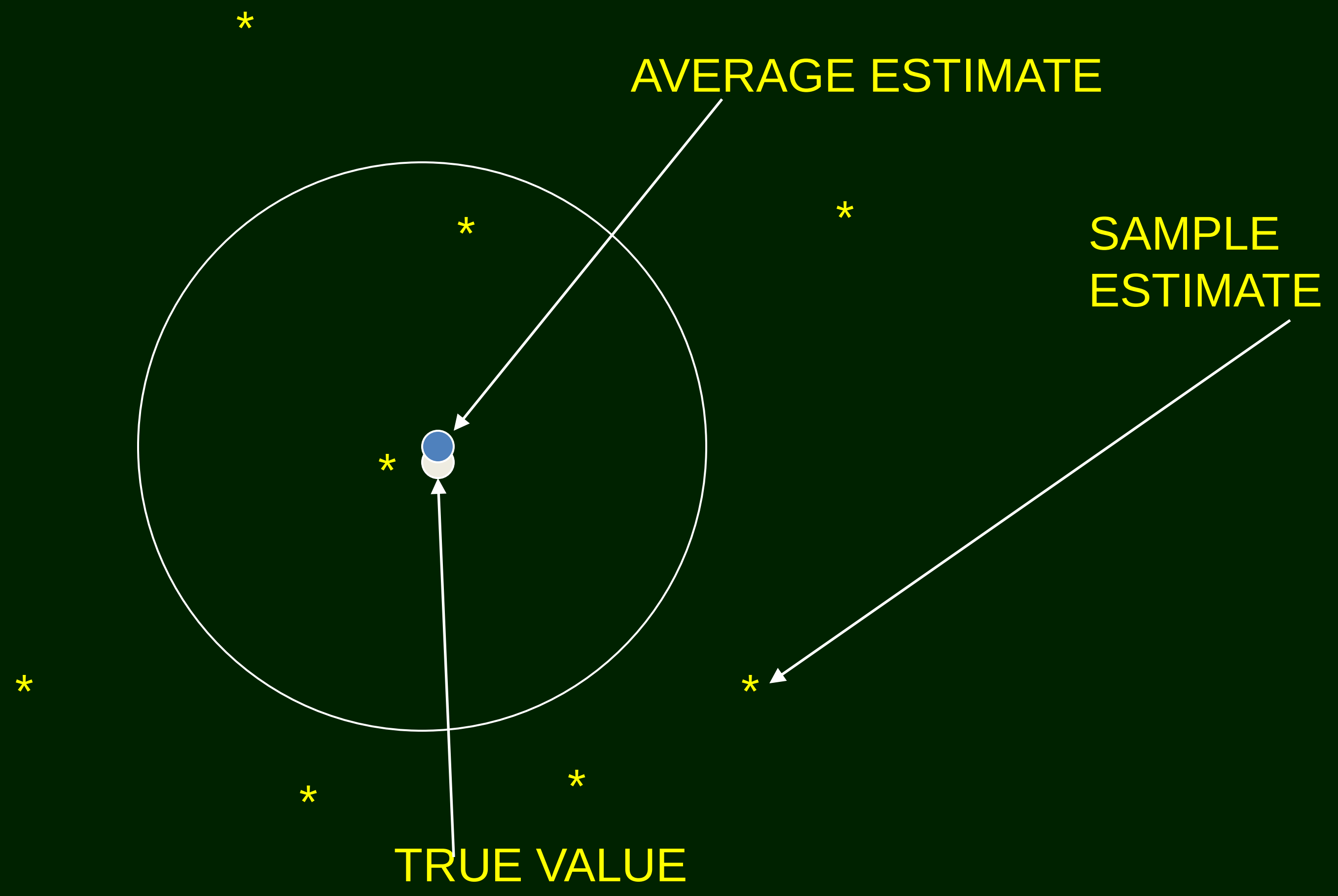
REPEATABLE (PRECISE)



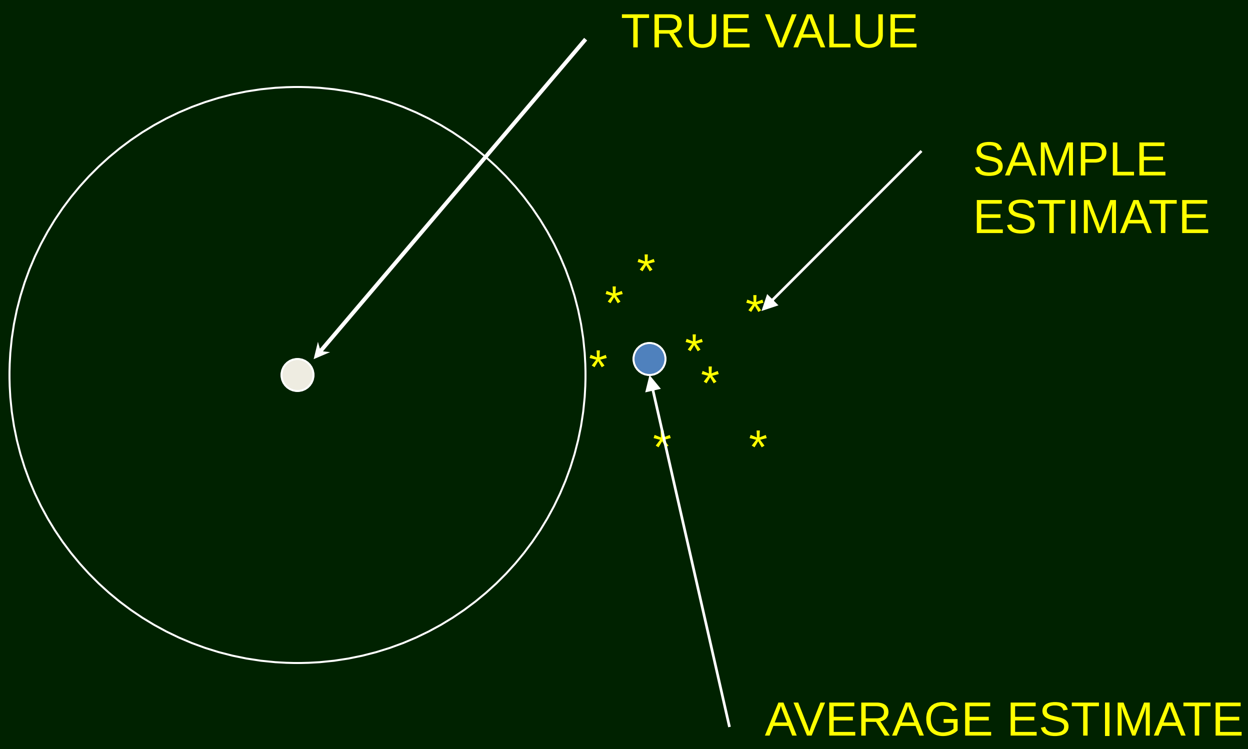
NOT REPEATABLE (IMPRECISE)



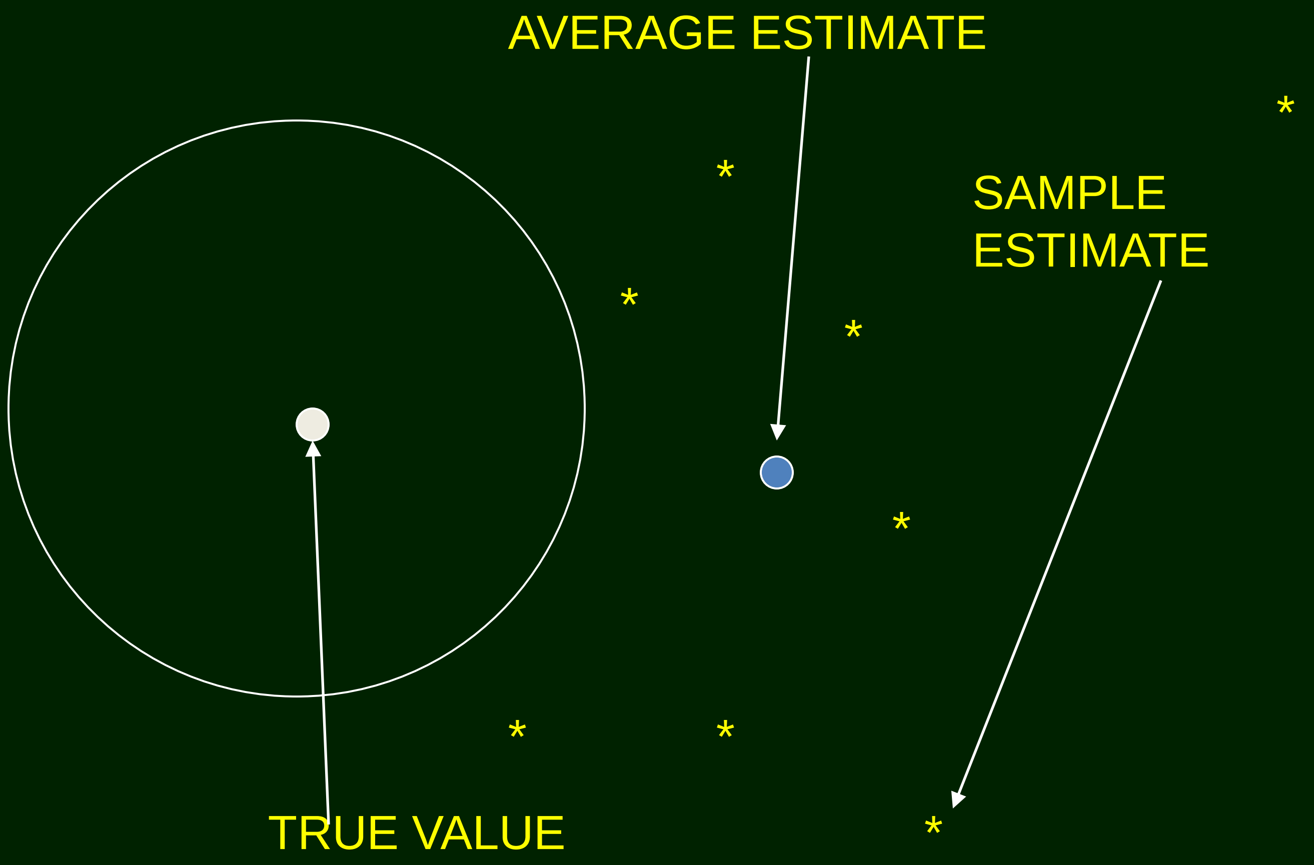
CAN BE IMPRECISE BUT UNBIASED



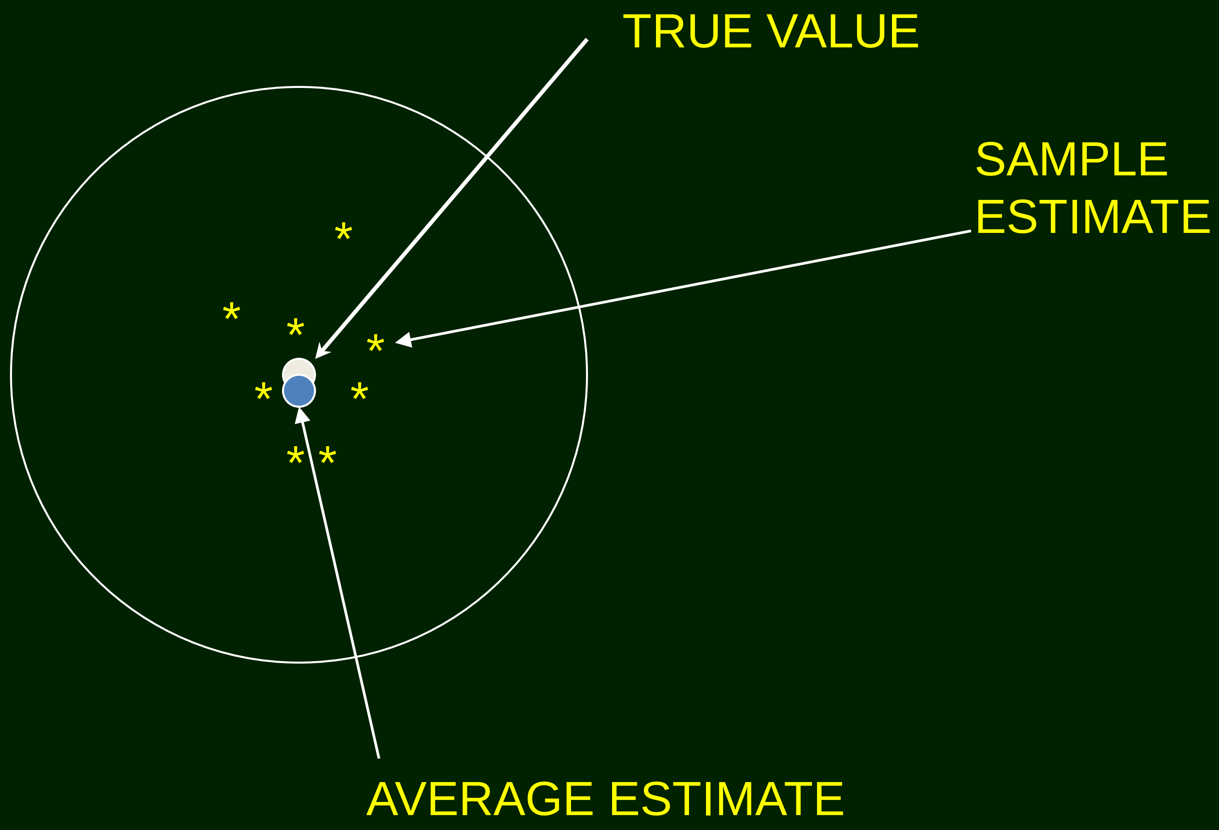
PRECISELY BIASED



IMPRECISE AND BIASED!



ACCURATE=UNBIASED & PRECISE



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- Splitting a transect into two and treating them as separate transects
- Treating individuals in a cluster as independent

HOW DO WE MAKE ESTIMATES ACCURATE ?

Control of variation

Results in more precise parameter estimates, and more powerful statistical tests

Methods of controlling variation:
- increase sample size
- use of stratification or blocking
- use of auxiliary covariates to eliminate nuisance sample-to-sample variation

GENERAL APPROACH OF SAMPLING

Purpose: obtain sampling units from a population to estimate population parameters

Since entire area of interest/ population cannot be surveyed, select a sample of areas, based on which inferences can be made to the entire area of interest/ population

Samples are collected in such a way that what is observed in the sample represents what is not observed

INITIAL STEP: ASSESSING RESOURCES, CONSTRAINTS

1. **Material resources:** money, equipment, vehicles, logistics
2. **Human resources:** numbers, field skills, technical skills
3. **Logistical constraints:** accessibility, weather
4. **Social constraints:** social factors, cultural aspects

Sampling Design Process

What is the objective?

What are the appropriate sampling units? Size, shape, placement, Quantities measured

Field sampling must be representative of the population of inference

Define Population

Determine Sampling Frame

Determine Sampling Procedure

Probability Sampling
- Simple Random Sampling
- Systematic sampling
- Stratified Sampling
- Cluster Sampling
- Adaptive Sampling

Non-Probability Sampling
- Convenience
- Judgmental
- Snowball
- Quota

Determine Appropriate Sample Size

Execute Sampling Design

Selecting a Sampling Design

- **Probability sampling - equal chance of being included in the sample (random)**
  - simple random sampling
  - systematic sampling
  - stratified sampling
  - cluster sampling
- **Non-probability sampling - - unequal chance of being included in the sample (non-random)**
  - convenience sampling
  - judgement sampling
  - snowball sampling
  - quota sampling

Non-Probability Sampling

- **Subjective procedure in which the probability of selection for some population units are <u>zero</u> or <u>unknown</u> before drawing the sample.**

- **information is obtained from a non-representative sample of the population**

- **Sampling error can not be computed**

- **Survey results cannot be projected to the population**

Types of Non-Probability Sampling

- ***Convenience Sampling***
  - A researcher's convenience forms the basis for selecting a sample.
    - people in my classes
    - Mall intercepts
    - People with some specific characteristic (e.g. bald)
- ***Judgment Sampling***
  - A researcher exerts some effort in selecting a sample that seems to be most appropriate for the study.

Types of Non-Probability Sampling

- ***Snowball Sampling***
  - Selection of additional respondents is based on referrals from the initial respondents.
    - friends of friends
  - Used to sample from low incidence or rare populations.
- ***Quota Sampling***
  - The population is divided into cells on the basis of relevant control characteristics.
  - A quota of sample units is established for each cell.
    - 50 women, 50 men
  - A convenience sample is drawn for each cell until the quota is met.

  (similar to stratified sampling)

Probability Sampling

Simple random sampling (SRS)
n units are selected in a way that every unit has the same probability *n/N of being selected*

Sampling typically without replacement, can also do random sampling with replacement

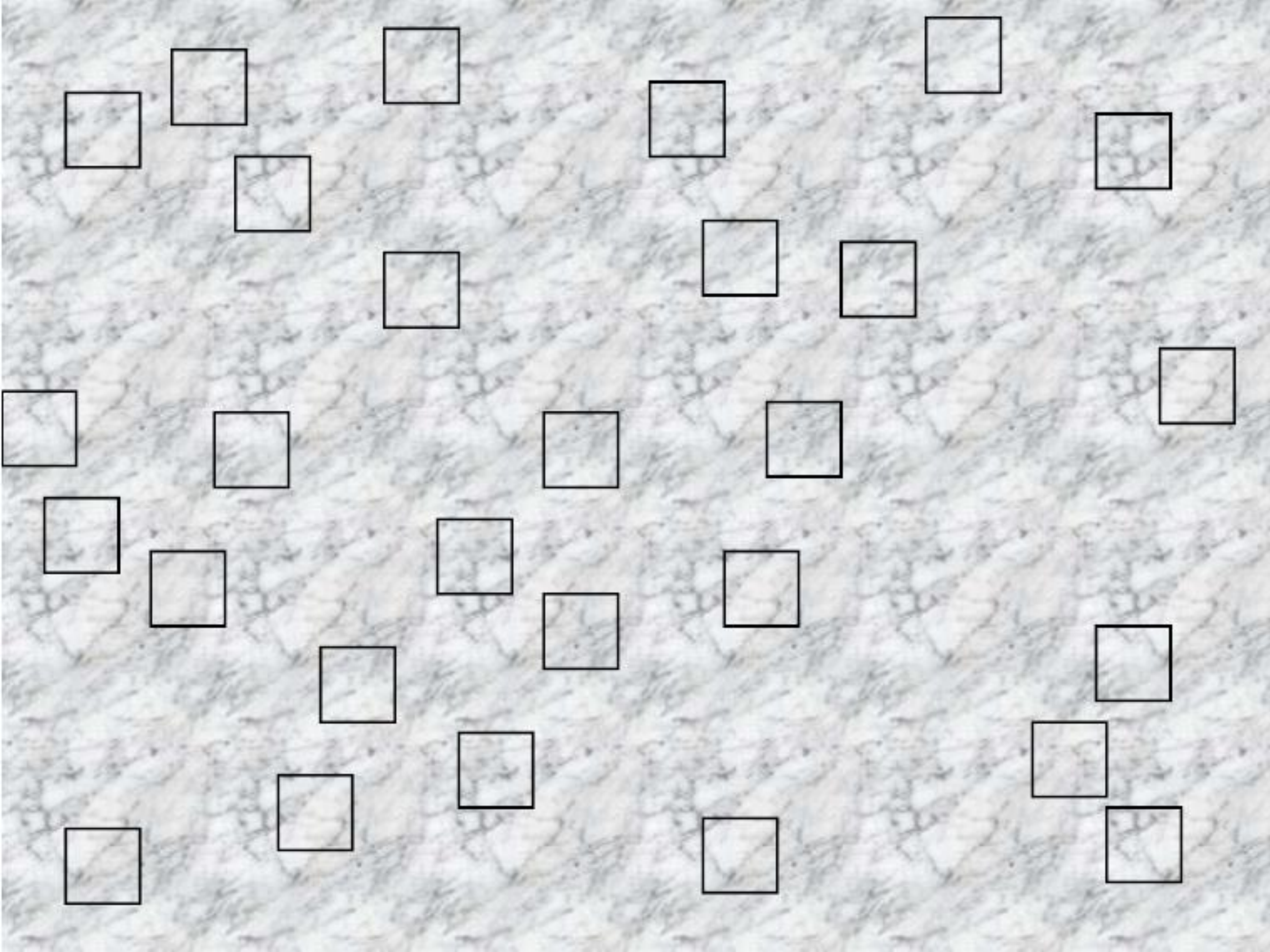
Simple to implement and derive estimates of mean and variance, but precision can be 'improved'…

May not provide good coverage of area of interest

How to sample randomly?

Objective: To select n units out of N such that each ${}_{N}C_{n}$ has an equal chance of being selected

Procedure: Use a table of random numbers, a computer random number generator, or a mechanical device to select the sample



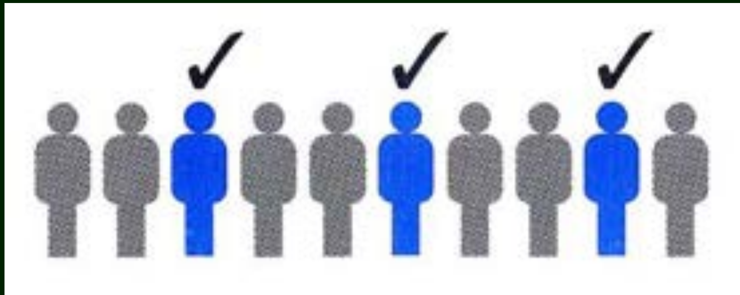
Systematic (or uniform) sampling

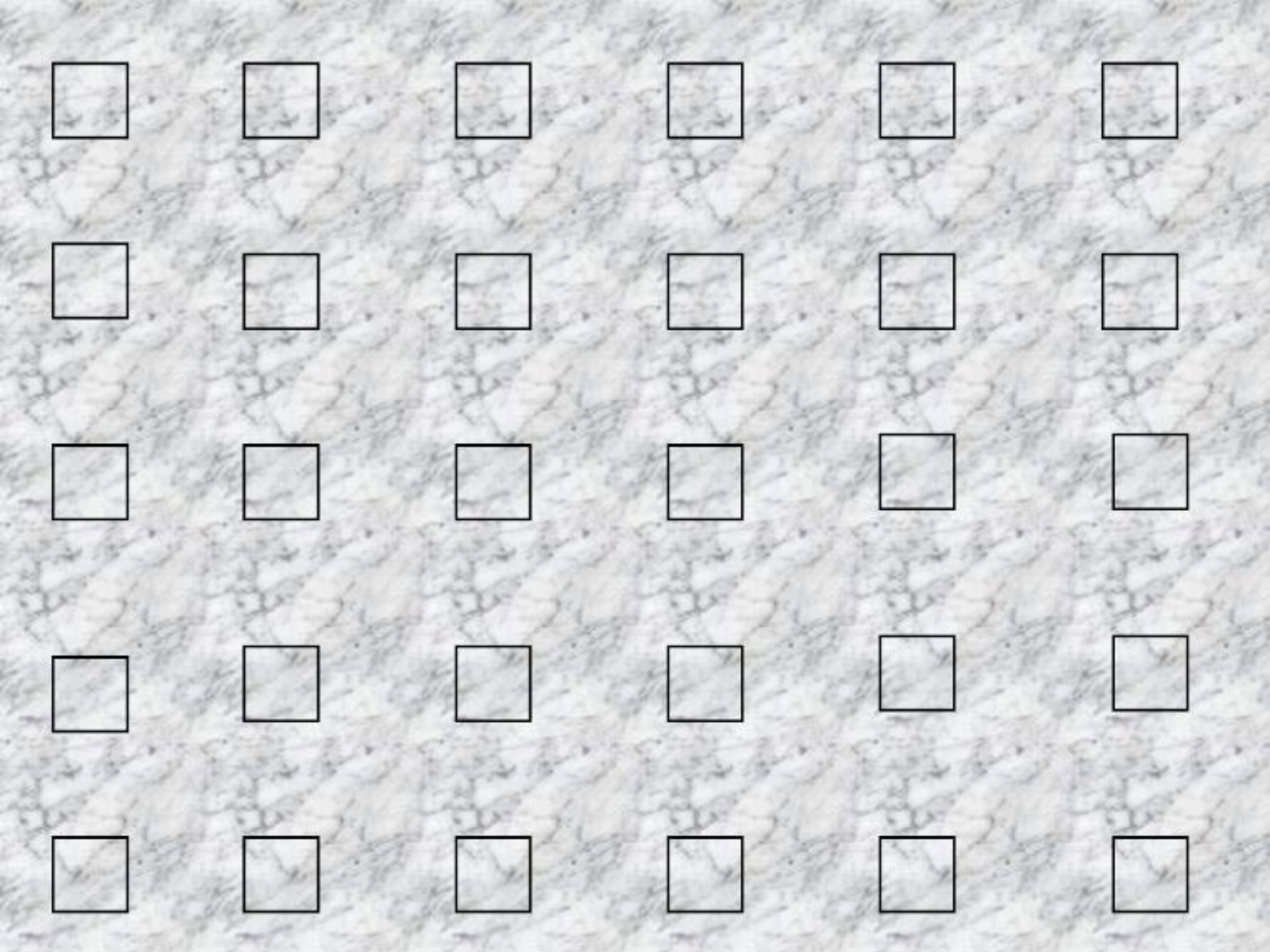
Randomized selection of a first sampling unit, and systematic (nonrandom) selection of sampling units thereafter

Equivalent to SRS if the ordering of individuals is independent of the attribute being measure
e.g.: - Survey of roadside vegetation, with samples every 10th km

Can provide much better sample coverage than a simple random sample

However, if there are systematic but undetected patterns in the population units, a systematic sample can badly misrepresent variation in the data





Stratified random sampling

Takes advantage of population structure to improve estimator precision

Stratify the population into groups of similar units
-population variation primarily reflects variation between groups

Requires some prior knowledge of variation in abundance
e.g. - Divide study area into strata according to vegetation types, use Simple Random or Systematic Sampling WITHIN strata

- Stratification by age or sex

Stratified random sampling

Useful if variable of interest is expected to vary across DISCRETE groups/ areas

Mean should be same/ similar to SRS, but variance estimates MUCH LESS, if large part of population variance is indeed between strata

Allocation of sample sizes

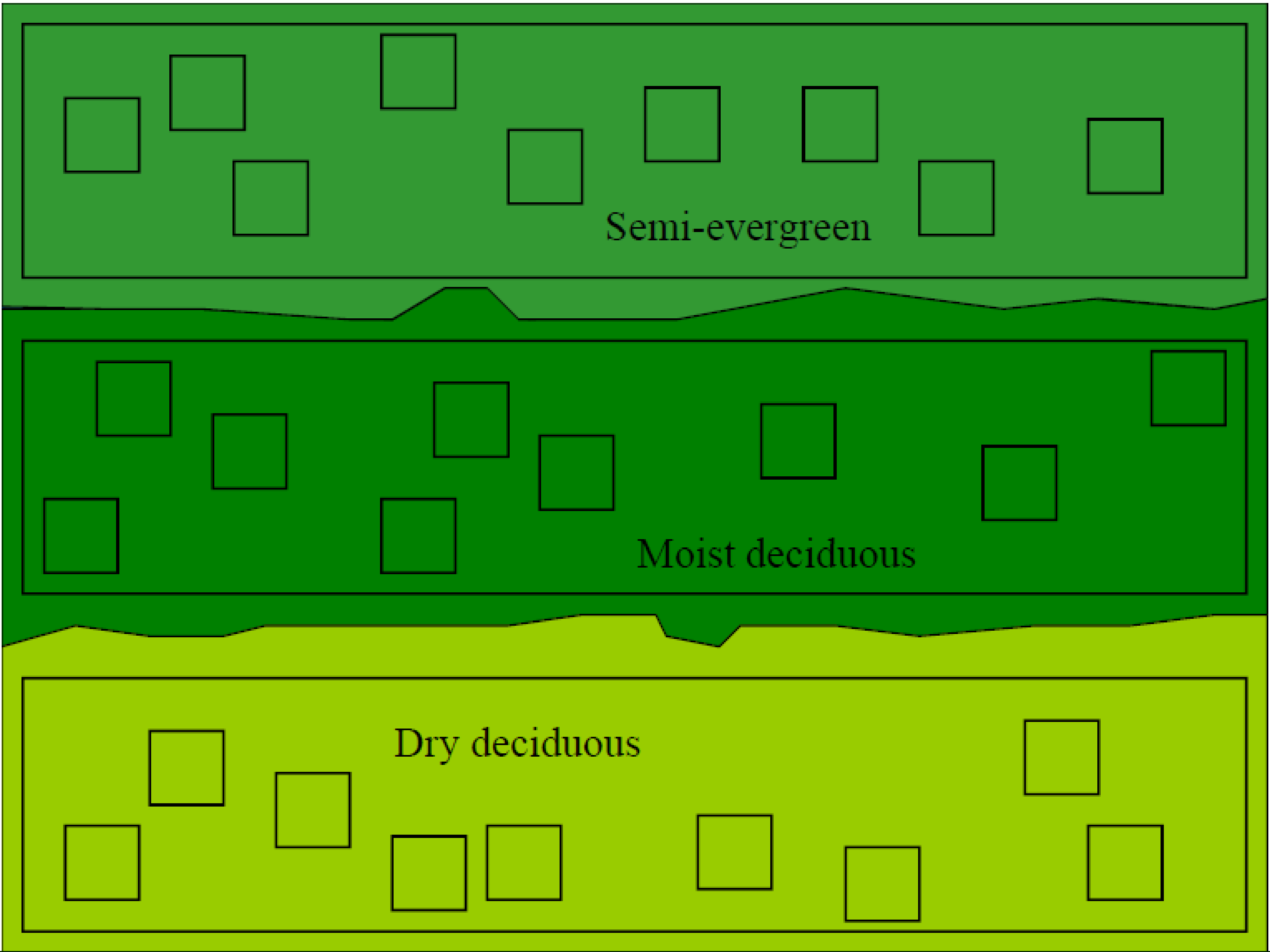
-Proportional allocation (by stratum size)

- Optimal allocation to minimize variance, given differences in stratum sizes, within-stratum variances, and per unit costs

Stratified random sampling

- **Direct Proportional Stratified Sampling**
  - The sample size in each stratum is proportional to the stratum size in the population
- **Disproportional Stratified Sampling**
  - The sample size in each stratum is NOT proportional to the stratum size in the population
  - Used if

1) some strata are too small
2) some strata are more important than others
3) some strata are more diversified than others


Semi-evergreen
Moist deciduous
Dry deciduous

Cluster sampling

Takes advantage of population structure to improve estimator precision

Clustering divides the population into groups of dissimilar units

- population variation primarily reflects within-group variation

Requires some prior knowledge of variation in abundance

e.g. Divide study area into clusters along the density gradient, such as transects radiating away from a river. Select a simple random sample of clusters—

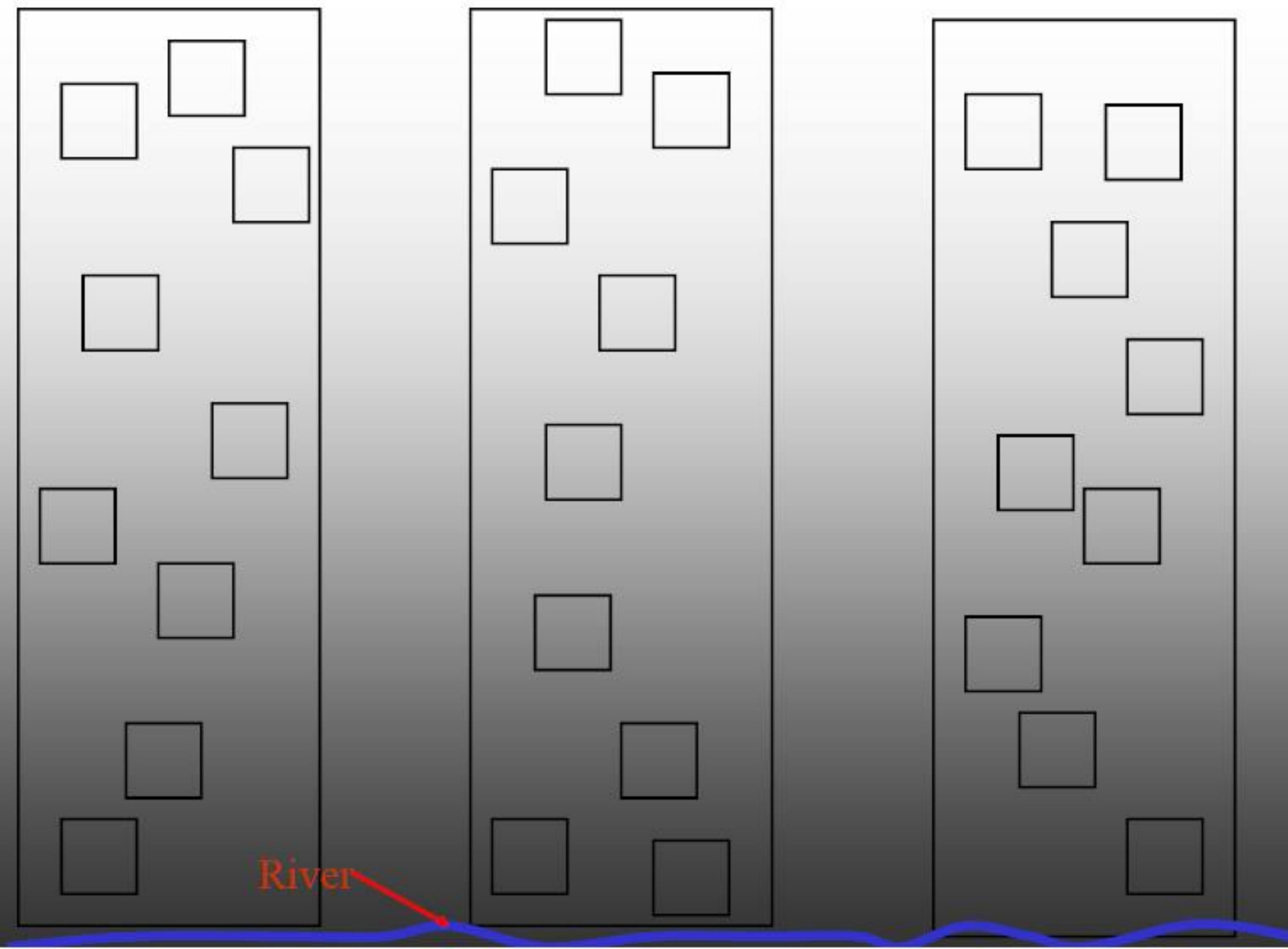
every unit in a selected cluster is included in the sample

Cluster sampling

Mean should be same/ similar to SRS, but variance estimates MUCH LESS, if large part of population variance is indeed within clusters

Only a limited number of clusters need be sampled to obtain estimates of population parameters

Clustering is beneficial if within-cluster variation is large relative to among-cluster variation


River

When to use stratified sampling

- If primary research objective is to compare groups
- Using stratified sampling may reduce sampling errors

When to use cluster sampling

- If there are substantial fixed costs associated with each data collection location
- When there is a list of clusters but not of individual population members

