Lecture 2

How many are there? Estimating abundance

WILD3810 (Spring 2019)

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Readings:

Mills 54-63

Powell & Gale 169-173; 177-180

Abundance

> the number of individual organisms in a population at a particular time

Also referred to as **population size**

Why measure abundance?

Abundance is the central state variable of a population

How many are there?

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Abundance is the central state variable of a population

How many are there?

- Setting harvest limits

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- Maintaining viable populations of threatened/endangered species

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Abundance is the central state variable of a population

How many are there?

- Setting harvest limits

- Maintaining viable populations of threatened/endangered species

- Monitoring non-native/invasive species

Estimating abundance

Why not just count every individual?

Sometimes we can (census)

But usually:

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But usually:

1) Not practical

- Area too big

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But usually:

1) Not practical

- Area too big

2) Not every individual detected

- Elusive

Why not just count every individual?

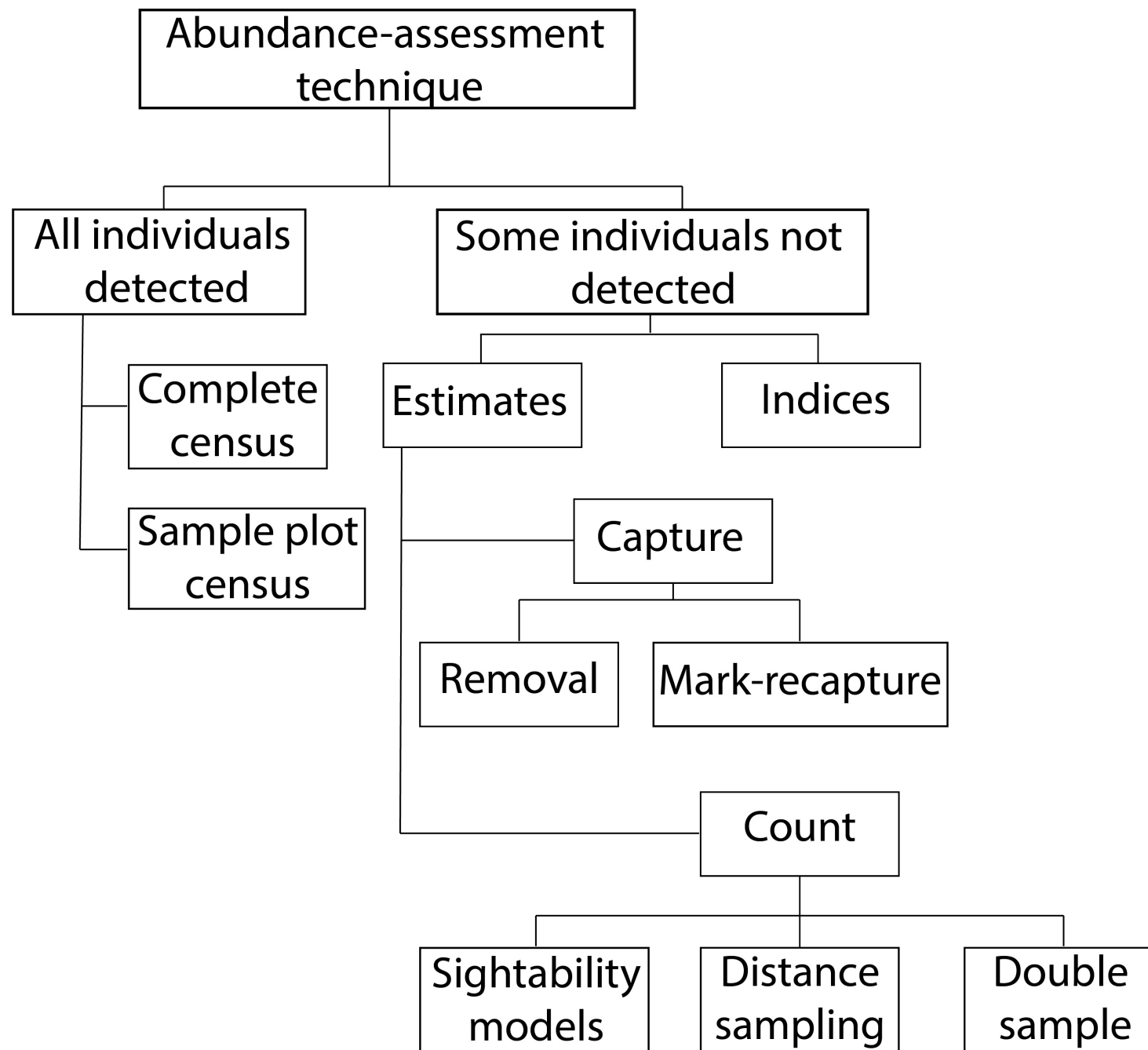Sometimes we can (census)

But usually:

1) Not practical

- Area too big

2) Not every individual detected

- Elusive

So we have to **estimate** abundance [1]

Estimation methods

Q1: Abundance or index?

