Analysis of Environmental Data

Data, Sampling, and Intro to Frequentism

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What's In This Deck?

Slides	Key Take-Home Concepts
• All about data • Samples/Populations • Intro to Frequentism	• Data: measurement and scales. • What is the Frequentist paradigm? • Frequentist interpretation of populations and samples • Null and alternative hypotheses • Frequentism may challenge your intuition.

- The course and assignment websites are complicated
  - I’ve done my best to logically organize materials.
  - This is a hard class and there are a lot of materials!
  - Assignments are meant to be as incremental and self-guiding as possible.
  - I’ve tried to make the conceptual leaps you have to make are incremental and reasonable.
  - If you feel that there was not enough info in the intros/walkthroughs, please let me know sooner rather than later.
  - Let’s make sure you haven’t missed part of the instructions/walkthroughs or that I have left out important info!
  - I want to make sure everybody knows how to navigate the tab system on the website; please check out the Echo360 video (it’s brief).
  - If after a reasonable amount of time you are still confused… reach out!

- Evening and weekend availability
  - I try to respond as quickly as I can, however it’s not always as quickly as I would like.
  - On evenings and weekends, I try to monitor email, but I’m won’t always be near my phone and/or computer.
  - If you request an extension from Friday evening to Sunday, I may not be able respond before it’s due, but I’ll grant the extension when I have a chance.
  - First few weeks of the semester are always a flurry: I am to decrease my response time.
  - If I don’t respond, I may have lost track ofyour email. Please don’t be shy about re-emailing.

Announcements: Office Hours

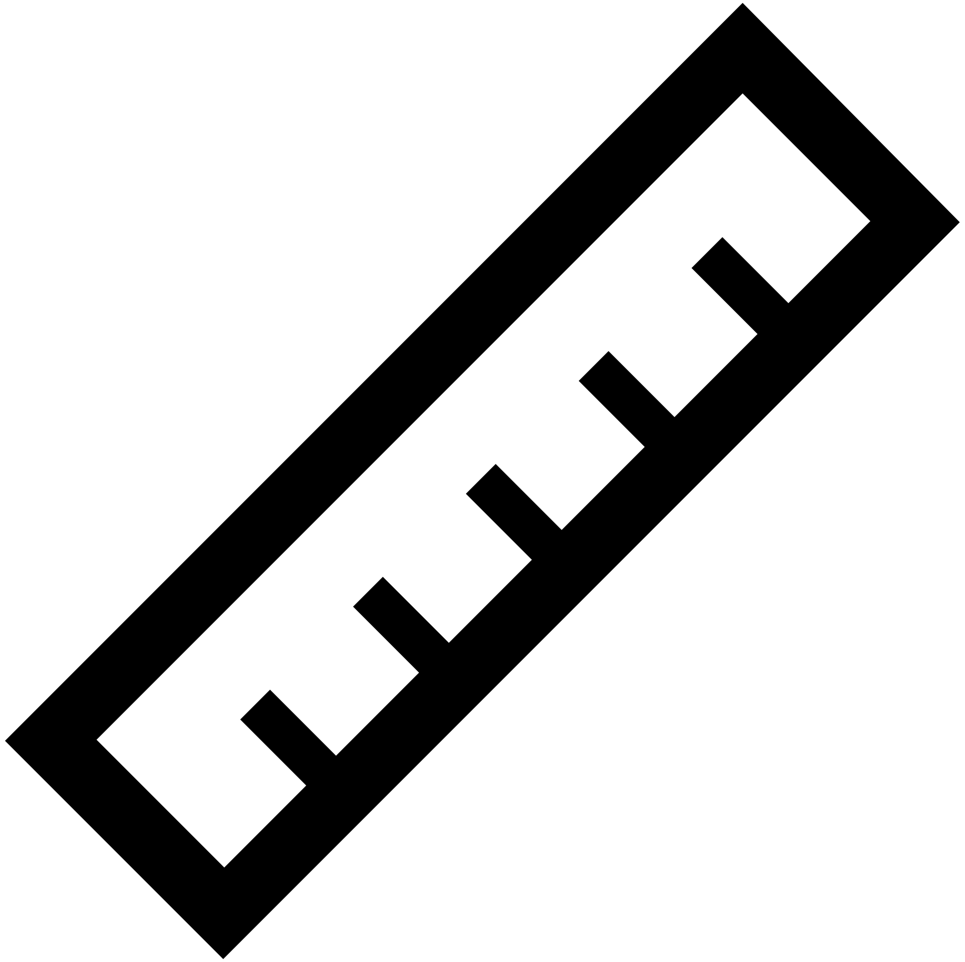
- My regular hours are Tuesday 1 – 2 in my office (room 311)
- Ana's regular hours are Monday noon – 1:30 (in the library)
- Ana will be adding more hours, watch for an announcement and check Moodle.

Data and Measurement

Scale

How do we measure data?

- What do we mean by *scale*?
- Measurement scale terms:
    - Discrete, continuous
    - Numeric, categorical
    - ratio, interval



Scale

The word *scale* has a lot of meanings… In our context *measurement scale* or *data scale* refers to:

- A measurement scheme that answers questions like
  - Is it numerical?
    - Can it have negative numbers?
    - Can can it contain fractions?
    - Is there a *true zero*?
  - Is it categorical?
    - Is there a meaningful ordering of the categories?