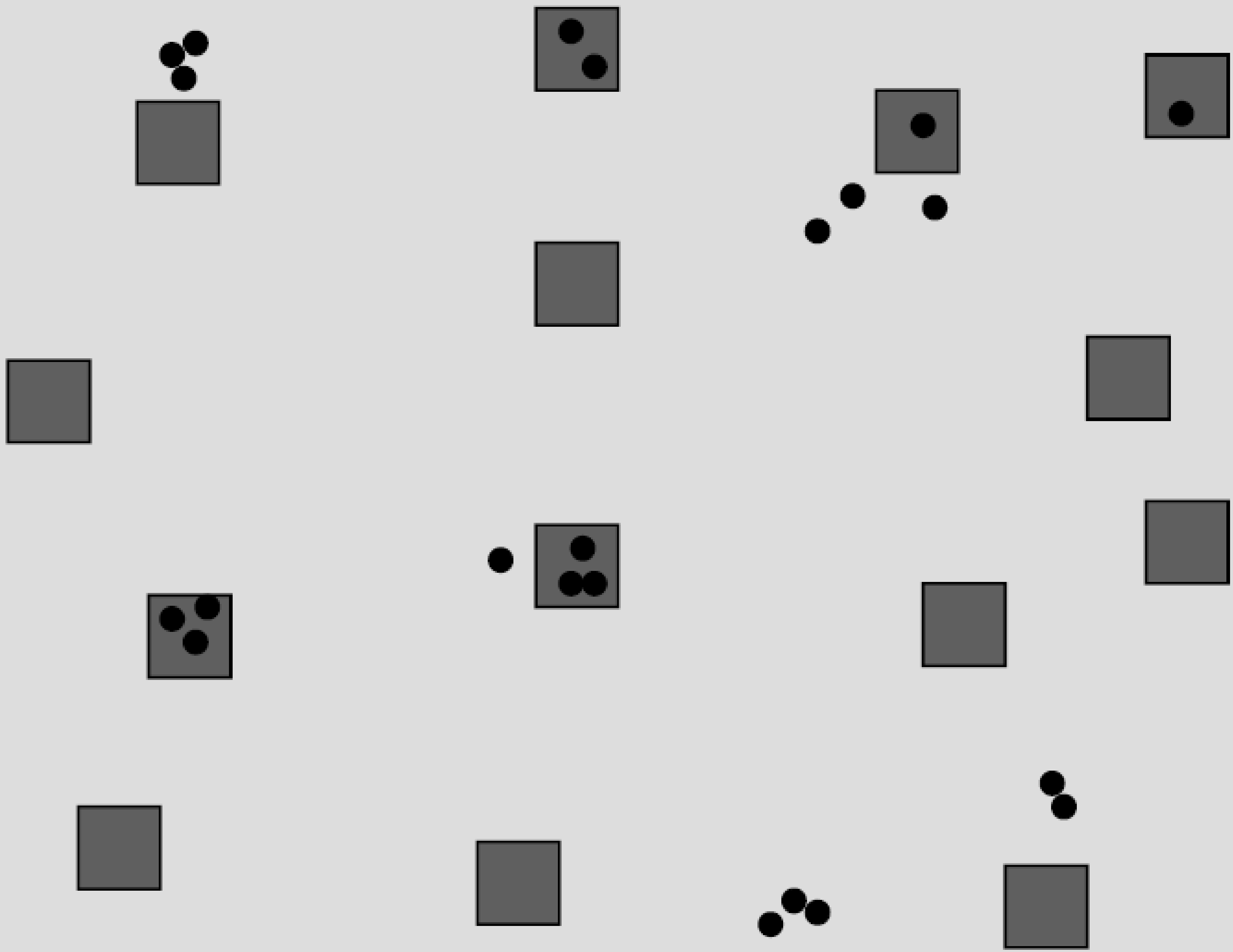
Adaptive sampling

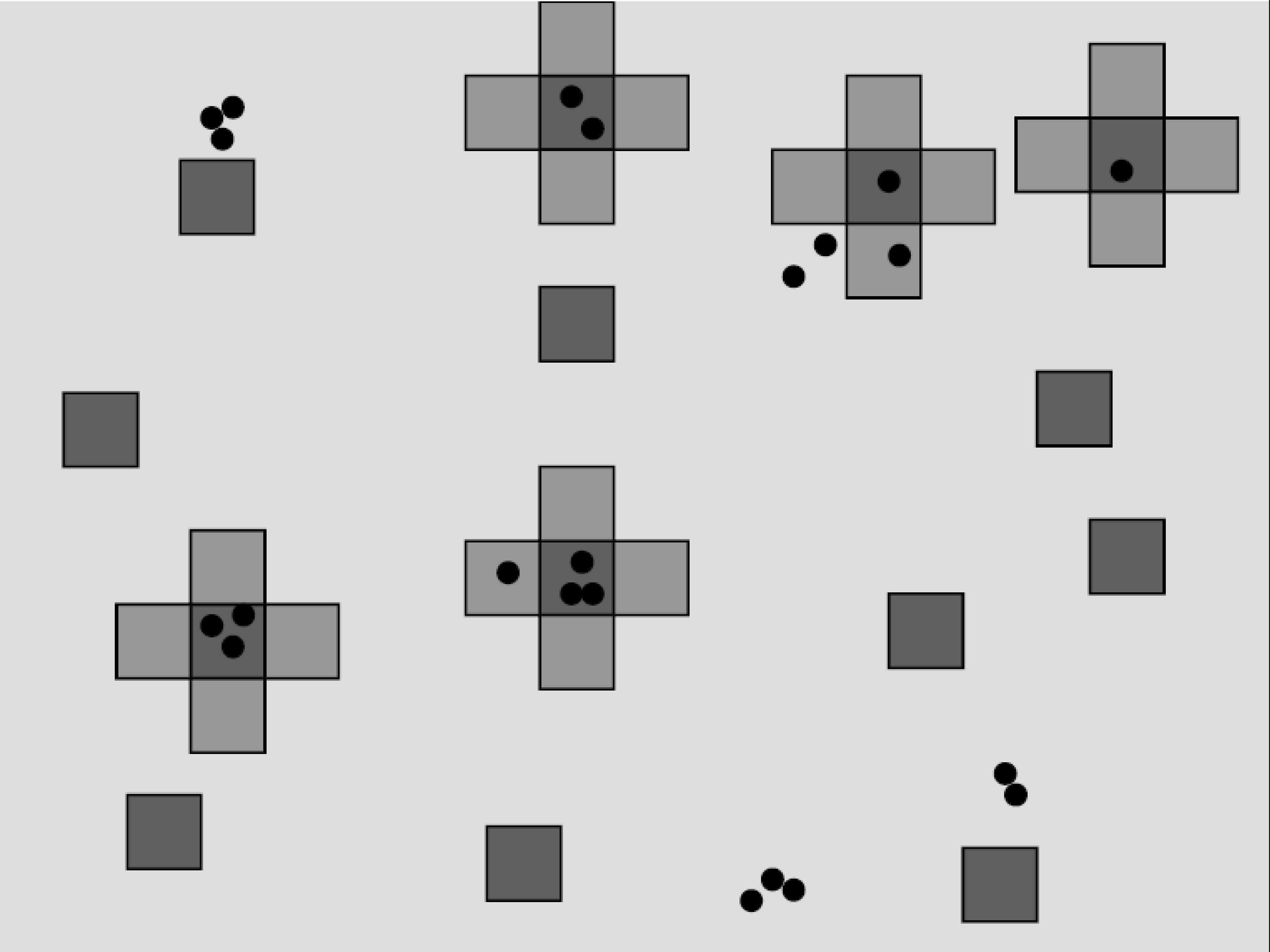
Basic idea:

-Start with an initial sample coverage (e.g., systematic sampling design)

- Based on results, increase sample coverage wherever animals were found in the initial sample

Advantageous when animals have a patchy distribution





Probability Vs. Non-Probability Sampling

- **Non-probability sampling is less time consuming and less expensive.**
- **The probability of selecting one element over another is not known and therefore the estimates cannot be projected to the population with any specified level of confidence.**
- **Quantitative generalizations about population can only be done under probability sampling.**

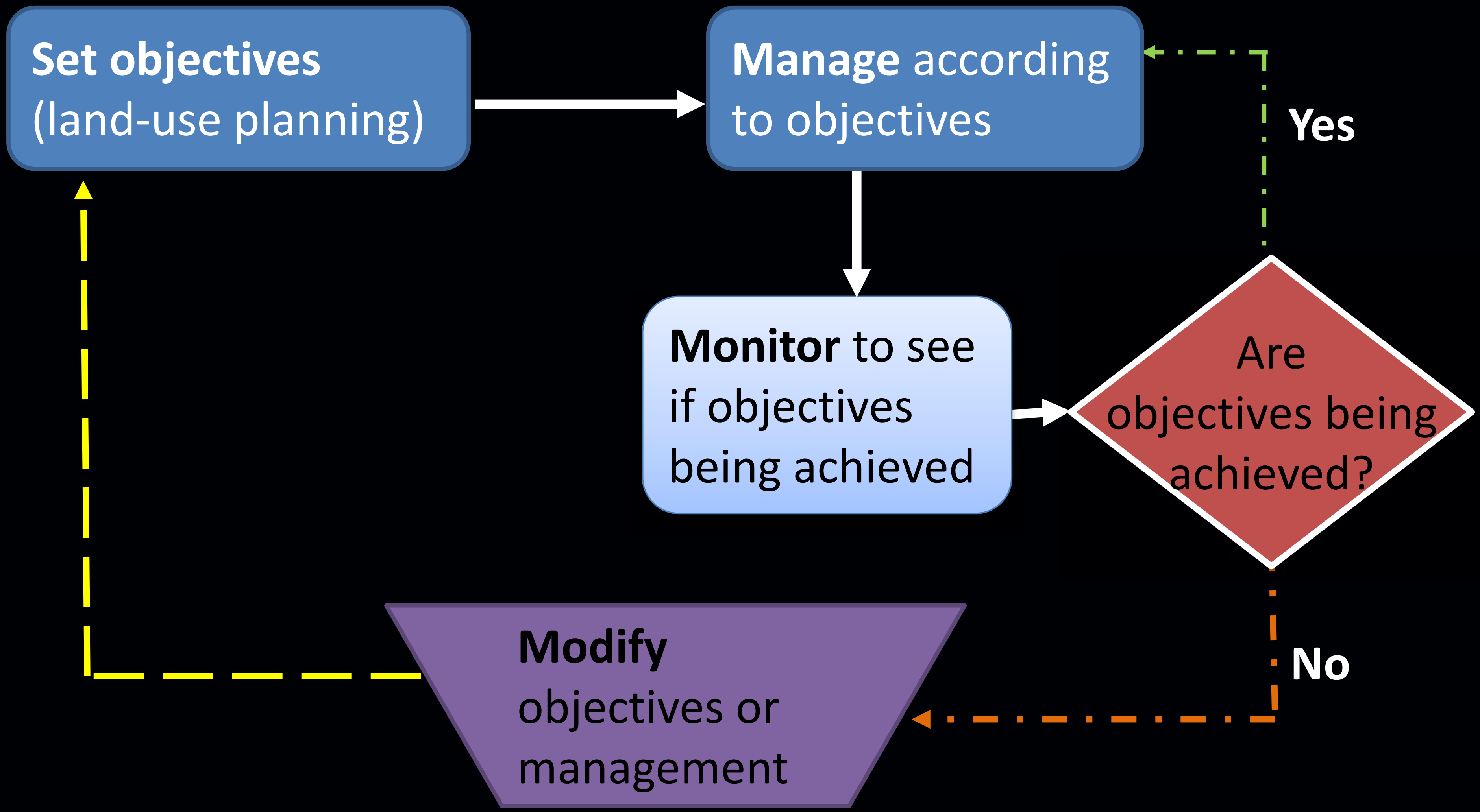
Take Home Message

- Even when all the options exist, it is often unclear which sampling method should be used.
- Test different options, using hypothetical data if necessary.
- Choose the most cost-effective approach; that is, choose the sampling method that delivers the greatest precision for the least cost.

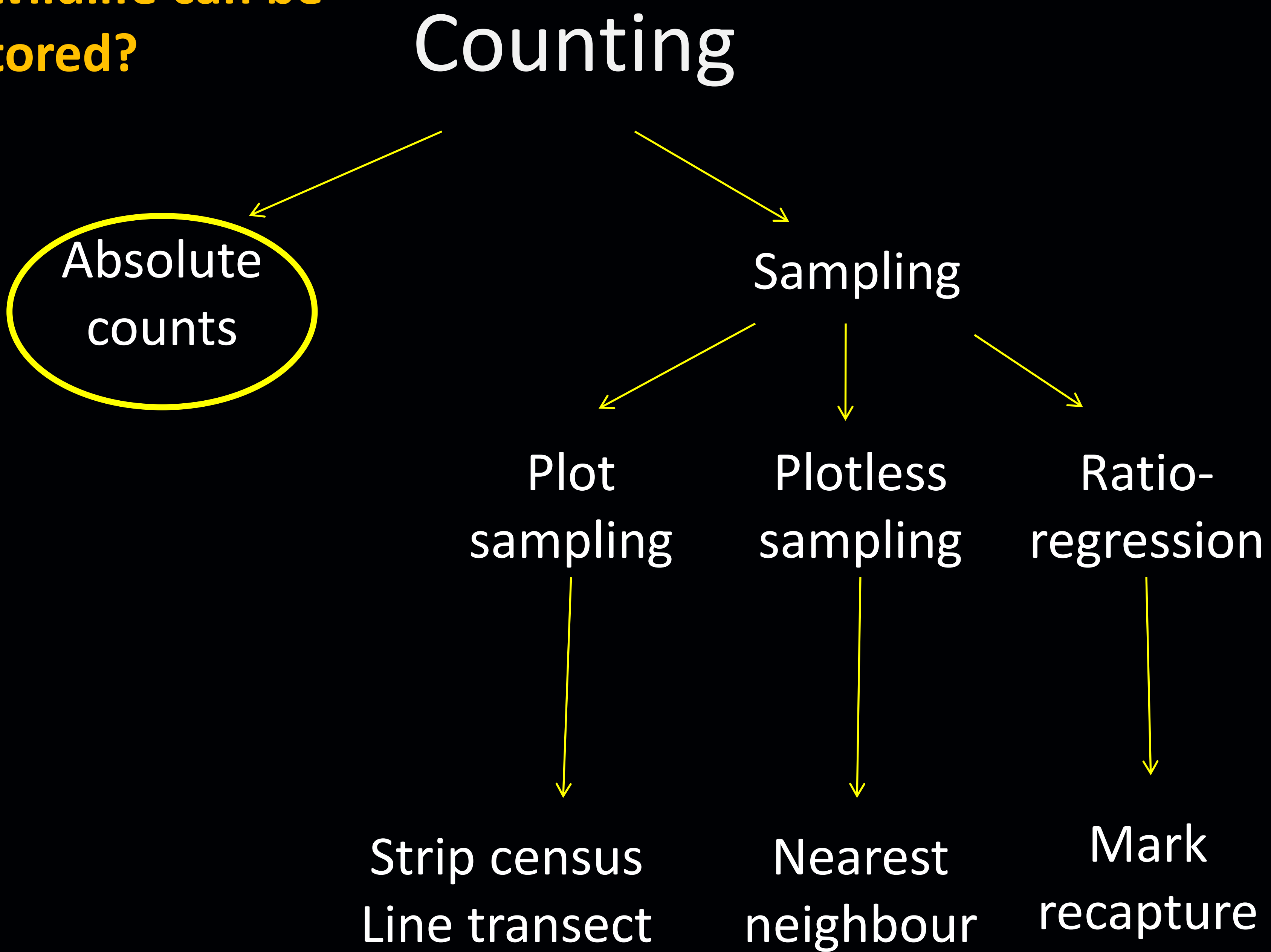
Wildlife Population Sampling Techniques and Applications of Conservation Tools

Conservation needs adaptive management

Monitoring is needed for adaptive management



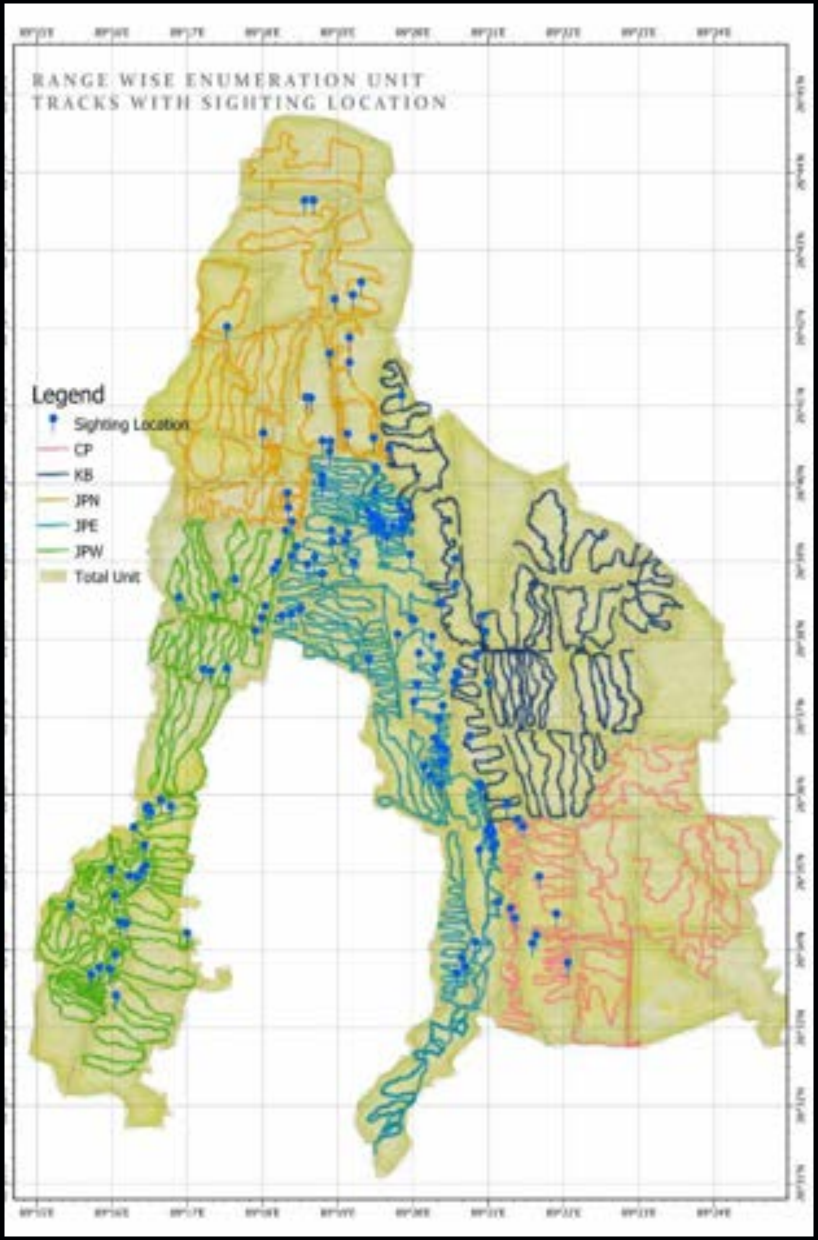
How wildlife can be monitored?

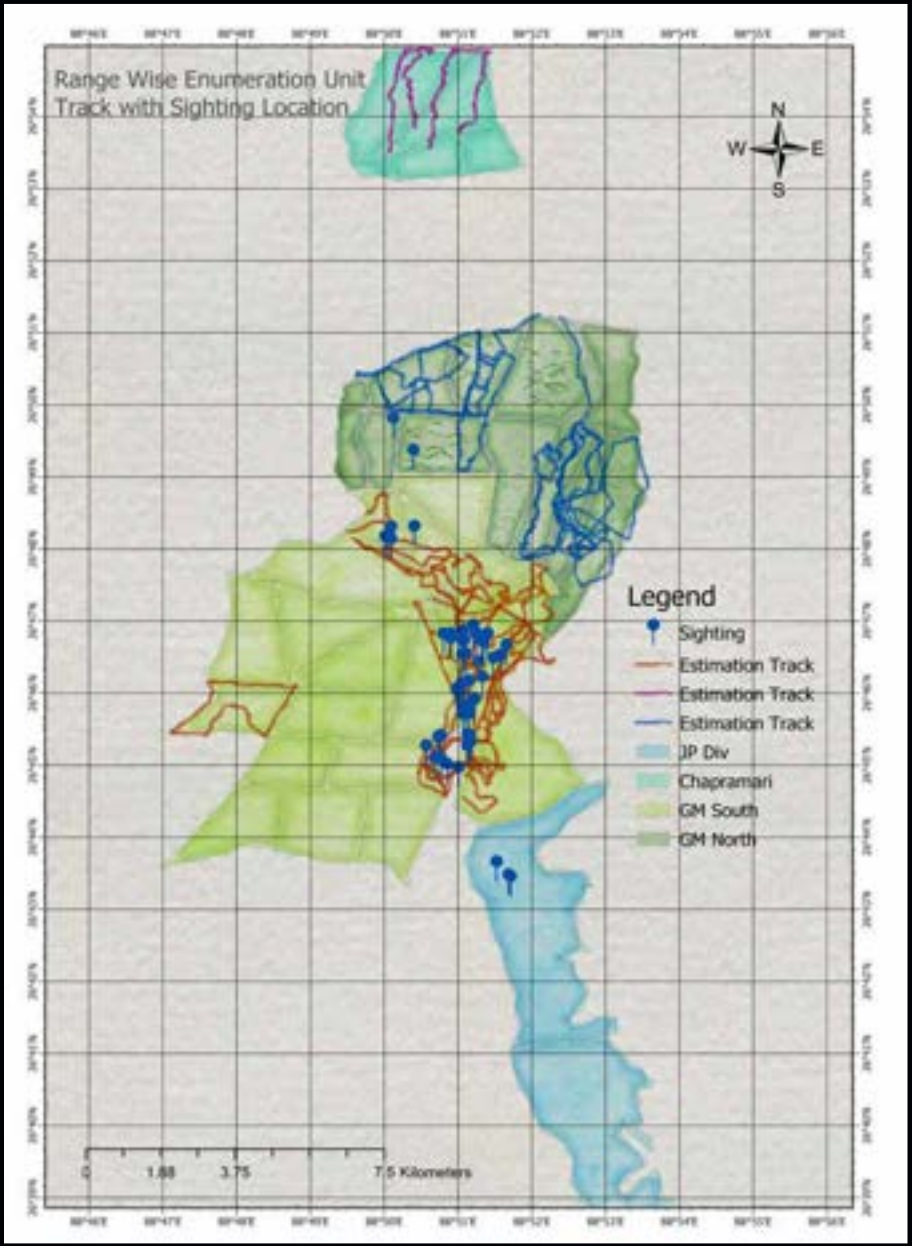


Absolute counts

Absolute counts

Block counts

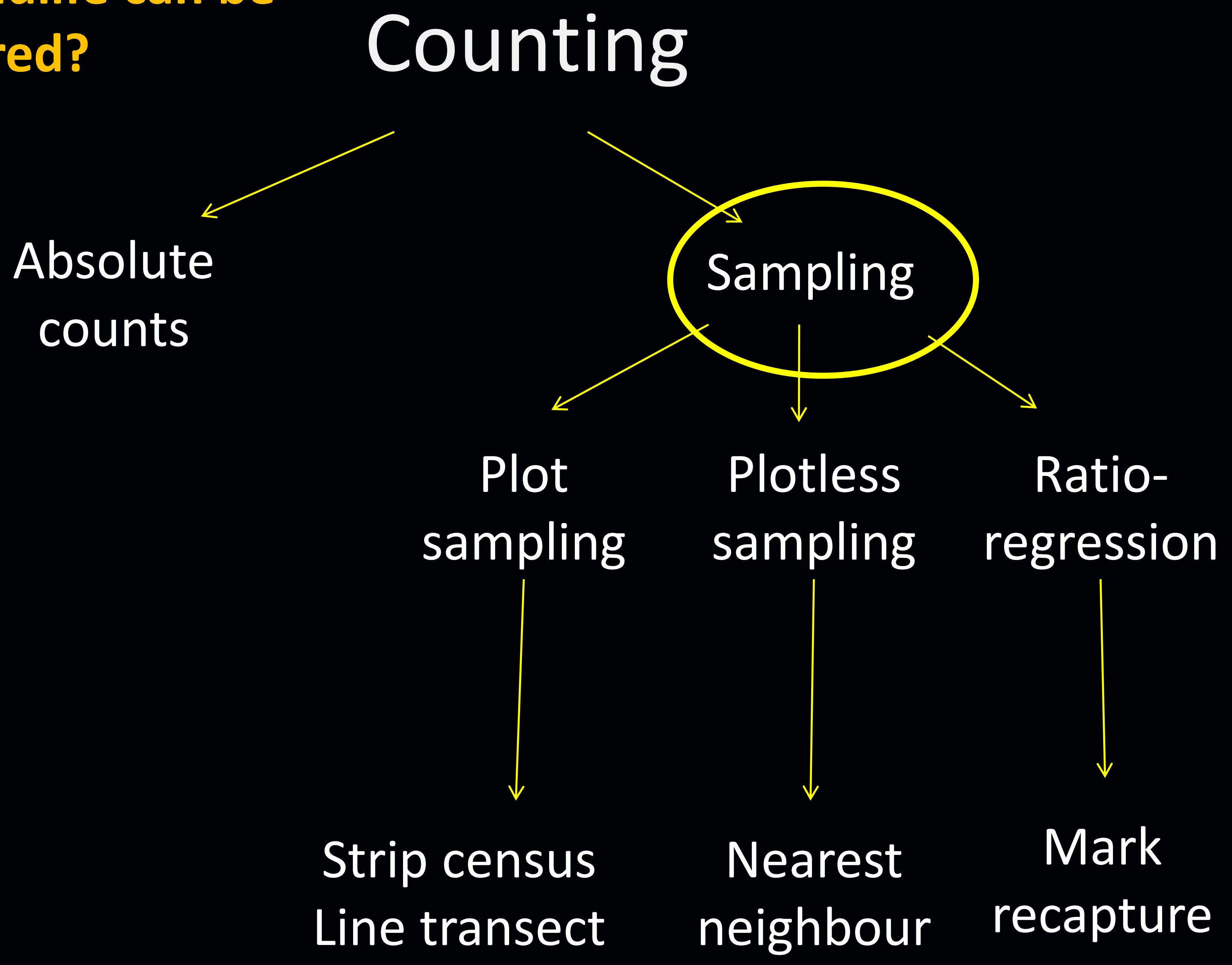




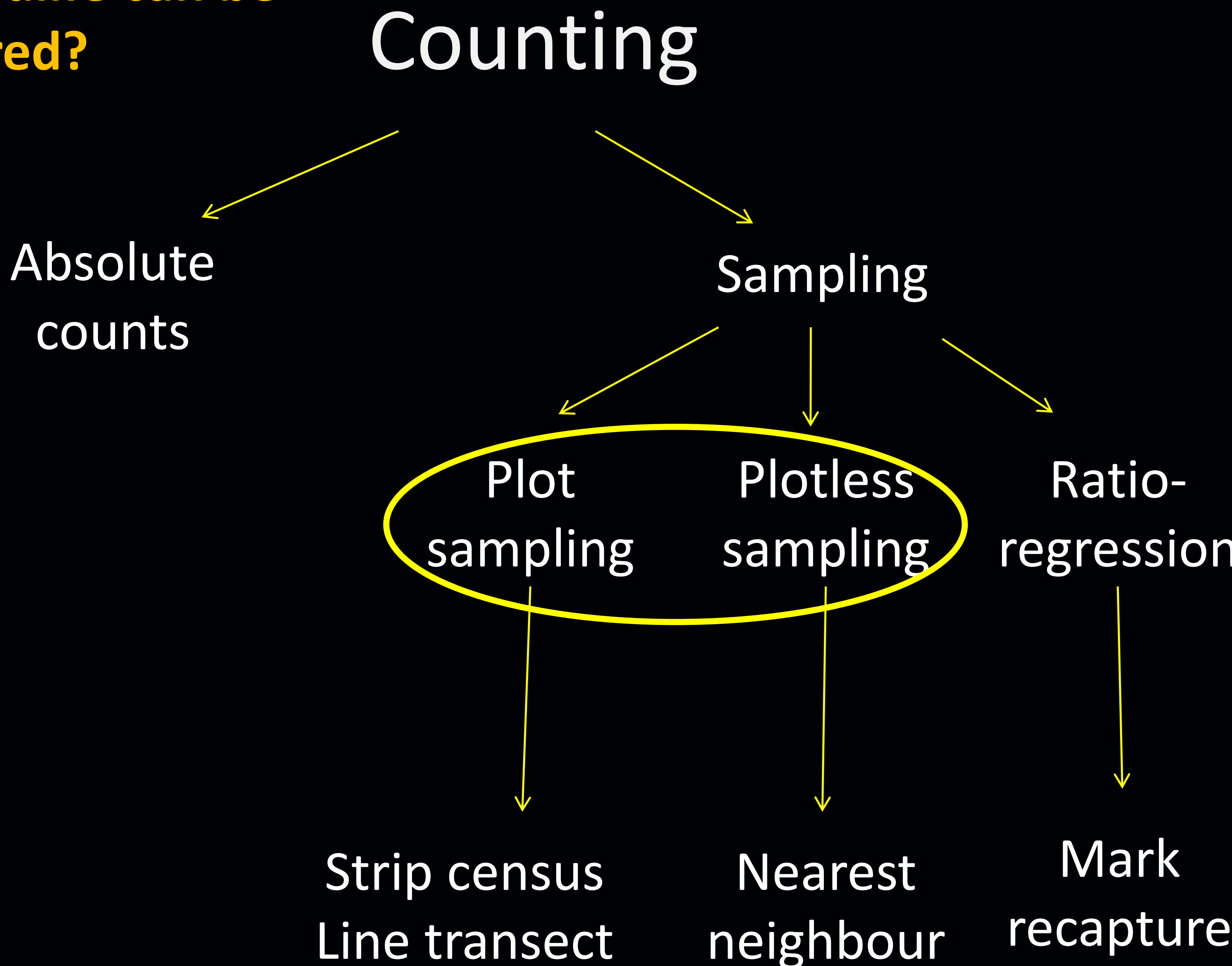
Absolute counts

Waterhole counts

How wildlife can be monitored?



How wildlife can be monitored?



ESTIMATING PLANT POPULATIONS/COMMUNITIES

Field Techniques – Counting Plants

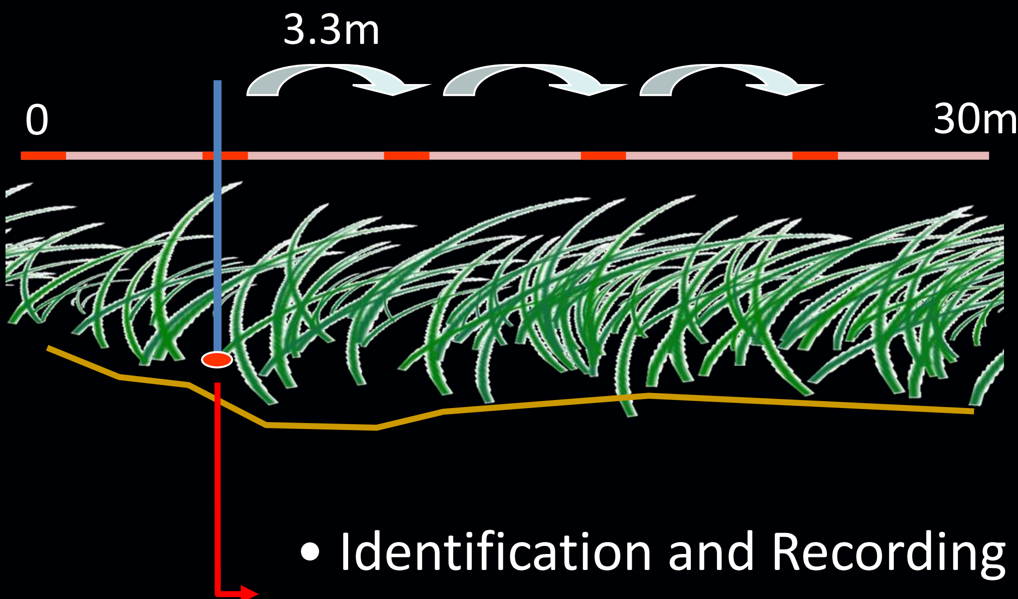
Trails and Transects

Quadrats

Provides abundance as well as density estimates

Herb cover

1) Point-intercept method

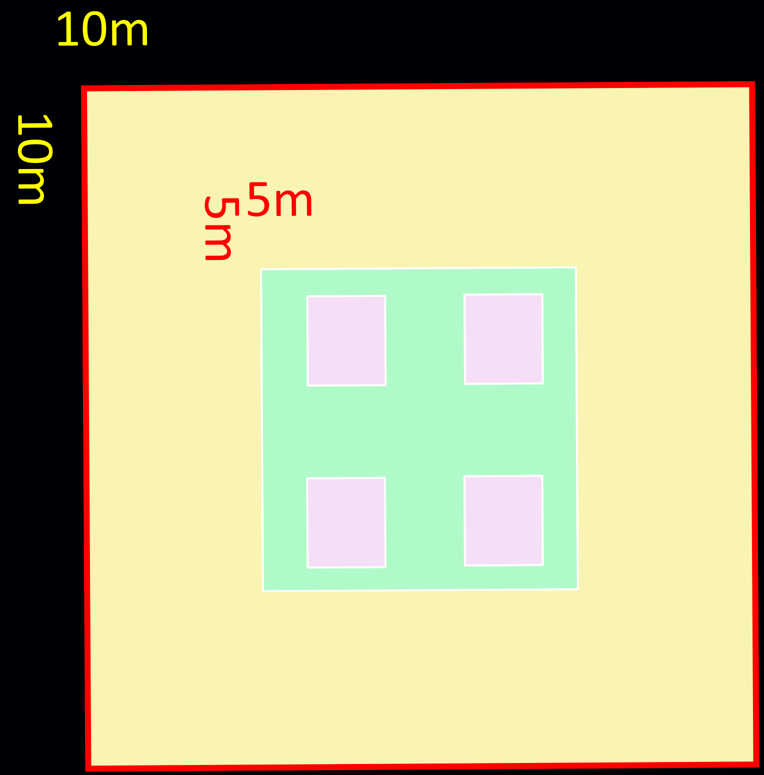


- Identification and Recording of all plants hit by the pin

Permanent plots

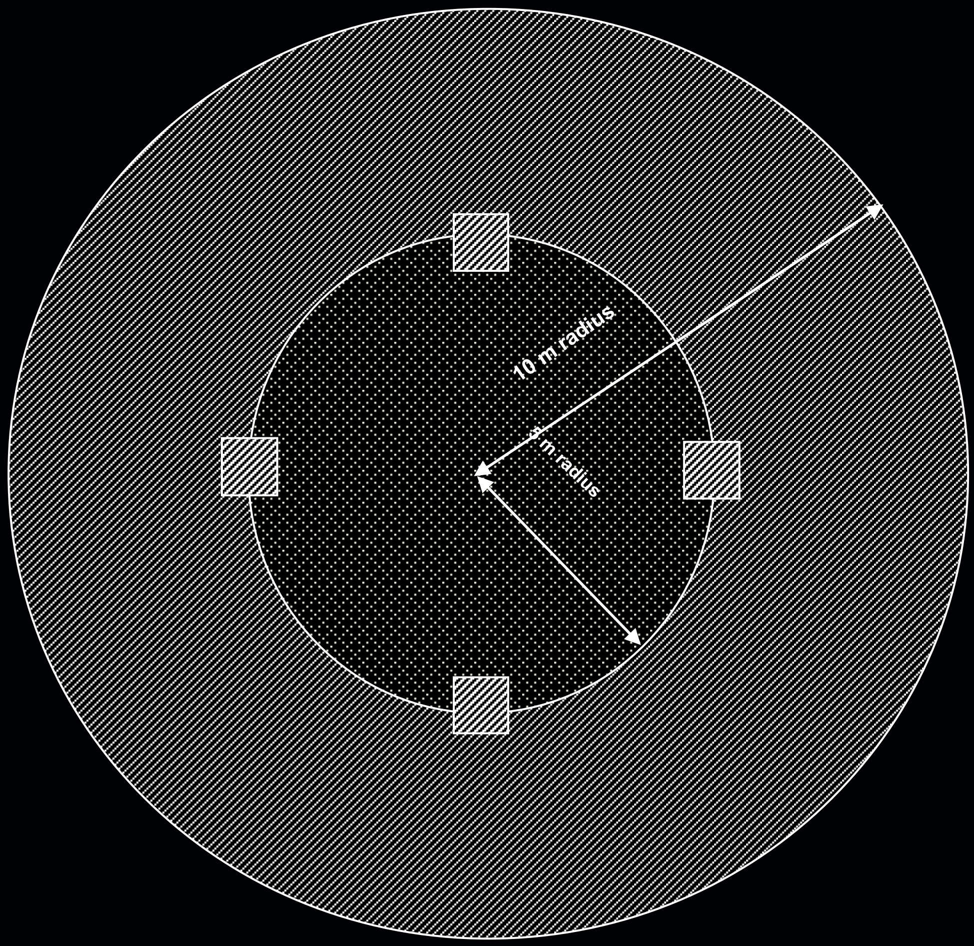
Rectangular or Square plot (Quadrate)

Relėve plot (10m x 10m) or (20m x 5m)



Circular plots

Concentric Circular plots for different vegetation layers



Plots' details

10m radius plot for trees

5m radius plot for sapling, shrub & climbers

1x1m plots for seedling & herbs/grasses

What to measure?

