

Fundamentals of Forest Sampling

- Why Forest Sampling
- Sampling Theory Terminology
- Why Use a Sample?

Readings:

- Avery and Burkhart Sampling Chapters
- Elzinga Chapter 5 (website)
- USDA Sampling Handbook 232 (website)

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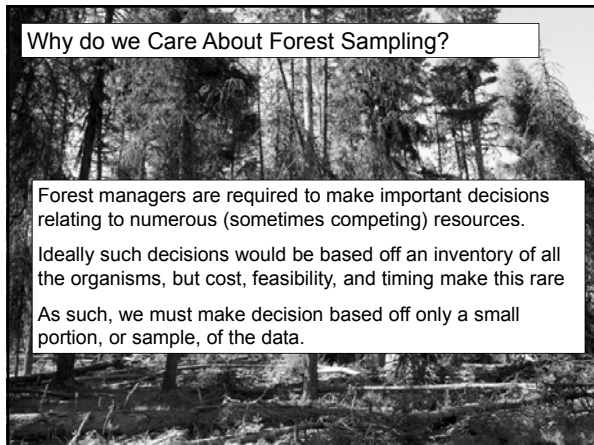
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Why do we Care About Forest Sampling?

Forest managers are required to make important decisions relating to numerous (sometimes competing) resources.

Ideally such decisions would be based off an inventory of all the organisms, but cost, feasibility, and timing make this rare

As such, we must make decision based off only a small portion, or sample, of the data.

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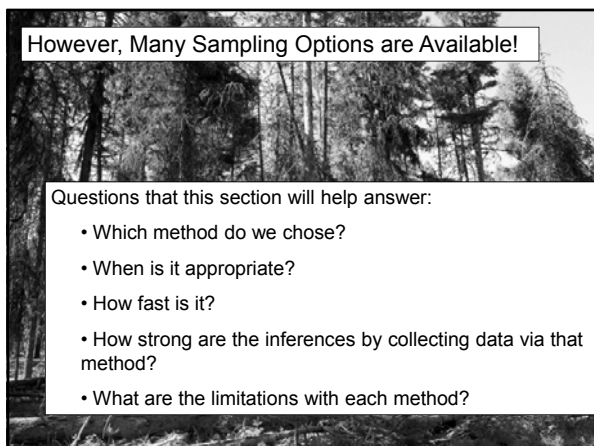
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However, Many Sampling Options are Available!

Questions that this section will help answer:

- Which method do we chose?
- When is it appropriate?
- How fast is it?
- How strong are the inferences by collecting data via that method?
- What are the limitations with each method?

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## Sampling Theory: Terminology



Common Terms Include:

- Statistical Study
- Sampling
- Data
- Sampling Unit
- Frame
- Population
- Parameters
- Statistics
- Accuracy and Bias
- Distributions
- Confidence

Port Valley, Okla., Forest, Sept., 1964. A group of students from the forest stand, near a site on which all trees are marked on an aerial photograph. Long and clear.

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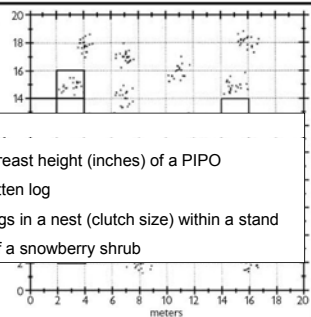
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## A "statistical study": A process that always involves measurements to produce numbers

Sample information			Population parameters	
Coordinates		# of plants	Total population size: 400 plants	
2	2	4	Mean # plants/quadrat: $\mu = 4$	
6	4	0	Standard deviation: $\sigma = 5.005$	
16	4	3		
12	6	2		
14	6	5		
6	8	10		
0	12	0		
2	12	6		
14	12	0		
2	14	20		

**Examples:**

- The diameter at breast height (inches) of a PIP0
- The length of a rotten log
- The number of eggs in a nest (clutch size) within a stand
- The height (cm) of a snowberry shrub



Interval = ± 361 plants

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## Sampling: process of inferring properties of a population from only a sample of that population