Indices

We don't always need to know exactly how many individuals there are

Sometimes we just want to know the **relative** change in population size over time (or space).

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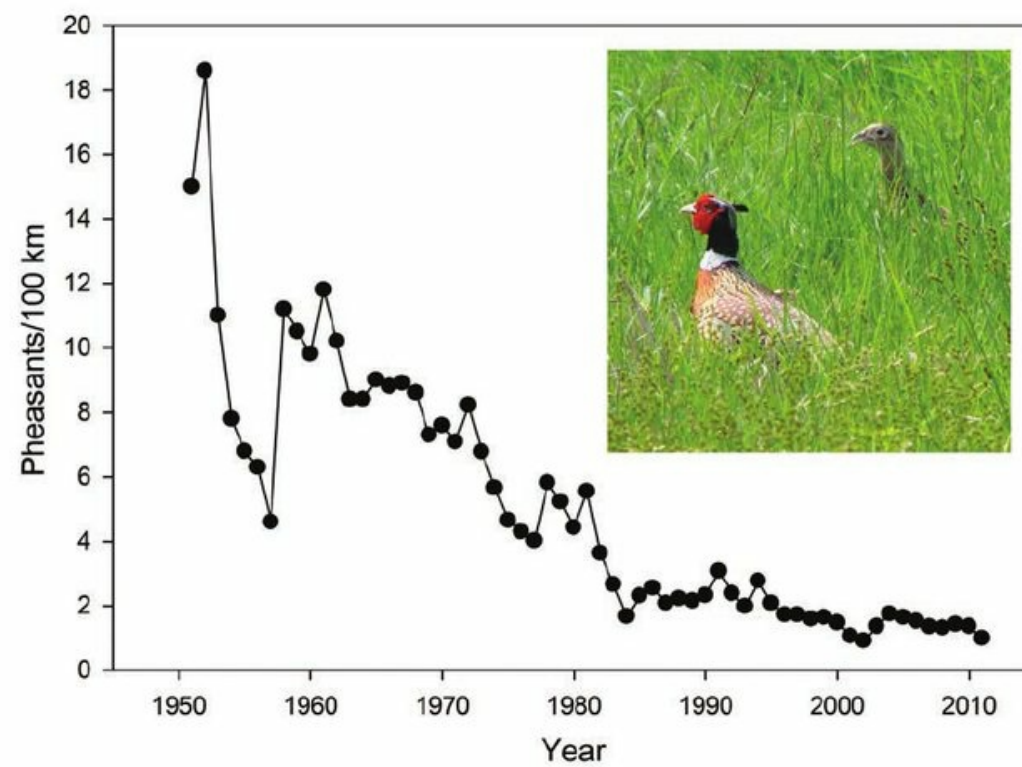
In this case, we can use an **index**

> counts C that are correlated with the actual number of individuals N
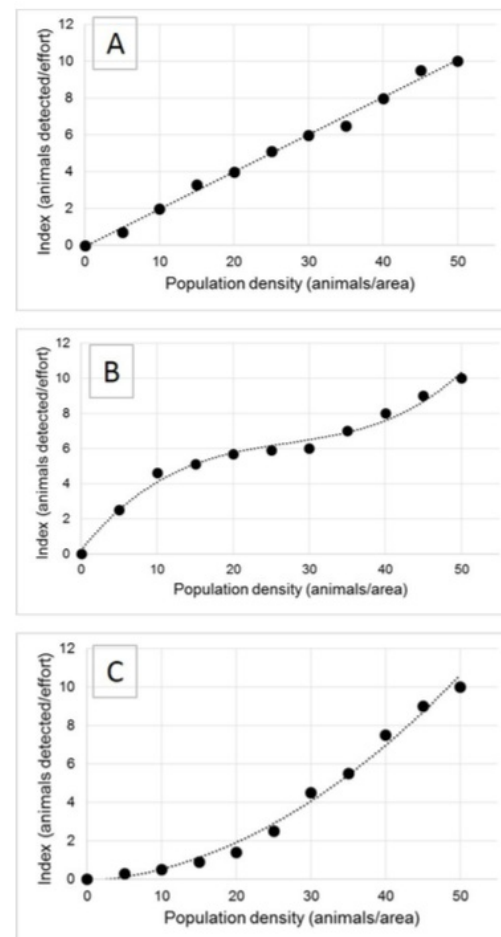
Indices

Example

Rural Mail Carrier Survey

Indices

Problems

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1) What if the relationship between N and C is not linear? [2]

Indices

Problems

1) What if the relationship between N and C is not linear?