For trees: Species identification, Total count, Tree height, GBH, Cover percentage

For shrubs: Species identification, Total count, Clump diameter, Height, Cover percentage

For herbs and grasses: Species identification, Total count, Height, Cover percentage

Other necessary parameters

Elevation, Aspect, Slope, Distance to water source and road/trail, Rock cover percentage, Barren

Disturbance

- Number of cut, lopped or debarked trees or shrubs
- Trampling of herbs and grasses
- Number of any human sign
- Dung count for livestock and pack animal presence
- Any other specific variable

Canopy

- Canopy cover percentage
- Canopy spread

Vegetation : Canopy Cover

- ✓Subjectively classify the canopy cover as <0.1, 0.1-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, >0.8

Vegetation & Human Disturbance Survey

- ✓Along every 200 m on established transect
- ✓List 5 tree & shrub species in order of dominance within 15m radius
- ✓List signs of wood cutting, lopping, grass cutting, human trails within 15m radius

ESTIMATING ANIMAL POPULATIONS/COMMUNITIES

Field Techniques – Pilot survey

Open ended reconnaissance

Knowledge of local people

Opportunistic encounters

Helps in planning further rigorous estimations ~ Pilot surveys

Field Techniques – Sign survey

Trails

Natural available paths utilized

Recording of indirect signs of presence and direct sightings as well

Provides relative abundance measures

Relative Abundance

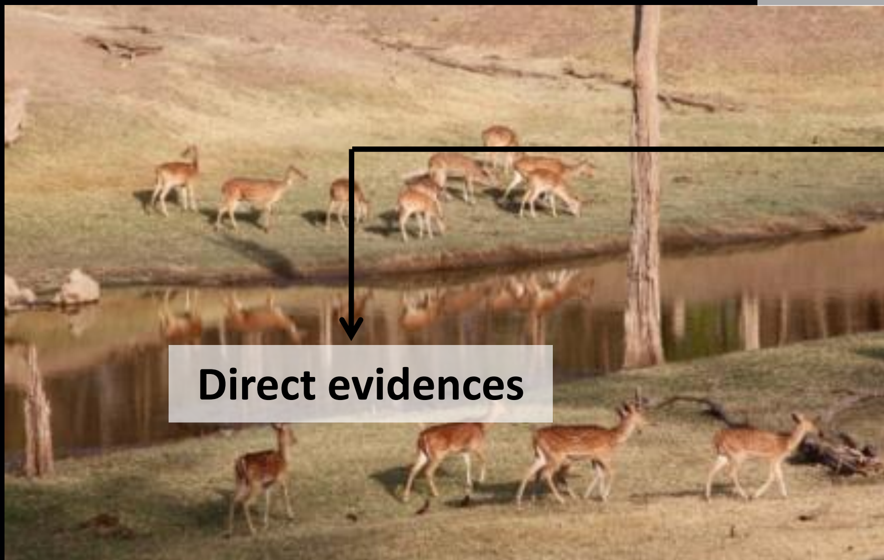
Indirect evidences

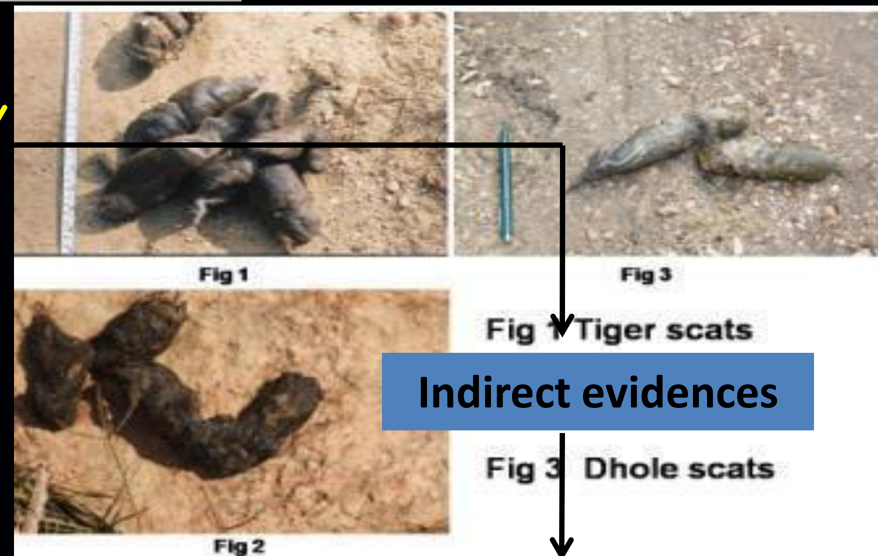
- Animal signs (Scat, Dung, Hoofmarks, Calls etc.)

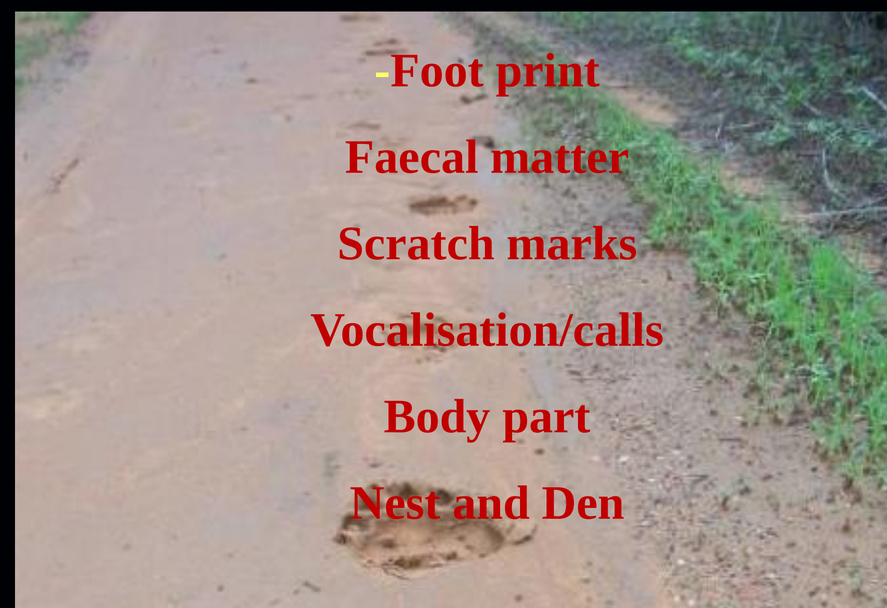
Encounter rates

- Animal tracks, sightings

Animal Signs







Examples: Carnivore signs

Pugmark

The first attempt to enumerate tigers from their pugmarks was made in 1934 (Nicholson W. J.)

A systematic methodological approach for recording pugmarks for *census*, was advocated by Choudhary, S.R.,(1970, 1971) and followed by Panwar (1979*a*), Sawarkar (1987), and Singh (1999).

Track plot:

- It is well documented that different soil surface may give the different impression of same individuals

- To reduce this bias and get reliable data it is important to use uniform soil depth (0.5 to 1 cm, or track plot (TP) on trails used by tigers (Galentine, S., 1996)

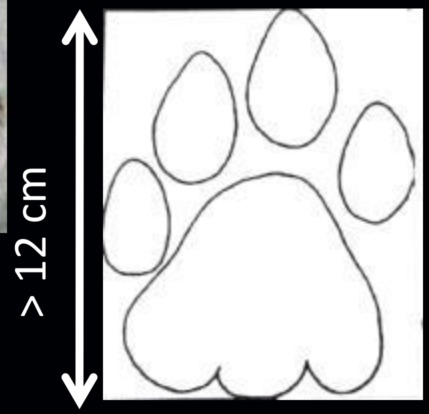
Field Craft contd..

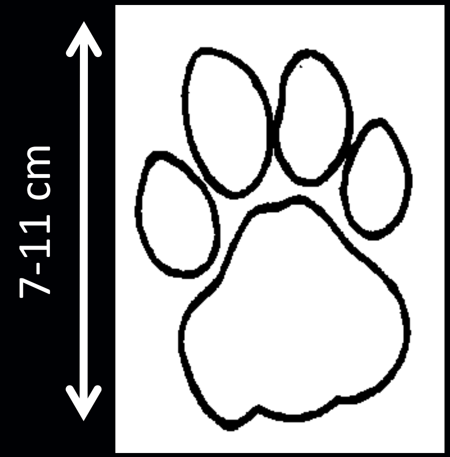
Cat Family

Dog Family

Pugmark

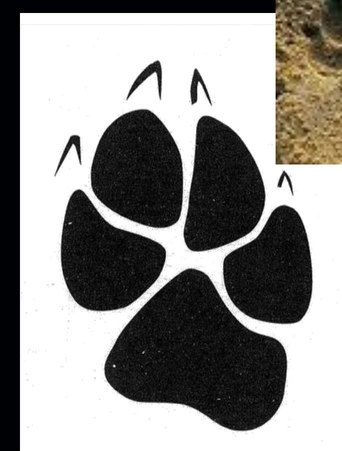
Tiger and leopard



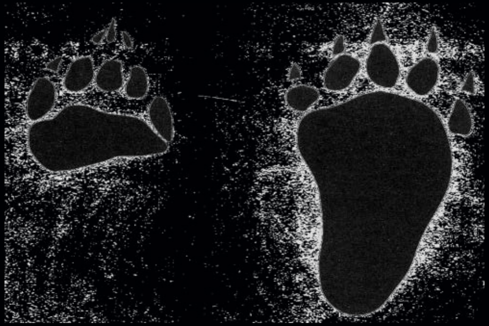


Spoor/Pugmarks

Jackal, Wolf , Hyena



Sloth Bear



Data collection:

- Early in the morning
- Animal trails/PIPS
- Plaster cast
- Tracing paper
- Ancillary information on location, date, and substrate




Carnivore Sign Survey

- ✓Intensive search for carnivore sign
- ✓Minimum 15 km search in most likely areas in each Beat
- ✓3-5 searches each of 4-6 km
- ✓Important to record distance covered in each search





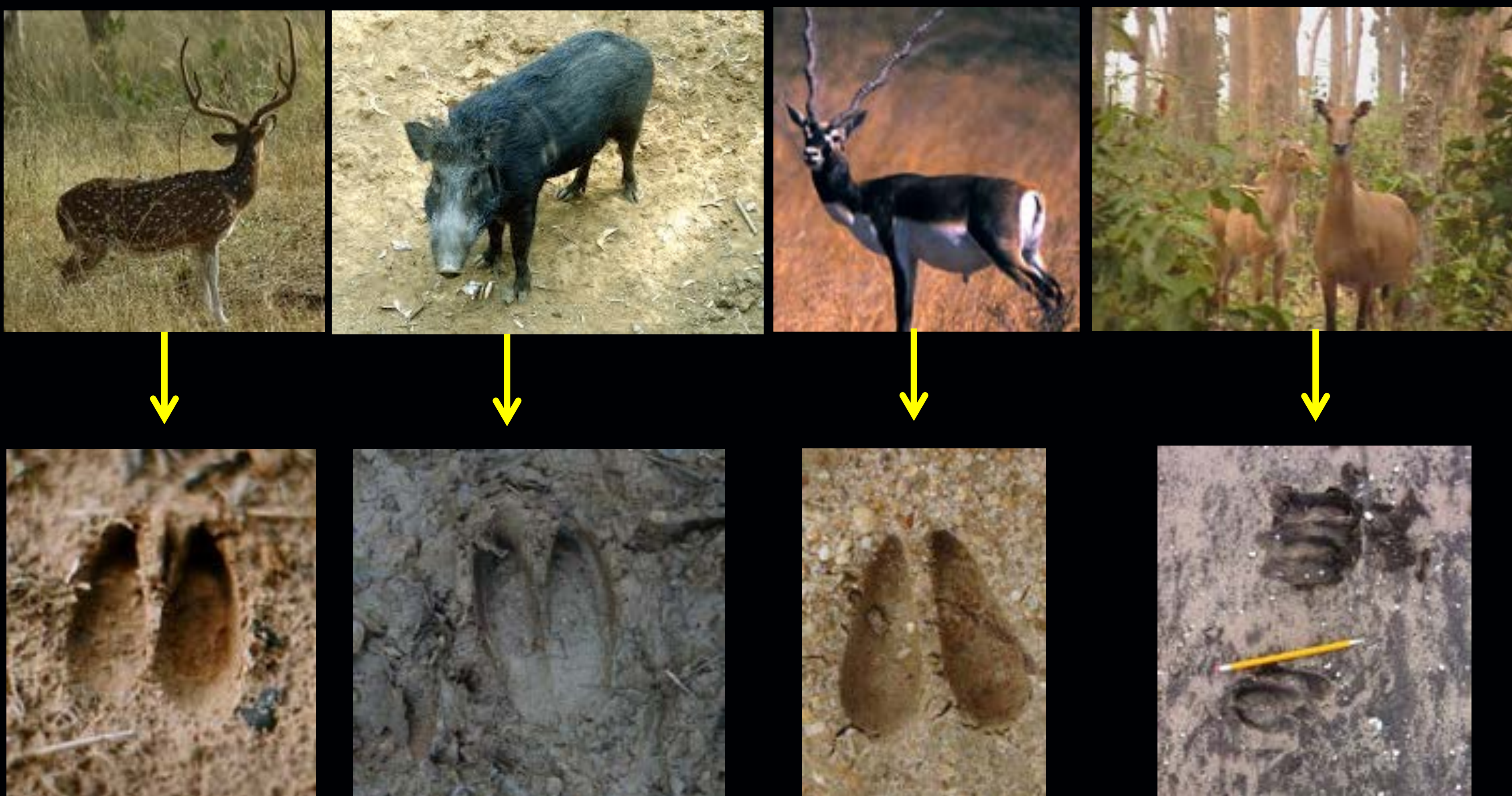
Examples: Ungulate signs



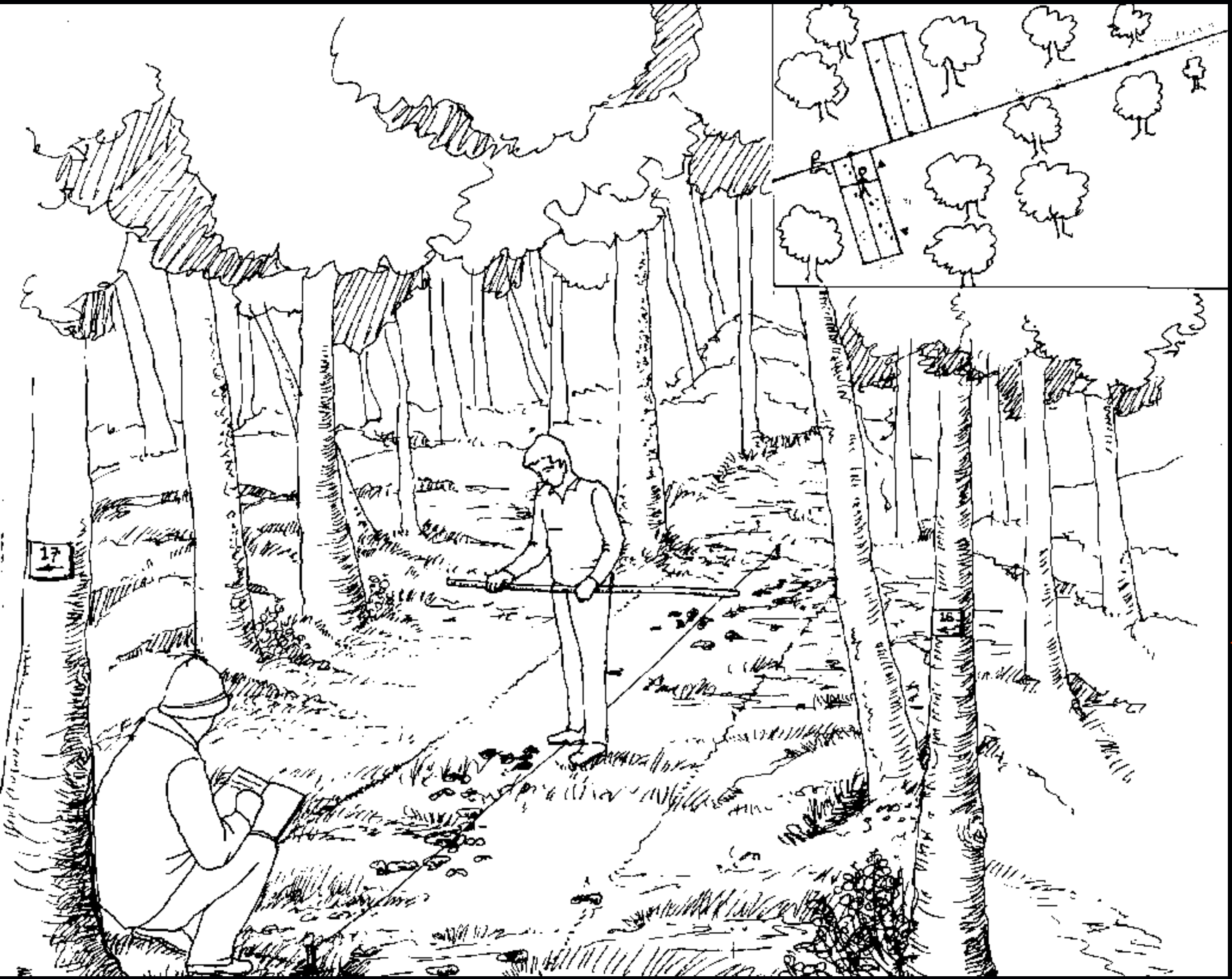


Hoof mark

Wild Ungulates



Ungulate Pellet Counts

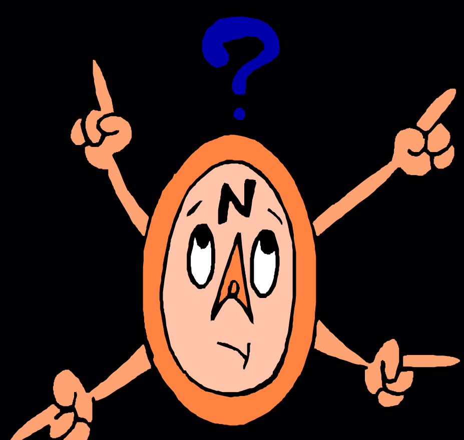


- ✓ At 5 random locations along the trail/line transect (at least 200m apart) sample a 2 by 20 m strip.
- ✓ Classify and count ungulate pellets to species (wild & domestic)

Quantitative Population Analysis

How many are there?

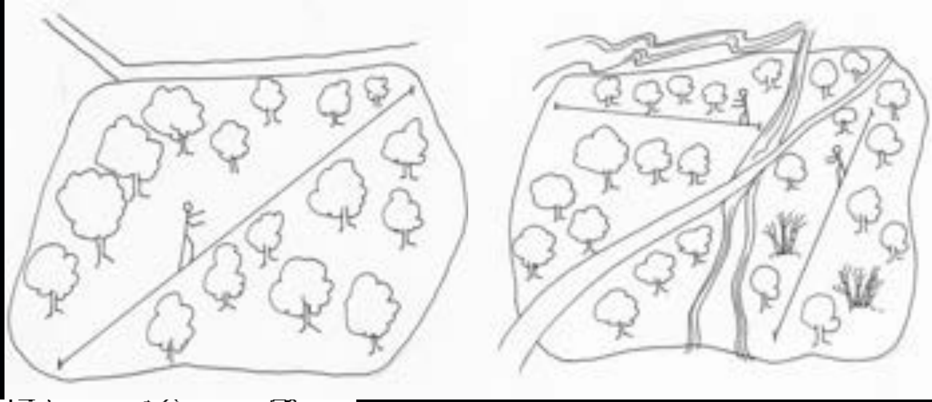
- Distance sampling
  - Line transect
  - Point transect
- Mark-recapture
  - Mark-recapture
  - Mark-resighting
  - Mark-removal

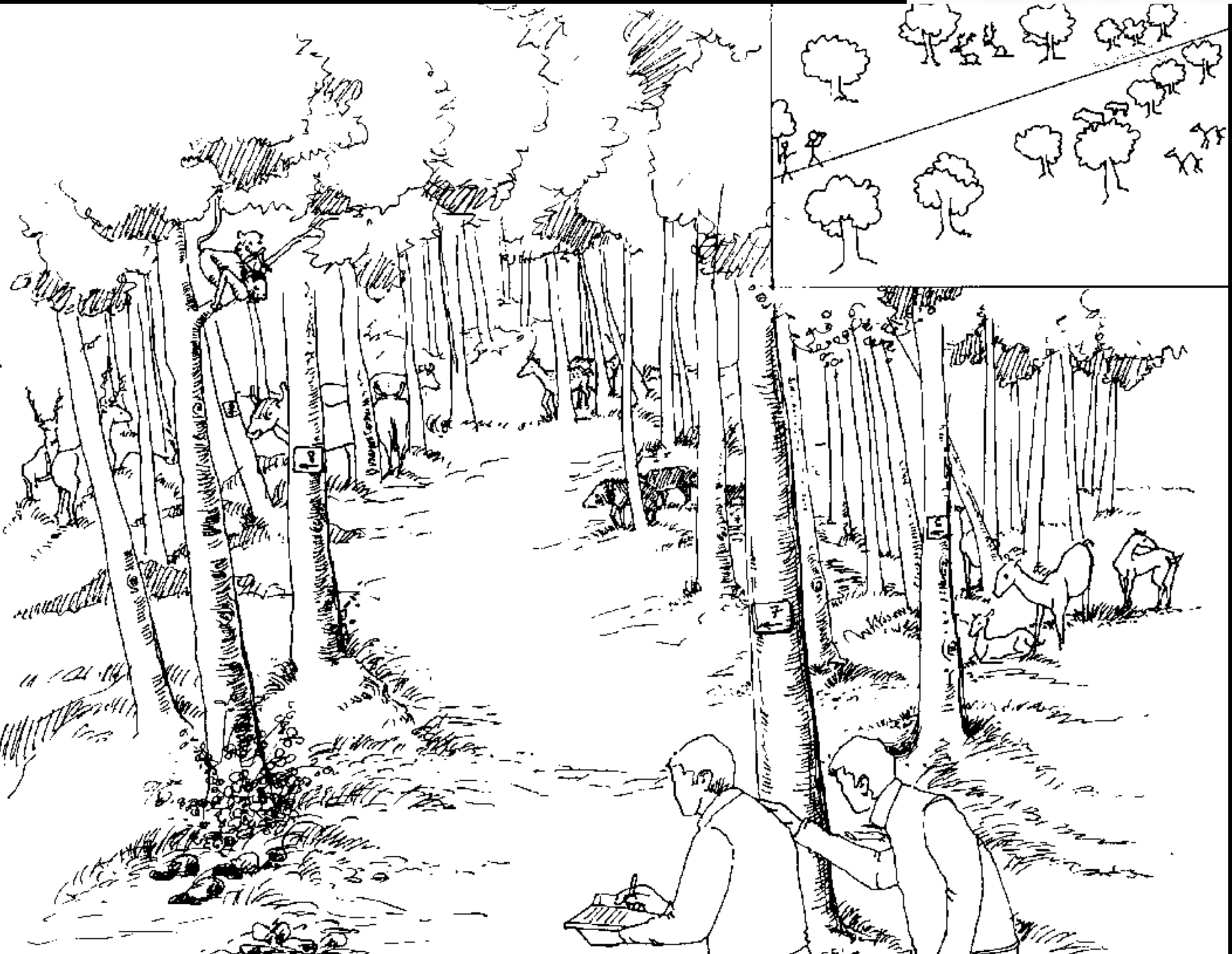


1) *Leading to questions on population demographics and trajectory*

2) *Transect counts*

Ungulate Encounter Rates

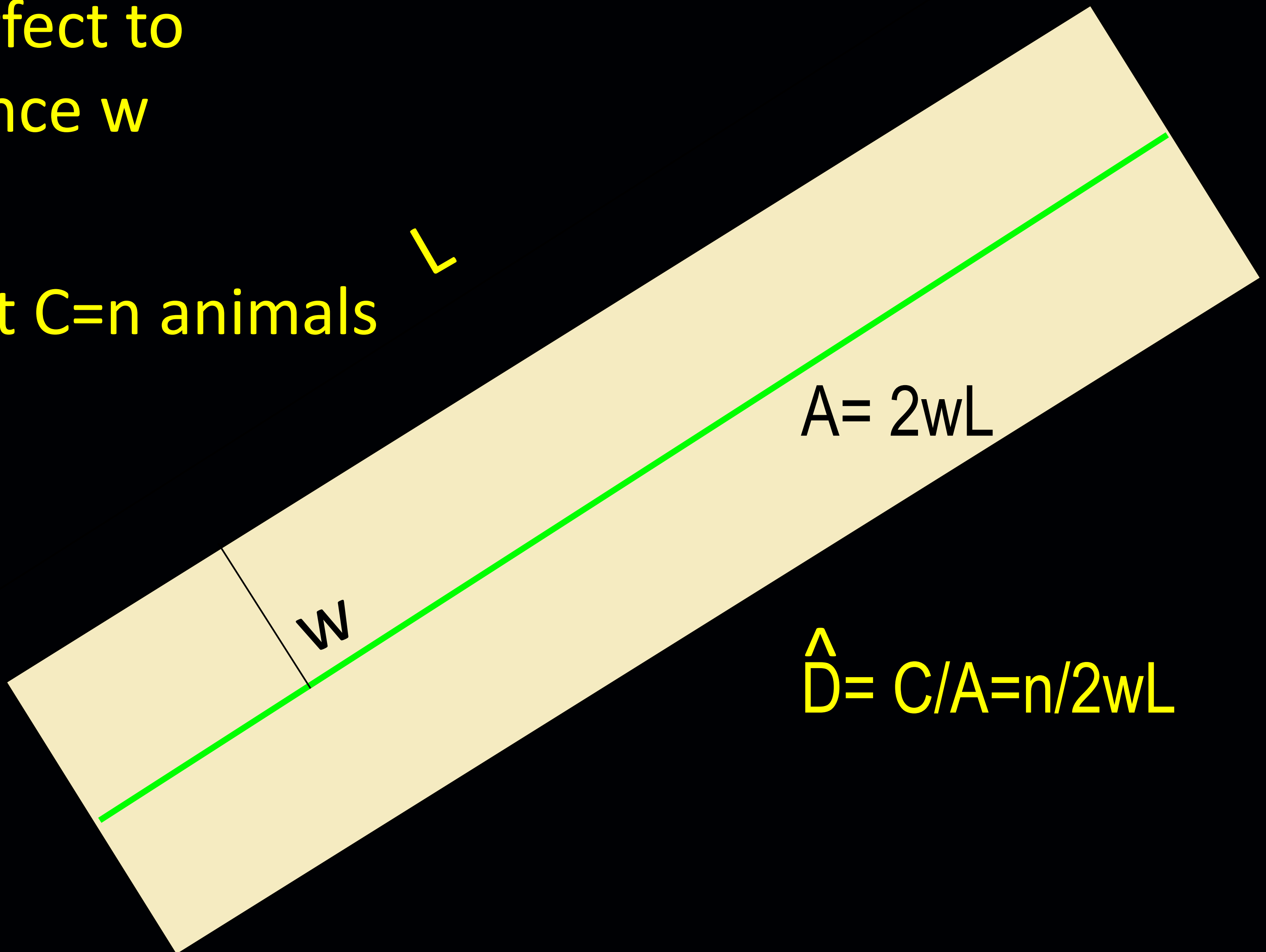




- ✓Establish line transect 2-4 km (or seg. >2 km) in each beat.
- ✓Walk early morning. Count no. of each species, group size, young of the year.

Perfect detection

- Assume detection is perfect to distance w
- Count C=n animals

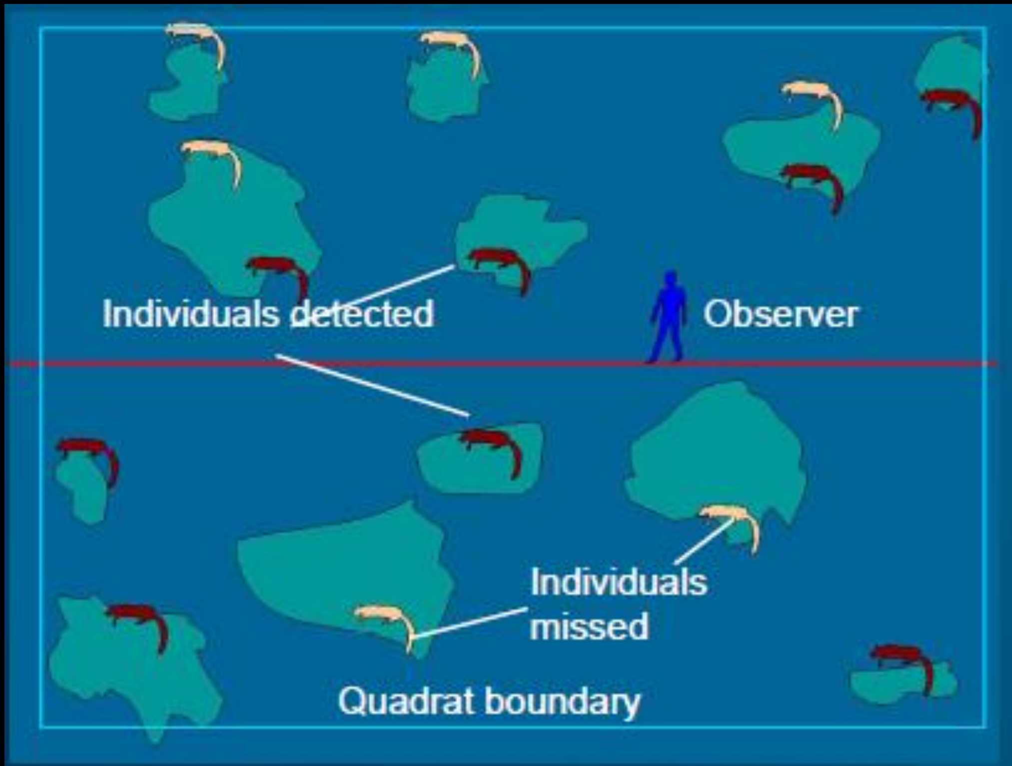


$\hat{D} = C/A = n/2wL$

We can't assume this!

- Detection may (probably is) < 100%

- Detection may be (probably is) variable



How many are there?

- **Numbers detected per some unit of measure that does not translate directly to density**
- **Unverified indices can also lead to poor assumptions about populations – most commonly a lack of detectability estimates—THE DREADED *p* FUNCTION**

1) ***Effects of time, weather, and habitat***
2) ***Non-relationship to actual population size***

COMPARING ABUNDANCES, TREND

N = abundance, or true number of animals
C = count statistic, or number of animals (or sign) counted
p = proportionality constant, detection probability

Time/Place 1 | Time/Place 2

$$N_1=C_1/p_1 \qquad N_2=C_2/p_2$$

A GOOD INDEX REQUIRES….

Time/Place 1 | Time/Place 2

$$N_1=C_1/p \qquad N_2=C_2/p$$

INDICES HAVE SOME ADVANTAGES……

1. Simpler, cheaper, easier to get, more 'precise'

2. Pretend ***p remains unchanged because of:***

Standardization: season, effort, skills, personnel

…AND MANY PROBLEMS

1. In the real world ***p changes because of:***

a. Factors you know about and control,

b. Factors you know but cannot control, and

c. Factors you know nothing about…so the estimates are biased, direction unknown…

Makes sense to estimate ***p if you can….***

2. Often the extra effort/ difficulty involved is imaginary, does require more systematic data collection….

Distance sampling

- Focus on producing density estimates
  - D=N/A
- Two main methods used –
  - Line transect
  - Point Count
- *Uses distance between the observer and the animal and from that distance, an area is calculated to give an 'A'. The number of contacts within 'A' and you have the 'D'*

Assumptions

- Transects or points are representatively placed with respect to animal density.
- Objects directly on the line or at each point are always detected.
- Objects are detected at their initial locations prior to natural movement or movement in response to the observer's presence.
- Distances and angles should be accurately measured.
- Sighting of animals are independent events

Choice of methods

- Line transect: Better for low density and more mobile species
- Point counts better for skulking species or a large number of species.

Positioning of transects

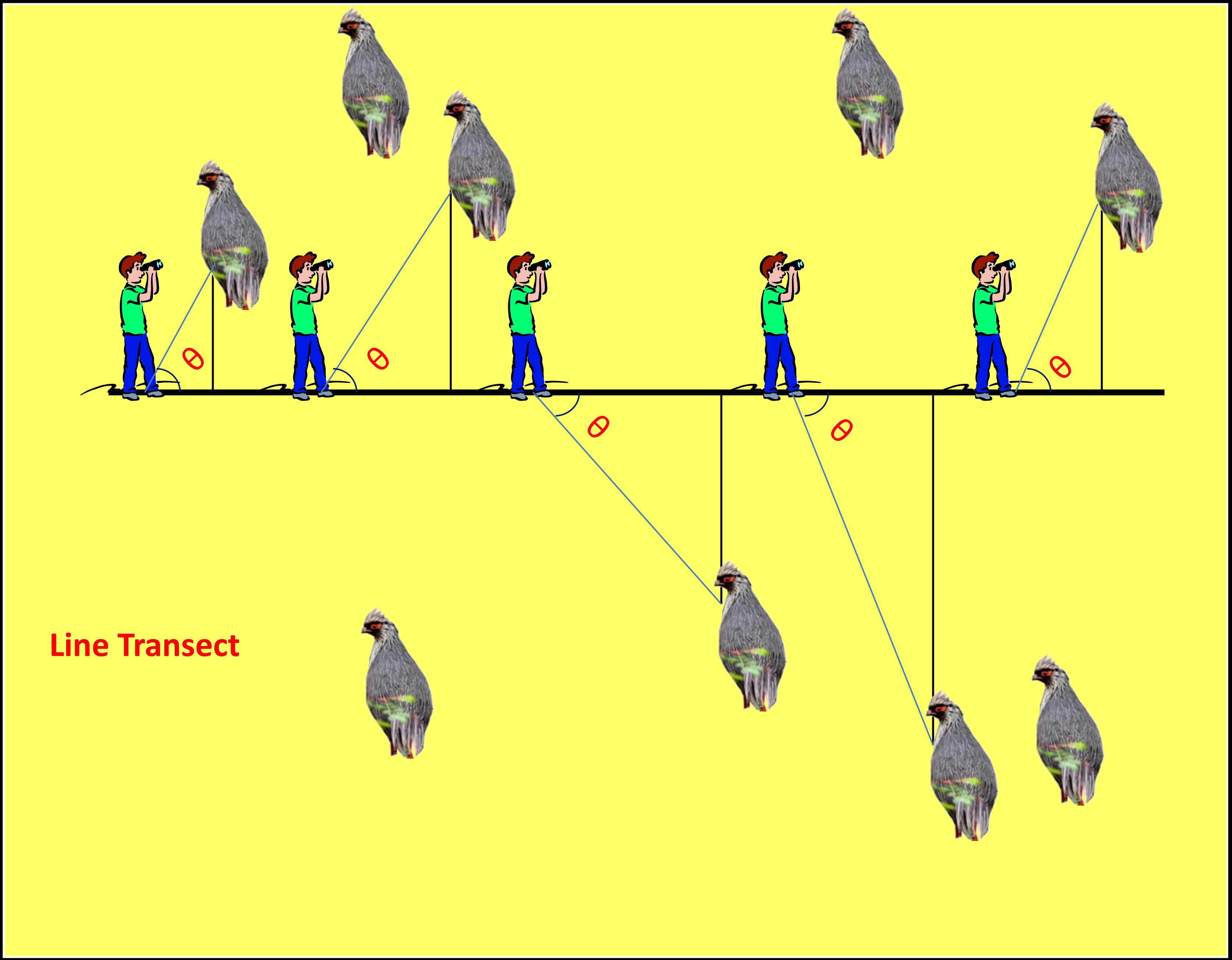
- Randomly or through a stratified random sampling.
- Representativeness and adequacy enables extrapolation
- Bias (along existing trails or roads) provides an index of density.
- How many and how long?
- Depends on a prior knowledge of the area.

Data collection

- One or more lines traversed by an observer
- Count individuals (or groups) detected from the line and measure distance from the detected animal to the line
- Transects may be traversed on foot, horseback, in a vehicle, or in a helicopter or fixed-wing aircraft.
- If fixed width of strip is counted, and if all organisms in the strip are seen, estimates are simple!
- Long, skinny quadrats.
- Use counts and distance to estimate
  - Detection functions
  - Density

Measurements

- Need perpendicular distances to detected animals
- Can use sighting distances & angles + trigonometry
- Sighting distances along will not work!