Sample information			Population parameters	
2	2	4	Total population size: 400 plants	
6	4	0	Mean # plants/quadrat: $\mu = 4$	
16	4	3	Standard deviation: $\sigma = 5.005$	
12	6	2		
14	6	5		
6	8	10		
0	12	0		
2	12	6		
14	12	0		
2	14	20		

**Sample statistics (n = 10)**

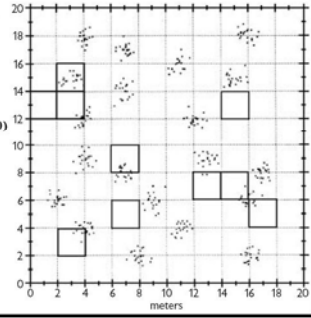
Mean # plants/quadrat:  $\bar{x} = 5.0$

Standard deviation:  $s = 6.146$

**Population estimate**

Estimated population size = 500 plants

95% confidence interval = ± 361 plants



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Data: Collected from measuring a sample, which is made up of sampling units.

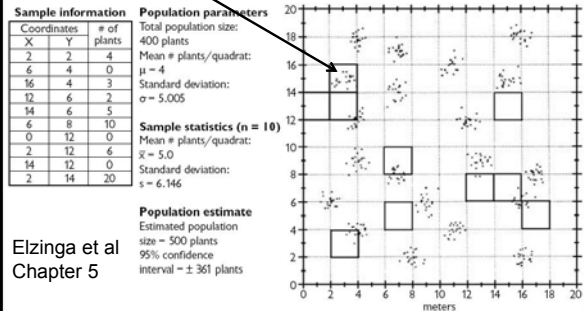


FIGURE 5.1. Population of 400 plants distributed in 20 clumps of 20 plants. This figure shows a simple random sample of ten 2m x 2m quadrats, along with sample statistics and true population parameters.

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Sampling Unit: The part that the population of interest is divided into. This is what we infer from

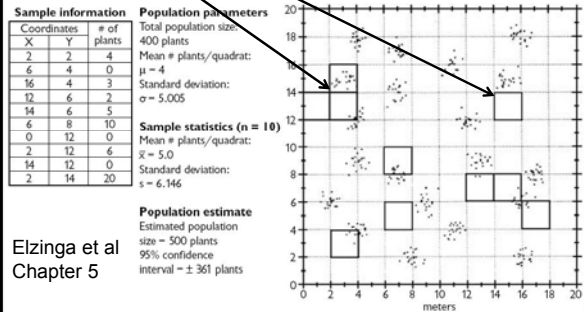


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Sampling Unit: This is often called the experimental unit and is the physical unit from which the measurement is obtained

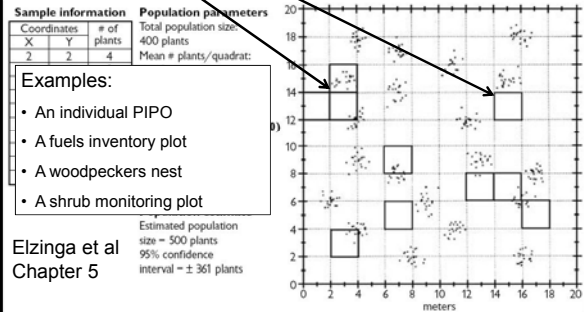


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Frame: A construct that highlights the boundaries of a population

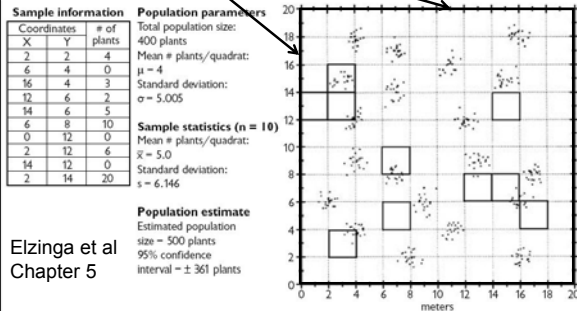


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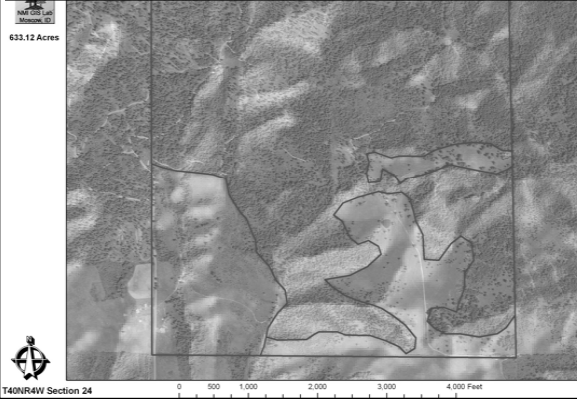
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Frame: A construct that highlights the boundaries of a population