Scale

A measurement scale is what we use to *quantify* a variable, i.e. an *attribute* of a sampling unit.

The choice of scale may be context-dependent:

- Does it reflect an intrinsic property of a variable?
- Does it reflect an intrinsic property of how we choose to measure it?

For example: age measured in years vs. age measured in age class.

Numeric or Categorical

Is our variable *quantitative* or *qualitative*?

Numeric measurement scales: our variable is measured as a numeric quantity.

Qualitative: our variable can be classified into a *category*.

Does our *qualitative* variable have a sensible *order*?

- Categories that have a meaningful order are called *ordinal*
  - There may be an order, but the inter-category intervals cannot be directly compared.
- If there is not an intrinsic order they are *nominal*.

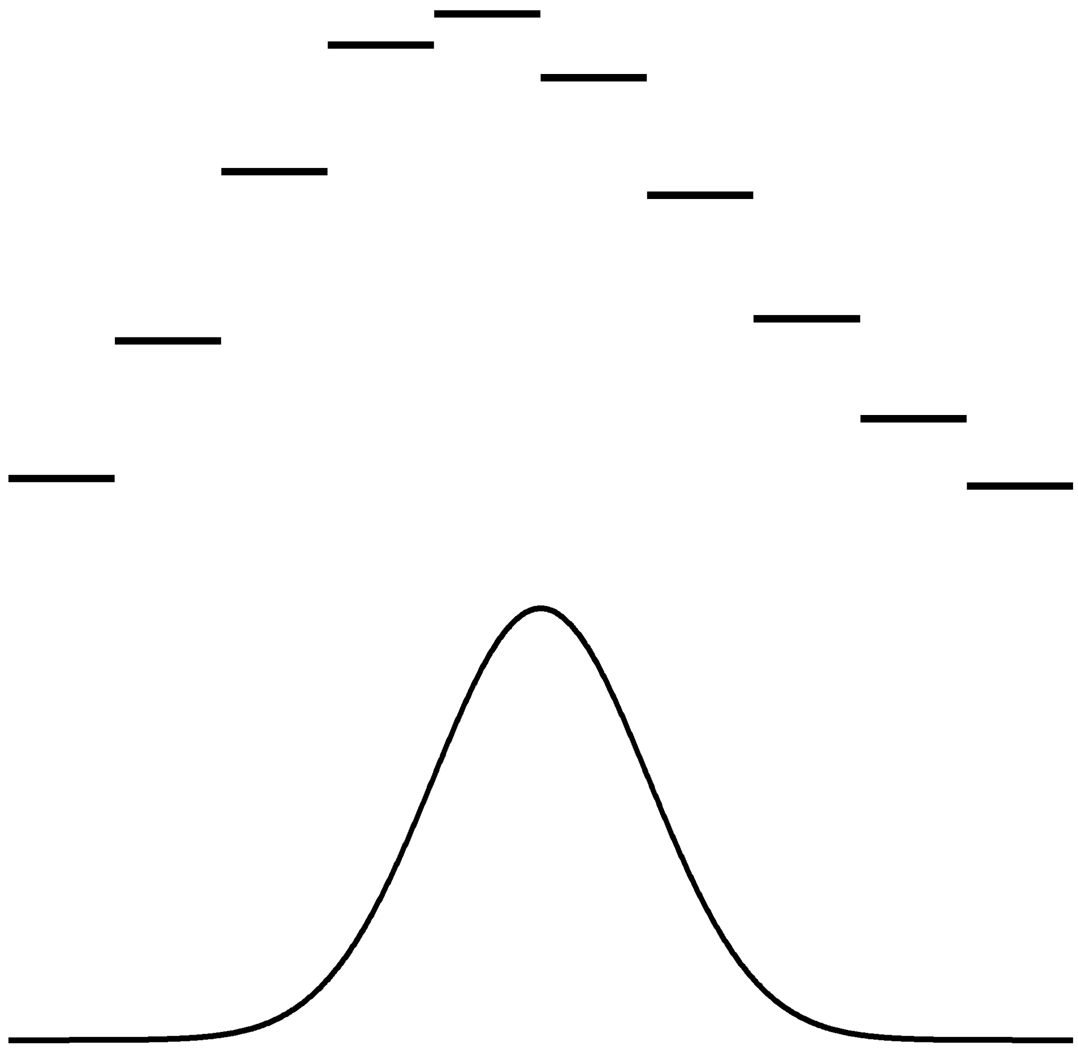
Numeric Scales: Discrete and Continuous

Discrete cannot take on intermediate values

- Counts, presence/absence, etc

Continuous variables can *in principle* take on any intermediate value:

- They are *real* or *rational* numbers.
- Our ability to measure may not capture intermediate values, but they are still continuous.



Interval and Ratio scales

Is there a *true zero*?

- Degrees in Kelvin: *absolute zero* is the absence of movement of particles.
  - You can't go lower than *absolute zero*.
- Degrees in Celsius: zero is centered around the freezing point of water.
  - Negative values are possible.