2) What if the observation process changes? [3]

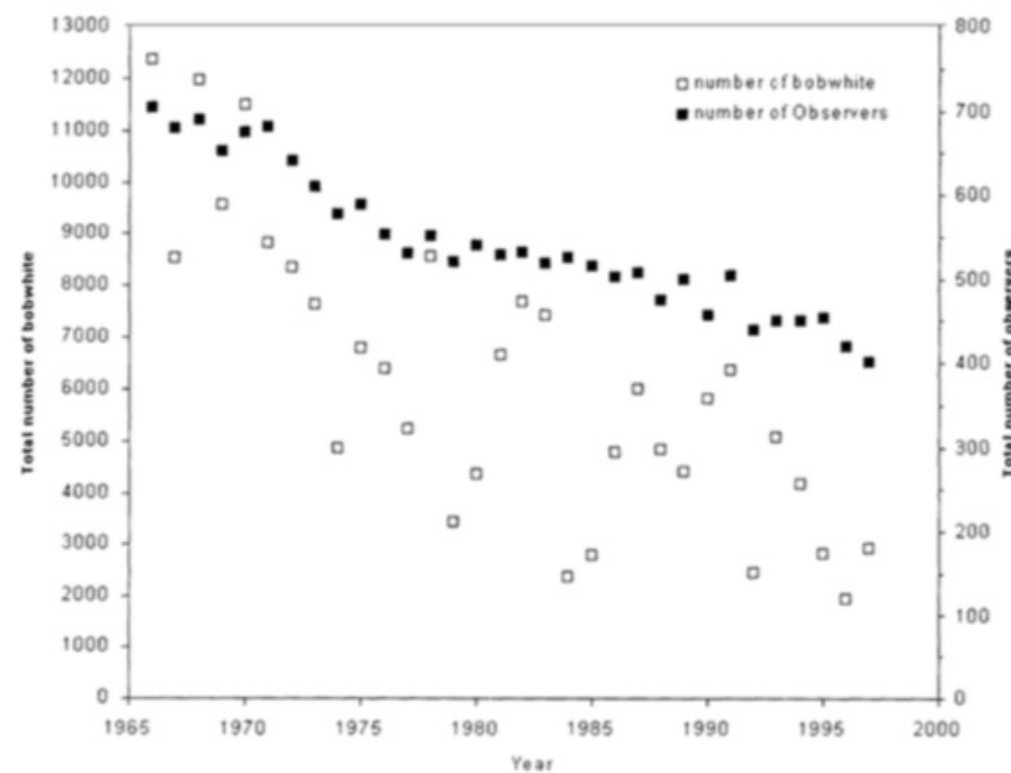Figure 1. Yearly trends in statewide total count of northern bobwhites (Colinus virginianus) and the total number of participating observers in the Kansas Rural Mail Carrier Survey, 1966–1997.

Indices

Problems

1) What if the relationship between N and C is not linear?

2) What if the observation process changes?

Without standardized survey protocols, it is impossible to distinguish between changes in abundance and changes in the observation process

Estimates

Estimates

Estimates attempt to correct for sample area and imperfect detection to estimate N from C

$$\hat{N} = \frac{C}{P_{area}\hat{P}_d}$$

P_{area} is the proportion of the study area sampled by our surveys

$\hat{P}_d$ is the estimated [4] probability that an individual that is present in the population is detected by our surveys

Q2: Is $\hat{P}_d = 1$?

Census

If $\hat{P}_d = 1$, we detect every individual in our sampling area

When counts are equal to the true number of individuals, this is referred to as a **census**

Census

Excercise

1) Divide into groups of (about) 3

2) Remove all of the beans from the cup and count

3) Record how many beans are in the cup (N)

4) Return all of the beans to the cup

Complete vs. sample plot census

Complete census

> count of every individual in the population (usually not possible)
>
> C = N

Sample plot census

> count of individuals within sample plot(s)

Sample plot census

$$\hat{N} = \frac{C}{P_{area}}$$

Sample plot census

$$\hat{N} = \frac{C}{P_{area}}$$

Example

- $C = 23$
- $P_{area} = 0.1$

Sample plot census

$$\hat{N} = \frac{C}{P_{area}}$$

Example

- $C = 23$
- $P_{area} = 0.1$
- $\hat{N} = 23/0.1 = 230$

Sample plot census

Exercise

1) Divide back into your groups

2) Place your empty cup on the scale and press 'Tare'

3) Remove a portion of the beans from the first cup and place them in the empty cup; record the weight