θ
θ
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θ
Line Transect

General approach

- Use auxiliary (distance) data to estimate detectability and an "average effective ½-width" (w)
- Adjust counts (C) by this estimate to get an unbiased estimated of D and (as appropriate) N

$$\hat{D} = C/\hat{A} = C/2\hat{w}L$$

Distance estimation (cont'd)

- We use the x_i distances to estimate fit a function f(x) based on a detection function g(x)
- With randomly placed transects the observed distances are modeled by

$$f(x) = \frac{g(x)}{\int_0^w g(x)dx}$$

Distance estimation (cont'd)

- Under the assumption that detection on the line is perfect g(0) =1 so

$$f(0) = \frac{1}{\int_0^w g(x)dx} = 1/\overline{w}$$

$\overline{w}$ = "average half-width"

Distance estimation (cont'd)

- Finally– the estimate of density

$$\hat{D} = \frac{n}{2L\overline{w}} = \frac{n\hat{f}(0)}{2L}$$

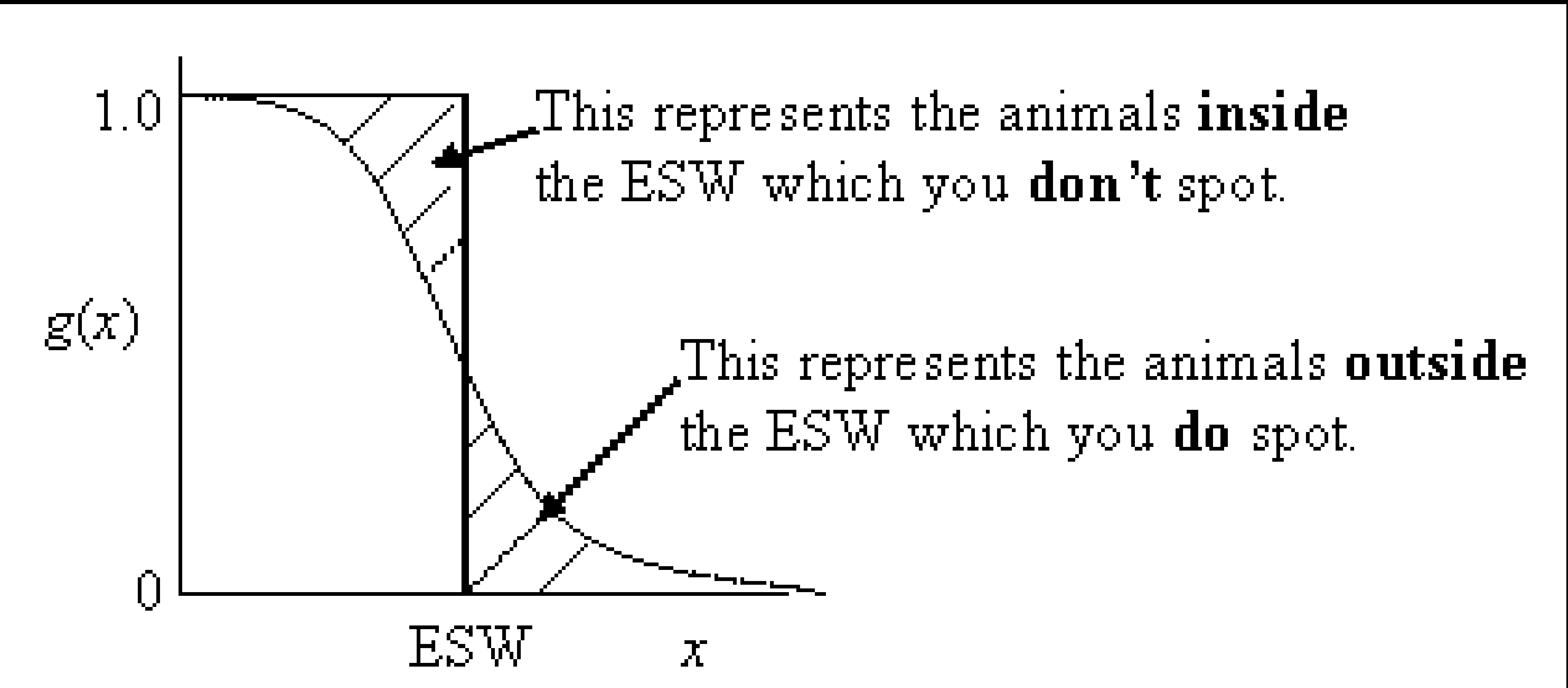
Boils down to

- Finding a suitable form for g(x) and estimating its parameters
- Use g(x) to estimate f(0)

- Use f(0) to estimate D (and its variance and confidence limits)

Detection Function (β)
These birds
not detected
These birds detected
Distance

Variability in detection due to species behavior and habitat condition affect accuracy and precision.



Line transect design

- Appropriate measurements
- Appropriate effort (line length, number of lines)
- Replication (multiple lines)
- Stratification

Sampling effort

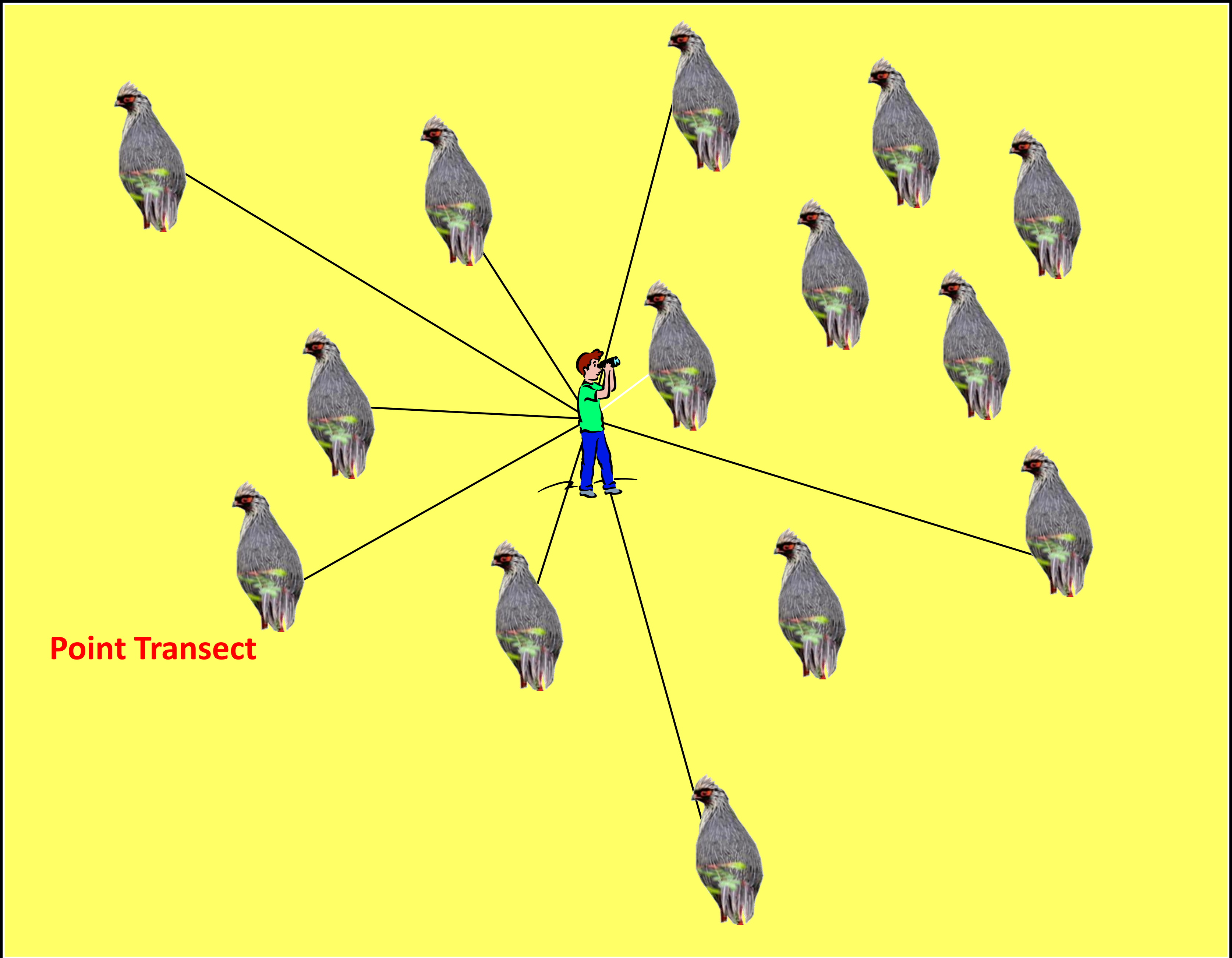
- Need sufficient observations (detections) to build g(x) model
  - Rule of thumb: n > 30 detections (at least)
- Sampling effort = line length (usually)
  - Increasing line length
  - Multiple (replicate) lines ←better

Sampling units- random placement

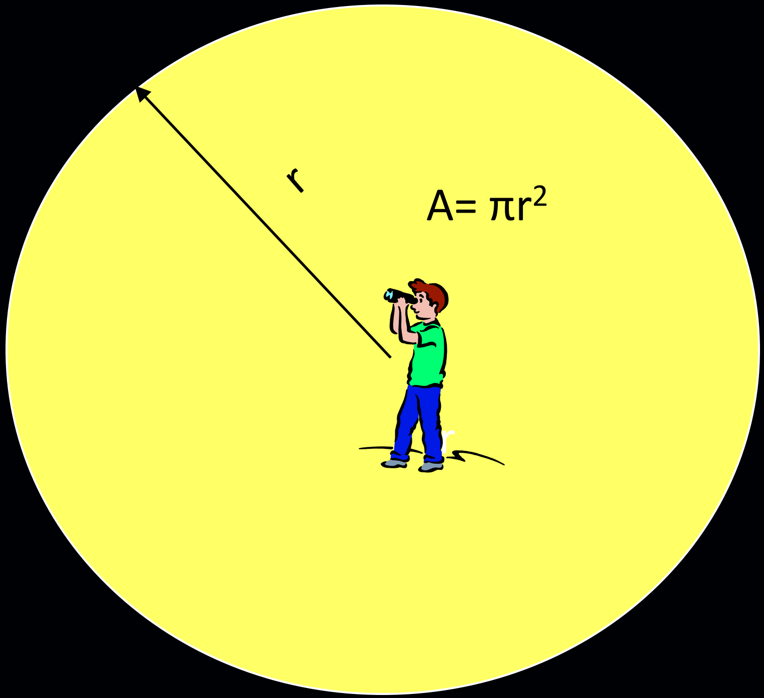
Stratified sampling

Point sampling

- Same basic idea as line transect
- Sampling units are now POINTS instead of lines


Point Transect

Perfect detection



Single point

$$\hat{D} = \frac{n}{A} = \frac{n}{\pi r^2}$$

k replicate points

$$\hat{D} = \frac{n}{k\pi r^2}$$

Imperfect detection

- Don’t assume that detection =100%

- Detection probability decreases as distance from point increases (detection function)

General approach

- Use auxiliary (distance) data to estimate a detectability function h(r)
- Estimate an “average effective radius r”
- Adjust counts (n) by this estimate to get an unbiased estimate of D and (as appropriate) N

Distance estimation (cont'd)

Estimate of density

$$\hat{D} = \frac{n}{\pi \bar{r}^2} = \frac{n\hat{f}'(0)}{2\pi}$$

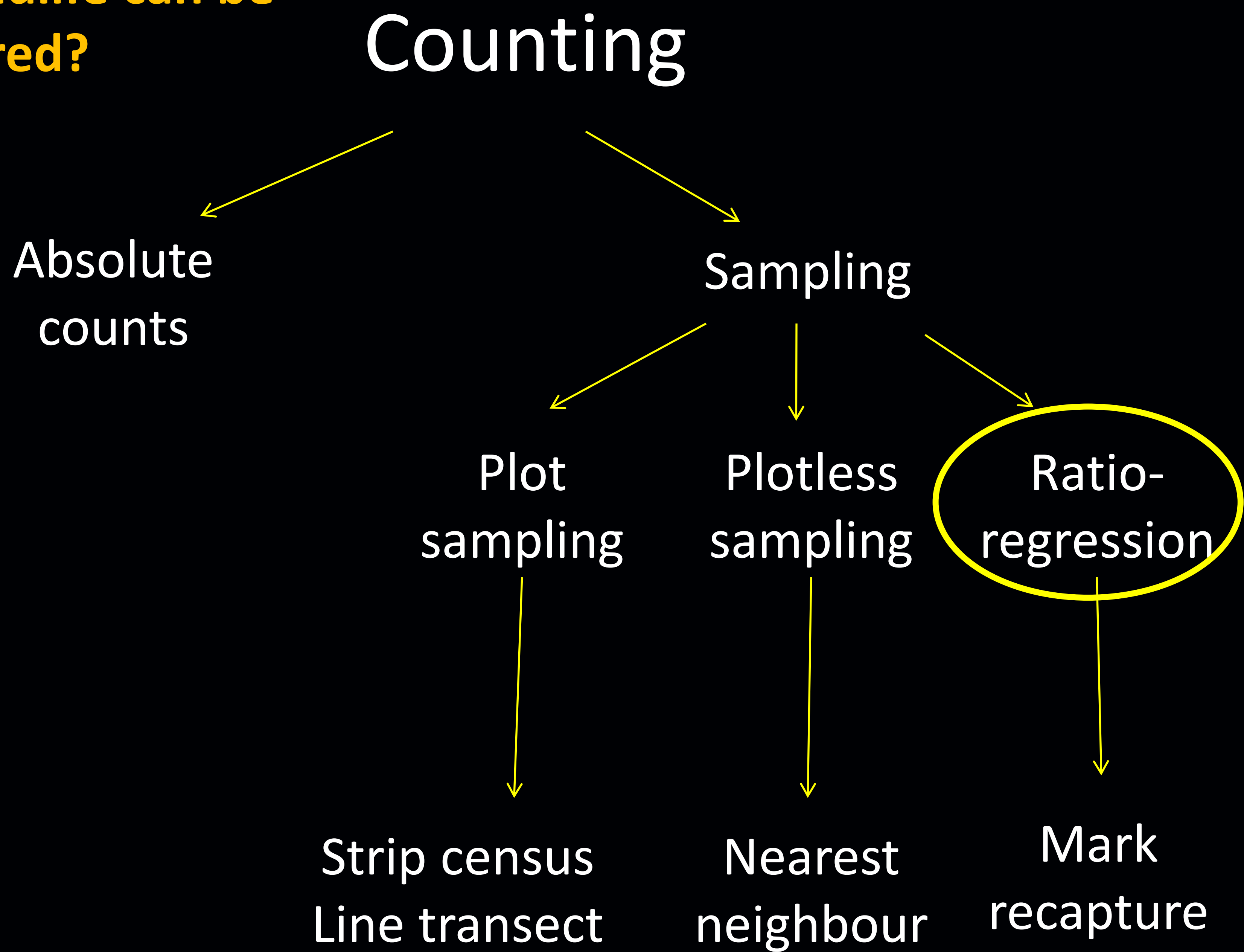
$$\hat{D} = \frac{n\hat{f}'(0)}{k2\pi}$$

k replicate points

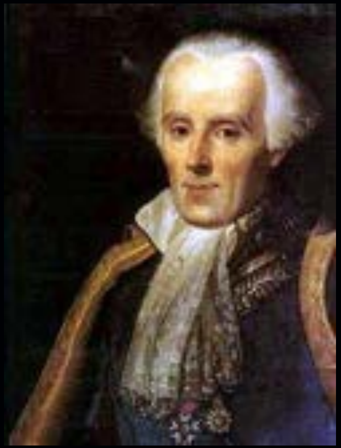
Conclusions

- Robust estimation of density from line transect and point sampling
- Allows for heterogeneity of detection, stratification
- Program DISTANCE allows flexible modeling and model evaluation in an integrated framework

How wildlife can be monitored?



Laplace experiment



Early capture recapture approach (1802)

All live births marked in France = 1,000,000 in 1801 (marked)

Census (with live births) in communities = 2,037,615
Marked births in this sample = 71,866

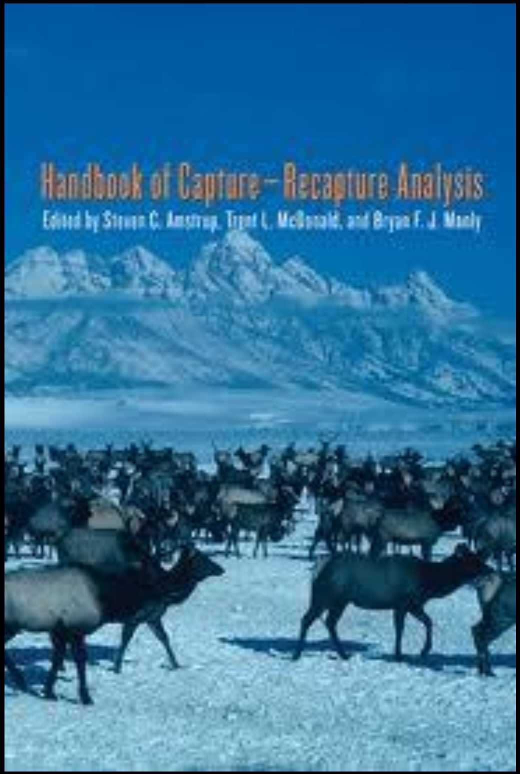
The ratio of marked in the sample, *P* = 71,866 / 2,037,615 = 0.035

Marked live births should be similarly related to population size, *N*
= 1,000,000 / 0.035 = 28,328,612

$$\hat{N} = \frac{C}{\hat{p}}$$

Mark Recapture Analysis

Individual / group recognition



Mark-Recapture

•The basic idea is to take some animals from the population and mark them for future identification.

•Then they are returned to the population, where they then mix into the population.

•The simplest mark-recapture technique assume that the re-mixing of the population is uniform so that, when you capture a second group from the population, there is an equal chance of capturing marked and unmarked individuals.

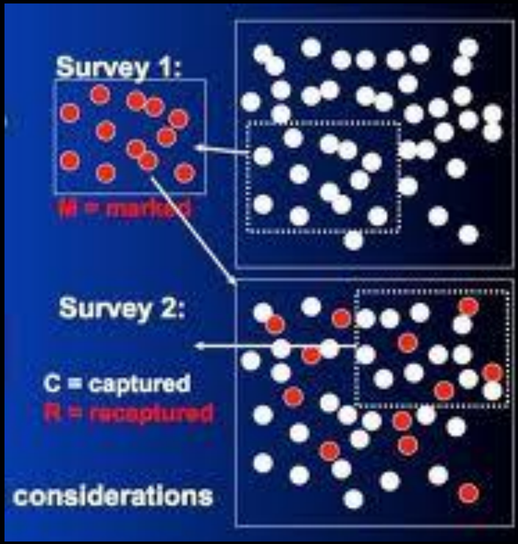
•The population size is estimated from the fraction of captures that are marked individuals.

Capture-recapture Models for Closed Populations

2-Survey Lincoln-Petersen Estimation

Catch animals, mark and release into population (n_1) –1^{st} Survey

Recapture animals, record number with (m_2) & without marks (n_2) –2^{nd} Survey



$$\frac{n_1}{N} \approx \frac{m_2}{n_2} \Longrightarrow \hat{N} = \frac{n_1 n_2}{m_2}$$

Can be extended to *K*-Surveys Schnabel Estimation

Capture-recapture Models for Closed Populations

Estimation focus on abundance, *N*

Assumptions

- Closure : demographic & geographic
  closed CR surveys completed within brief time

- Independence : individual encounter history

- **Equal catchability : issue of heterogeneous detectability**
  mobile vs. sedentary, colourful vs. cryptic, big vs. small
  home-range centers away from trap-array

- Marking: no tag loss, no influence on survival/behaviour
  trap shyness or happiness

Variants of Closed Capture-recapture Models

Incorporates variability in capture probability due to:

Time – M(t)

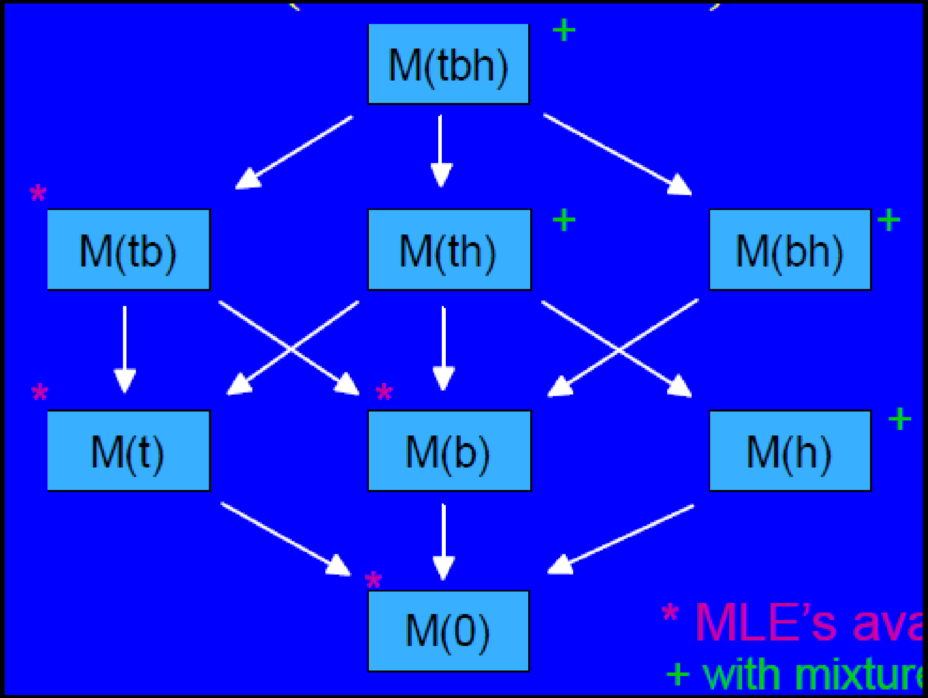
Behaviour /Trap response – M(b)

Individual heterogeneity / uniqueness – M(h)

… and combinations of

these sources of variation

(Otis et al 1978)



Capture History Modeling

Capture History	M_0	M_t	M_b
111	ppp	$p_1p_2p_3$	pcc
110	$pp(1\text{-}p)$	$p_1p_2(1\text{-}p_3)$	$pc(1\text{-}c)$
101	$p(1\text{-}p)p$	$p_1(1\text{-}p_2)p_3$	$p(1\text{-}c)c$
100	$p(1\text{-}p)(1\text{-}p)$	$p_1(1\text{-}p_2)(1\text{-}p_3)$	$p(1\text{-}c)(1\text{-}c)$
011	$(1\text{-}p)pp$	$(1\text{-}p_1)p_2p_3$	$(1\text{-}p)pc$
010	$(1\text{-}p)p(1\text{-}p)$	$(1\text{-}p_1)p_2(1\text{-}p_3)$	$(1\text{-}p)p\ (1\text{-}c)$
001	$(1\text{-}p)(1\text{-}p)p$	$(1\text{-}p_1)(1\text{-}p_2)p_3$	$(1\text{-}p)(1\text{-}p)p$
000	$(1\text{-}p)(1\text{-}p)(1\text{-}p)$	$(1\text{-}p_1)(1\text{-}p_2)(1\text{-}p_3)$	$(1\text{-}p)(1\text{-}p)(1\text{-}p)$

$$L(N, p_1 \ldots p_t) = \frac{N!}{(N - M_{t+1})! \prod_i x_i} p^n (1-p)^{tN-n}$$

x_i denotes frequency of capture history

$n = n_1 + n_2 + \ldots + n_t$ denotes the total number of captures

Density Estimation

Why density? $\hat{D} = \hat{N} / A$

Problem: Area from which captured animals are drawn is unknown

Conventional solution: Effective Trap-area
Boundary strip to include animals whose home ranges overlap the trap-array
Homerange radius – telemetry or ½ MMDM

Wilson & Anderson 1985

Robust solution: Spatially Explicit Capture Recapture model
Hierarchical modeling of spatial detection & density process
Maximum likelihood or Bayesian data augmentation technique

Efford & Borcher 2008, Royle et al 2009

Capture-recapture Models for Open Populations

Cormack-Jolly-Seber Model

Focus is on estimating vital rate, *S*

Assumptions

- All marked animals have similar capture and survival probabilities at time *i*
- Marks are not lost or incorrectly recorded
- Mortality during the sampling period is negligible
- Independence of fates (affects variance estimates only)

2009

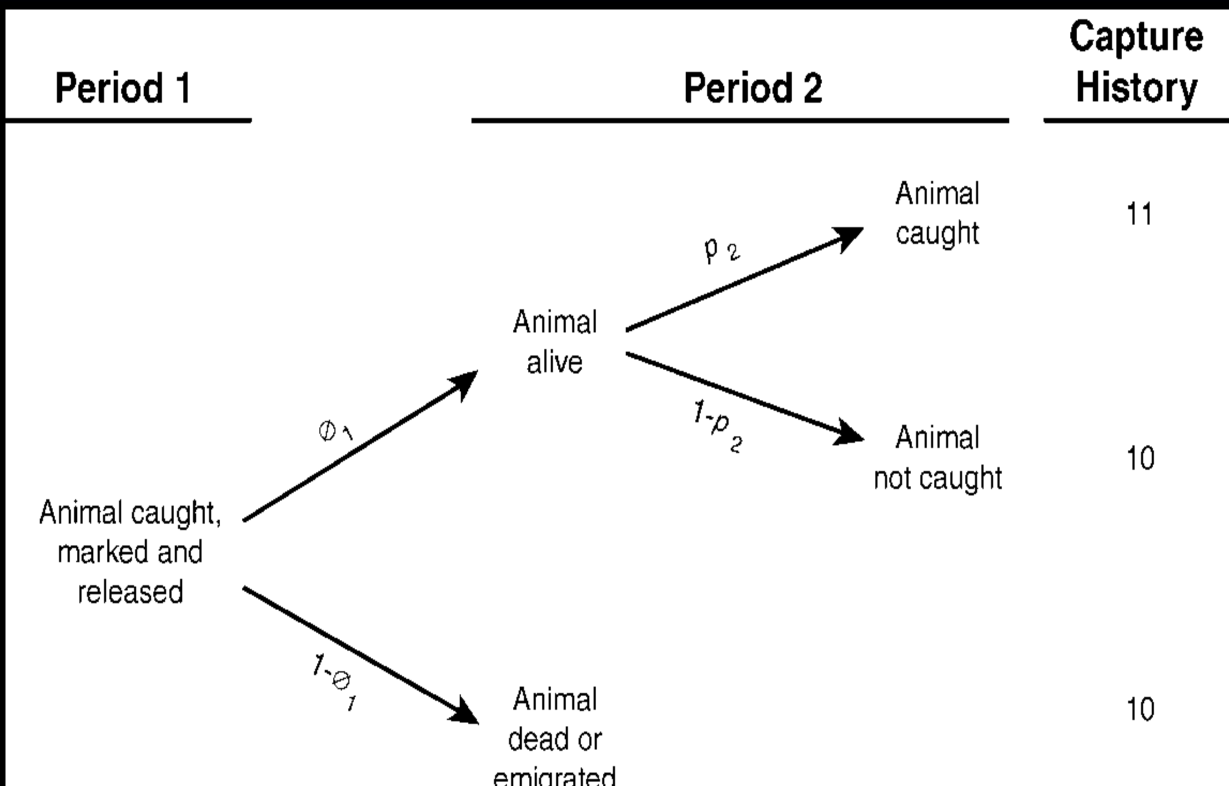
2010

2011

Capture-recapture Models for Open Populations

Cormack-Jolly-Seber Model

φ_i = survival probability, i to $i+1$
p_i = capture probability at time i



Model

$$\phi_1 p_2$$

$$\phi_1(1-p_2)$$

$$1-\phi_1$$

Software for Capture Recapture Analysis

Problems with mark-recapture

- Trapping is cumbersome
- Permissions
- Sample size and effort

Field Techniques – Population estimation

Physical trapping

Capture – recapture framework

Trapping, marking, release and repetition

Gives relatively good population estimates

Not feasible for many large mammals

Popular Trap Types

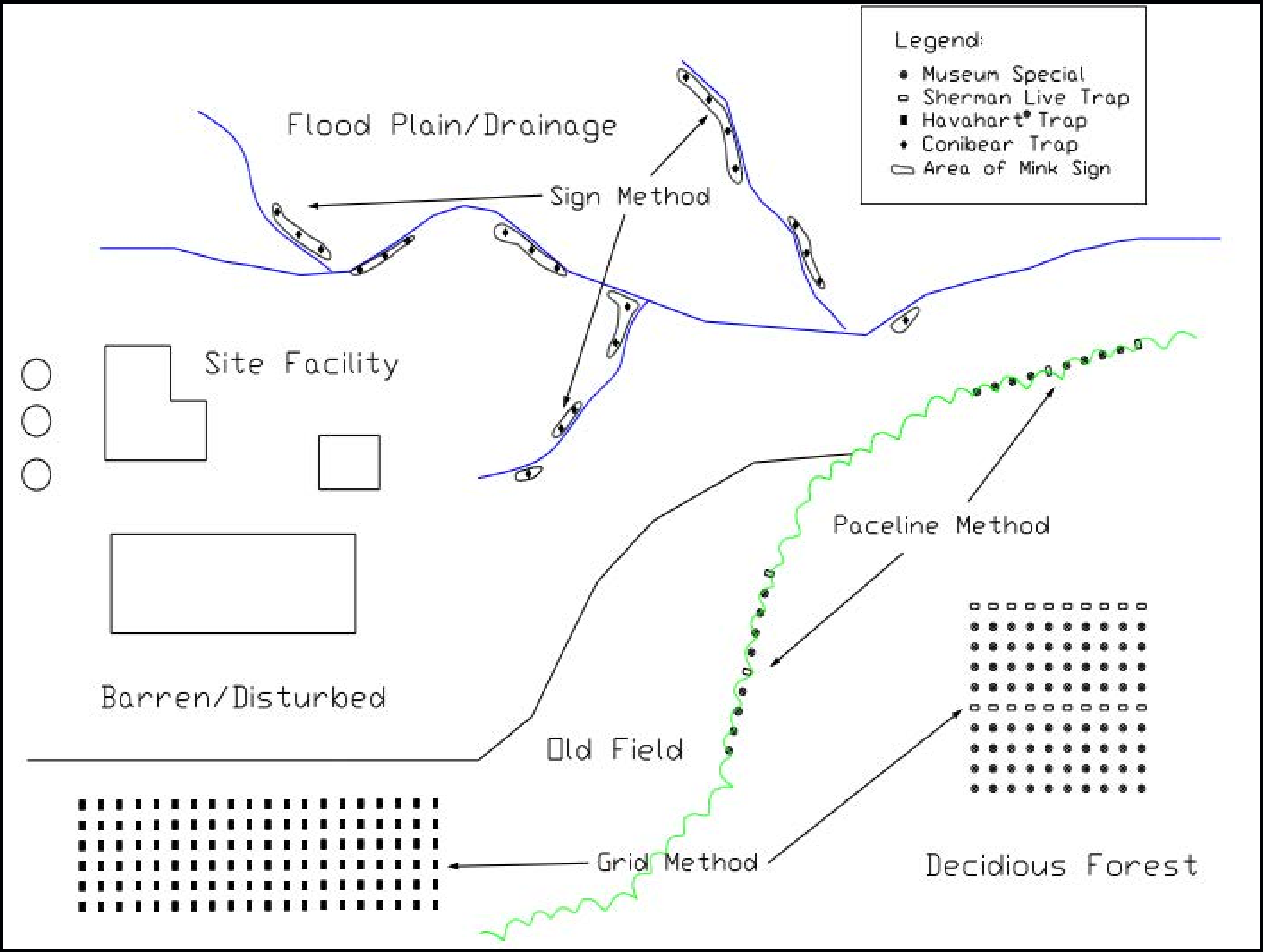
Collapsible Tomahawk trap for squirrels, small carnivores and large rats

Standard-sized collapsible Sherman trap

Victor trap

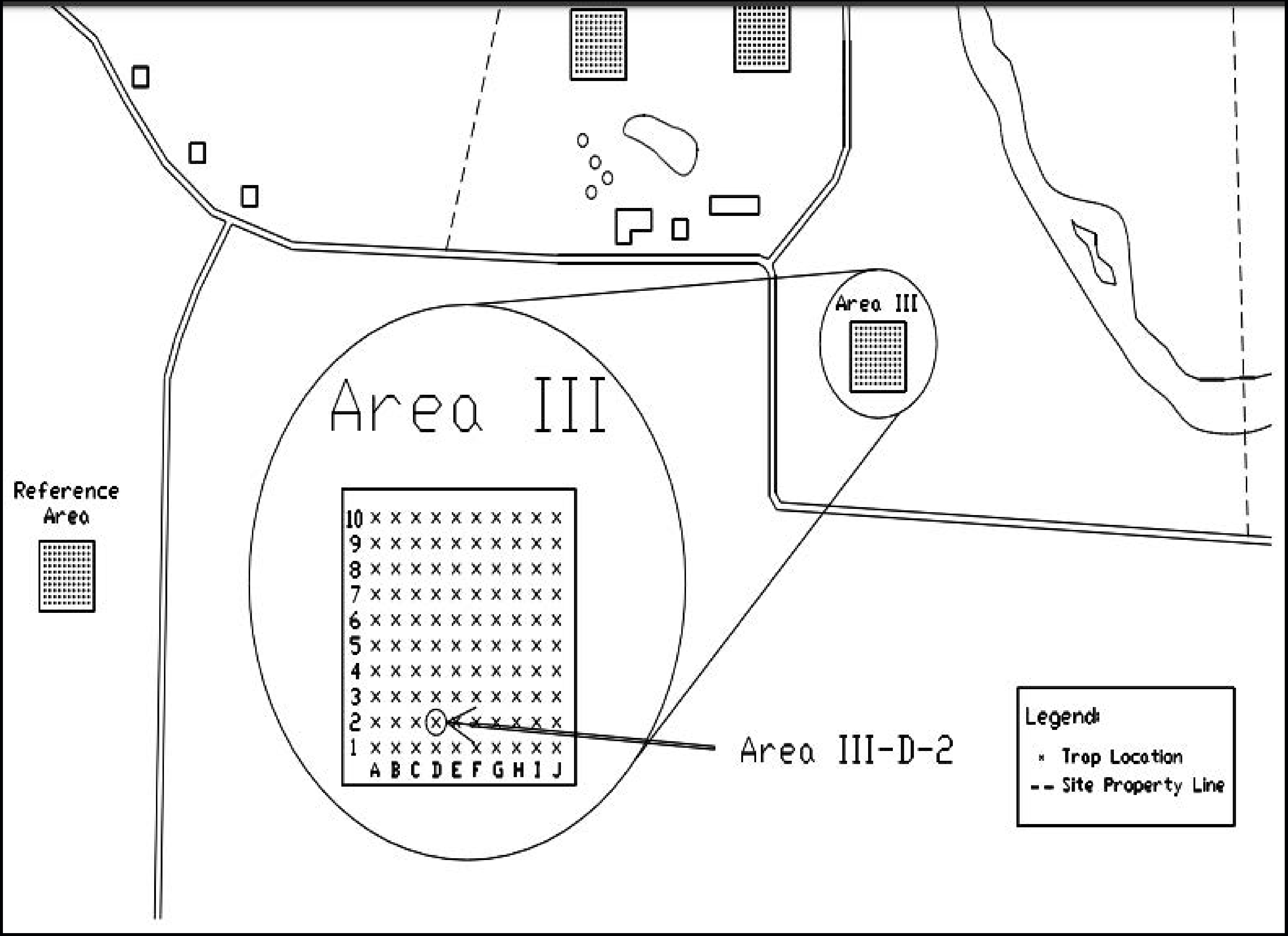
Museum Special snap trap

Trap Design



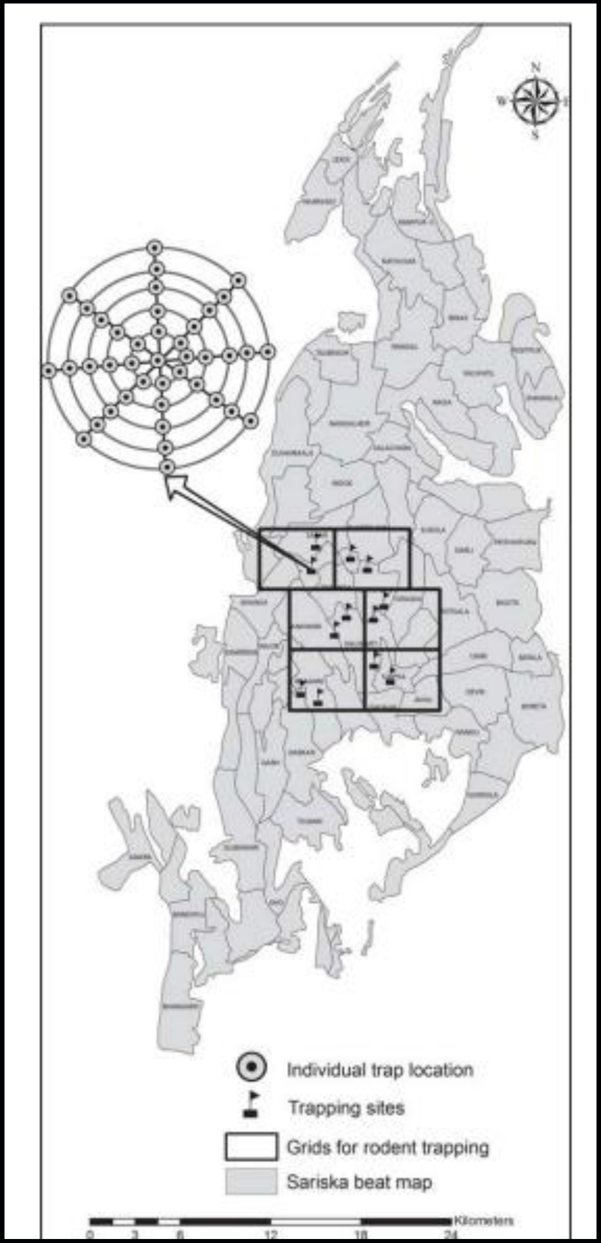
Legend:
Museum Special
Sherman Live Trap
Havahart® Trap
Conibear Trap
Area of Mink Sign
Flood Plain/Drainage
Sign Method
Site Facility
Paceline Method
Barren/Disturbed
Old Field
Grid Method
Decidious Forest

Trap Design



Reference Area
Area III
Area III
10 9 8 7 6 5 4 3 2 1
A B C D E F G H I J
Area III-D-2
Legend:
Trap Location
Site Property Line

Web Trapping Design



- Web trapping design (Anderson et al. 1983)
- Requires rodent captures to be collected from the trapping web
- Treats the data as distance measures from the center of the web

Camera Trapping

Camera trapping

Also based on capture – recapture framework

Non-invasive and more logistically feasible

Movement/heat sensitive automated cameras

Feasibility limited by ability to identify individual variation in morphology



Camera Traps

A camera that traps an animal through a photo using an automatic trigger.