Interval scales can have negative numbers

Ratio scales are non negative

Circular Scales

Circular scales wrap a maximum value back to zero

- Circular scales are not as common, but they occur when thinking about angles.
- Examples include wind direction and aspect
  - Both are measured in degrees (or radians).

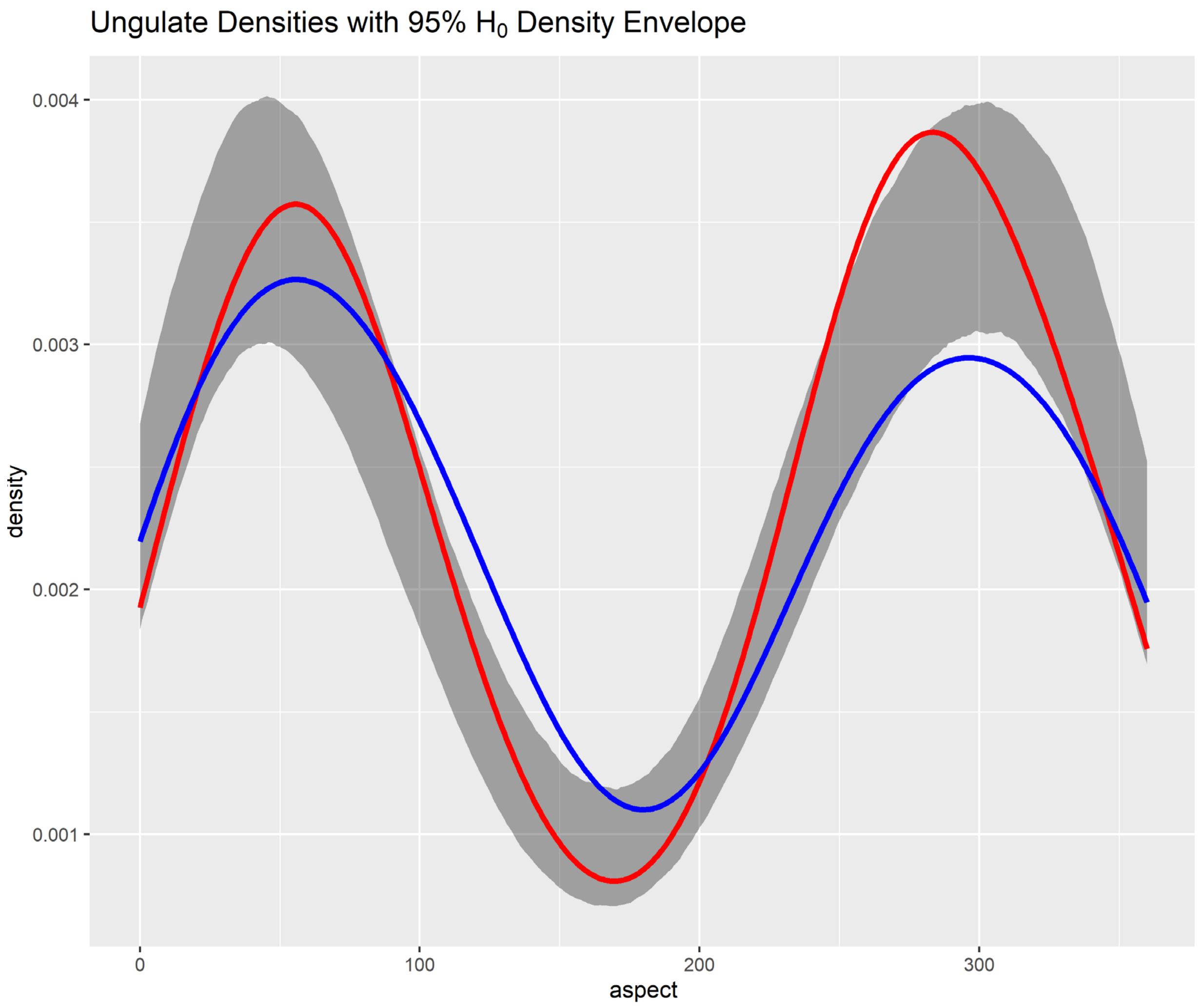
Modulo operator

- The wrapping behavior of circular scales is just like addition in *modular algebra*.

Circular Scale: Aspect

Circular scales work well for things like days of year, direction, etc.

An example of circular data in practice: the aspect of ungulate herd location observations in mountainous terrain:



Converting Among Scales

Sometimes it's convenient, or necessary, to convert a variable to a different scale.

For example: consider count data that consist of mostly 0 and 1, with only a few values greater than 1.

- It might be useful to convert this to binary data, i.e. presence/absence.