4) Count and record the number of beans you removed

5) Estimate $\hat{N}$ using: [1]

$$\hat{N} = \frac{number\ of\ beans\ removed}{weight/100}$$

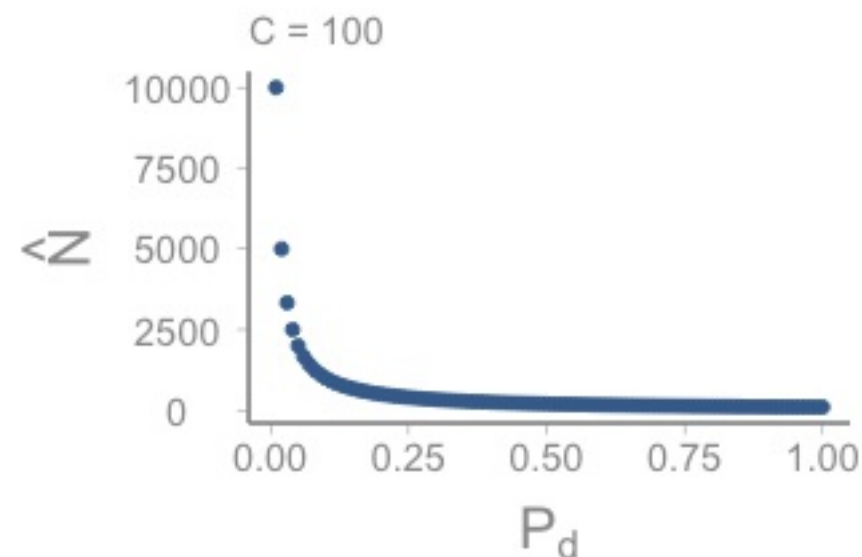6) Leave the beans in their current cups

Imperfect detection

Imperfect detection

Usually, $\hat{P}_d < 1$ (even for plants!)

Need to estimate $\hat{P}_d$, the probability of detecting an individual that is present in the populations

Many methods for doing so [5]

Q3: Capture or count?

Capture or count?

The major divide in the methods to estimate $\hat{P}_d$ is whether you are dealing with individually identifiable individuals or not.

Mark-recapture

- Individual ID known (physical or natural marks)
- Harder to collect
- (often) requires physical handling
- More information

Counts

- Individual ID not known
- Easy to collect
- Minimally invasive
- Less information

Capture-mark-recapture (CMR)

CMR includes a wide variety of related techniques and models

Traditionally, CMR referred to methods of capturing, marking, and then recapturing individuals at some point in the future

This results in a **capture-history** for each individual [6]:

Individual 1: 101101

Individual 2: 011001

Capture-mark-recapture

From capture-histories, we can estimate:

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability
- survival

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability
- survival
- movement

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability
- survival
- movement
- recruitment

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability
- survival
- movement
- recruitment
- individual growth

Capture-mark-recapture

From capture-histories, we can estimate:

- abundance
- detection probability
- survival
- movement
- recruitment
- individual growth
- populations trends

Capture-mark-recapture

CMR methods are not restricted to physical captures and recaptures [7]

Capture-mark-recapture

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Capture-mark-recapture

CMR methods are not restricted to physical captures and recaptures [9]

Capture-mark-recapture

CMR methods are not restricted to physical captures and recaptures [10]

Capture-mark-recapture

CMR methods are not restricted to physical captures and recaptures

What ties all of these methods together is that we have individual-level capture-histories

Capture-mark-recapture

Exercise

1) Divide into groups your groups

2) Record how many beans you removed in the previoius exercise (call this n_1)

3) Count the same number of black-eyed peas and put them back in the original cup (these are your marked individuals)

4) Cover and shake/stir the cup

Lincoln-Peterson (LP) model

LP is one of the first and most basic **closed** CMR models

Closed population models:

> the number of individuals in the population does not change between sampling
> occasions. No births, no deaths, no movement in or out

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> Key questions for determining whether population is closed:

- When are the birth pulses? Do they happen a specific time of year (colonial birds) or continuously (humans)

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- How often do individuals die? Rarely (elephants) or commonly (insects)
- How often do individuals move in/out of the population? Territories (breeding birds) vs. roaming (migrating elk)

Lincoln-Peterson model

Basic logic

On the first occasion, we capture n_1 individuals

Lincoln-Peterson model

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What proportion of the total number of individuals is n_1?