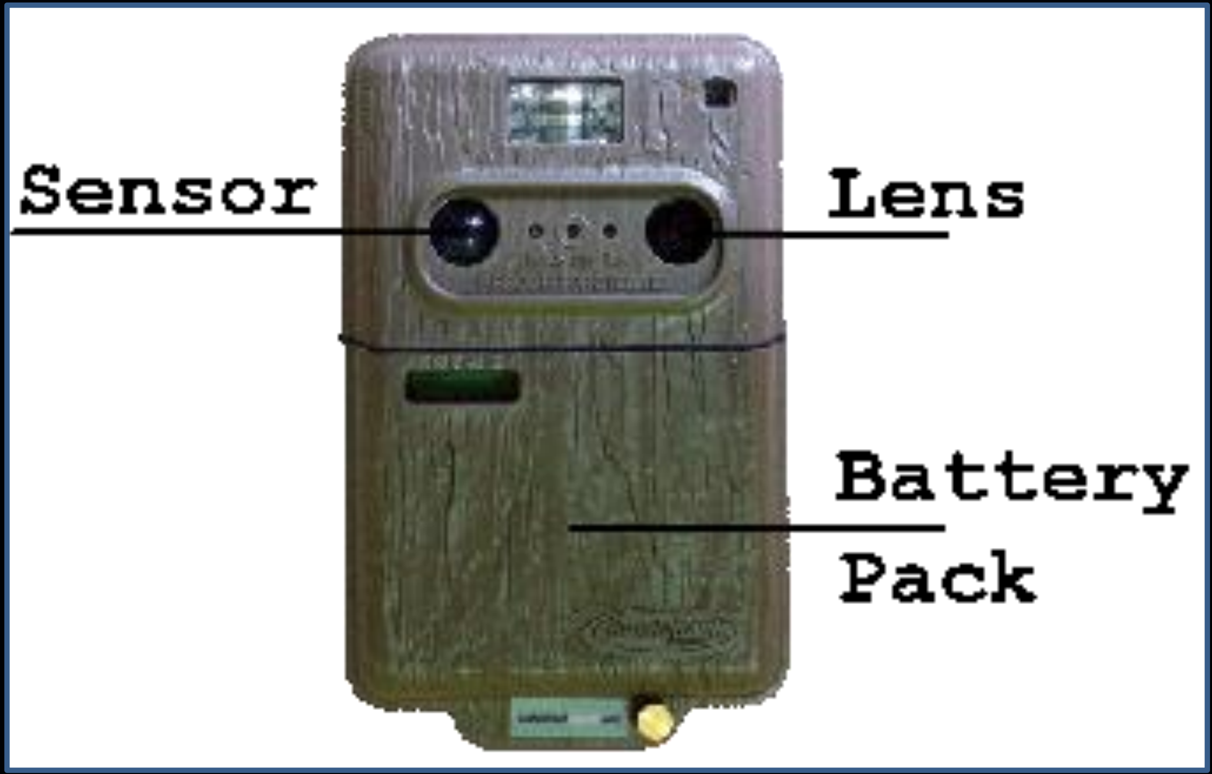
Three main components

1. Camera
2. Sensor (motion/heat sensors) (passive Infrared PIR)
3. Micro controller

Components of a camera trap

1. Camera (Film or digital)

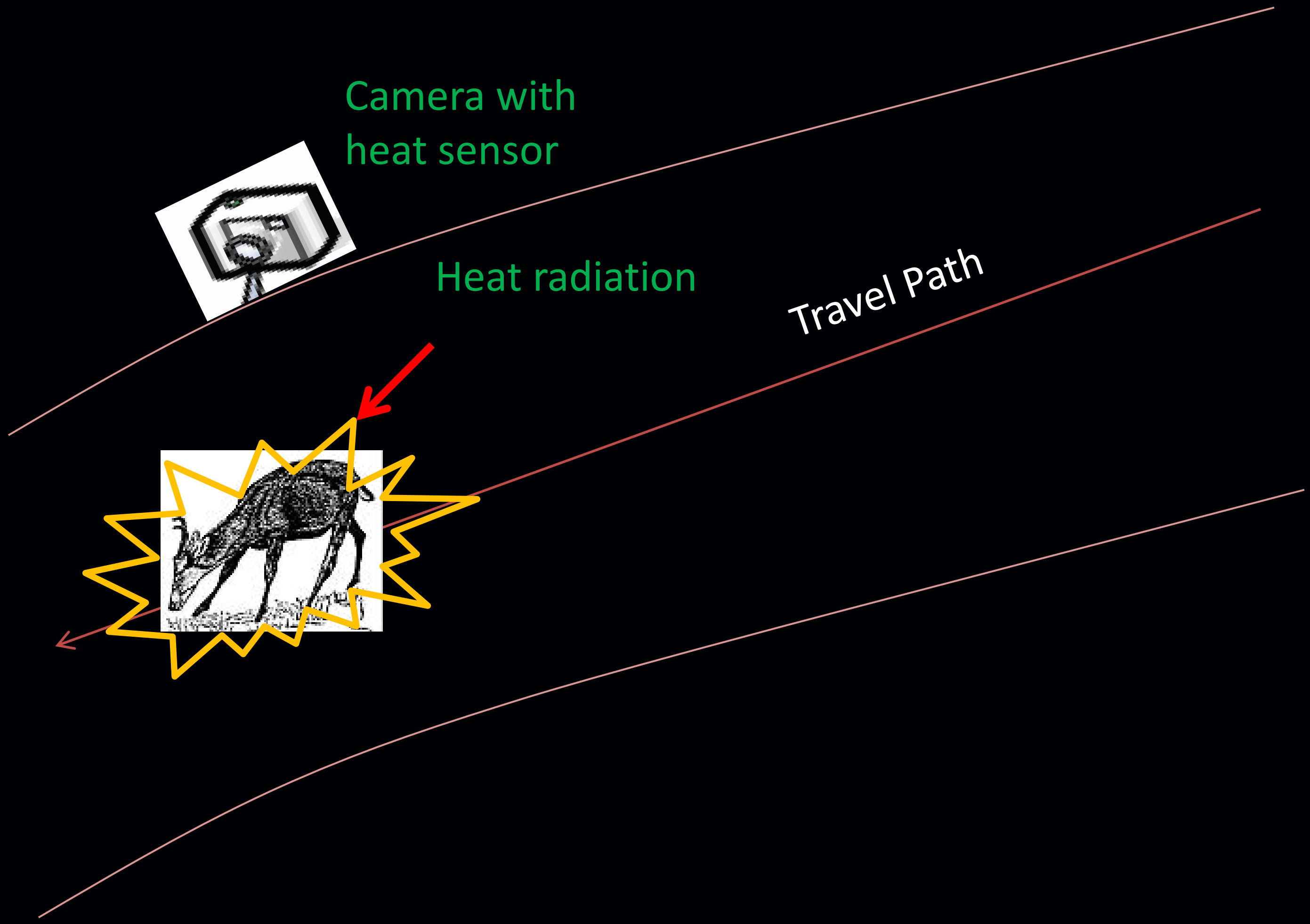
2. Tripping device that fires the camera


Sensor
Lens
Battery
Pack


WHITE Series
20MP
12:42 PM
A
Date
Year
Menu
B
Time
Test
5 Sec
15 Sec
30 Sec
1 Min
3 Min
OFF
Arm
Video
Off
On
IMAGES ARMED DWELL B LOW
88/88
AM
PM
RAYOVAC
Alkaline
IR.2.1-1408

Passive trigger device

Passive infrared systems are triggered when a moving animal (or object) with a different temperature than ambient temperature crosses the camera’s detection zone.



Camera Types

The earliest models used traditional film and a one-shot trigger function. These cameras contained film that needed to be collected and developed like any other standard camera.

More advanced cameras utilize digital photography, sending photos directly to a computer. Some cameras are even programmed to take multiple pictures after a triggering event.

Video is also an emerging option in camera traps, allowing researchers to record running streams of video and to document animal behavior.

Where to set the camera trap?

Where there is maximum chances of locating animals

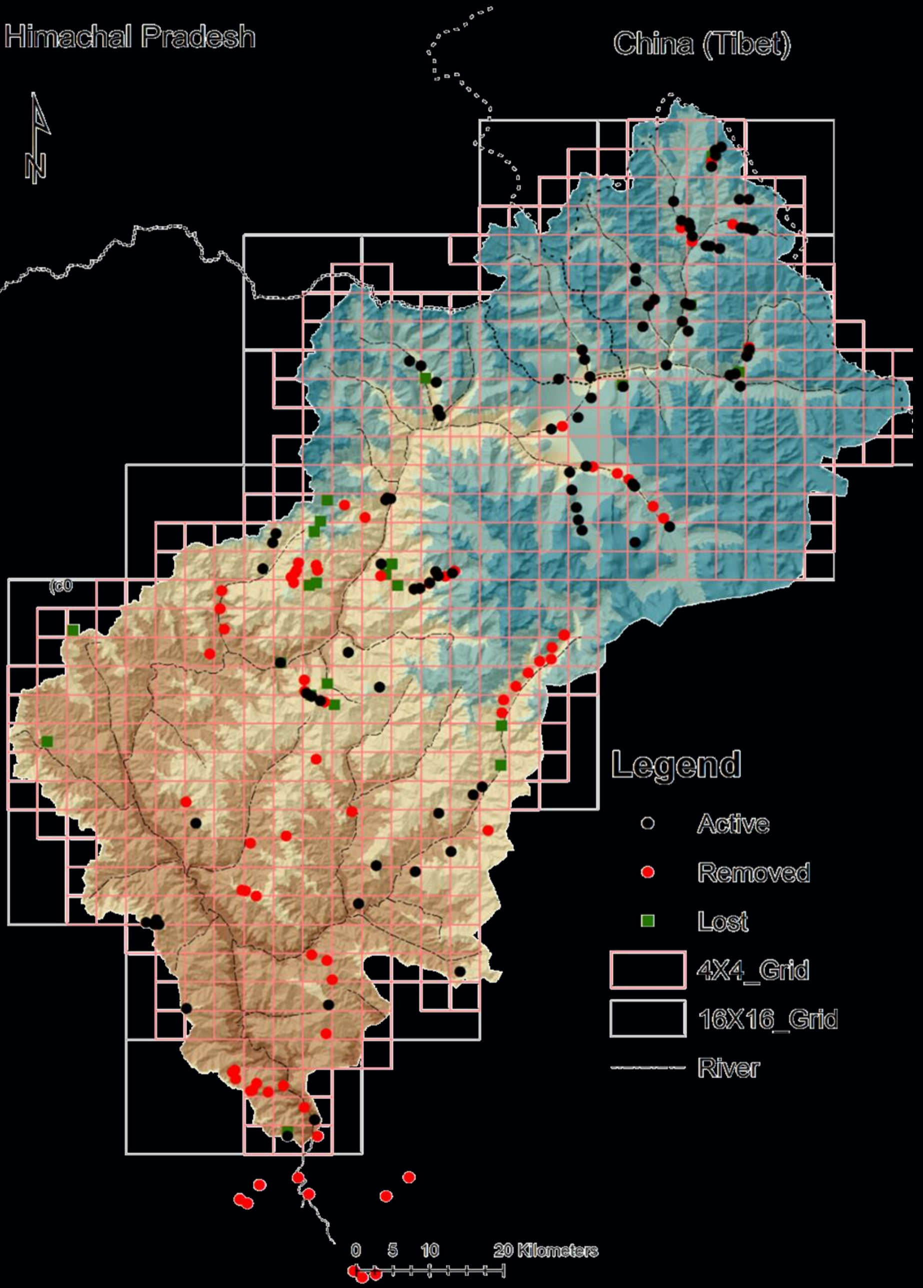
Waterholes

Kills

Stream beds

trails

Designing Camera trap Survey



Grid based: Home range of the target species, depends on the objective

Habitat specific: Equal effort or proportional to the availability

Placement

- Concealed
- Approximately at the height of the animal
- A pair of traps set opposite to each other so that both flanks are captured.

Selecting suitable places for camera traps



- Do a careful preliminary reconnaissance survey to examine the animal signs (tracks, scrapes, scratch, scent, faecal matter etc.) indicating past use
- Take help of knowledge of local forest department staff, naturalists and hunters to locate such sites

Good locations for camera trap placement

Forest road

Animal trail

Stream bed

Water holes

Mounting the camera traps

Depends on camera trap make and ground situations

Analysis

- Picture with dates (with temperature and moon phase and weather in some models)
- Trap sessions and number of animals identified determined
- Number of animals re-photographed determined by date.
- Number of animals calculated using mark-recapture formula

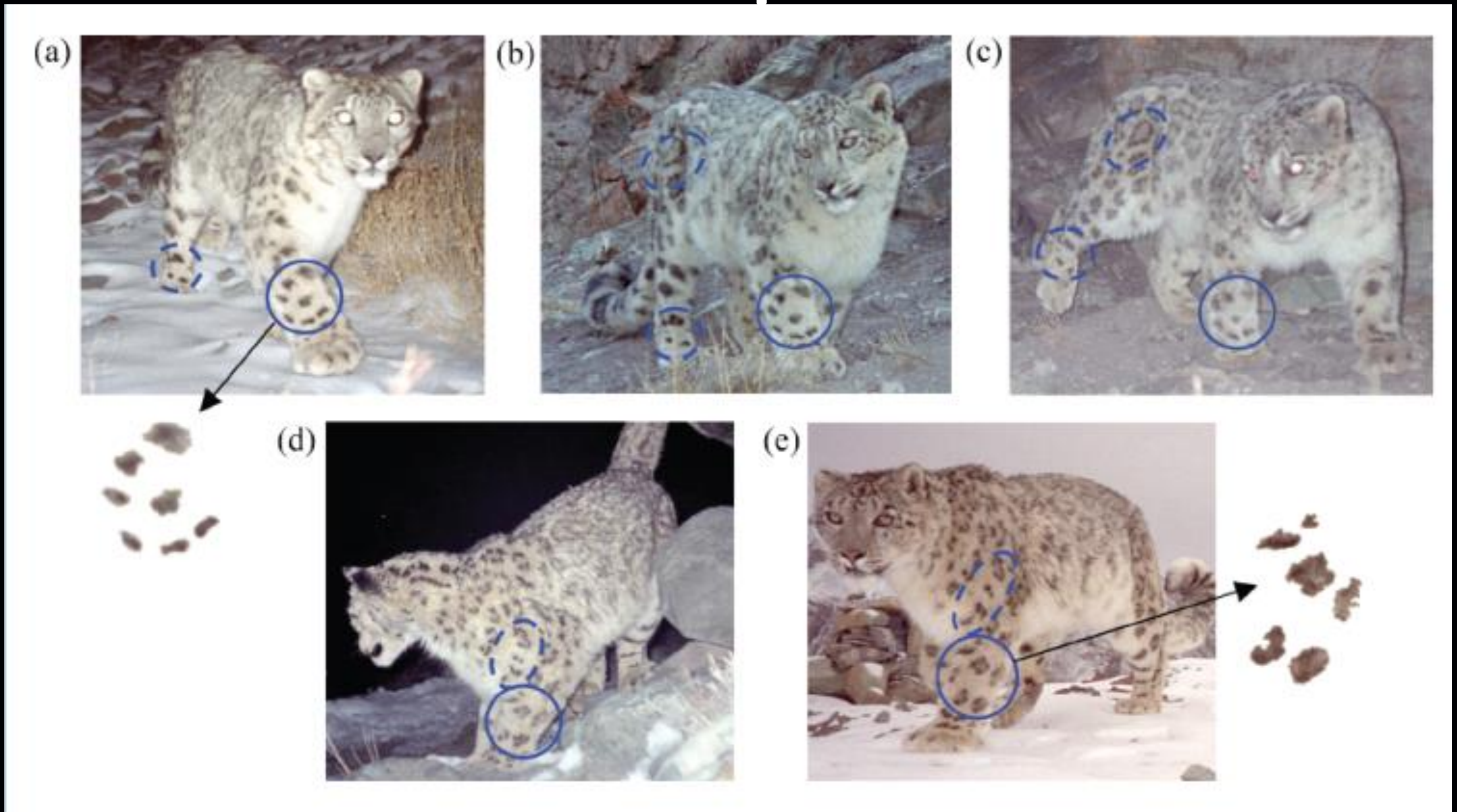
Camera trap photos help in individual identification

Animals with distinct individual coat patterns can be identified by camera trap photos

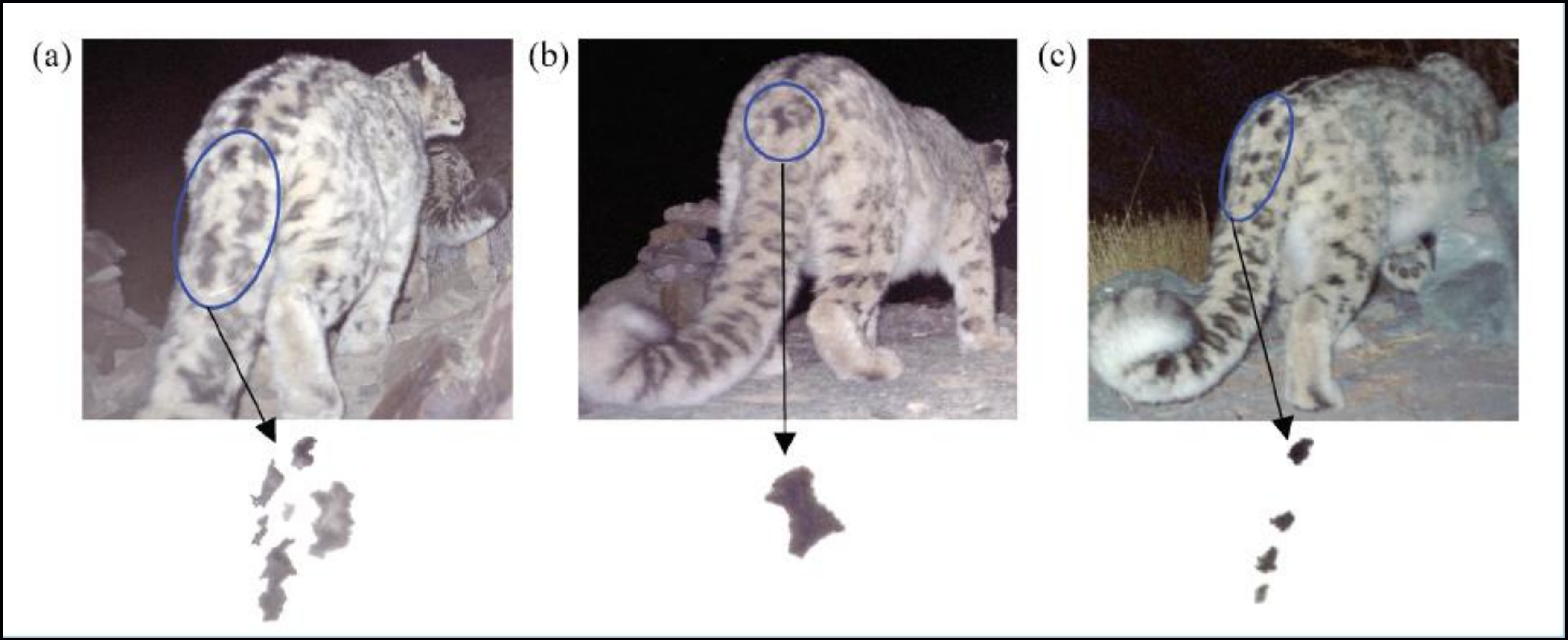
Snow leopard

Individual photographed at three different places

Other individual photographed at two different places

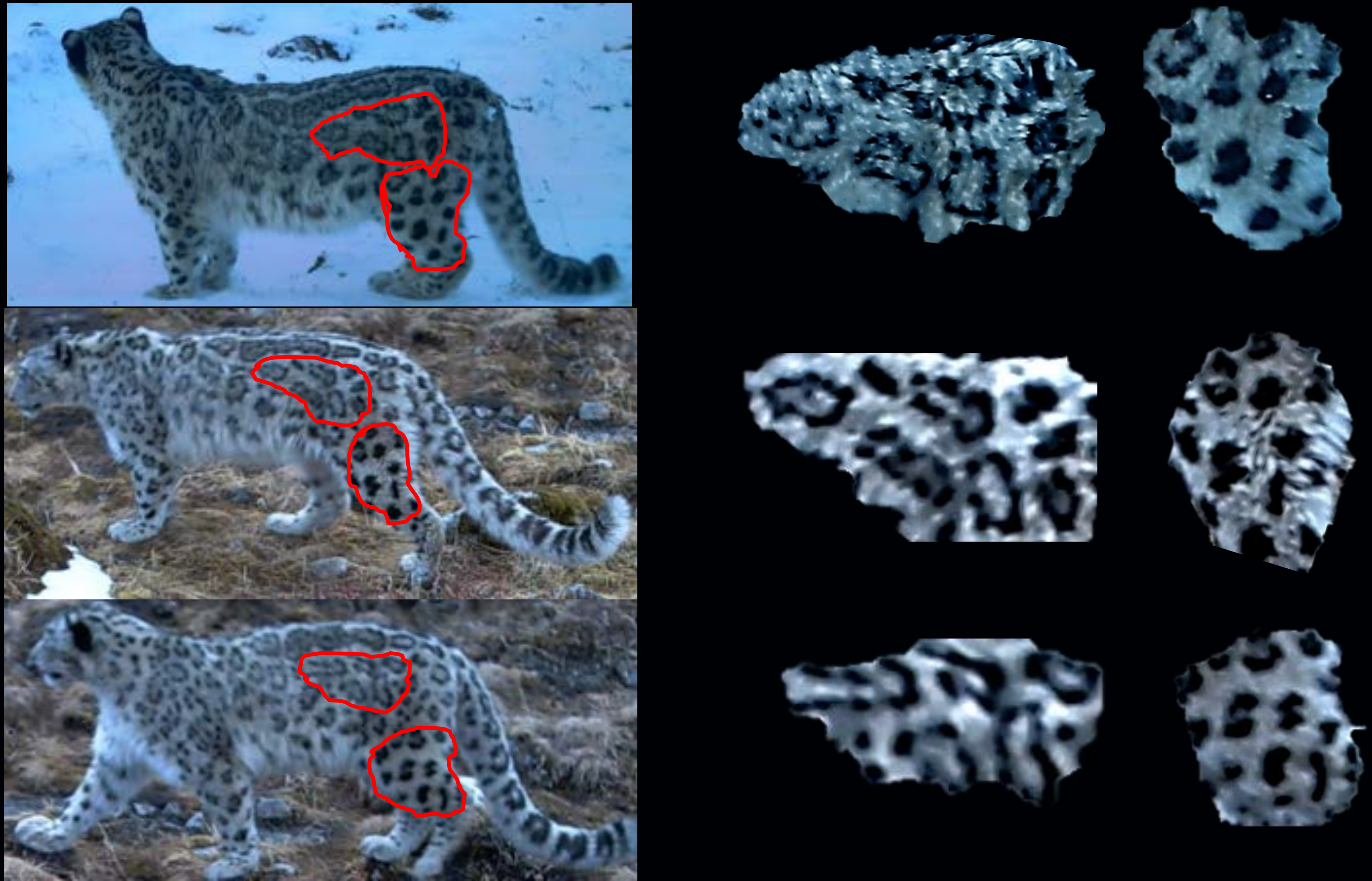


Snow leopard

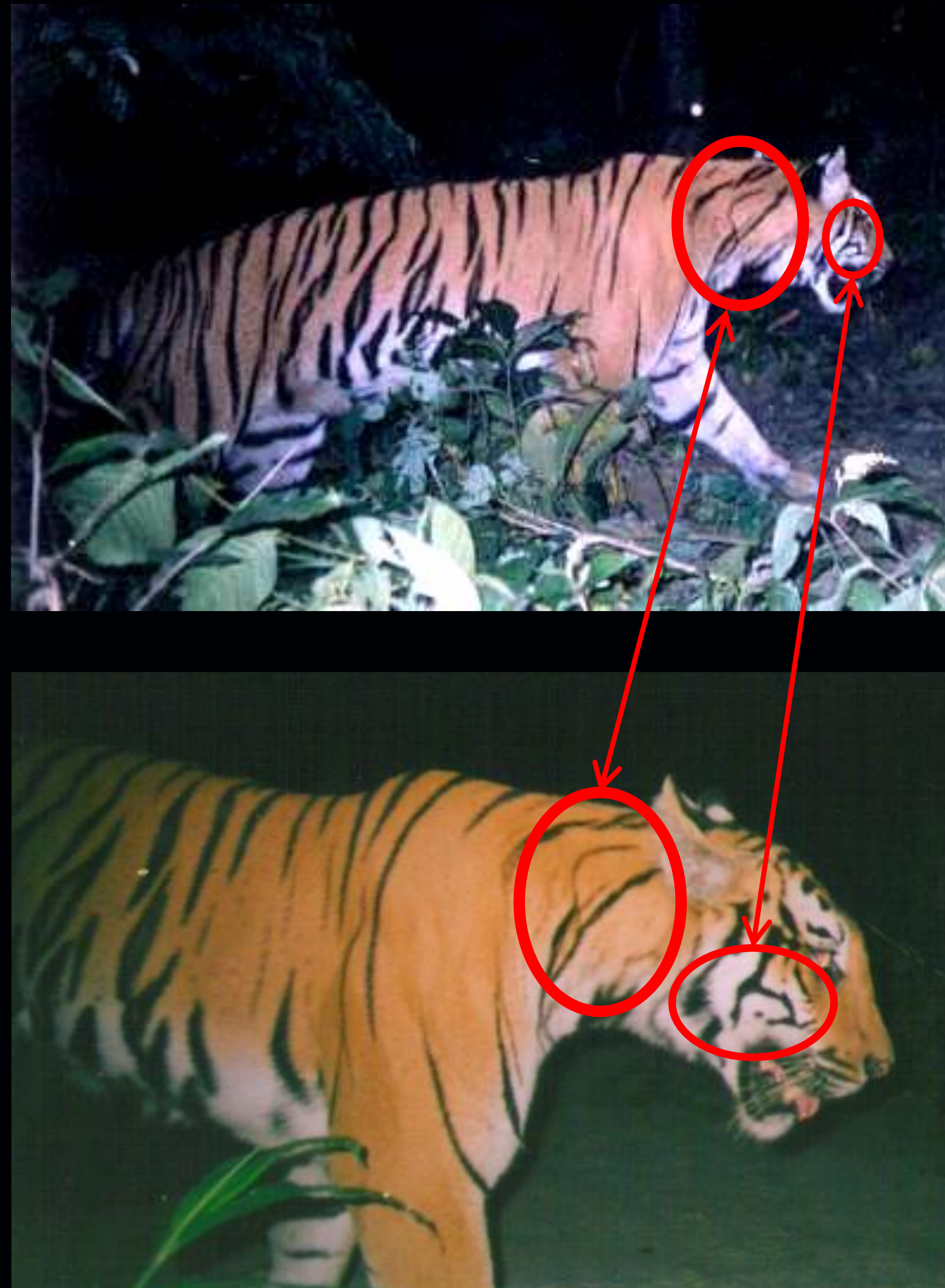


Three different individuals

Individual identification: snow leopard



Same individual



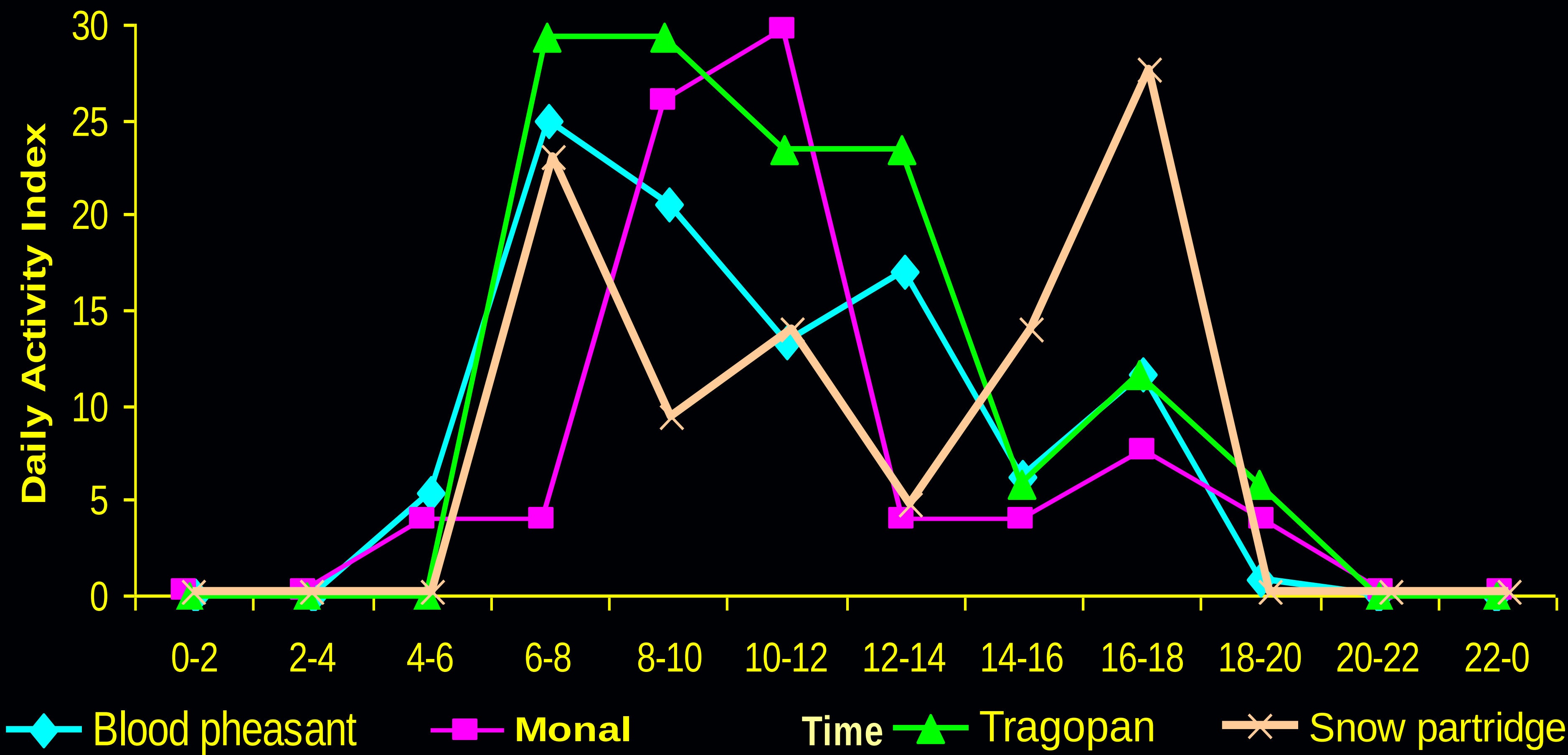
Different individuals

Mortality

Camera trap photo a tiger

Photo of same individual when died

Activity patterns



Chi square value = 104.92, df = 21, p = 0.00

Camera trap and DISTANCE

Methods in Ecology and Evolution

BRITISH ECOLOGICAL SOCIETY

Methods in Ecology and Evolution 2017, **8**, 1558–1565 doi: 10.1111/2041-210X.12790

Distance sampling with camera traps

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Summary

1. Reliable estimates of animal density and abundance are essential for effective wildlife conservation and management. Camera trapping has proven efficient for sampling multiple species, but statistical estimators of density from camera trapping data for species that cannot be individually identified are still in development.

2. We extend point-transect methods for estimating animal density to accommodate data from camera traps, allowing researchers to exploit existing distance sampling theory and software for designing studies and analysing data. We tested it by simulation, and used it to estimate densities of Maxwell's duikers (*Philantomba maxwellii*) in Taï National Park, Côte d'Ivoire.

3. Densities estimated from simulated data were unbiased when we assumed animals were not available for detection during long periods of rest. Estimated duiker densities were higher than recent estimates from line transect surveys, which are believed to underestimate densities of forest ungulates.

4. We expect these methods to provide an effective means to estimate animal density from camera trapping data and to be applicable in a variety of settings.

New Range Records

New Range Records

What can go wrong with camera traps ?

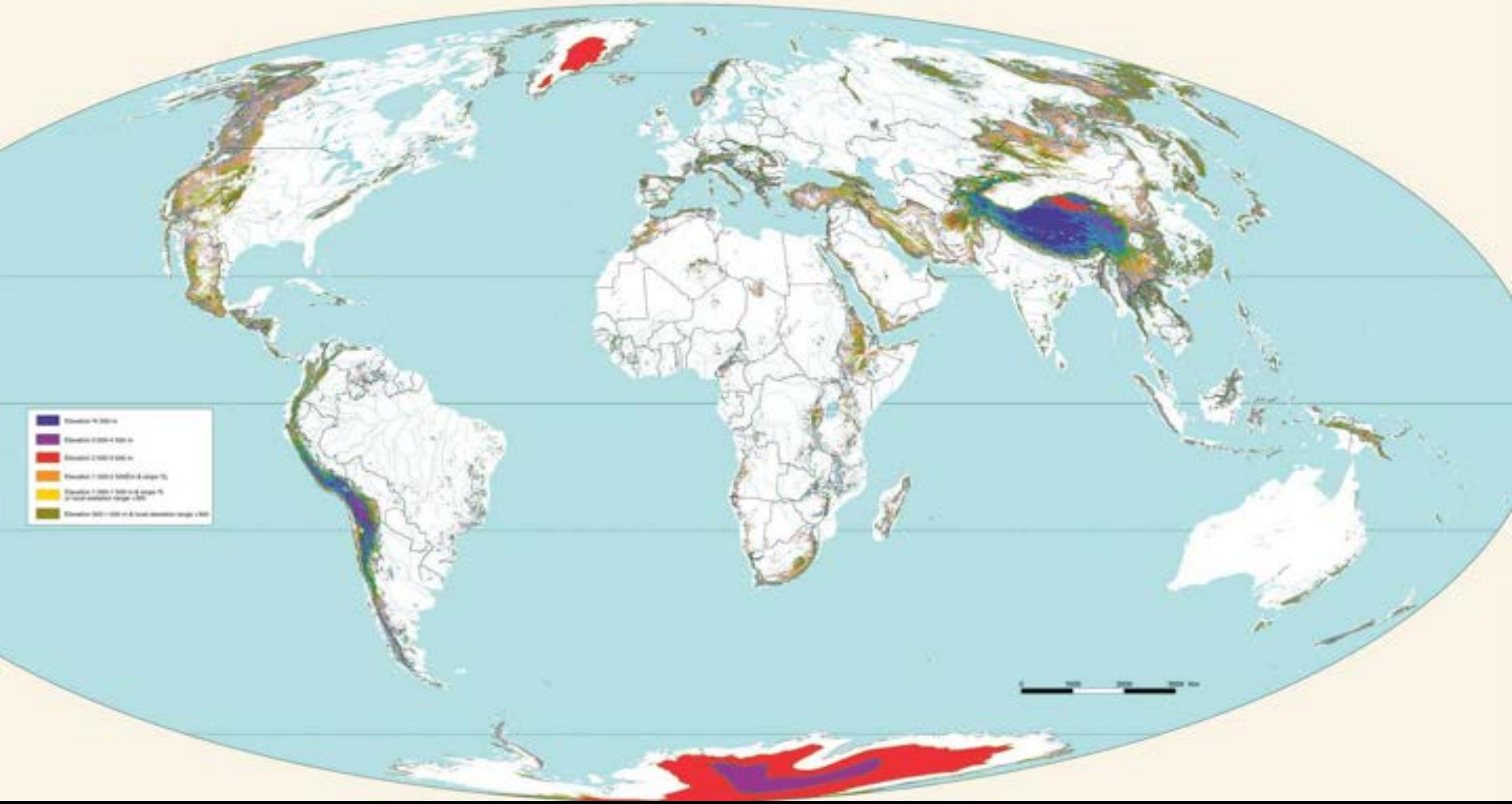
- Since flashlight is used to photograph the animals, they can avoid repeat visit to the trap site
- Extreme weather conditions (heat, humidity and cold) can affect camera functioning
- The batteries can fail
- People or other animals can disrupt the traps, Animal like elephant can trample the unit, poachers and trespassers can damage / steal the camera

Mountain Ungulates: Double Observer Sampling









- Distance sampling has been one of the most popular methods for assessing the density of large herbivores in tropical and temperate forests
- This method is subject to many assumptions that are hard to meet in mountainous landscapes
- Difficulty in obtaining random samples, the potential for unrecorded evasive movement and imprecision in recording perpendicular distances in mountainous terrain
- Most studies of ungulates in mountainous terrain have depended on total counts of the population or used some indirect index of abundance
- Censuses do not allow for an estimation of error to enable statistical comparison of changes in population over time
- Indirect indices of herbivore abundance allow statistical comparison, they do not provide reliable estimates of population number
- An inexpensive but rigorous, reliable and replicable method of sampling ungulate abundance in mountainous terrain, which can allow for some measure of sampling error, is much needed

The Double Observer Technique

- The double-observer technique was originally developed to estimate the detection probabilities of aerial surveys of various taxonomic groups

- Based on the principles of mark-recapture theory. Involves two observers searching for and counting animals simultaneously, while ensuring that they do not cue each other. Capitalizes on the fact that theory allows for population size to be estimated based on just two surveys

- Forsyth and Hickling (1997) applied the double-observer approach for estimating the abundance of Himalayan tahr (*Hemitragus jemlahicus*) in New Zealand.