Aggregating into categories

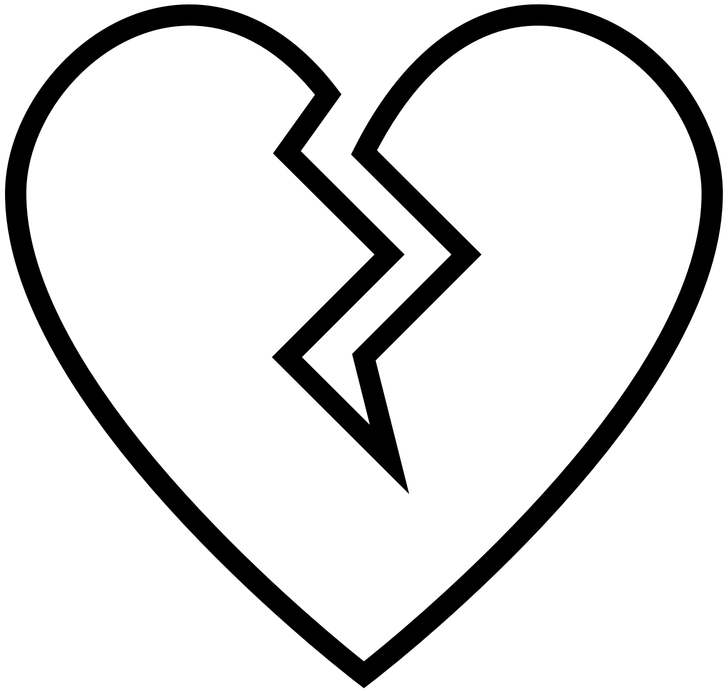
- Age, size, weight classes
- These convert numeric into ordinal scales.

Converting Among Scales

Some conversions are *destructive*: you lose information in the conversion process.

Aggregating numeric scales into categories.

- e.g. converting absolute ages into age classes:
  - If you know the age, you can assign to an age class.
  - If you know only the age class, you can't make the reverse transformation.



🎹 🎶Baby, don't break my data! 🎶🎹

Data Scales and Statistical Models

Most of the time we build models using numbers, on either discrete (integers) or continuous scales.

Theoretical (parametric) distributions as models

- Remember that we fit models to data, not the other way around.
- Sometimes theoretical distributions are only *approximately* good models for our data.
  - For example: the Normal distribution often fits data, such as weights, very well, but its sample space includes negative numbers.
  - Some discrete distributions that are useful for count data allow for unrealistically large observations.

The Row Data Paradigm

Storing your data in a Row Data format will simplify your life! Most of the datasets we work with can be written in a 2-dimenaional table.	
Rows	**Columns**
• Rows are observations • Rows are samples • Rows are sampling units (sometimes) • A row is a collection of observations on a single entity. • Rows are	• Columns represent attributes • Columns are variables • Columns are properties • Columns are fields

Row Data Paradigm – What is it?

A Toy Example

Species	Time	Moods	Body Mass	Ambient temperatu re
Crow	13:05	Sassy	413	25
Raven	10:01	Serious	980	-25
Snowy Owl	01:47	Hungry	2101	NA
Snapping Turtle	13:45	Angry	30000	15

Why should I use it?

- Corresponds to common and convenient data structures in R and other programs.
- Data type/scale is consistent within a column.
- It's easy to look up an attribute (in a column) for an individual (a row).
- Non row formatted data will cause lots of data import headaches!

Sample and Population

Prelude to Frequentist Thinking

Concepts and Learning Objectives

- Key differences between population and sample
- Parameters and statistics
- Description and inference
- Statistical and ecological populations
- Sampling units

Populations and samples

Populations are large

- We [typically] **cannot observe all** individuals in a population
  - This is a cornerstone of Frequentist thinking
- We have to make informed guesses about the population from *samples*

Samples are a subset of a population

- We **can observe all** sampling units in a sample
- We can completely characterize the properties of a sample

We use the sample to make informed guesses about the population

- This is the heart of inferential statistics.

Populations, samples, parameters, and statistics

Population/sample and parameter/statistic are *parallel* concepts

- **Populations** have ***parameters***, intrinsic characteristics of the entire population.
    - We can't calculate population parameters directly.
- We can calculate ***statistics*** from **samples**.

We use statistics to infer information about population parameters

- This is the basis for *inferential statistics*.

Samples, Sampling Units, and Variables

- A sample is a **group of observations** taken from a larger *population*.
- A sampling unit (SU) is the unit/entity/thing of interest for the research question.
- A variable is an attribute of the SU

Populations, Samples, Sampling Units, and Variables

All of these concepts form a *nested* structure:

- A statistical population is [usually] a subset of an ecological population
- A sample is a subset of a statistical population
- One sampling unit is a subset of a sample
- A Variable is a quantity measured on a single sampling unit

Statistical and ecological populations

We'll use Bullheads to illustrate the differences.

Brown Bullhead illustration by Duane Raver (USFWS)

What is an ecological, or biological, population?

The collection of all possible sampling units.

- The scale of the research question may or may not encompass the entire ecological population.
- A *statistical population* is usually a subset of the *ecological population*.
- A ecological population does not generally vary based on the scope of a research question.