$$p = \frac{n_1}{N}$$

Lincoln-Peterson model

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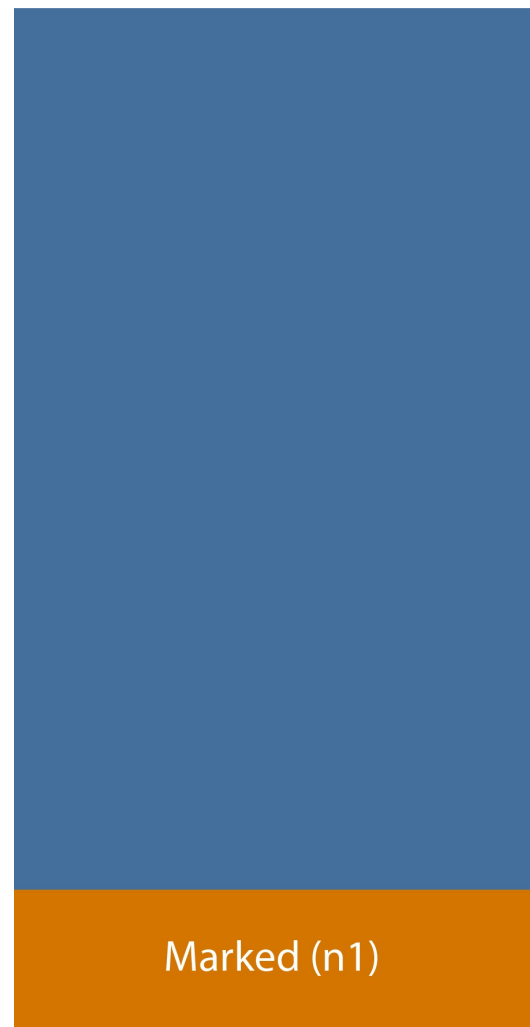
If we knew p, we could estimate N as $\dfrac{n_1}{p}$

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Example

If p is 35% and $N = 100$, n_1 should be approximatley 35 individuals.

Lincoln-Peterson model

Basic logic

Lincoln-Peterson model

Basic logic

On the first occasion, we capture n_1 individuals

Lincoln-Peterson model

Basic logic

On the first occasion, we capture n_1 individuals

On the second occasion, we capture n_2 individuals

Lincoln-Peterson model
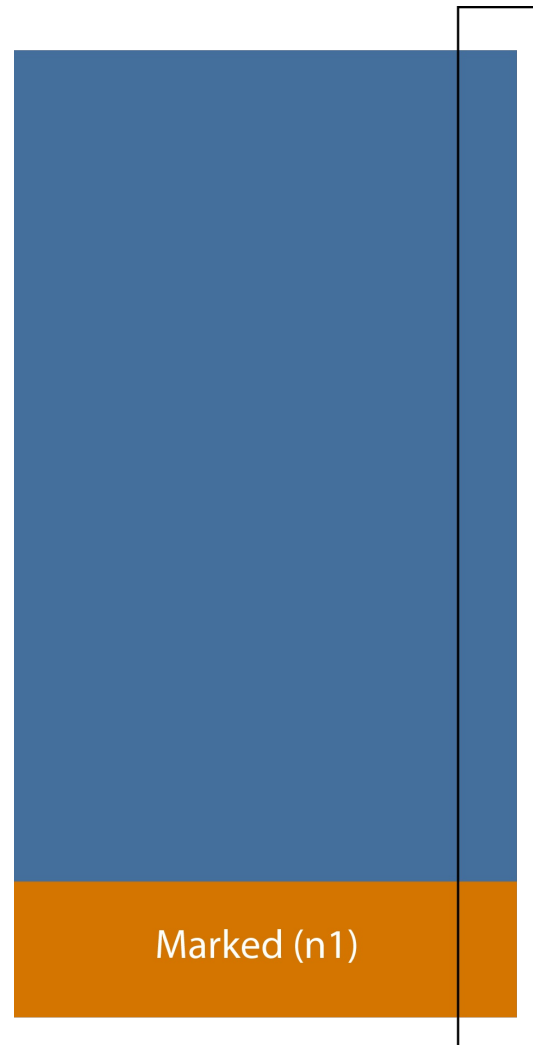
Basic logic

On the first occasion, we capture n_1 individuals

On the second occasion, we capture n_2 individuals

- m_2 of those individuals were captured and marked on the first occasion

Lincoln-Peterson model

Basic logic

Population (N)

Lincoln-Peterson model

Basic logic

Lincoln & Peterson realized that:

$$\frac{m_2}{n_2} = \frac{n_1}{N}$$

Lincoln-Peterson model

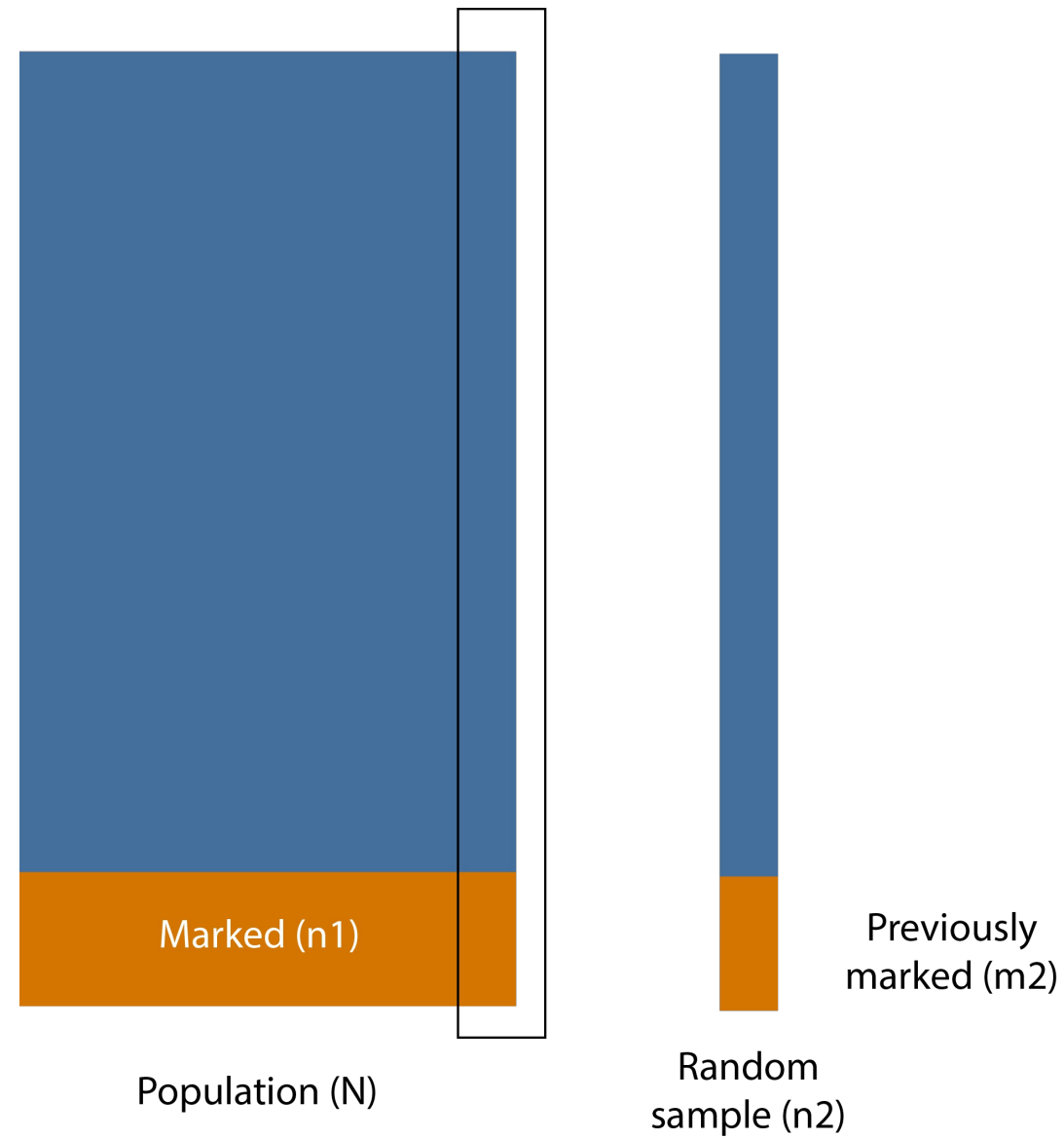**Basic logic**

Lincoln & Peterson realized that:

$$\frac{m_2}{n_2} = \frac{n_1}{N}$$

We can rearrange that to solve for N:

$$N = \frac{n_1 n_2}{m_2}$$

Lincoln-Peterson model

Basic logic

Marked (n1)

Population (N)

Previously marked (m2)

Random sample (n2)

Lincoln-Peterson model

Exercise

1) Take a second handful of beans from the cup

2) Count and record the total number of beans (this is n_2)

3) Count and record the number of black-eyed peas in the sample (this is m_2)

4) Estimate $\hat{N}$ using the formula above [12]

Uncertainty

Lincoln-Peterson model

It is very unlikely that $\hat{N} = N$

But, with large sample sizes, LP is **unbiased** [13]:

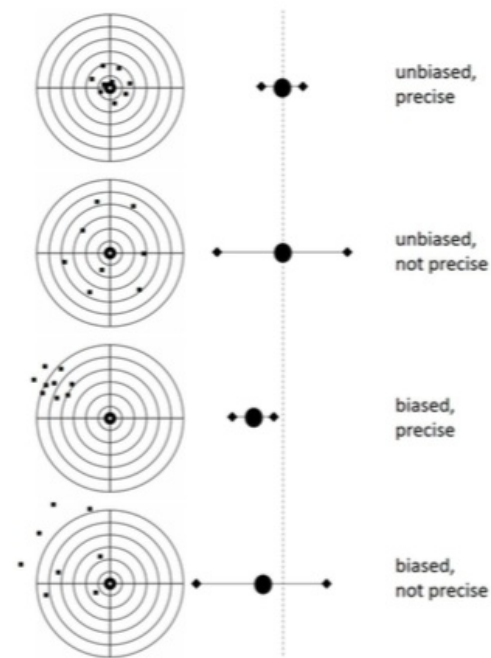> **on average** $\hat{N}$ will be equal to N