Assumptions

- Each animal group detected can be individually identified
- The population being surveyed should be closed during the period of the two surveys
- The surveys generate simple random samples of all the groups in the population

Each animal group detected can be individually identified

Post-survey discussion between the two observers to ascertain the unique identity of each herd sighted during each pair of surveys using information on group size, age–sex classification of the groups and location and time of sighting each group

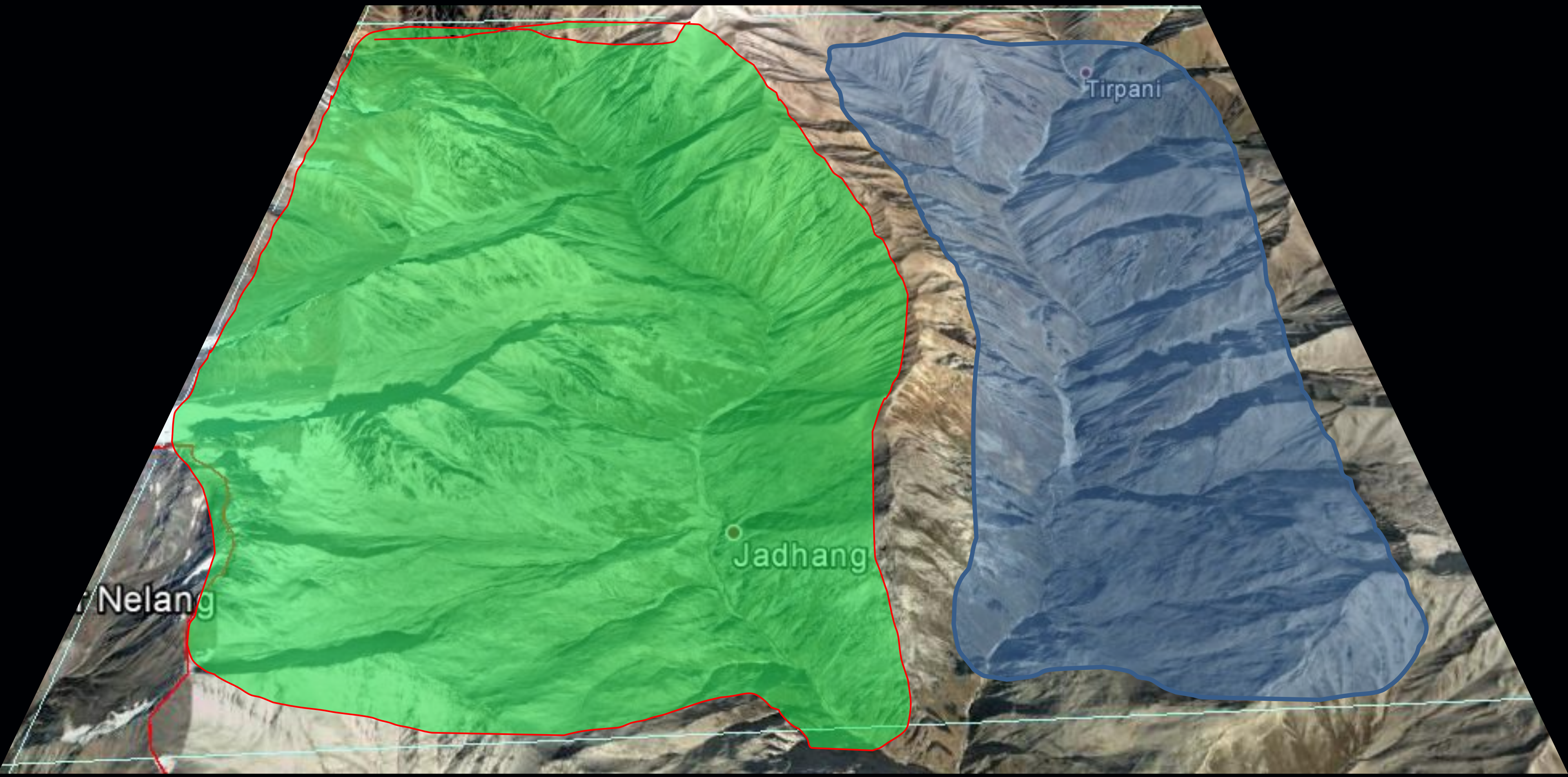
The population being surveyed should be closed during the period of the two surveys

1. Study areas should be delineated by high mountain ridges (approx. 5,700 m)

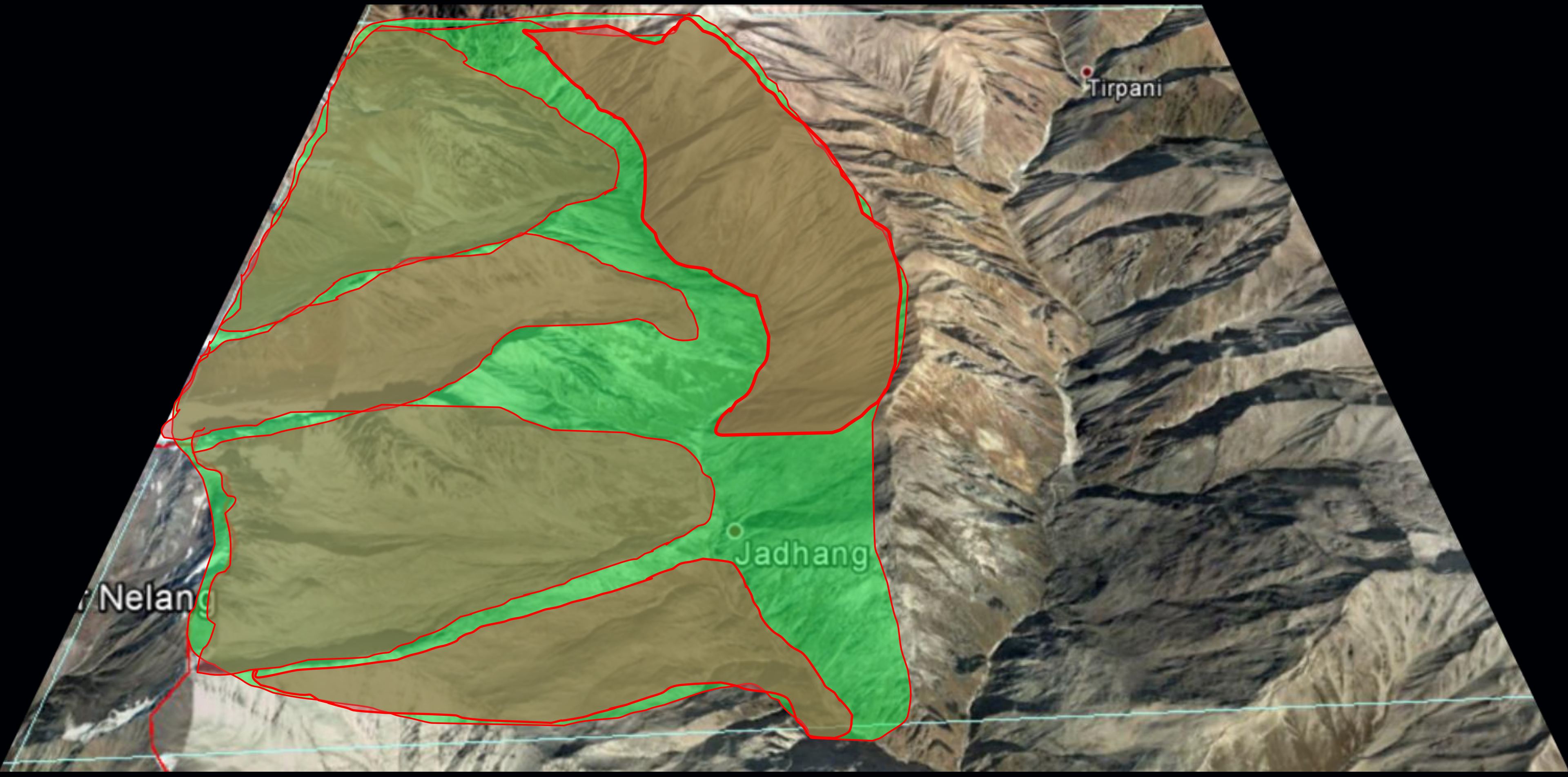
2. Each study area can be further divided into survey sites of 20–30 km^2

3. Each of these smaller areas should be surveyed separately to ensure that no gaps larger than daily movement of the species is left out of the survey

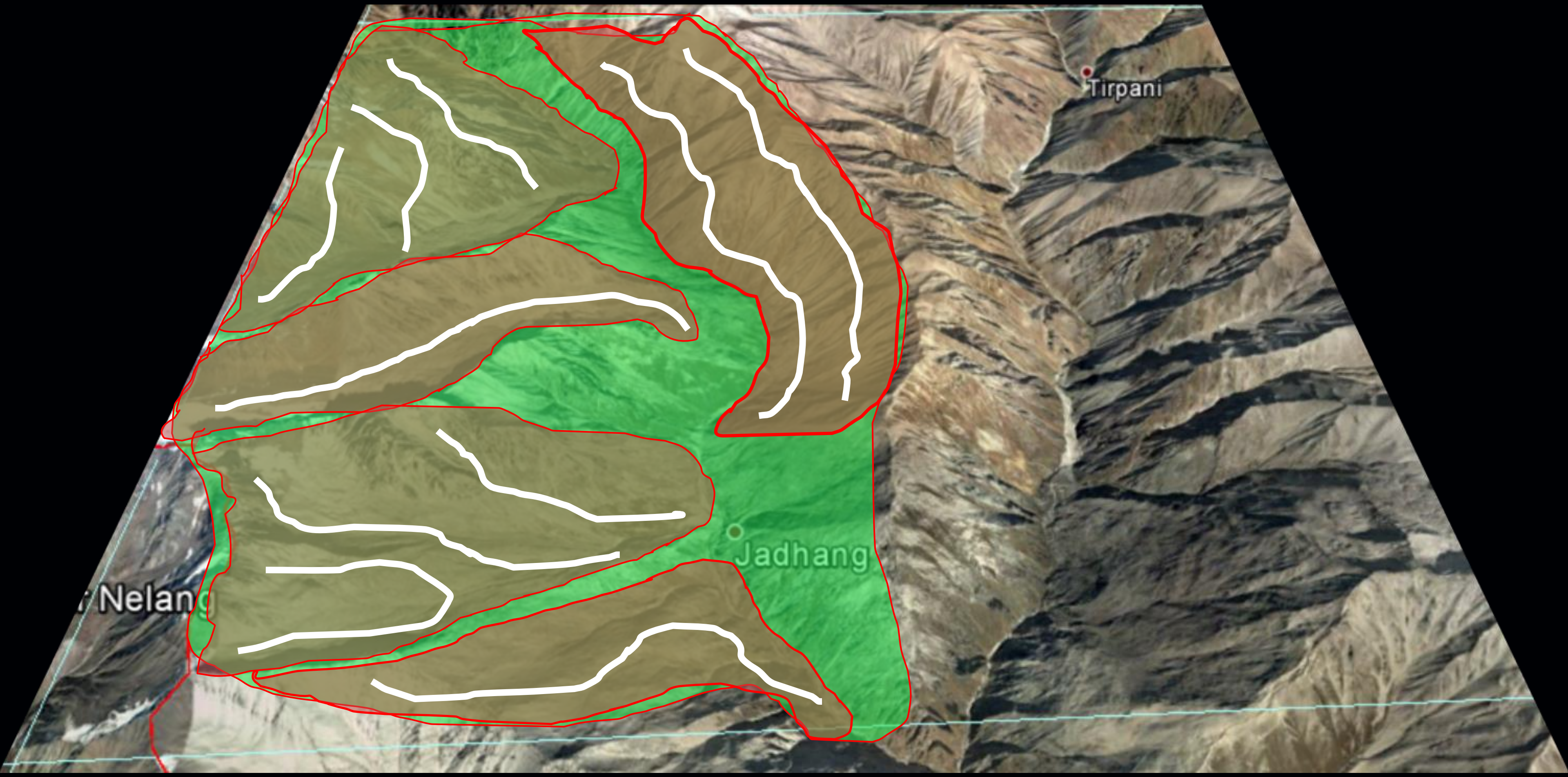
4. Surveys should be conducted within a few hours of each other to ensure that groups did not split or merge between the two surveys, leading to a change in the number of groups present.



Divide the study area into 100 km^2 blocks



Divide one 100 km^2 blocks into smaller blocks of 25 km^2



Predetermined trails in each block will be surveyed by two observers in a single day

Both the surveys can be conducted simultaneously or spaced

$\mathbf{p_{sl}}$ = probability of observer 's' detecting the 'l_{th}' group ('group-specific detection probability').

In simultaneous surveys, even though the observers do not cue each other, distance of the animal group to both of the observers and the activity of the animals is similar for both sets of observers. Thus, the probability of any group being detected by each of the set of observers is similar

$$\mathbf{p_{s1l} \approx p_{s2l}}$$

s1 and s2 are the two observers; the group-specific detection probability is similar for both observers

This can lead to overestimation of 'observer-specific detection probability' and thus underestimation of the number of groups.

What to do?

Walk along predetermined trails and scan using binoculars

The second observer started the survey c. 10-15 minutes or 1 hr after the first.

This duration was chosen to balance potential overestimation as a result of evasive movement of ungulates after the first survey and potential underestimation if the time between the two surveys was too short, resulting in a lack of independence between the two surveys

If the first observer came within the sight of the second, the second observer waited to increase the distance between the two. The protocol precluded any unintentional visual cues; for example, prolonged interest in a particular direction by one observer could influence the other observer's survey.

What to do?

The observers record ungulate group size, age × sex categorization, distance to group, the name of the pasture where the group was encountered, and any other matters that could help identify the observed groups

At the end of the survey the observers discussed and identified the groups seen by both observers and those seen by only one, based on group size and composition, location and any other notes.

Density will be estimated by dividing the abundance estimate by the area surveyed

Table 1 Results of spaced double-observer surveys of ibex *Capra ibex* and argali *Ovis ammon* in the Tost Mountains, South Gobi, Mongolia (Fig. 1), in 2012 and 2013.

	2012		2013	
Variable	Ibex	Argali	Ibex	Argali
No. of groups recorded by both surveyors	35	3	37	5
No. of groups recorded by first surveyor only	61	6	71	13
No. of groups recorded by second surveyor only	28	2	35	4
Estimated no. of groups	171.44	14	208.39	30.67
Variance in estimated no. of groups	221.12	9	351.11	39.29
Mean group size	5.24	7.73	5.04	7.5
Variance in mean group size	0.05	2.24	0.01	0.98
Estimated population	899	108	1,051	230
Variance in estimated population	7514.89	995.36	9559.01	3085.62
± 95% confidence interval	727–1,071	47–169	857–1,245	120–340
Total area (km^2)	1,400	1,400	1,400	1,400
Density	0.64	0.08	0.75	0.16
Distance walked per survey (km)	720	720	720	720
Estimated detection probability for first survey	0.56	0.6	0.51	0.55
Estimated detection probability for second survey	0.36	0.33	0.34	0.28

Other Field Techniques

Genetics

Again based on capture – recapture framework

Non-invasive and most logistically feasible

Feasibility limited by only bad sampling design or bad preservation

Field Techniques – Others

Dietary profiling

Direct observation and scat analysis

Ranging and habitat use

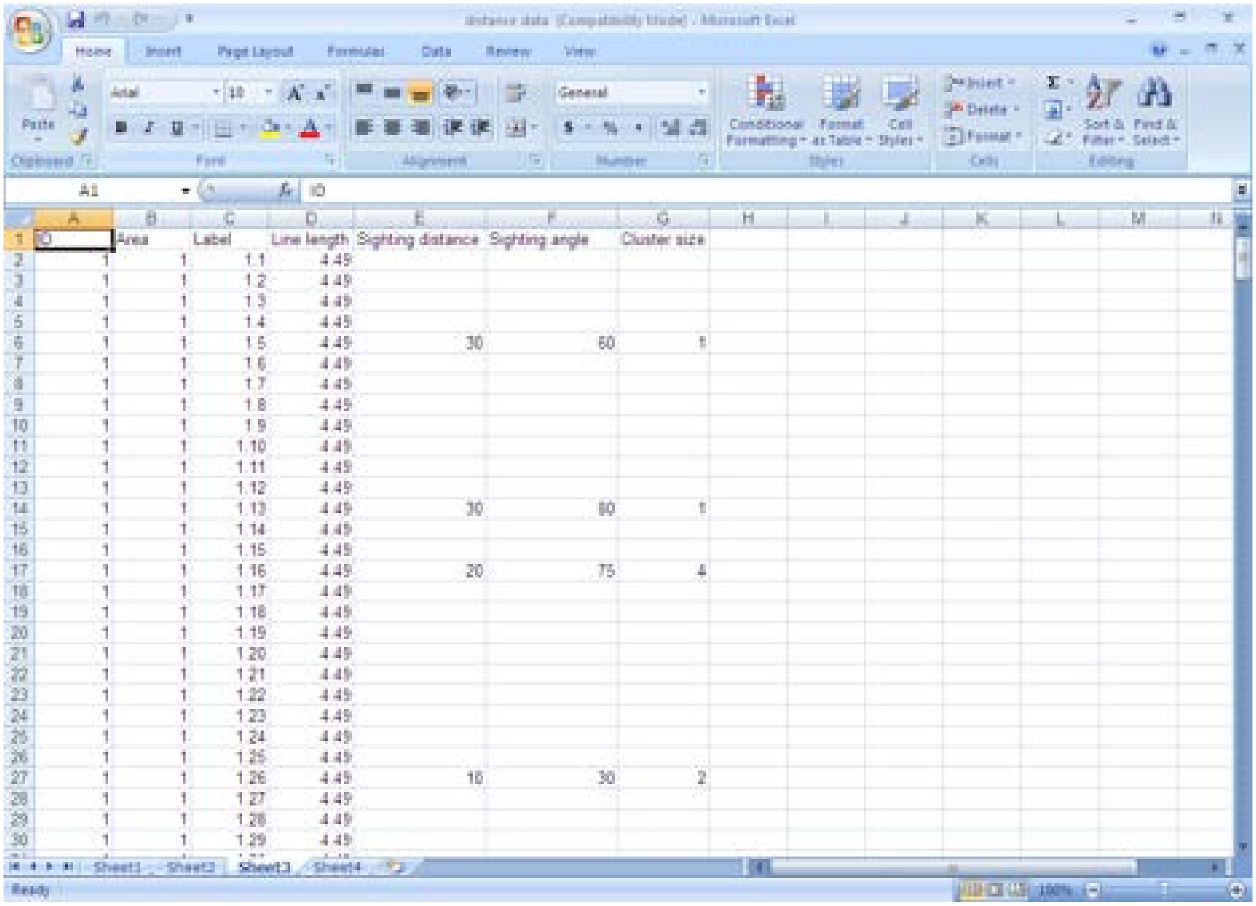
Radio telemetry and GIS tools

Behavioural observations

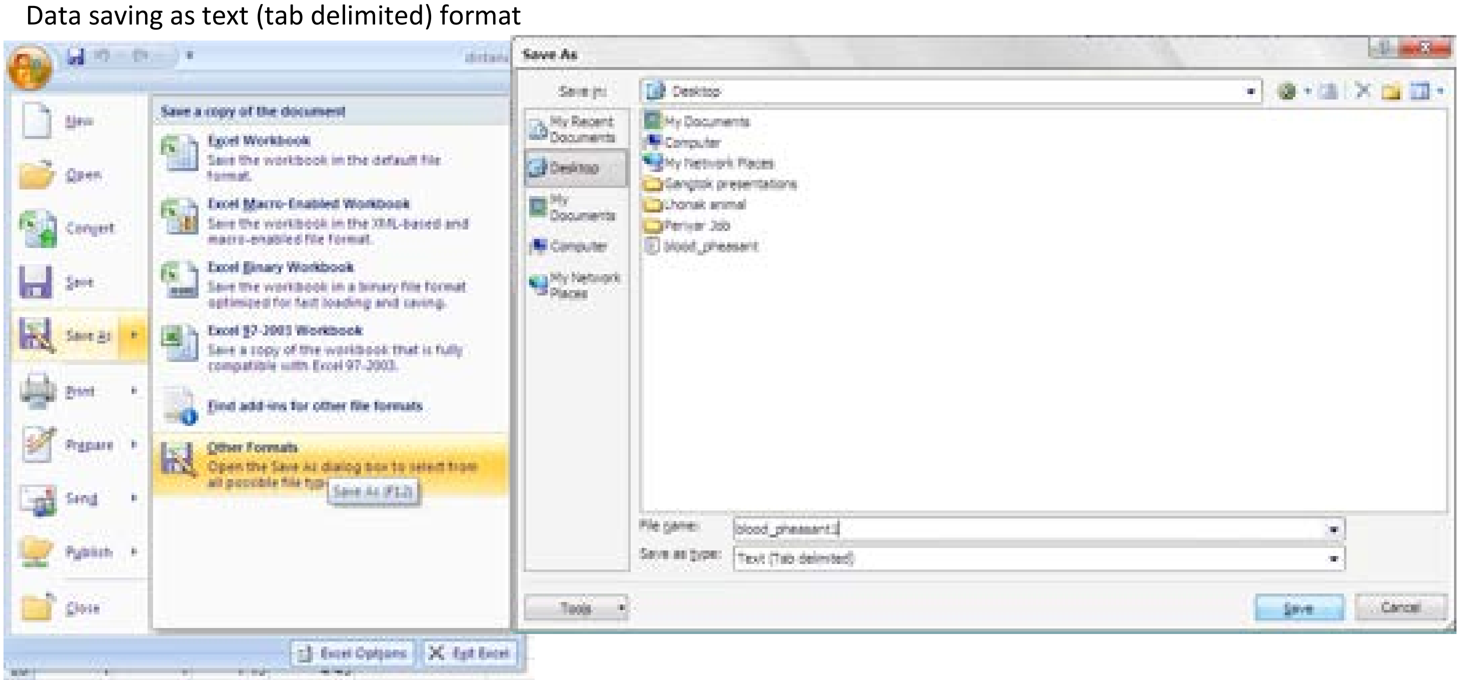
Direct observations only

Distance Analysis

Data Entry in Excel

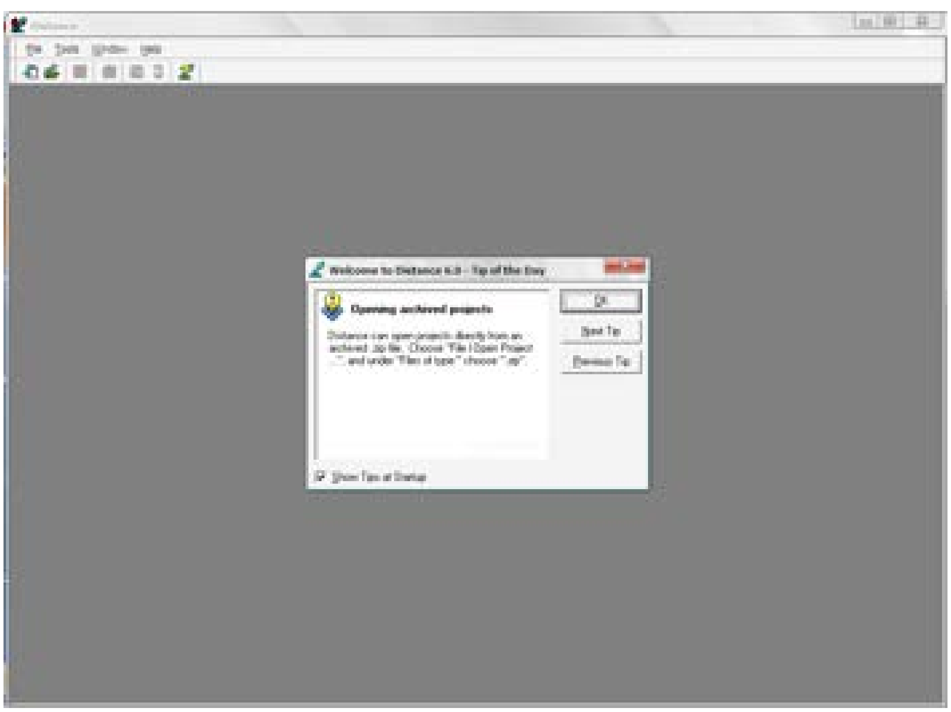


Data saving as text (tab delimited) format

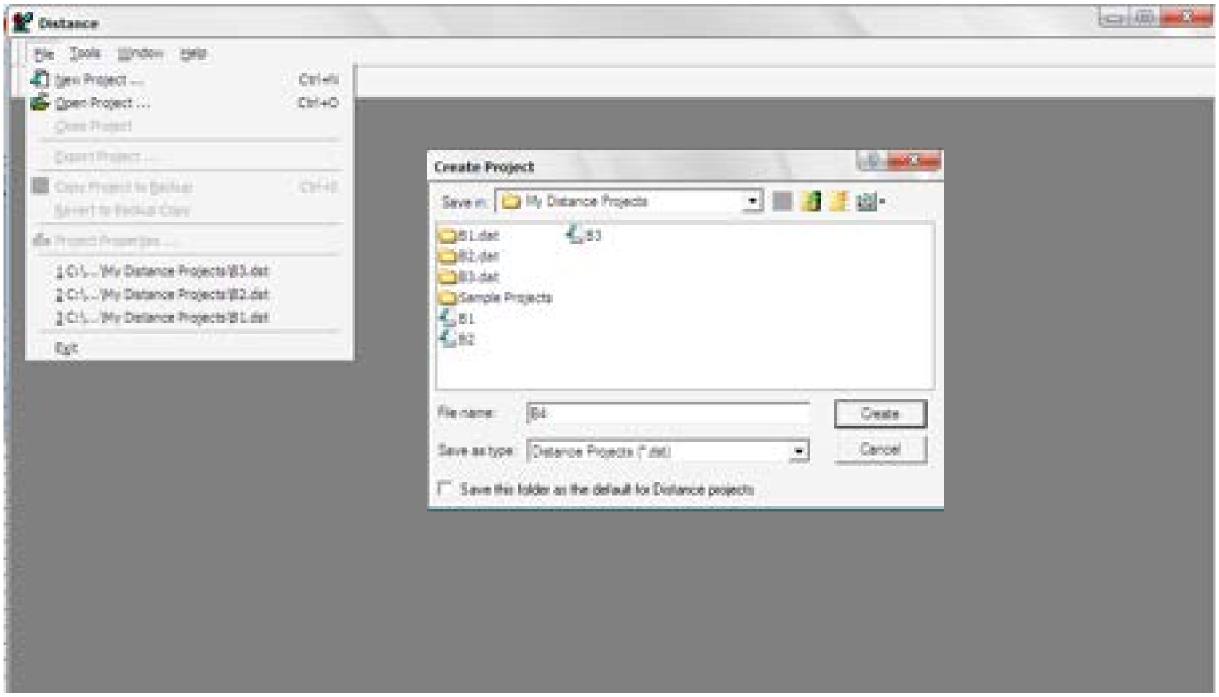


Opening Distance

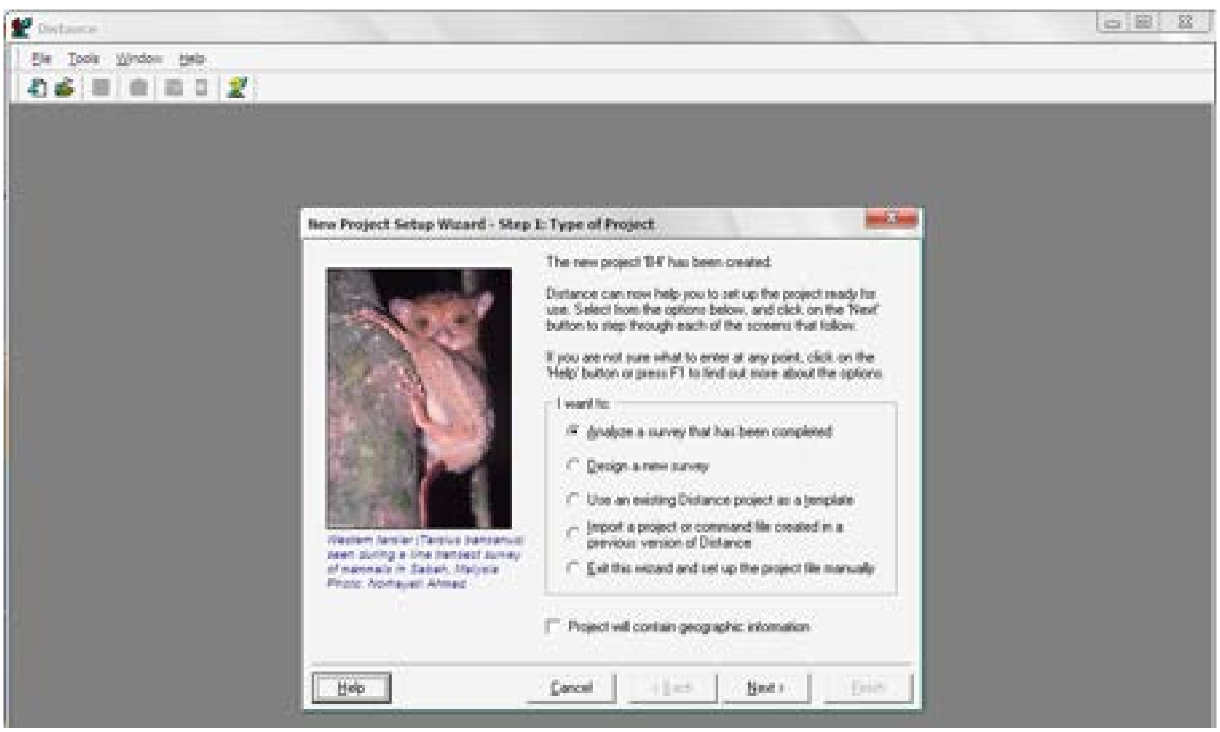
Start-up tip



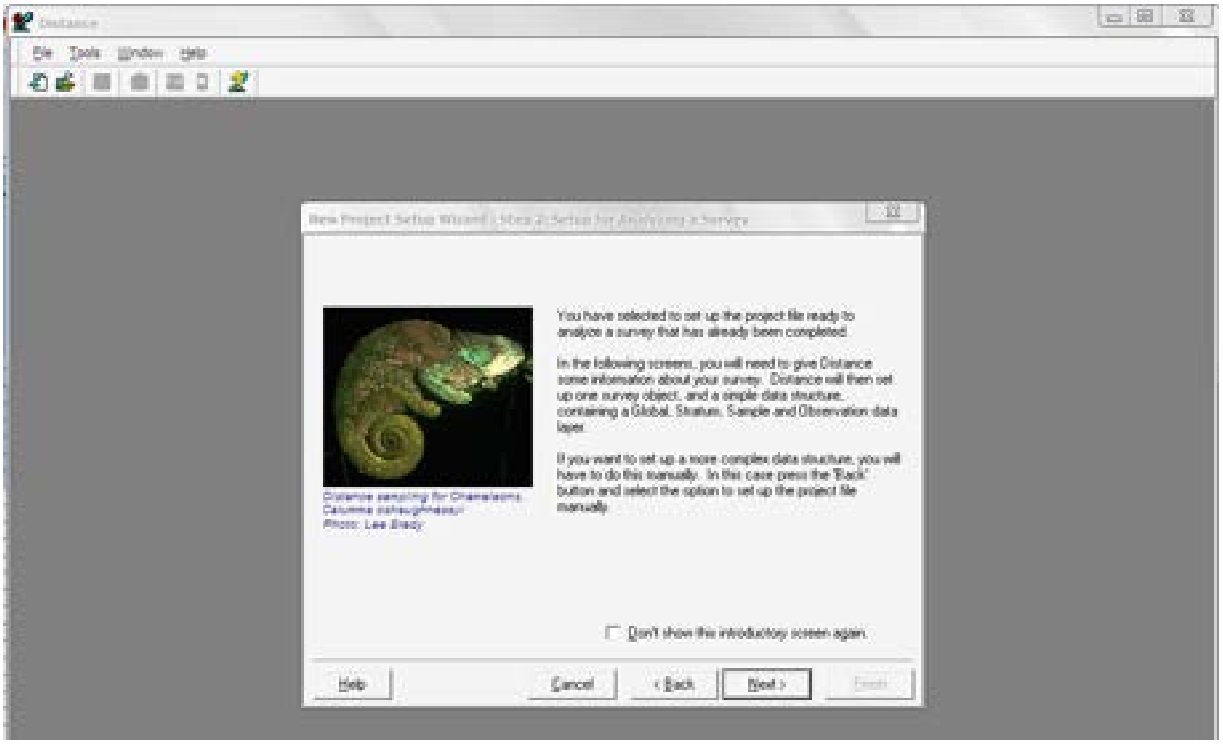
Opening a new project:-- File>New Project> File name> Create



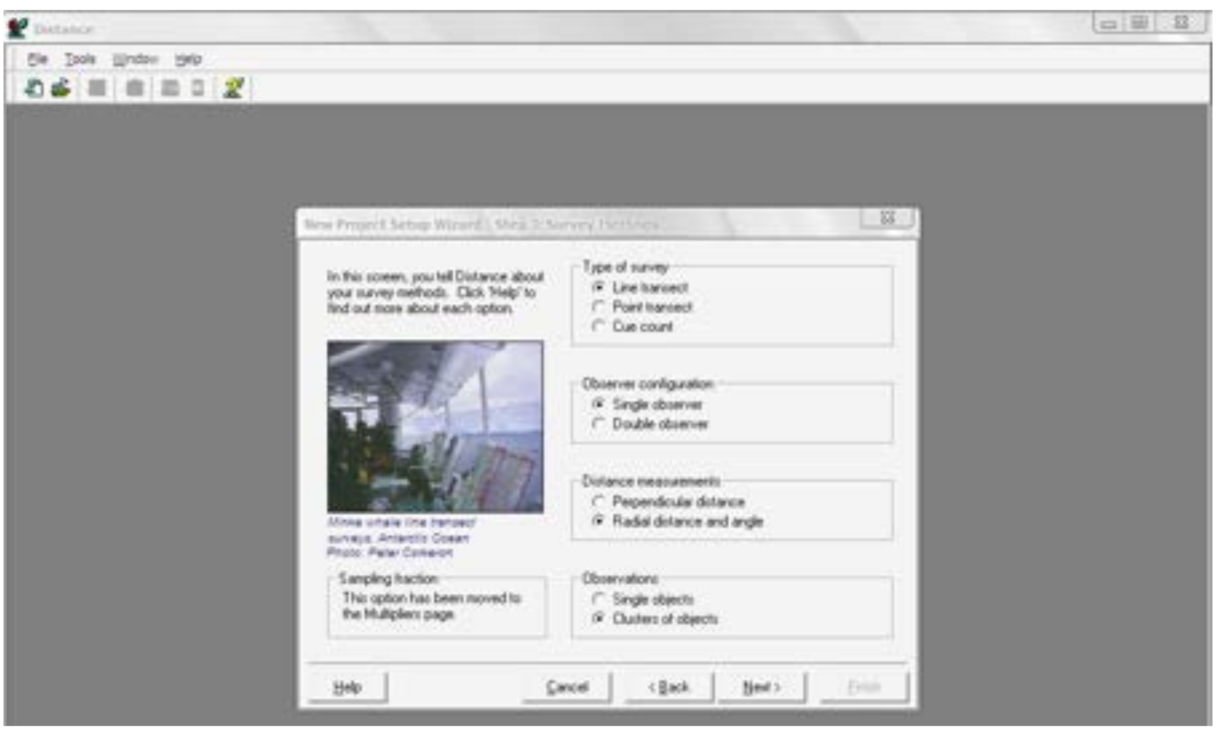
Step 1: Type of project—select Analyze a survey that has been completed