The bullhead ecological population

- All individual fishes across the entire species range

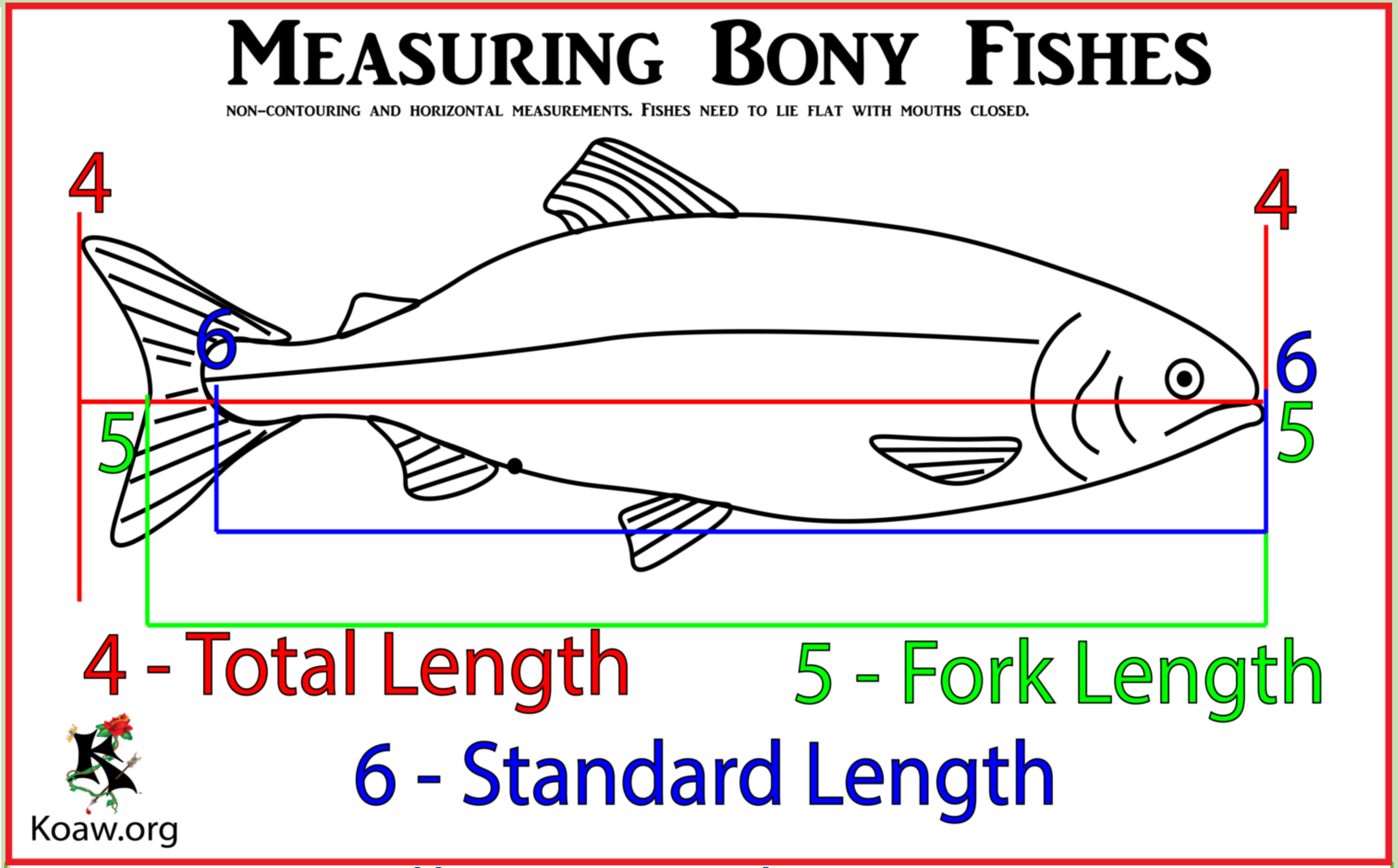
What is a statistical population?

The statistical population depends on the scope of the *research question*

- Suppose we were studying bullhead in a single lake:
    - ecological population: entire species range
    - statistical population: the lake
- What about bullhead in Massachusetts?
    - ecological population: entire species range
    - statistical population: all bullhead within MA
- Note that the ecological population did not change.

Bullhead sampling units and variables

- **Which bullhead attributes might we want to measure or observe?**



https://www.koaw.org/measuring-fishes

Bullhead sampling units and variables

Both the sampling unit and variables are context-dependent

- Suppose we were studying bullhead in a single lake:
  - sampling unit could be individual fishes
  - variable might be total length
- Suppose we wanted to compare average bullhead size in multiple lakes
  - The sampling unit might be *individual fishes* or *individual lakes*
  - The choice of SU would depend on our question

Sampling units are context dependent: McGarigal testimonies

Some interrelated questions to ask yourself for each testimony:

- What are the spatial and temporal scales?
- What is the statistical population?
- What are the sampling units?

Testimony 1: Spatio-temporal scales

- Temporal scale:
  - Observations were taken yearly for 10 years.
- Geographic scale:
  - A single mountaintop in the White Mountains National Forest

Testimony 1: Variables

Which quantities were measured?

1. year
2. ‘upper elevational distribution’

- This is vague in the text…
  - Is it the elevation of the highest observed nest?
  - Is it an average elevation of all nests of a set of high elevation species?

Testimony 1: Populations and sampling units

Populations

- Statistical: Collection of nesting sites on one peak
- Ecological: All possible nesting sites of the bird species considered.