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Population (or Universe/Universal Set): The collection of all the sampling units = what we want to learn about

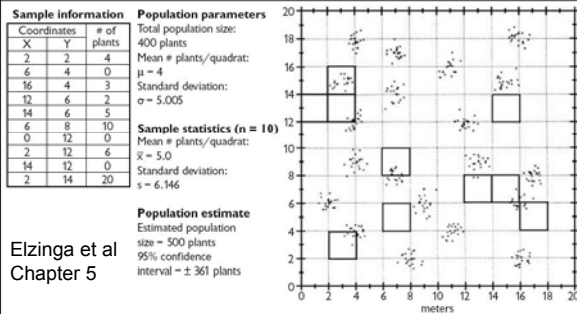


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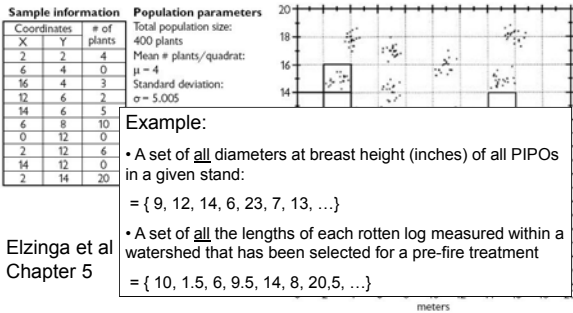


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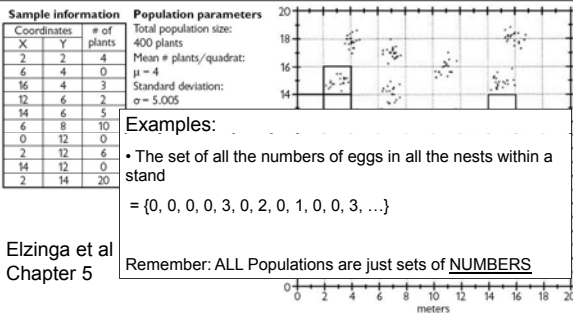


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A Sample: is any subset of the population

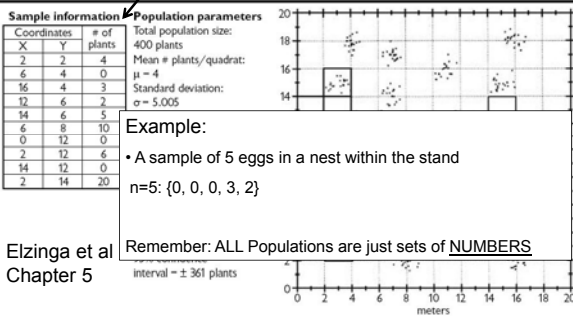
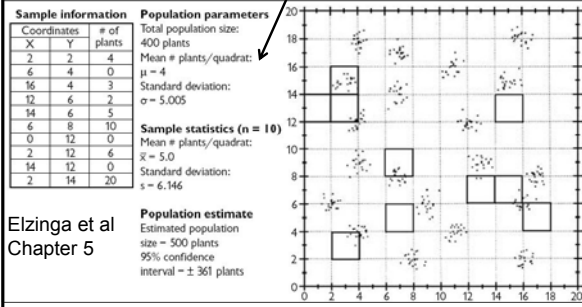


FIGURE 5.1. Population of 400 plants distributed in 20 clumps of 20 plants. This figure shows a simple random sample of ten 2m x 2m quadrats, along with sample statistics and true population parameters.