Figure 2.5: Illustrations of the concepts of bias and precision with shot patterns (left) (bull's-eye is truth; after White et al. 1982 and Williams et al. 2002) and 95% confidence intervals (right) (dotted line shows true parameter value, circle shows parameter estimate). The typical goal of an archer and an ecologist is shown at top as the combination of a lack of bias and high precision.

Lincoln-Peterson

For any given estimate, $\hat{N}$ will not exactly equal N

The difference between N and $\hat{N}$ occurs because we have to **sample** the true population

In any given sample, we might get a few more marked indviduals than expected, or a few less (flipping a coin)
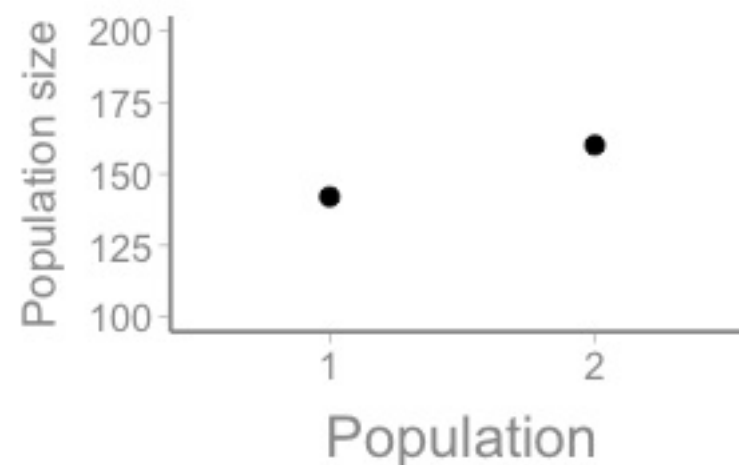
Measuring uncertainty

All estimated parameters require information about how certain we are in our estimate

We **cannot** make inferences about population parameters without providing information to interpret how confident we are in those estimates!

Example

We do a CMR study of two populations and estimate $\hat{N}_1 = 142$ and $\hat{N}_2 = 160$

Is $N_1 < N_2$?

Measuring uncertainty

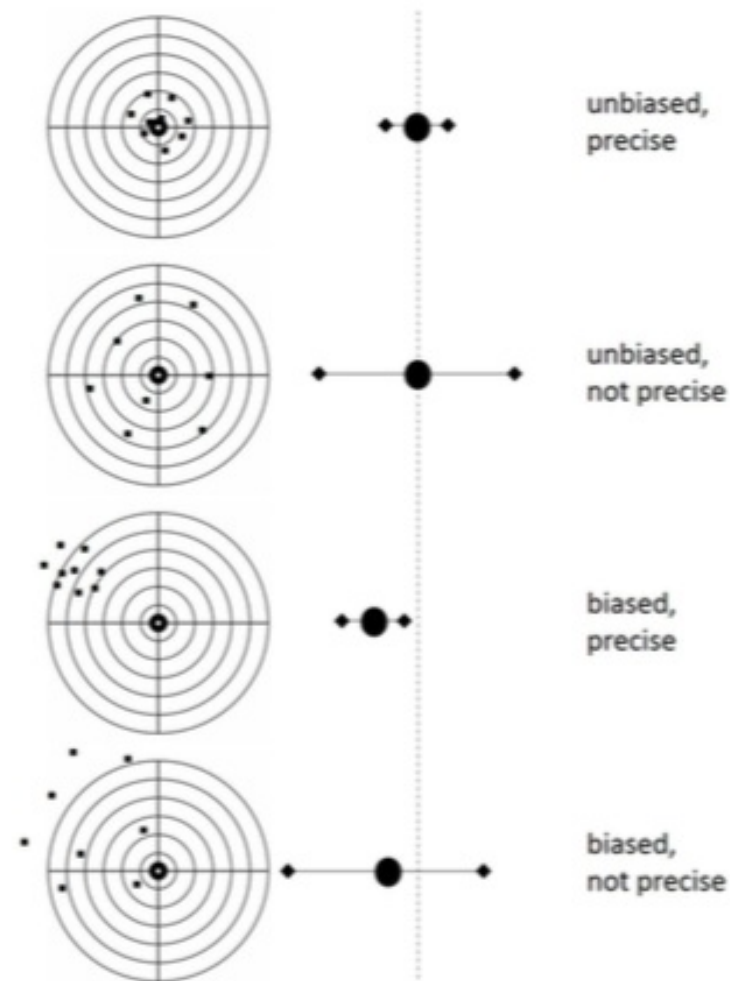Uncertainty measures on average how far off our estimate is from the true value