Sampling units

- The SU appears to be individual nesting sites.
    - But recall the ambiguity from the previous slide

Testimony 3: Scales

- Temporal scale:
  - Observations were taken yearly for 10 years.
- Geographic scale:
  - Entire White Mountains National Forest
- Same variables as before: year, ‘upper elevational distribution’

Testimony 3: Populations and sampling units

Populations

- Statistical population: Collection of nesting sites on all peaks in the White Mountains
- Ecological population: All possible nesting sites of the bird species considered.

Sampling units

- Appears to be individual nesting sites.
  - But recall the ambiguity from testimony 1
- The SU could also be individual mountain tops within the White Mountains in this testimony

Recap

- Key differences between population and sample
- Parameters and statistics
- Description and inference
- Statistical and ecological populations
- Sampling units

For Thursday

- ➢Start Deck 3
- ➢In-Class R: read the assignment description before class
- ➢There are 4 assignments due on the 12th, be sure to ask your questions ASAP!
  - Week 2 reading questions
  - Software Setup
  - Using Rnotebooks
  - Data Camp: Intro to R

In-Class R

- Let’s finish last Thursday’s activity!

Intro to Frequentist Thinking

Concepts and Learning Objectives

- Brief introduction to Frequentism
- Frequentist interpretation of populations and samples
- Null and alternative hypotheses
- Frequentism will challenge your intuition

What is Frequentism?

Inferential framework

- Most widely used framework.
  - It has many pros and cons
- Requires assumptions.
  - They are often reasonable, but sometimes not
- Many tools are robust to violations of assumptions
- Powerful theoretical basis and sophisticated analytical tools
- Frequentism focuses on the modeling *process*, not the outcomes of a particular experiment

Other frameworks exist… We'll only briefly discuss them in this course.

Frequentism essentials

Key Frequentist assumptions include

- Population exists, is infinite.
- Population parameters are true, but unknowable quantities.
- When we specify a model, there exist **true** model parameters (but they are unknowable).

Frequentism is based upon hypothetical infinite resampling

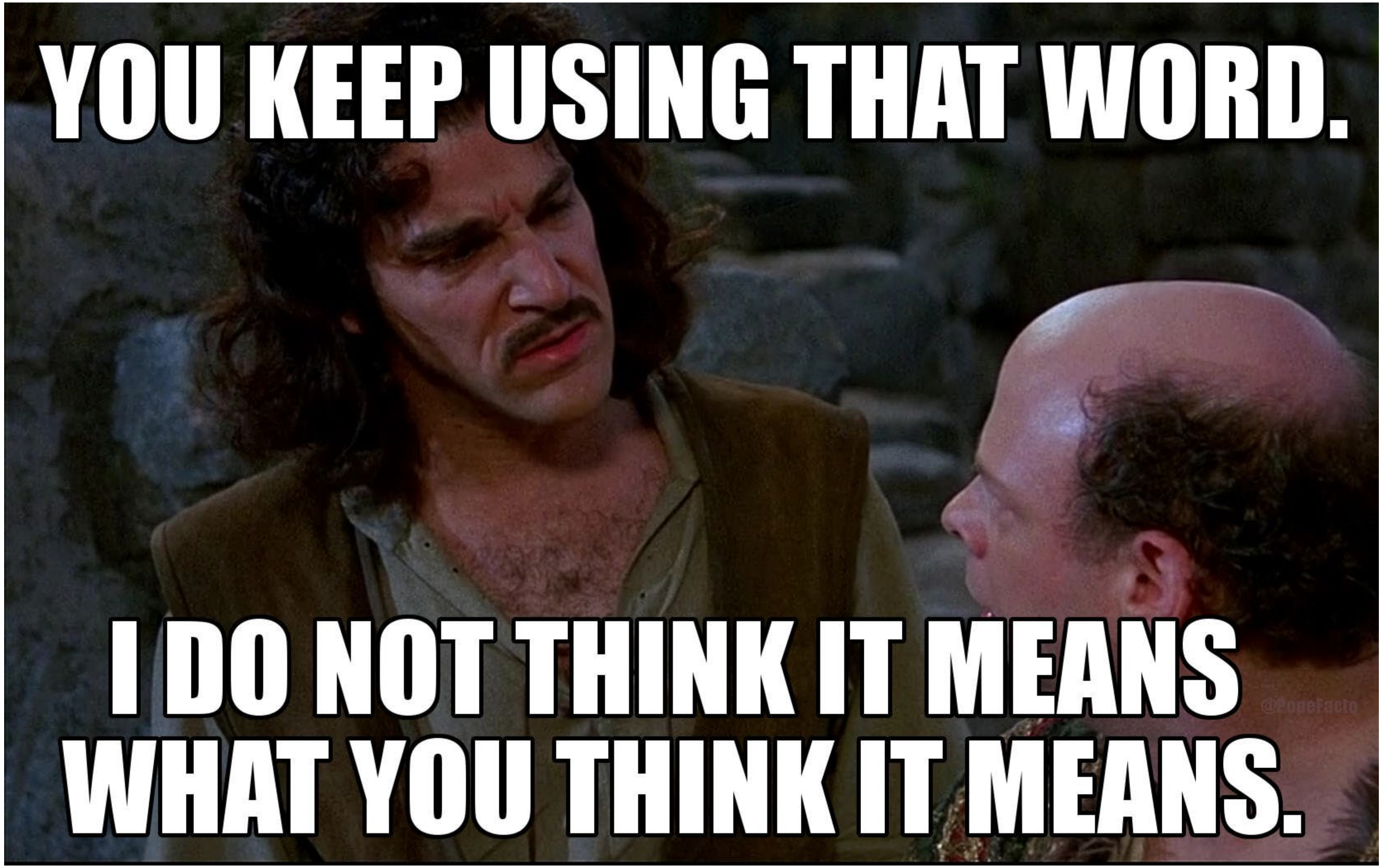
- Frequentist assumptions are often **asymptotically** true.
- Source of misconceptions about terminology

Hypothesis testing: H_0 **and** H_a

Null and Alternative models

- Hypothesis testing: allows for quantification of *confidence* and *significance*.