Parameters: Characteristics of a population (using all the data), such as total number of measures per sampling unit



The aim of sampling is to measure a representative sample of the population in to obtain a "reasonable estimate of your parameter"

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Population Parameters: Fixed, unknown, and only change if the population changes

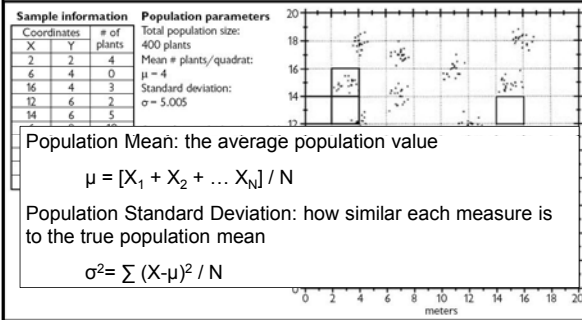


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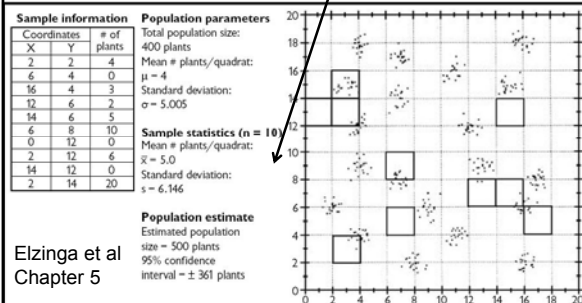
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Statistics: Estimates of your parameters population (using a sample), and their errors calculated from your samples



Note: Greek letters ( $\mu$ ,  $\sigma$ ) are used for parameters and Roman ( $\bar{x}$ ,  $s$ ) for Statistics

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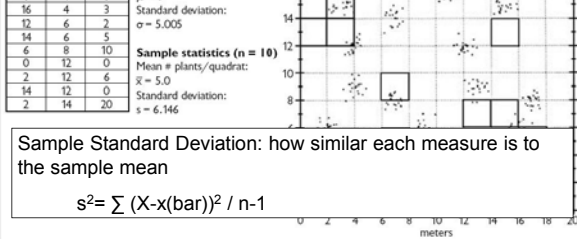
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Sample Statistics: Derived descriptors derived from a sample that provide estimates of the population parameter

Sample Mean: Estimate of the population mean from a sample

$$\bar{X} = \sum X / N$$



Sample Standard Deviation: how similar each measure is to the sample mean

$$s^2 = \sum (X - \bar{x})^2 / n - 1$$

FIGURE 5.1. Population of 400 plants distributed in 20 clumps of 20 plants. This figure shows a simple random sample of ten 2m x 2m quadrats, along with sample statistics and true population parameters.

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Distributions: The Law of Large Numbers states that as the sample size increases the sample statistics tend toward the population parameters, regardless of the population distribution

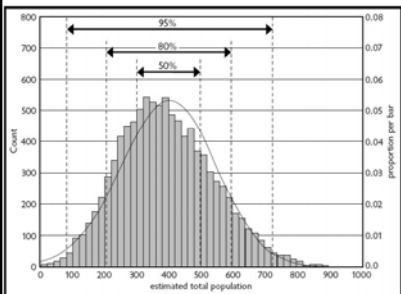


FIGURE 5.4. Distribution from sampling the 400-plant population 10,000 times using ten samples of 2m x 2m quadrats. The 95%, 80%, and 50% confidence intervals around the true population of 400 plants are shown. The smooth line shows a normal, bell-shaped curve fit to the data.

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Distributions: The Central Limit Theorem states that as the sample size increases the sample mean distribution tends towards normality, regardless of the population distribution

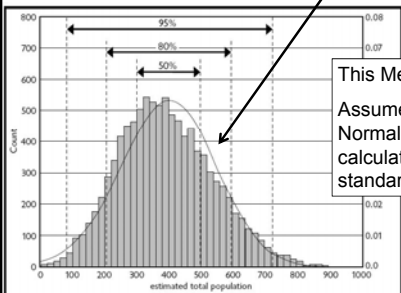


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This Means that:  
Assume a distribution is Normal and then can easily calculate its mean and standard deviation