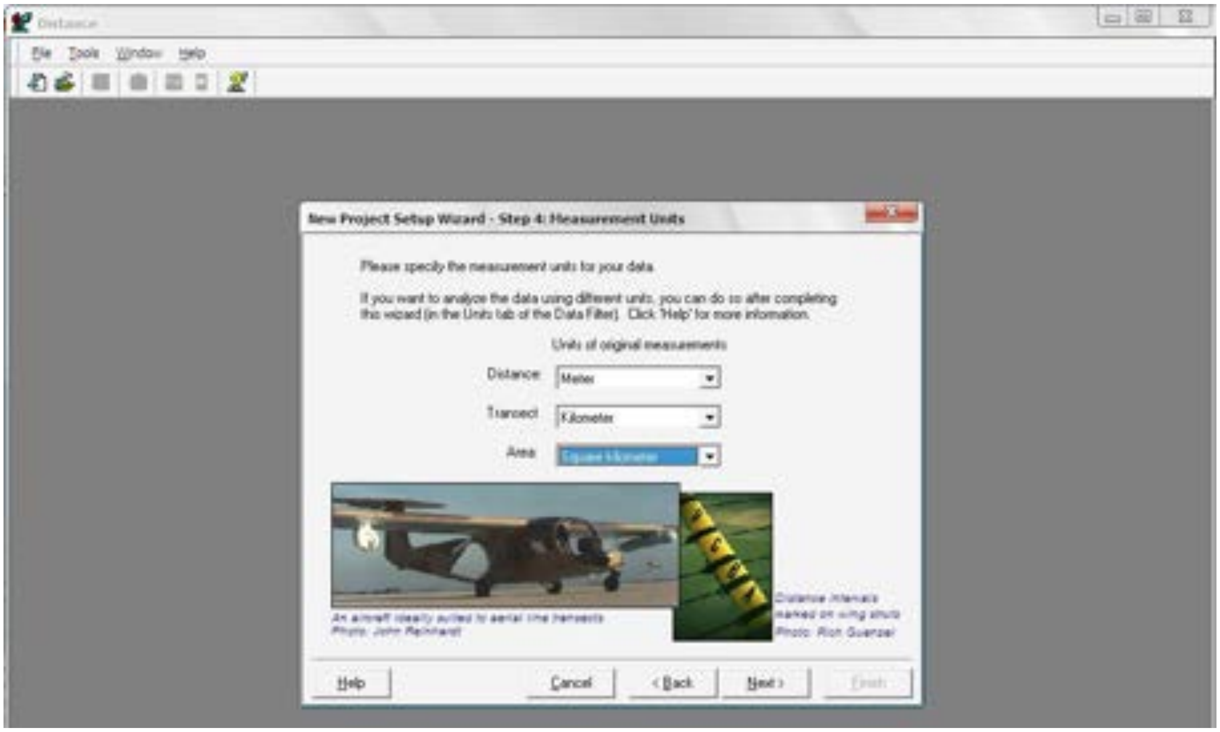
Step 2 Click next after reading



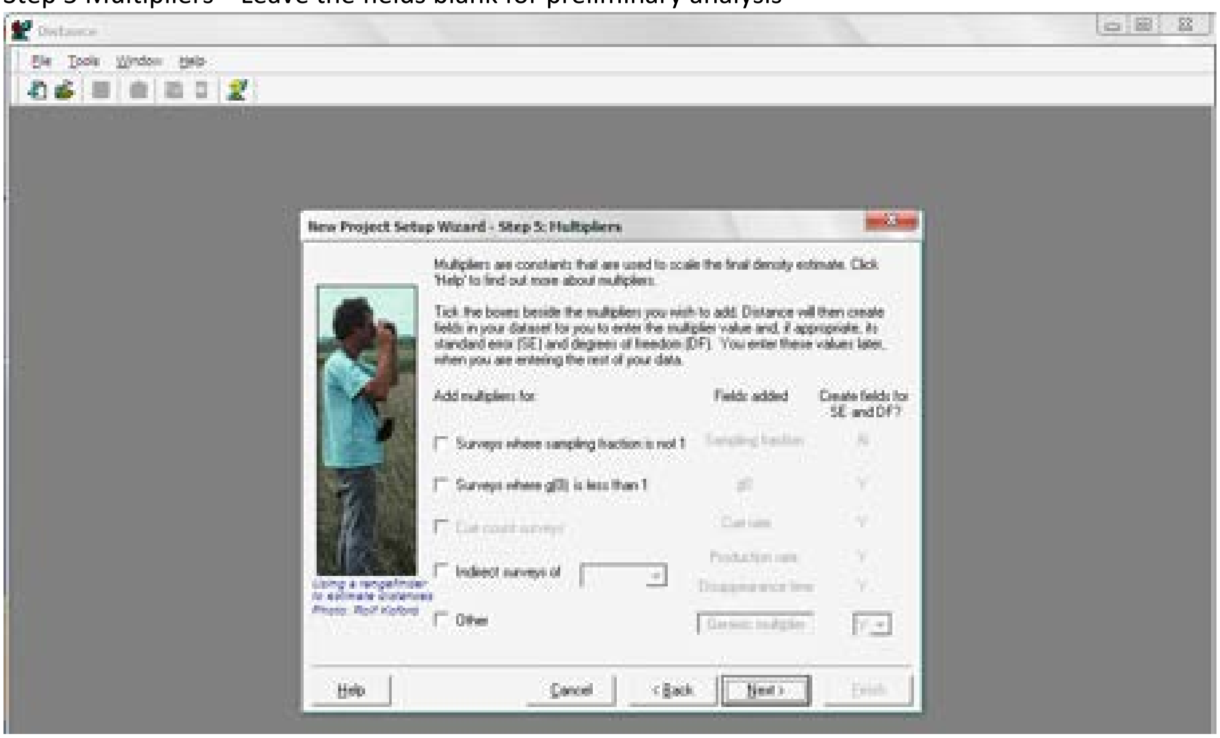
Step 3 Select survey methods accordingly: Line transect or point transect, Single observer or double observer, perpendicular distance or radial distance or angle, single object or cluster



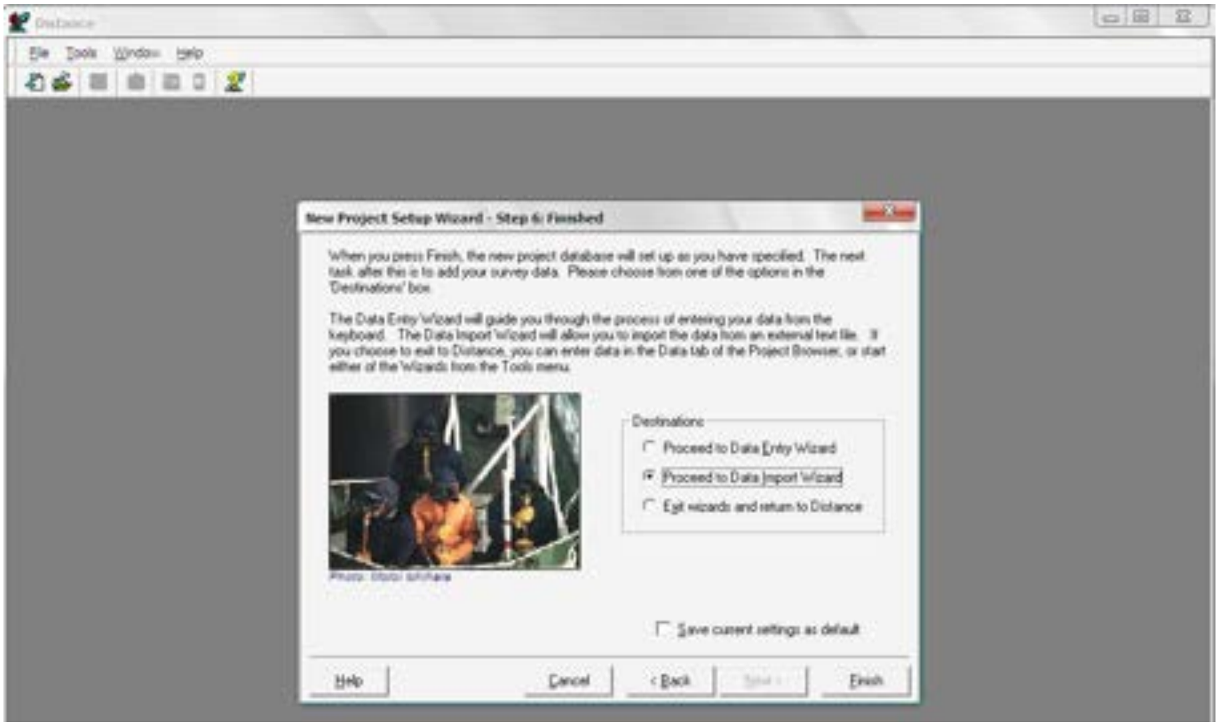
Step 4: Measurement units: Distance – Meter, Transect—Kilometer, Area—Square Kilometer



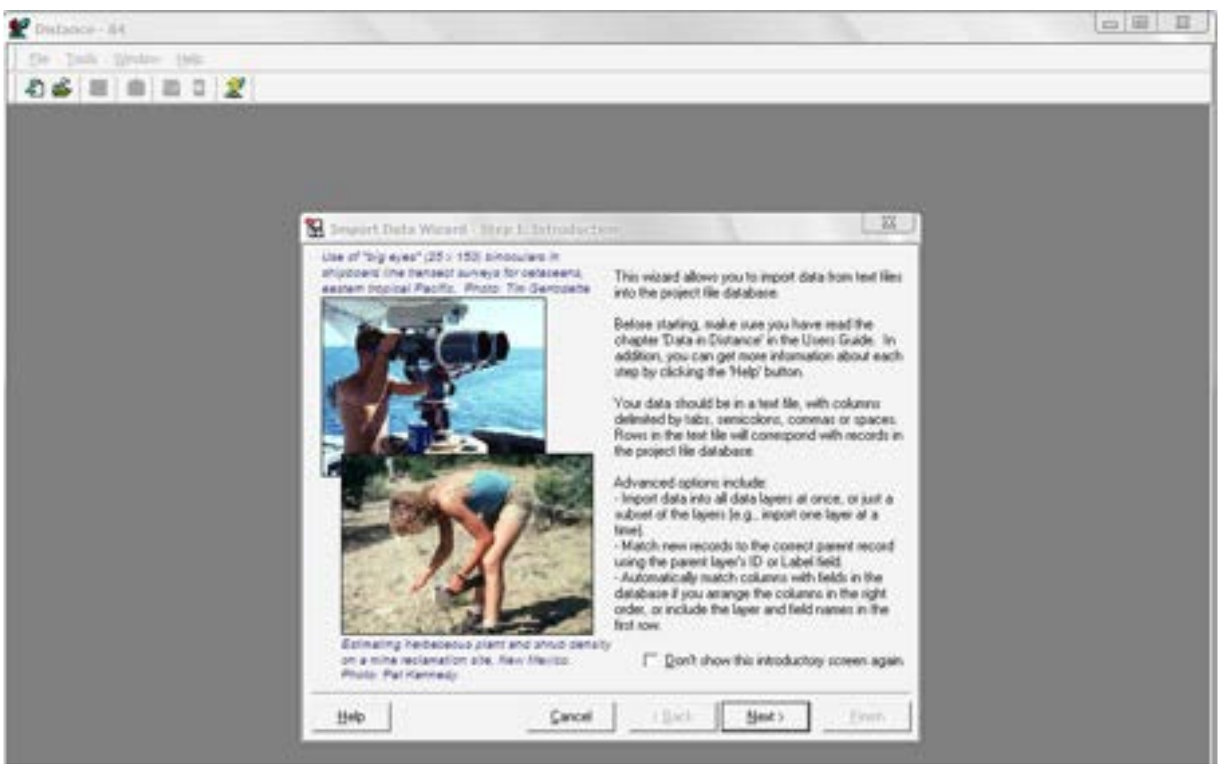
Step 5 Multipliers—Leave the fields blank for preliminary analysis



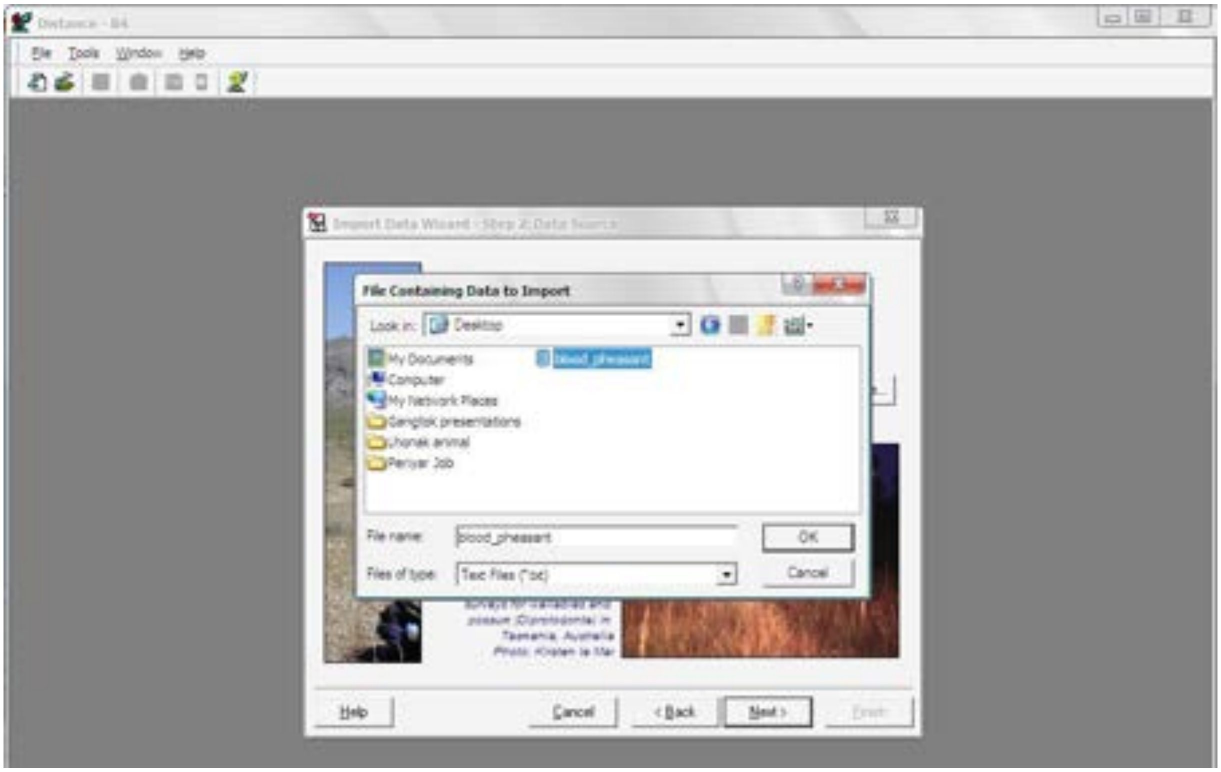
Step 6 Finish—Select “Proceed to data import wizard”, and click “Finish”



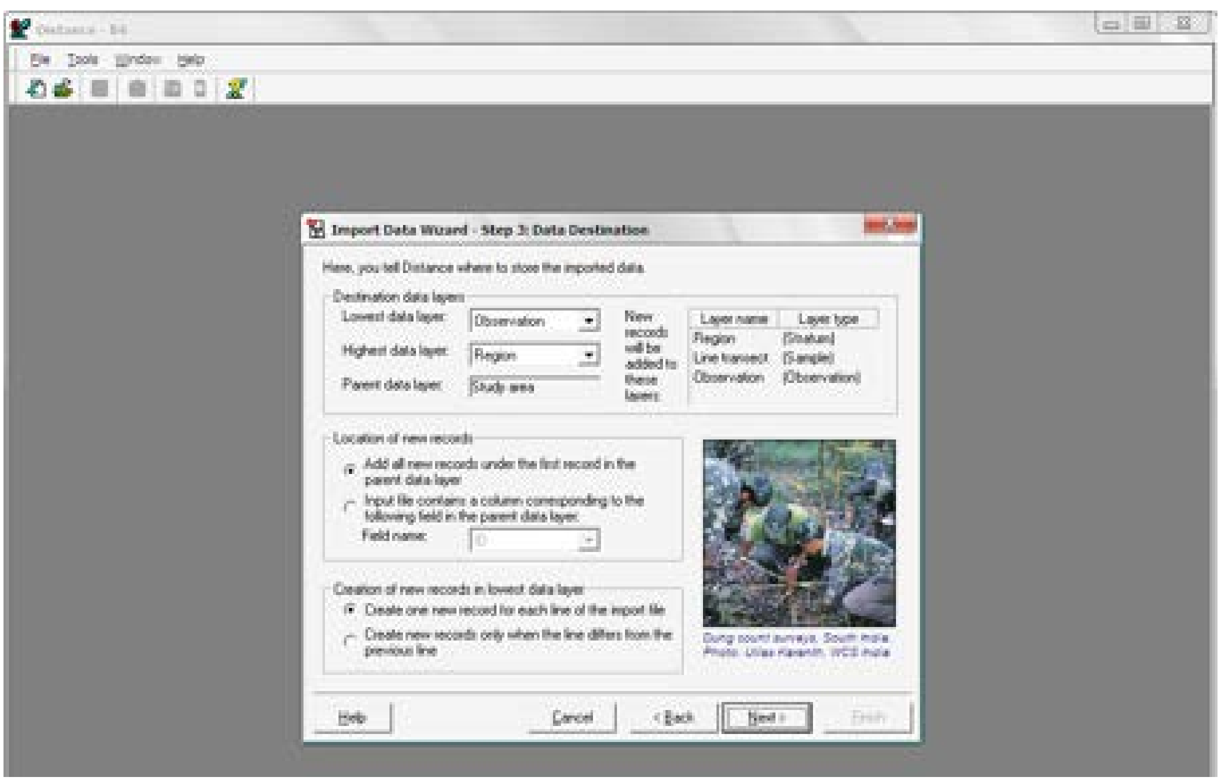
Importing data: Step 1—Introduction—read and click next



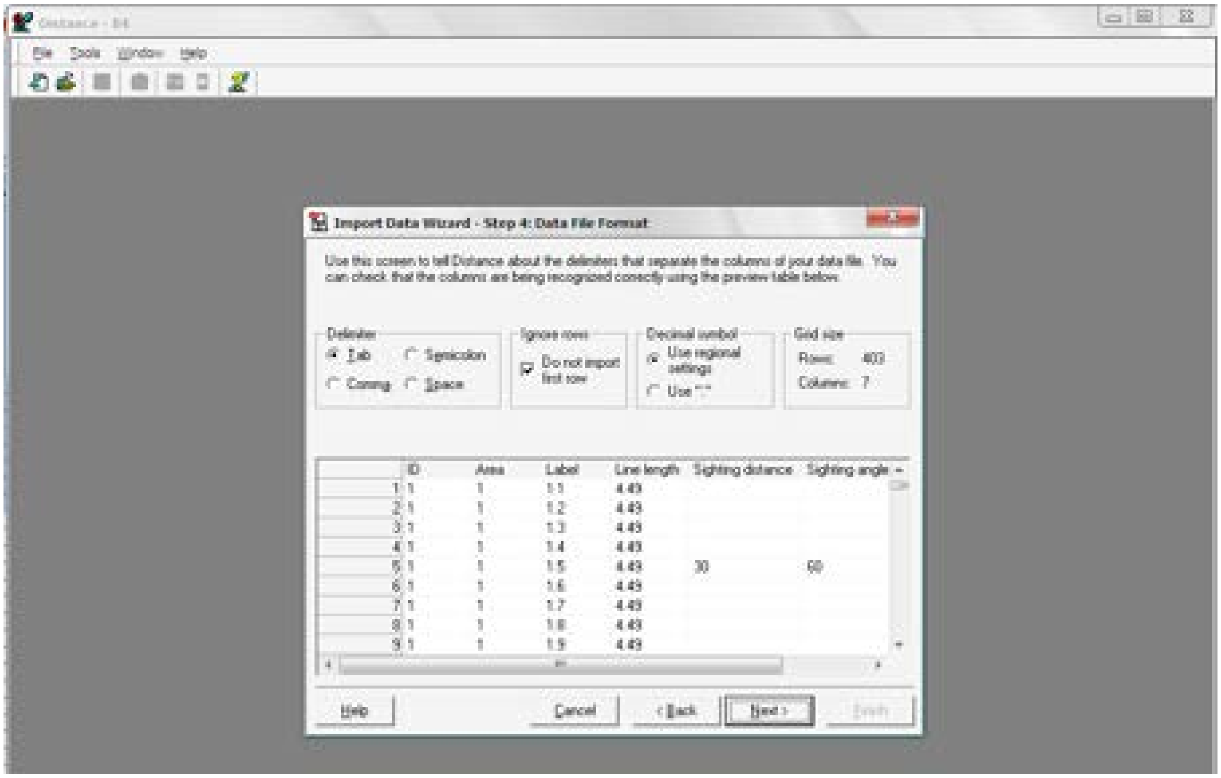
Step 2:Data import: Select the file from it's location such as desktop>Blood_pheasant.txt>ok



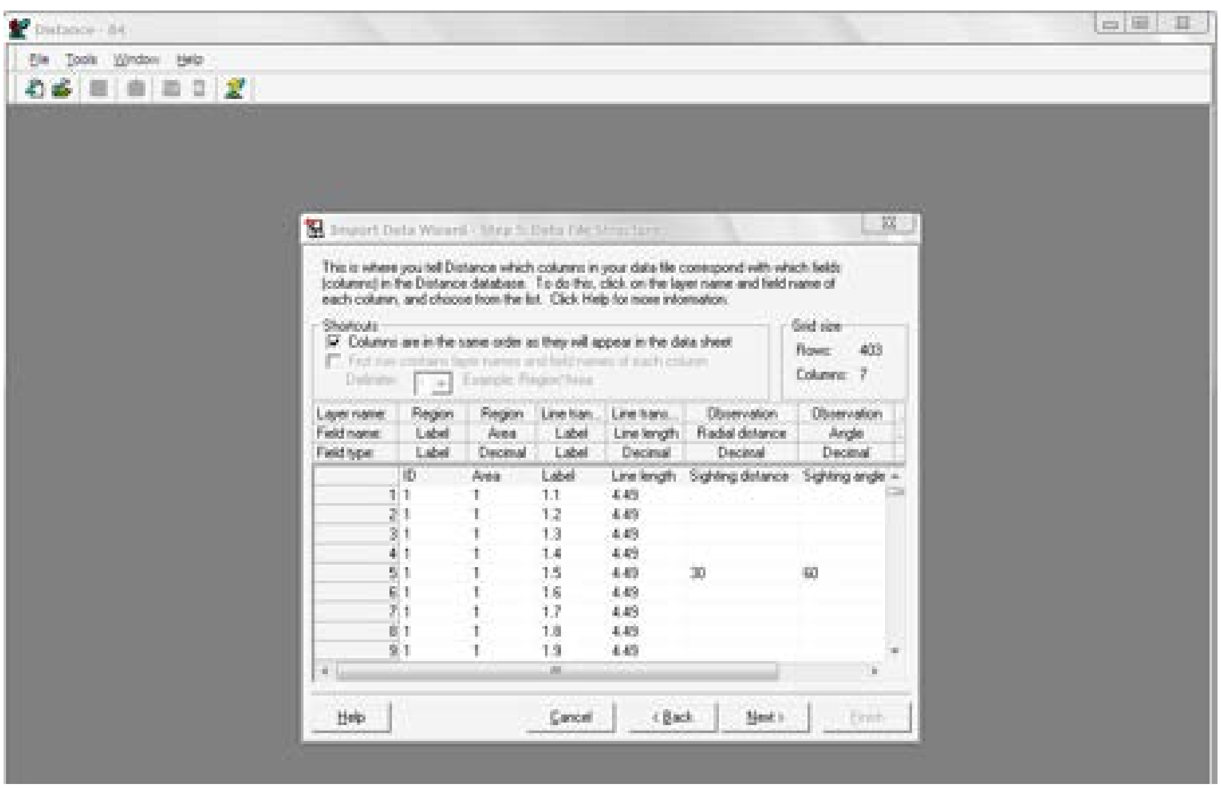
Step 3 Data destination—Lowest data layer—Observation, Highest data layer—Region> Click next



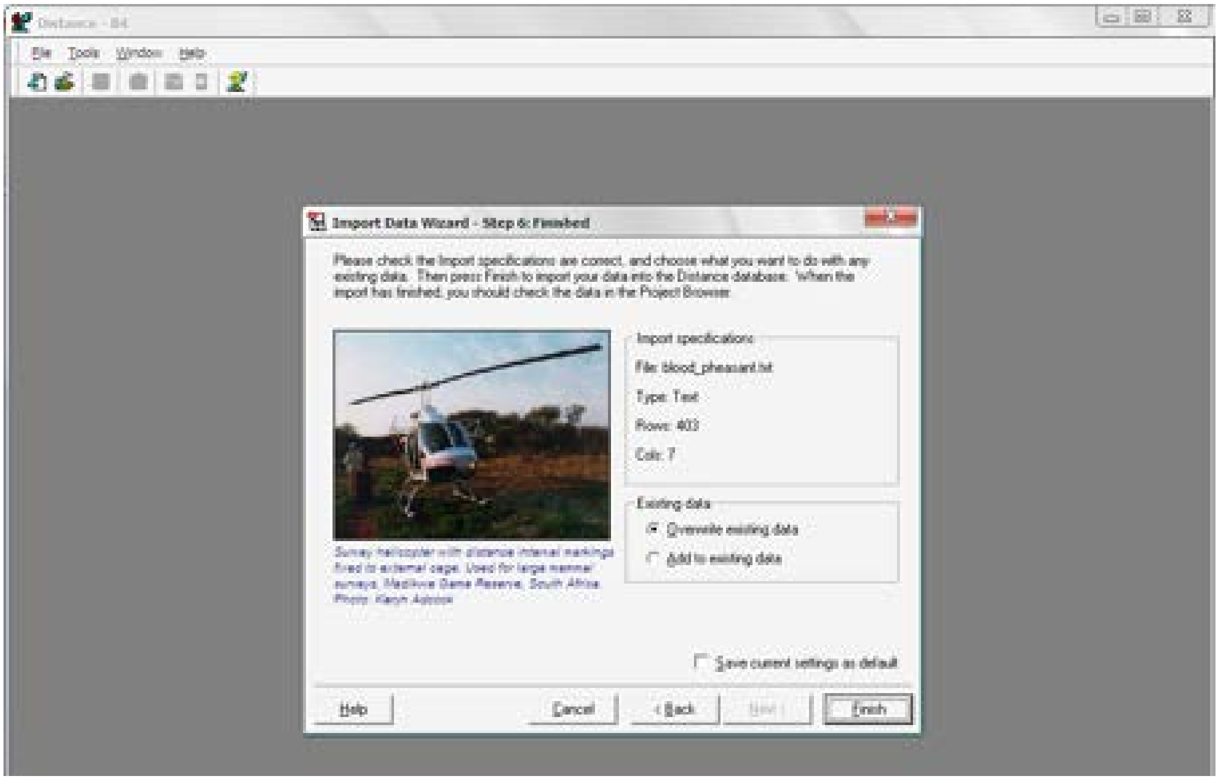
Step 4: Data file format---- Ignore rows> select the checkbox—Do not import first row> click next



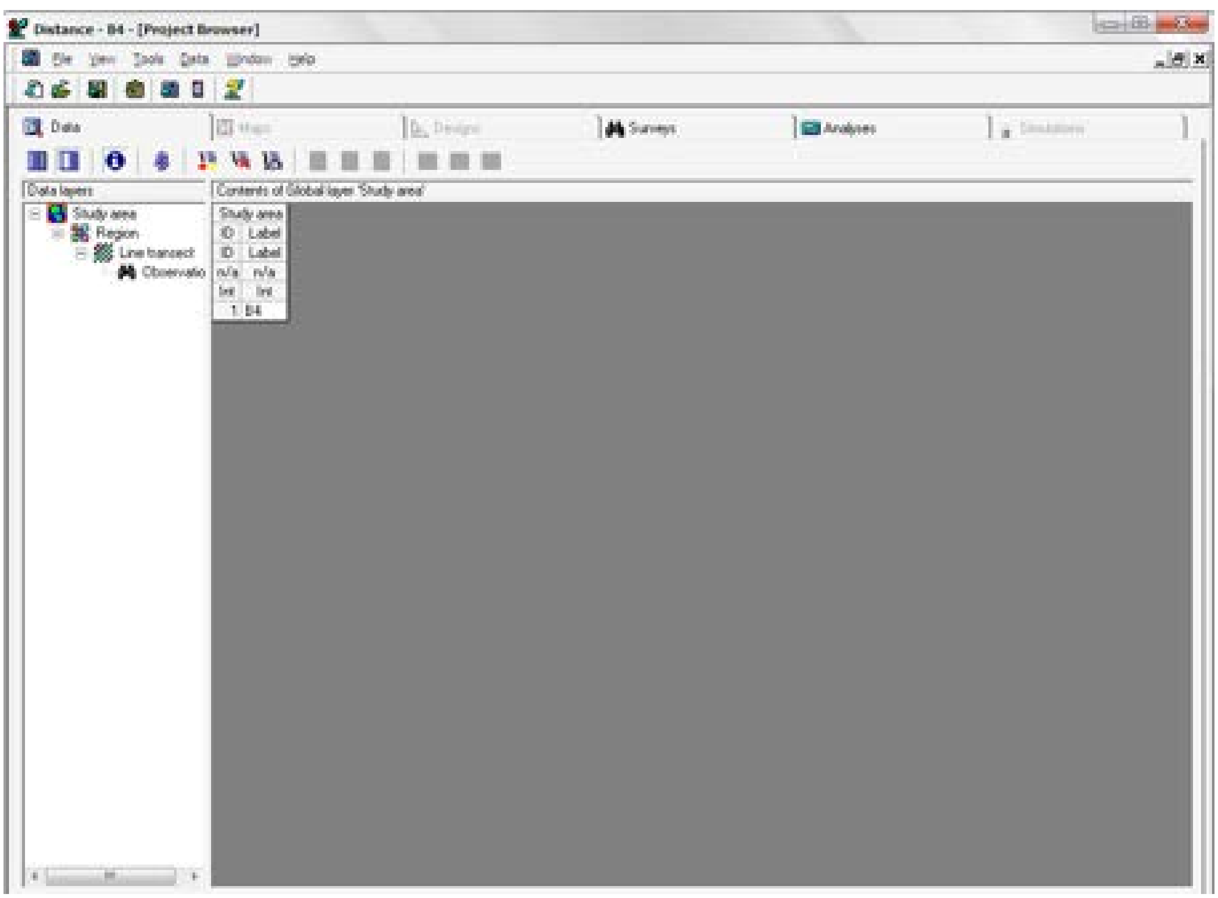
Step 5 Data structure: use shortcut—Click the checkbox “Columns are in the same order as they will appear in the data sheet” and then click next



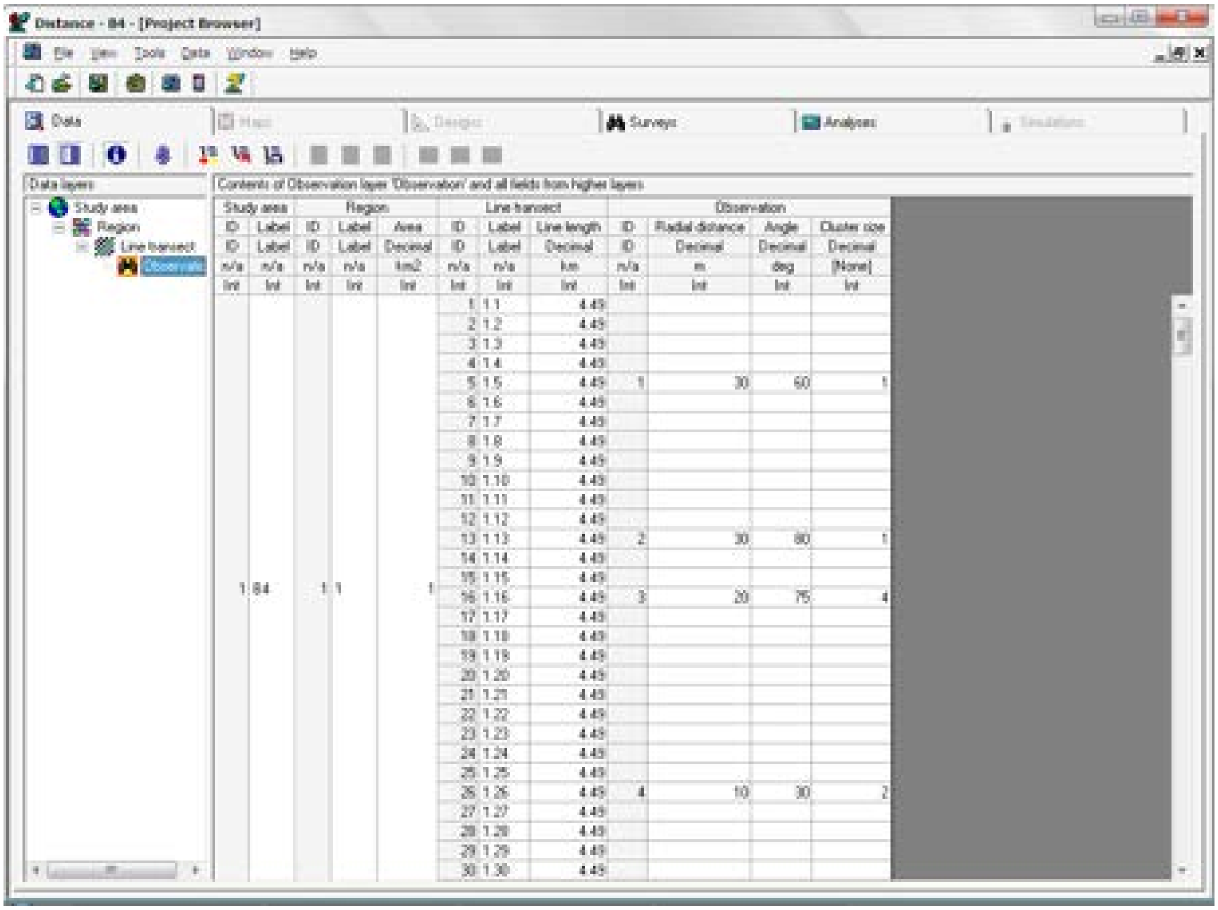
Step 6: Finish data import> Overwrite the existing data, and then click finish



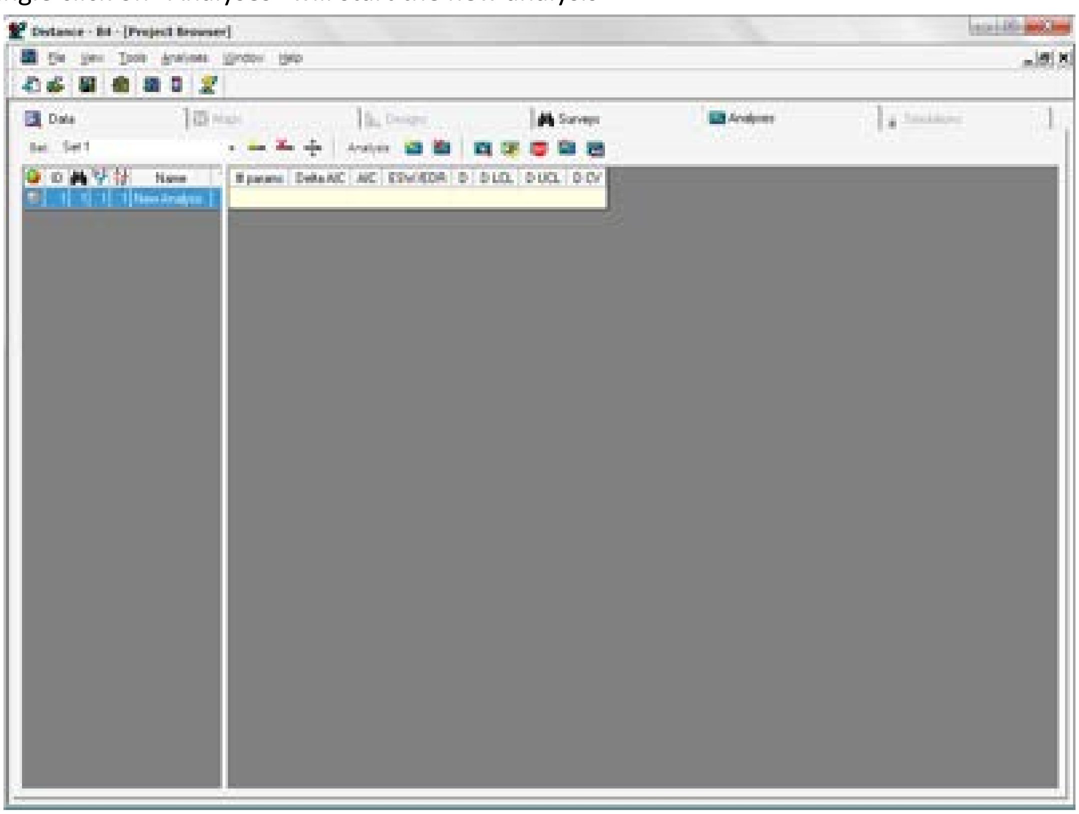
After finishing overwriting, Distance Project browser will appear