- 'Confidence' and 'significance' are tricky terms in statistics… They don't have the same meaning as in everyday language



bigmedium.com/ideas/mvp-does-not-mean-what-you-think-it-means.html

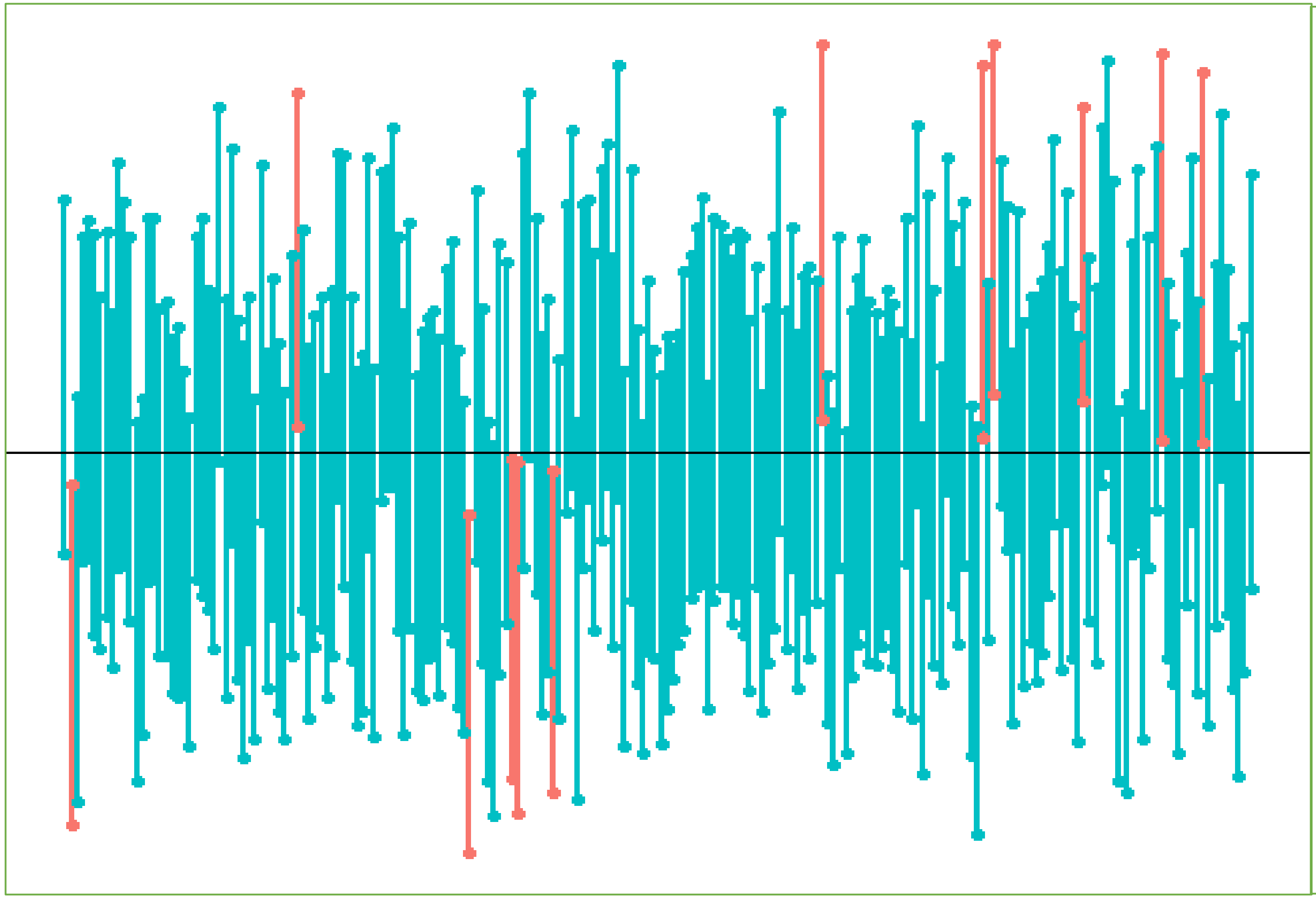
Note on terminology

Confidence* or *significance:

The Frequentist definition is a little hard to explain to non-statisticians, but we will get a chance to try!