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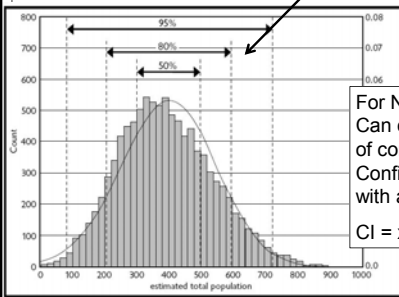
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A Note of Confidence: This is the measure of precision about the mean, such that Y% of the time our sample value will lie within a given range on the distribution



For Normal Distributions:  
Can calculate this range  
of confidence or  
Confidence Interval (CI)  
with a students t-table

$$CI = x \pm t * SE$$

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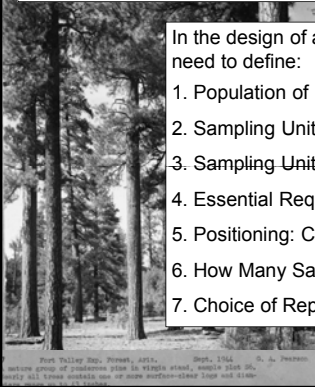
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### Sampling Design: First Steps



In the design of a sampling process we need to define:

1. Population of Interest
2. Sampling Unit
3. Sampling Unit Size and Shape
4. Essential Requirements
5. Positioning: Choice of Sampling Design
6. How Many Sampling Units (next lecture)
7. Choice of Representative Measures

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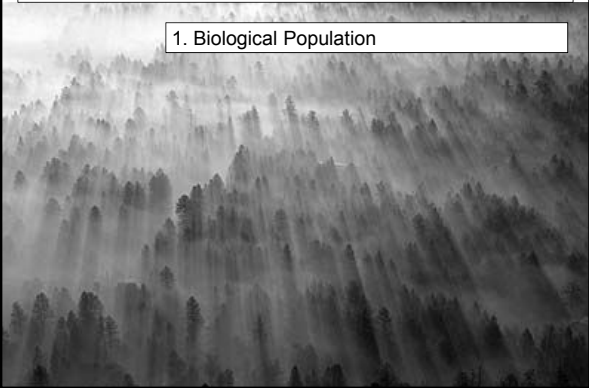
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### Sampling Design: Population of Interest



1. Biological Population

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Sampling Design: Population of Interest

2. Target Population: Trees within a 100 acre stand that you may manage



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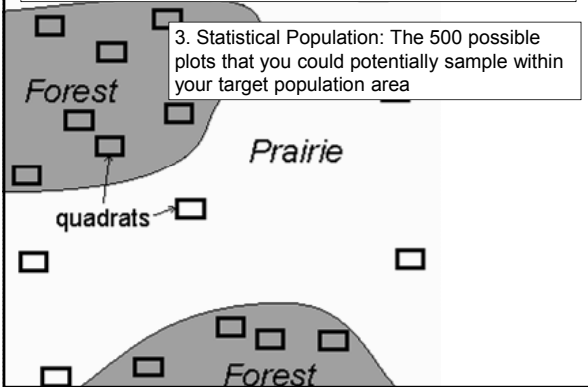
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Sampling Design: Population of Interest

3. Statistical Population: The 500 possible plots that you could potentially sample within your target population area



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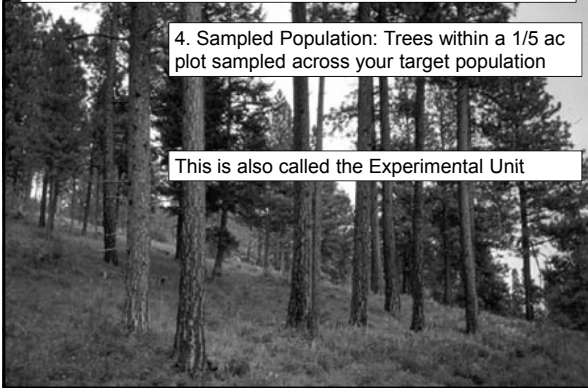
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Sampling Design: Population of Interest