Figure 2.5: *Illustrations of the concepts of bias and precision with shot patterns (left) (bull's-eye is truth; after White et al. 1982 and Williams et al. 2002) and 95% confidence intervals (right) (dotted line shows true parameter value, circle shows parameter estimate). The typical goal of an archer and an ecologist is shown at top as the combination of a lack of bias and high precision.*

Measuring uncertainty

Uncertainty measures on average how far off our estimate is from the true value

We measure spread as the **variance** of the samples [14]

We don't know the true value but statisticians have developed ways to approximate how far we are from the true value using only our data

Uncertainty of Lincoln-Peterson estimator

Variance of the LP estimator can be calculated as:

$$var(\hat{N}) = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2(m_2 + 2)}$$
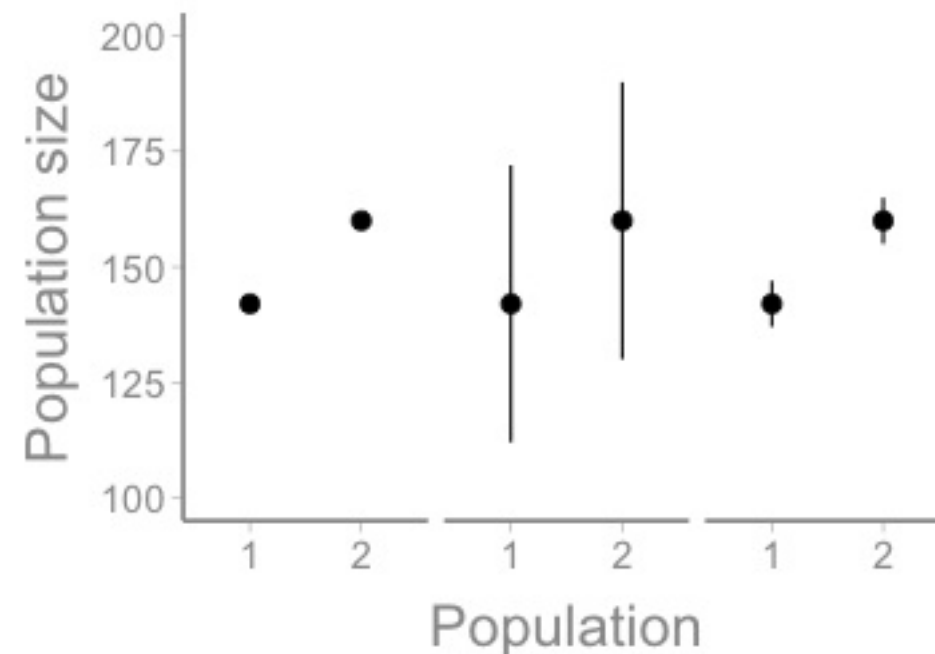
Assumptions of Lincoln-Peterson

All models have assumptions

Just as it's important to report variance, it's important to know the assumptions of our model and to make those assumptions clear

If we violate the assumptions, we can get the wrong answer!

Assumptions of Lincoln-Peterson

The assumptions of LP are:

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The assumptions of LP are:

1) the population is closed between samples

2) the marking of an animal does not effect p

3) marks are not lost between capture occasions

4) each sample of the population is a random sample of the population

What effects would violating these assumptions have on estimates of N?

Assumptions of Lincoln-Peterson

1) The population is closed between samples

- Violation of the assumption means that N either decreases (animals die/leave) or increases (animals are born/enter) between samples

- Can bias $\hat{N}$ high or low

- Address by sampling over a short period

Assumptions of Lincoln-Peterson

2) The marking of an animal does not effect p

- What happens if animals that are trapped on occasion one are less likely to be trapped later because they figure out that trapping is unpleasant?

$$\frac{m_2}{n_2} < \frac{n_1}{N}$$

- $\hat{N}$ will be too high

- Addressed by using less invasive trapping methods or through more advanced statistical methods

Assumptions of Lincoln-Peterson

3) Marks are not lost between capture occasions

- If marks are lost, individuals that should be in m_2 will be recorded as unmarked

- m_2 will be too low and $\hat{N}$ will be too high

- Addressed by double marking or looking for physical evidence of tag loss

Assumptions of Lincoln-Peterson

4) Each sample of the population is a random sample of the population

- What happens if our sampling only detects $\frac{1}{2}$ of the population? What happens if we only sample is really good habitat?

- Addressed by random sampling