What Confidence Interval Does Not Mean	What it actually means
"I'm are 95% sure my CI contains the true value." No: It either does or does not, but you can't know.	"If I were to repeat the experiment many times, approximately 95% of the CIs I construct would contain the true population parameter"

A set of 200 95% Confidence Intervals

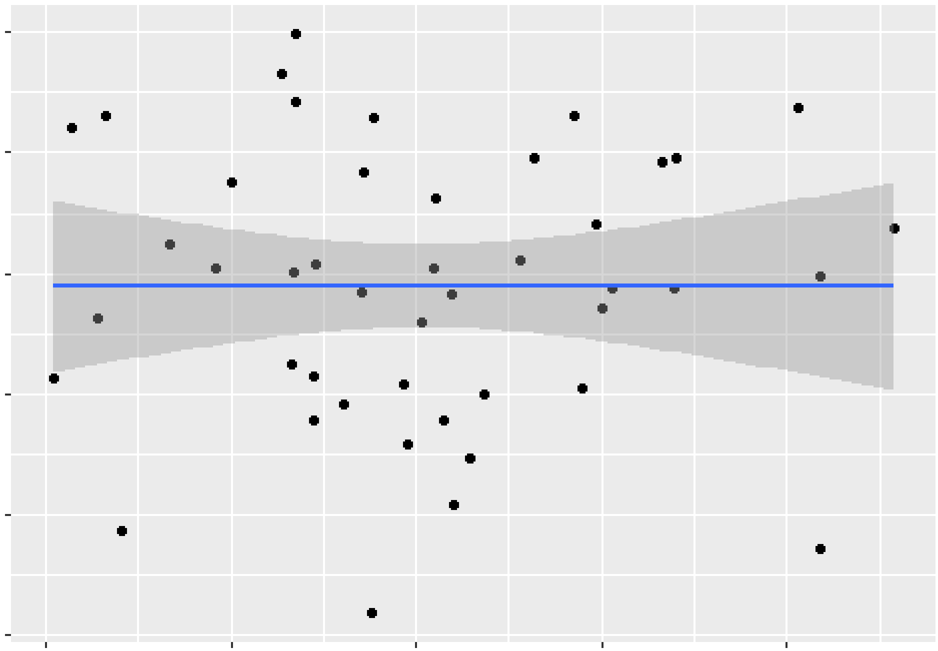


The red intervals do not contain the true value of the population mean

Frequentist Hypotheses

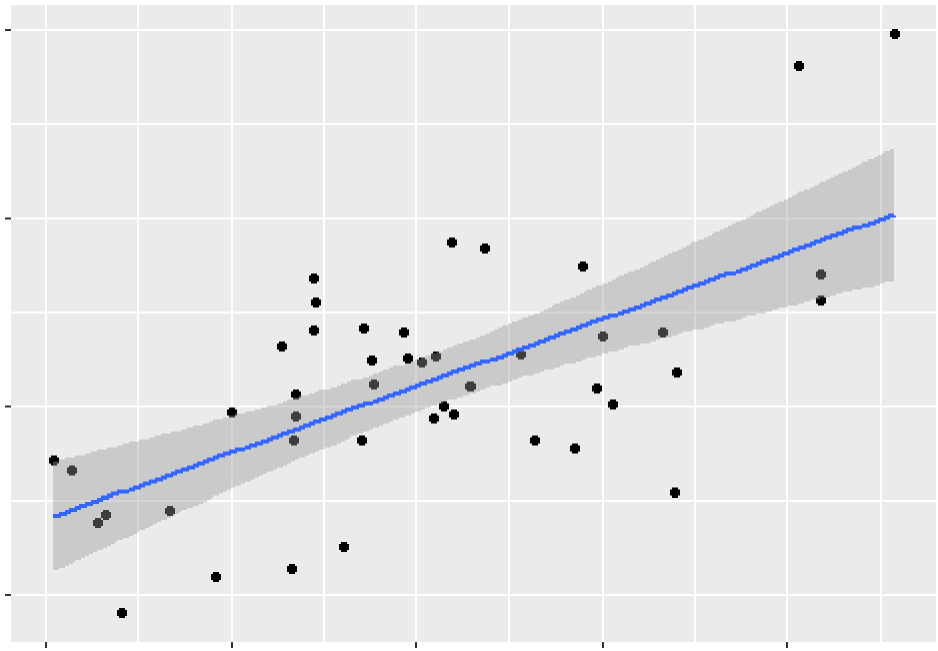
Null Model: This is what we should see if there is no relationship between x and y.

False Positives: Sometimes the Null is true, but by chance we observe a pattern like the plot on the right.



Alternative Model: This is what we want to observe if there is a relationship between x and y

False Negatives: Sometimes there is a true relationship, but by chance we observe a pattern like the plot on the left



Modeling in a Frequentist world

Frequentist modeling implements the Dual Model Paradigm

Focus is on modeling process

- A particular parameterization of a model is just one of infinitely many possible realization of a **stochastic process** process.
- Model realizations are our best guess about the **true** but **unknowable** model parameters.

Frequentist conceptual difficulties

Frequentist confidence is based on hypothetical infinite repeated sampling.

- Frequentist *confidence* and *significance* refer to repeating the process many times.

A particular sampling/modeling process may or may not be a good approximation of the real population.

- A particular CI either *does* or *does not* contain the true value. In the Frequentist world we can never know.

These concepts are difficult.

- One of the best ways to gain intuition is to explain to non-scientists.