4. Sampled Population: Trees within a 1/5 ac plot sampled across your target population

This is also called the Experimental Unit



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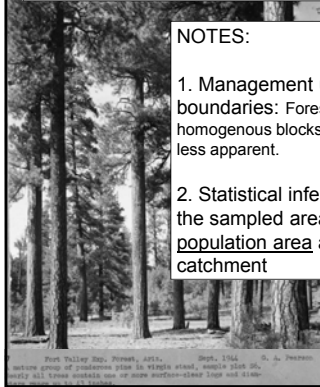
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### Sampling Design: Population of Interest



#### NOTES:

1. Management usually ignores biological boundaries: Forest stands are often defined via homogenous blocks but over time this may become less apparent.
2. Statistical inferences can only be made to the sampled areas within your targeted population area and not to the wider catchment

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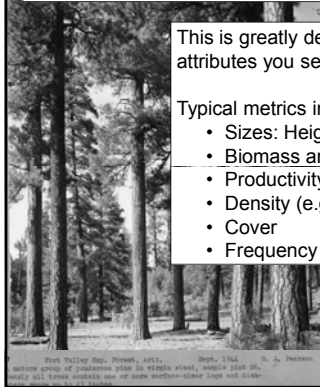
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### Sampling Design: What is the Sampling Unit



This is greatly dependant on the type of attributes you seek to measure.

- Typical metrics in forestry include:
- Sizes: Heights and Diameters
  - Biomass and Volume (e.g., Bd ft)
  - Productivity (e.g., NPP)
  - Density (e.g., SDI)
  - Cover
  - Frequency

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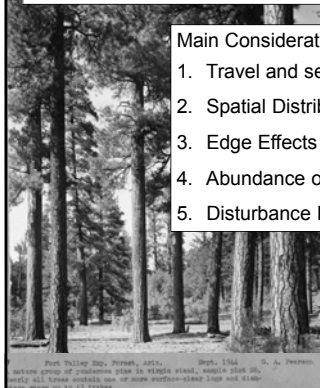
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### Sampling Design: Sampling Unit Size and Shape



#### Main Considerations:

1. Travel and set-up time
2. Spatial Distribution
3. Edge Effects
4. Abundance of Trees of Interest
5. Disturbance Impacts

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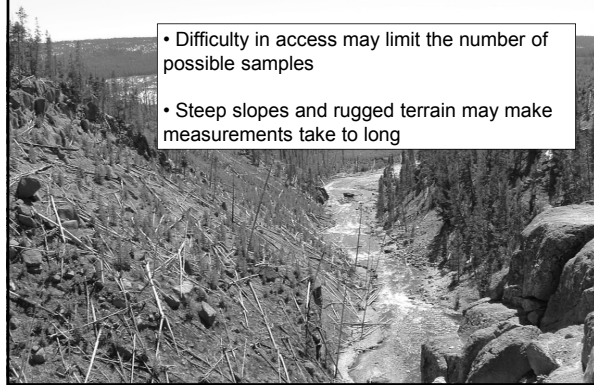
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### Sampling Design: Travel and set-up time



- Difficulty in access may limit the number of possible samples
- Steep slopes and rugged terrain may make measurements take too long

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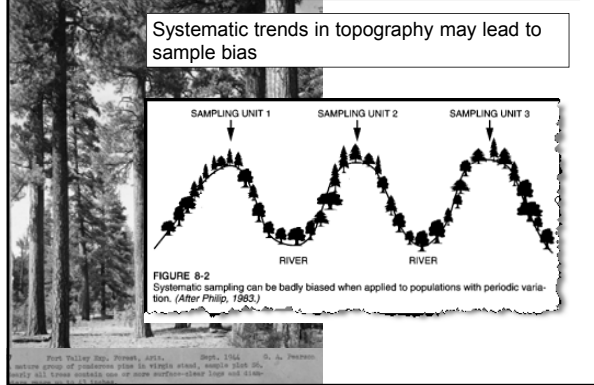
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### Sampling Design: Spatial Distribution



Systematic trends in topography may lead to sample bias

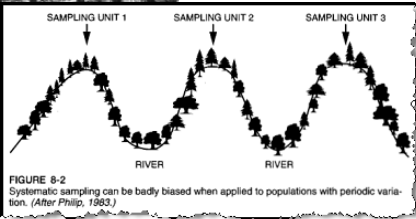


FIGURE 8-2 Systematic sampling can be badly biased when applied to populations with periodic variation. (After Philip, 1963.)