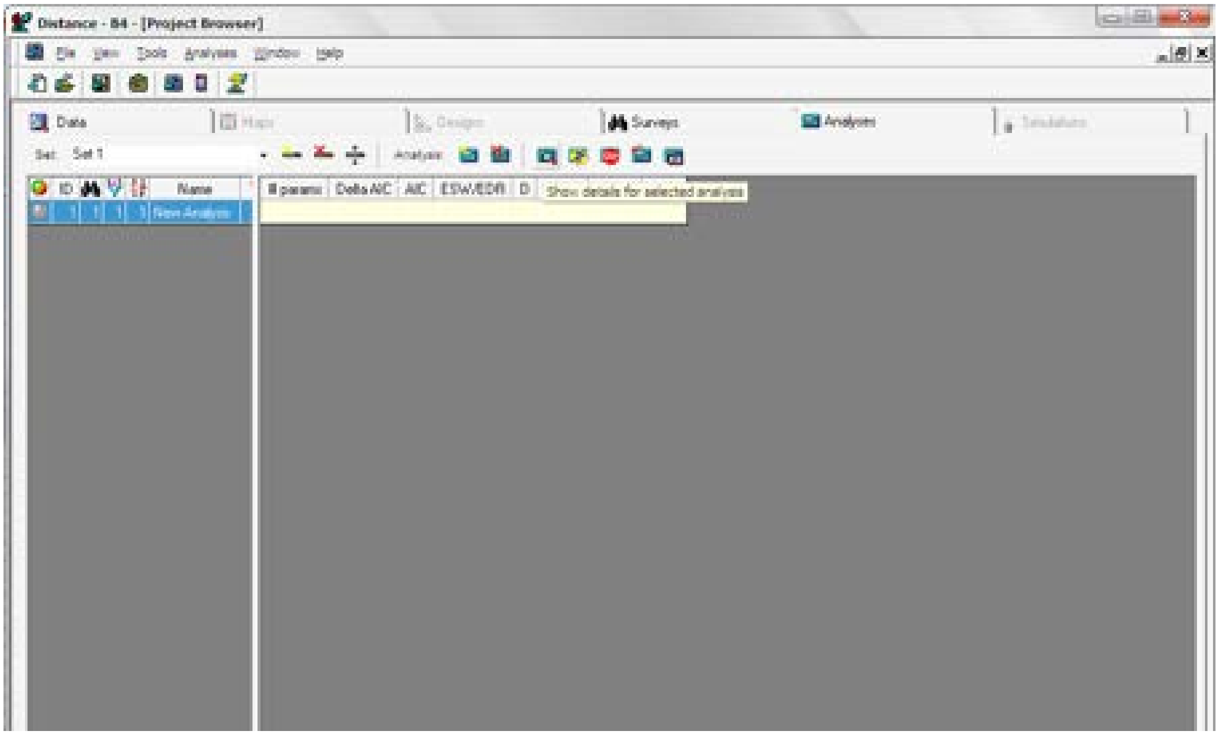
Click on Observation and the entire dataset will appear



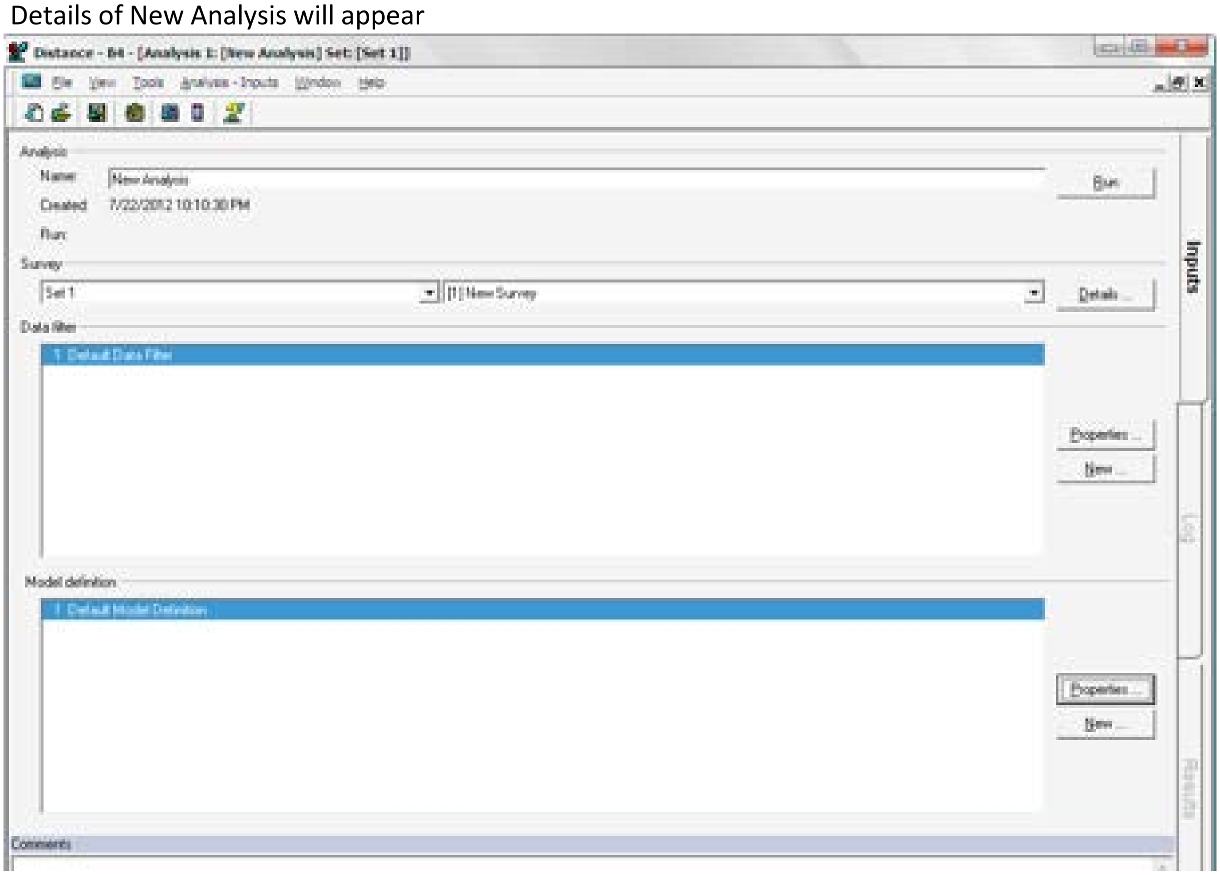
Single click on "Analyses" will start the new analysis



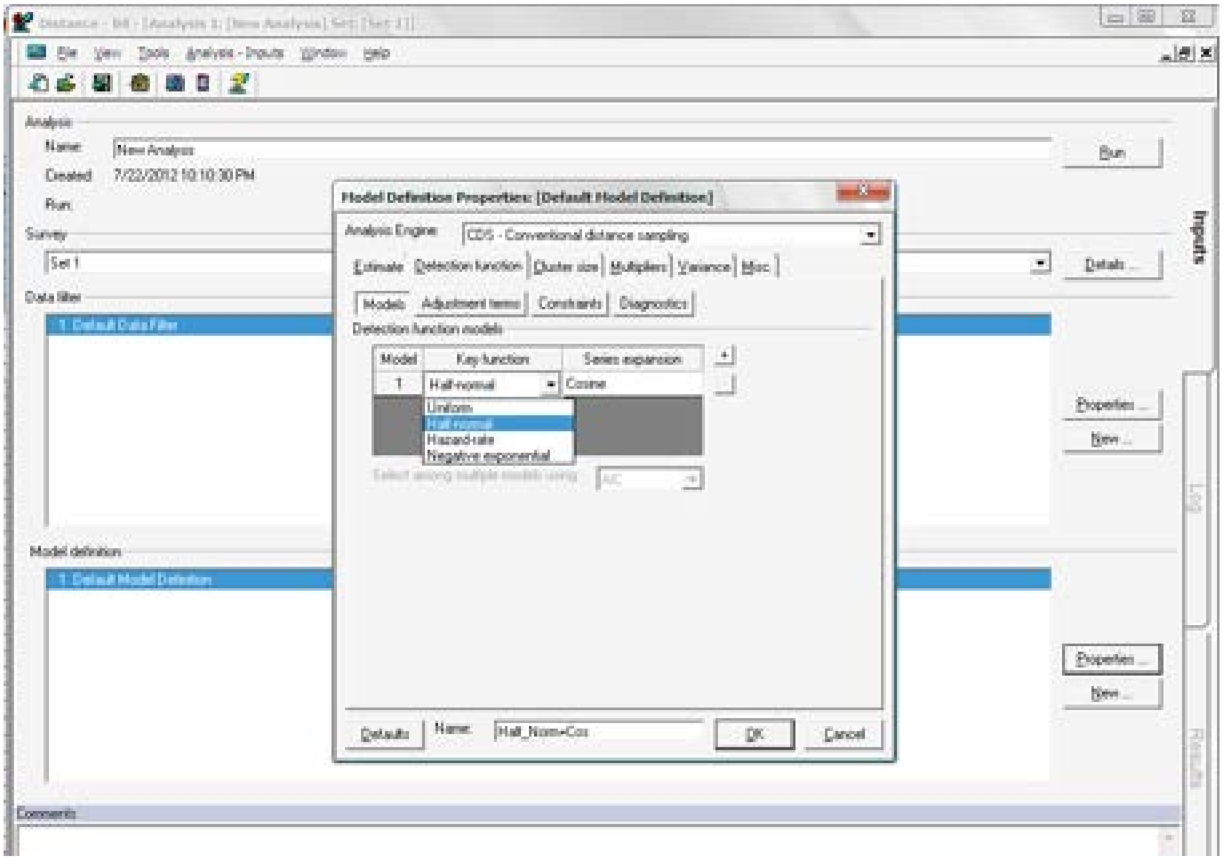
Select the gray circle (Double click) or select “show details for selected analysis” denoted by the magnifying glass, third symbol from left at “Analysis” section



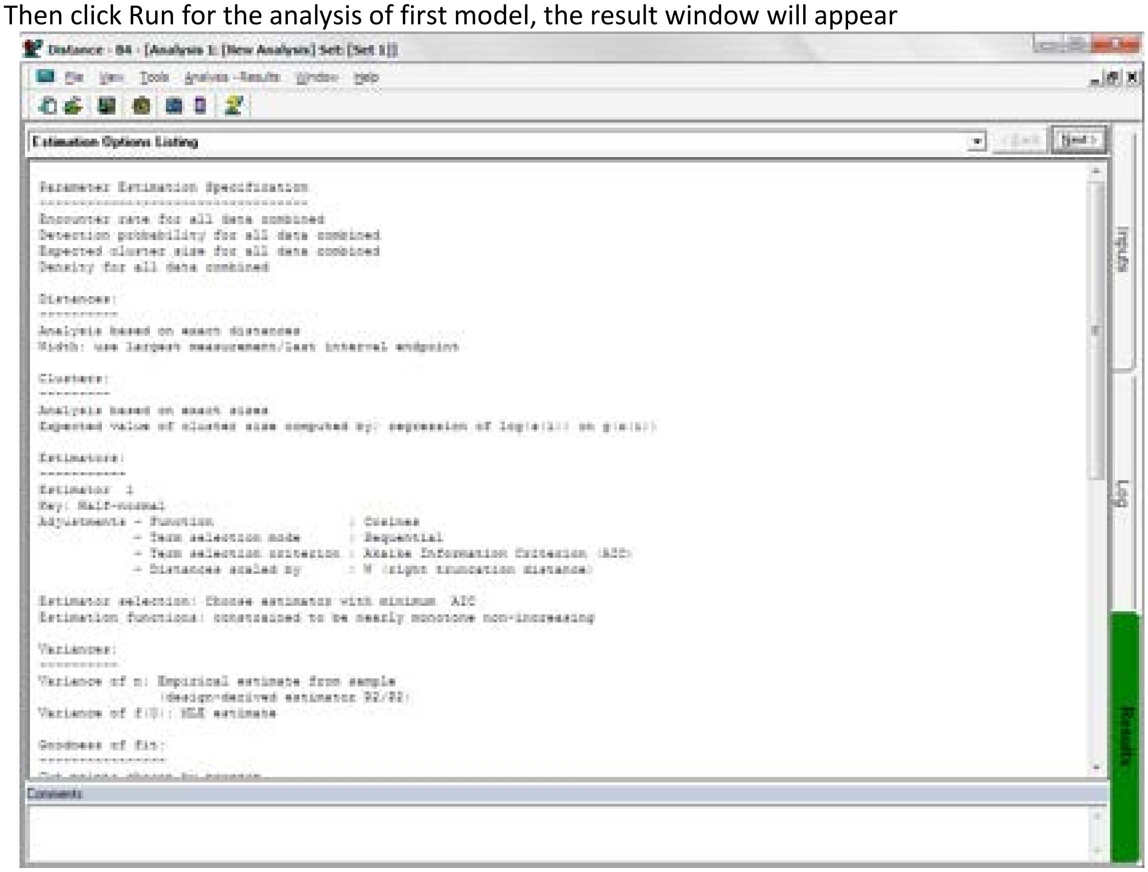
Details of New Analysis will appear



Click “Properties” in Model definition section, model definition property box will appear, click on “Detection function” tab and then select the key function and series expansion term, change the name accordingly, then click ok

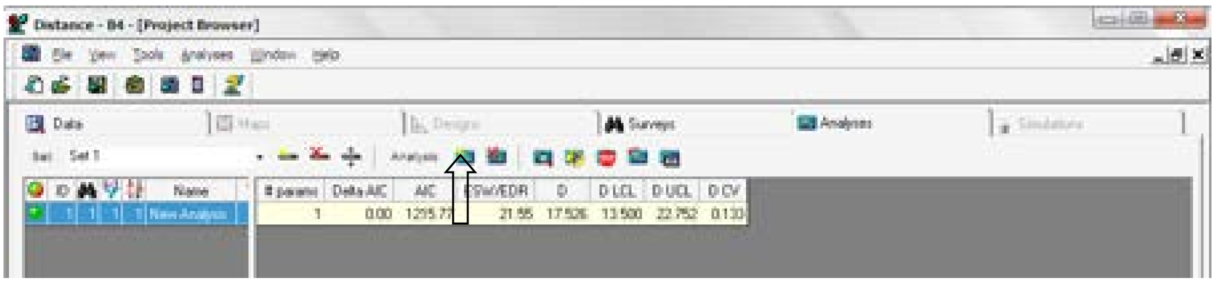


Then click Run for the analysis of first model, the result window will appear

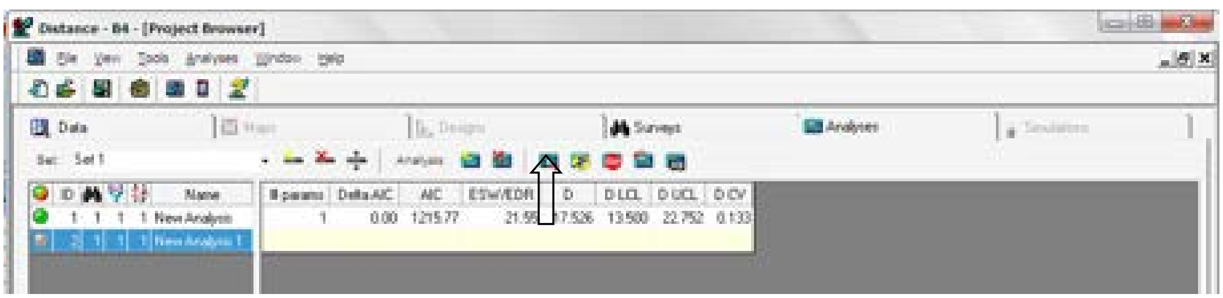


Click “View” and then select the “Project browser” or select the shortcut key from the second row, fifth from left

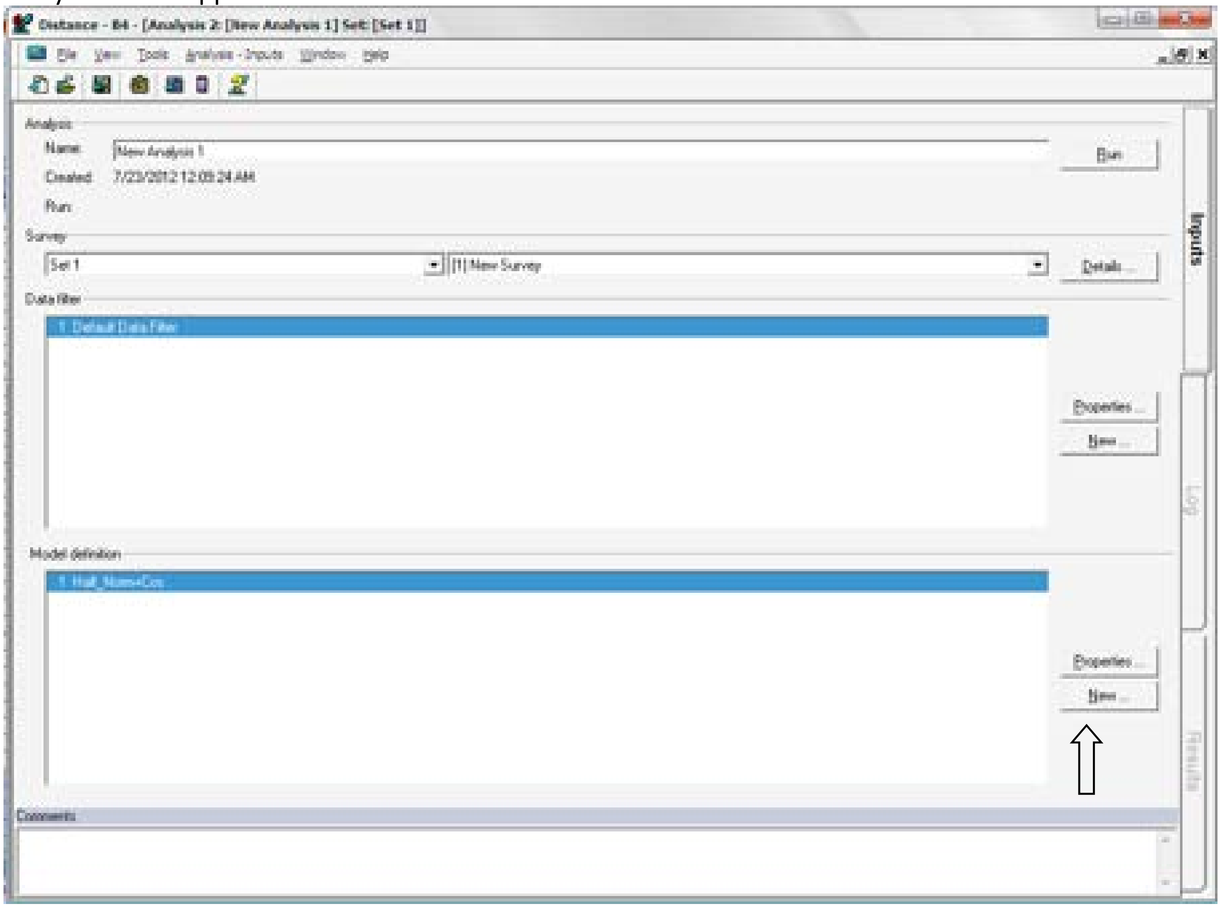
The result of the first analysis will appear



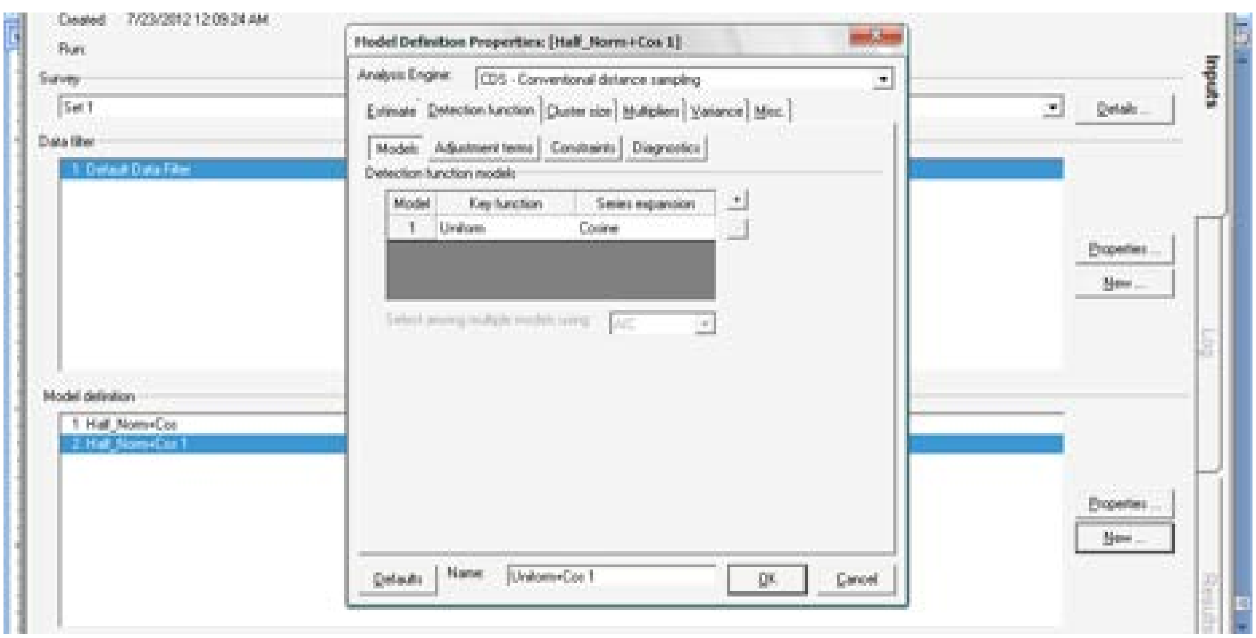
Now click on New Analysis button, first symbol from left at “Analysis section”, a new row will be added with the name New Analysis 2



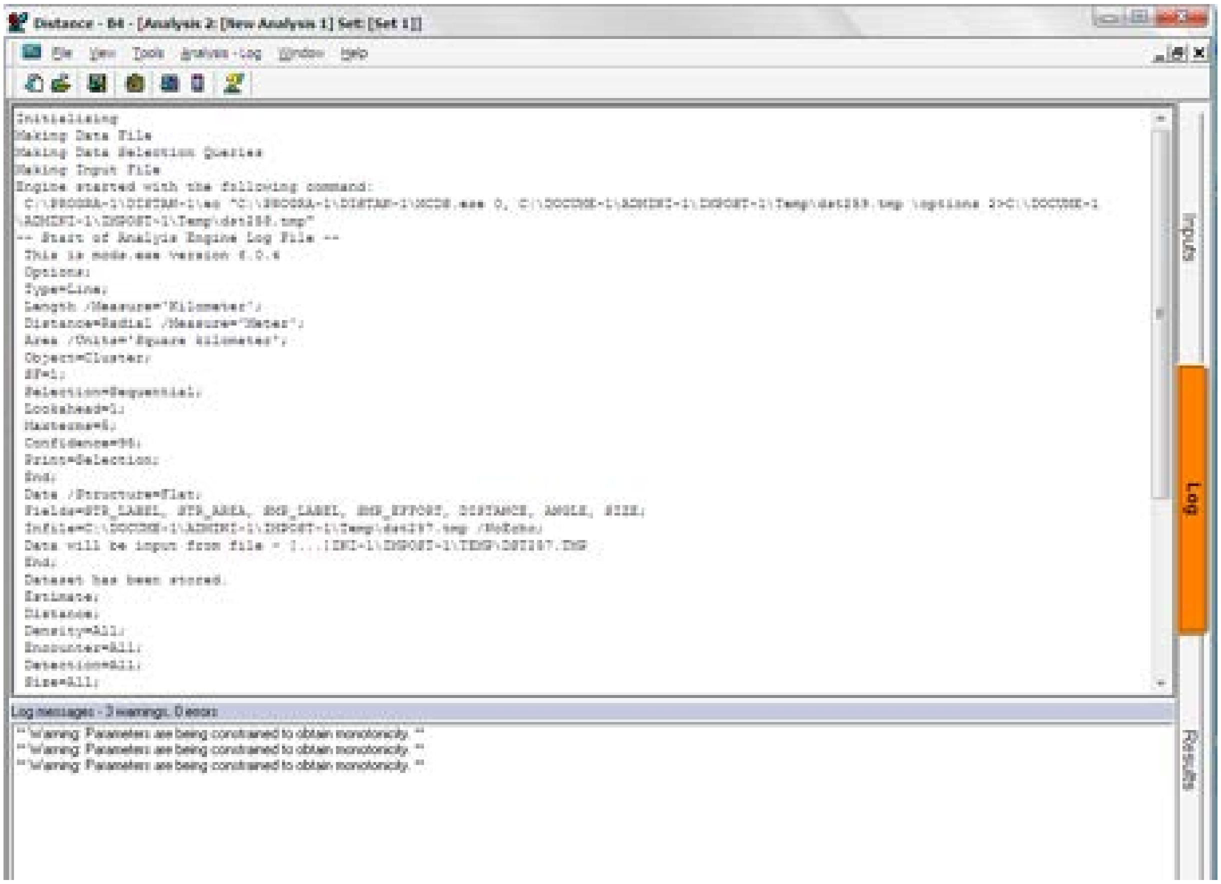
Select the gray circle (double click) or select "show details for selected analysis" denoted by the magnifying glass, third symbol from left at "Analysis" section; again the details for selected "New Analysis 1" will appear



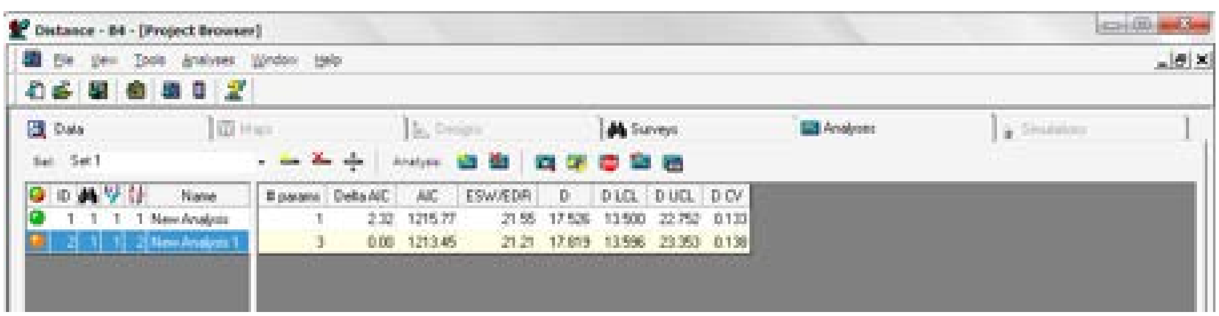
Click on "New" at Model definition section, then the model definition property box will appear, click on "Detection function" tab and then select the key function and series expansion term, change the name accordingly, then click ok



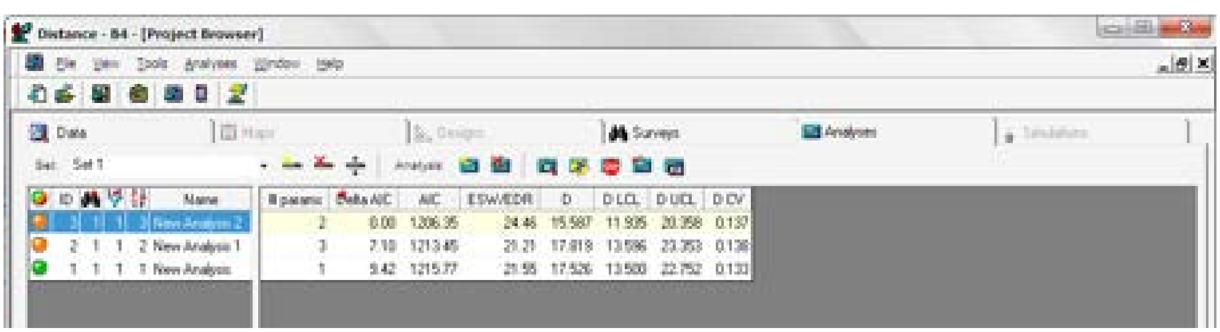
Click Run to run the second model, the result window will appear,



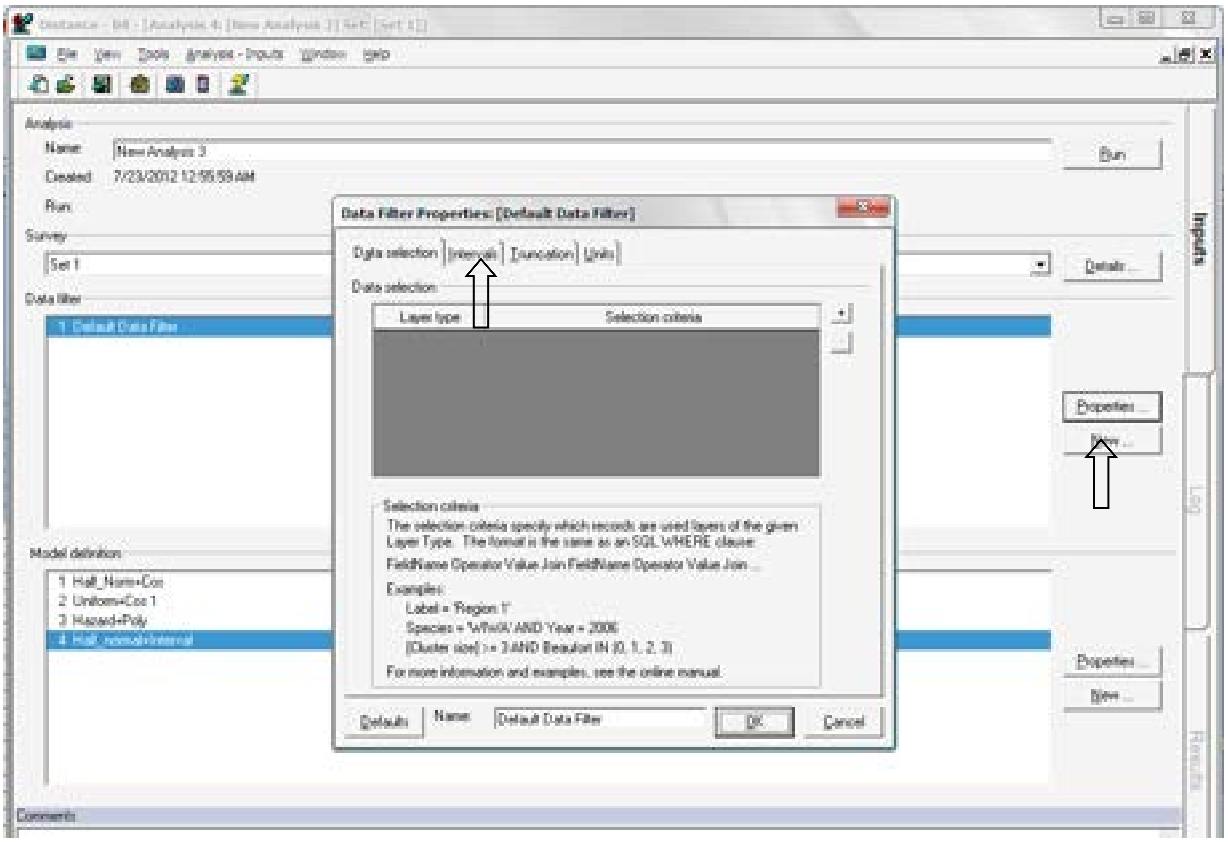
Click “View” and then select the “Project browser” or select the shortcut key from the second row, fifth from left, The results of both the first and second analyses will appear



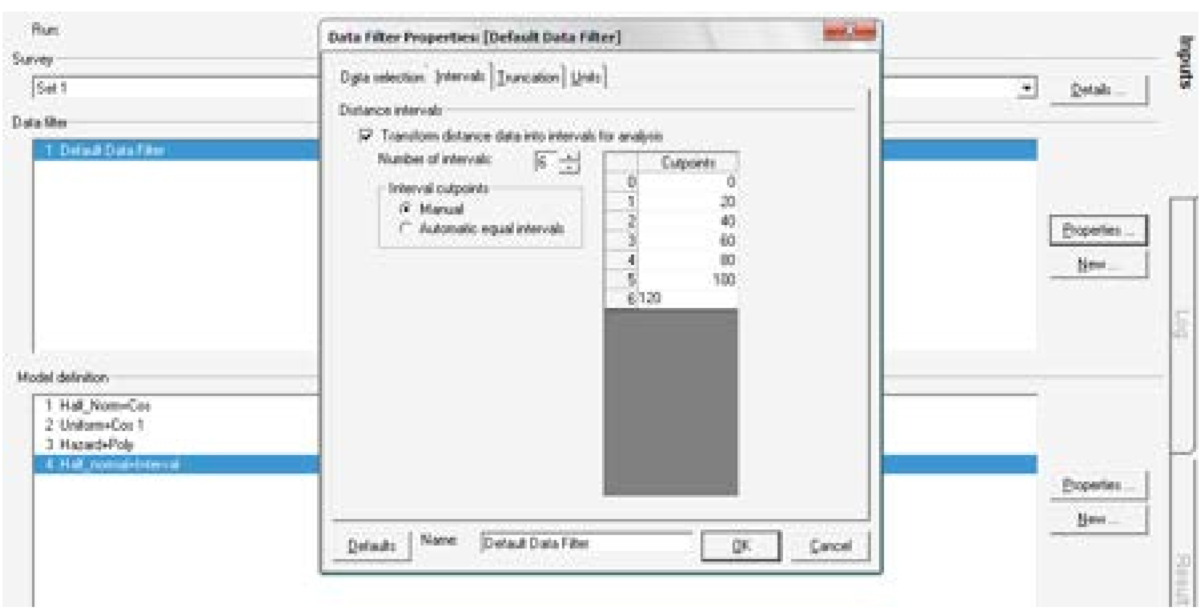
Following the same steps now analyze the third model and arrange the results according to increasing AIC values



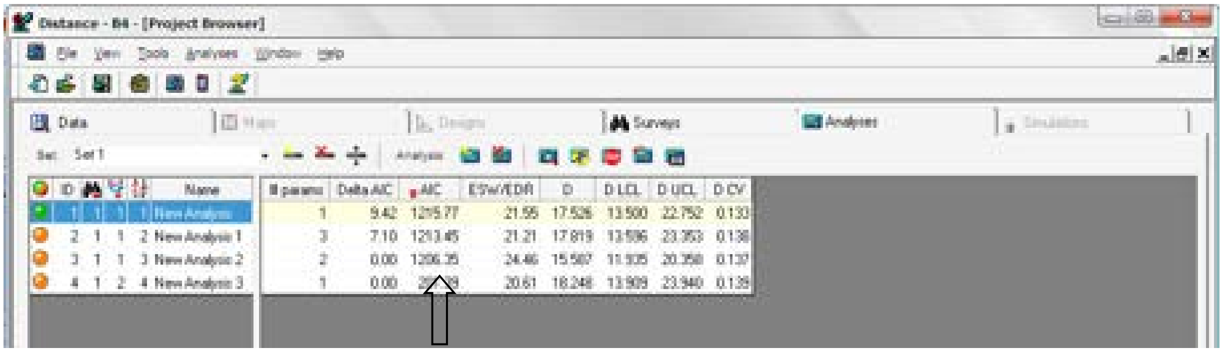
Now run new analyses by setting the intervals; the “details of the new analysis” window will appear, select the appropriate model and now select “New”, form “Data filter” section. Data filter property box will appear, select “intervals”



Click the checkbox “Transform distance data into intervals for analysis”. Select the number of intervals. Set the intervals using manual or automatic options. Change the name and click ok and click Run.



Again check the AIC values with other models following the same procedure and select the best model with lowest AIC value, in this case “New Analysis 3”, with intervals.



Double click on orange circle will show the results for “New Analysis 3”