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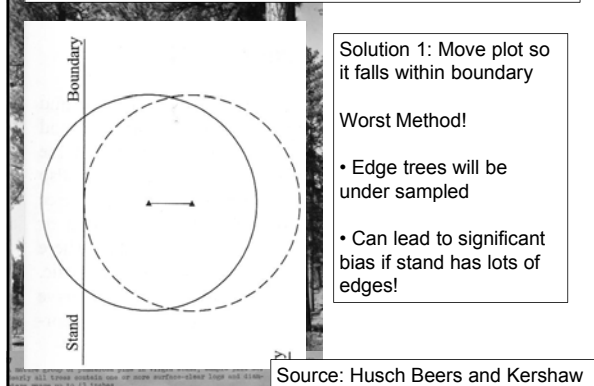
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### Fixed Area Plots: Edge Effects



Solution 1: Move plot so it falls within boundary

Worst Method!

- Edge trees will be under sampled
- Can lead to significant bias if stand has lots of edges!

Source: Husch Beers and Kershaw

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Fixed Area Plots: Edge Effects

Solution 2: Add additional radius to account for lost area

Intermediate Method

- Edge trees will be under sampled

Source: Husch Beers and Kershaw

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Fixed Area Plots: Edge Effects

Solution 3: Re-calculate area and only measure within stand

Intermediate Method

- Very time consuming as need to infer samples under correct areas

Source: Husch Beers and Kershaw

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Fixed Area Plots: Edge Effects

Solution 4: Establish exactly half a plot at the stand edge → Then double counts

Intermediate Method!

- Edge trees will be over sampled leading to bias

Source: Husch Beers and Kershaw

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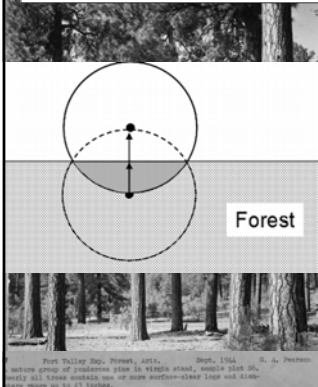
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### Fixed Area Plots: Edge Effects



**Solution 5: Mirage Plots**  
Intermediate method

- Lay out your plot and measure all the "in" trees
- Imagining the stand edge a mirror, lay out the mirror image of your plot with the plot centre outside the stand and measure the "in" trees
- Edge trees will be over sampled leading to bias

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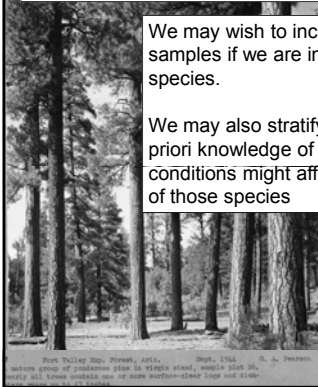
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### Sampling Design: Abundance of Trees of Interest



We may wish to increase our number of samples if we are interested in evaluating rare species.

We may also stratify our samples if we have a priori knowledge of what environmental conditions might affect the spatial distribution of those species

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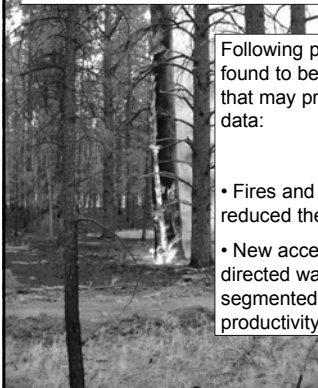
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### Sampling Design: Disturbance Impacts



Following plot selection the area may be found to be affected by a disturbance that may produce unrepresentative data:

- Fires and wind events may have reduced the stocking
- New access roads, power lines, re-directed water channels etc may have segmented stands or adversely affected productivity

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**Sampling Design: Sampling Unit Size and Shape**

Efficient plot sizes have sample sizes that are proportional to the variance of the parameters of interest, but that are small enough to be quickly collected

Fixed Area Plots: samples proportional to frequency → density estimates

Variable Area Plots: samples proportional to size → volume estimates

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**Sampling Design: Essential Requirements**

In any study there are three general requirements that should be considered

Should the Sampling Design be Random?  
How many plots (samples) are needed?  
Should we have sampling with or without replacement?

You can do anything in your sampling design. However, you need to make a conscious choice for everything you do

Generally, our choices should be guided on our resources and objectives

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**Sampling Design: Essential Requirements**

In any study there are three general requirements that should be considered:

1. Random (unbiased) Sampling

If your study does not contain some manner of random sampling you can not determine the probability of selection and therefore can not make statistical inferences about your population.

There are a "few" exceptions ...

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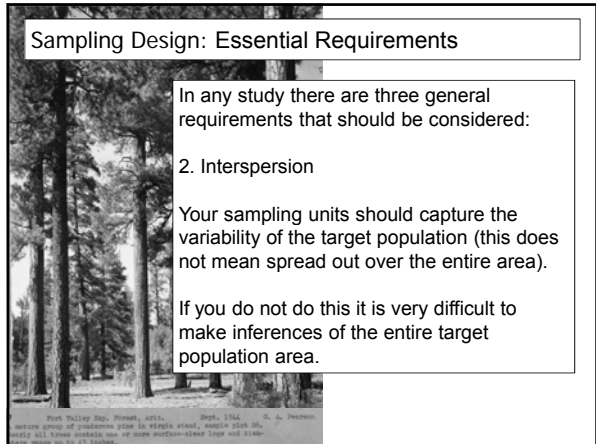
**Sampling Design: Essential Requirements**

In any study there are three general requirements that should be considered:

2. Interspersion

Your sampling units should capture the variability of the target population (this does not mean spread out over the entire area).

If you do not do this it is very difficult to make inferences of the entire target population area.




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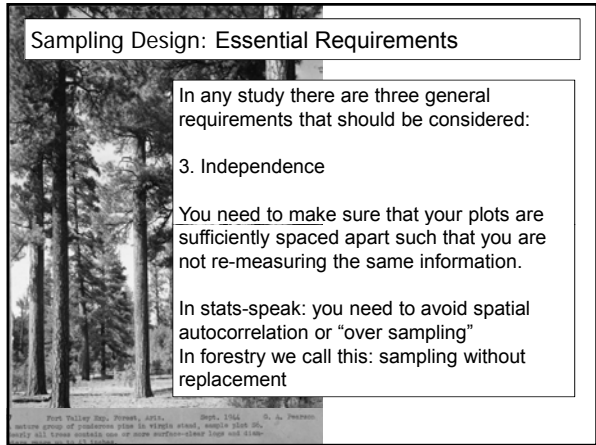
**Sampling Design: Essential Requirements**

In any study there are three general requirements that should be considered:

3. Independence

You need to make sure that your plots are sufficiently spaced apart such that you are not re-measuring the same information.

In stats-speak: you need to avoid spatial autocorrelation or "over sampling"  
In forestry we call this: sampling without replacement




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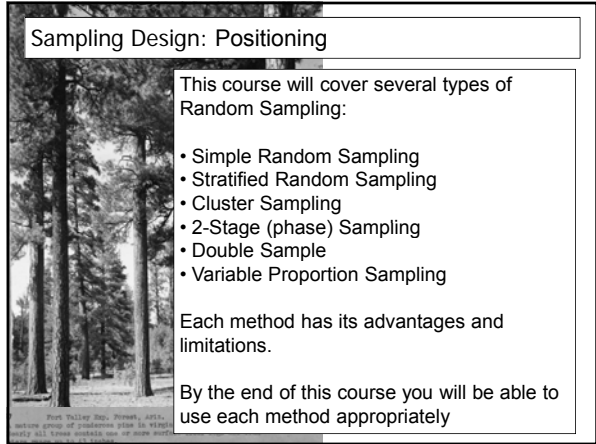
**Sampling Design: Positioning**

This course will cover several types of Random Sampling:

- Simple Random Sampling
- Stratified Random Sampling
- Cluster Sampling
- 2-Stage (phase) Sampling
- Double Sample
- Variable Proportion Sampling

Each method has its advantages and limitations.

By the end of this course you will be able to use each method appropriately




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