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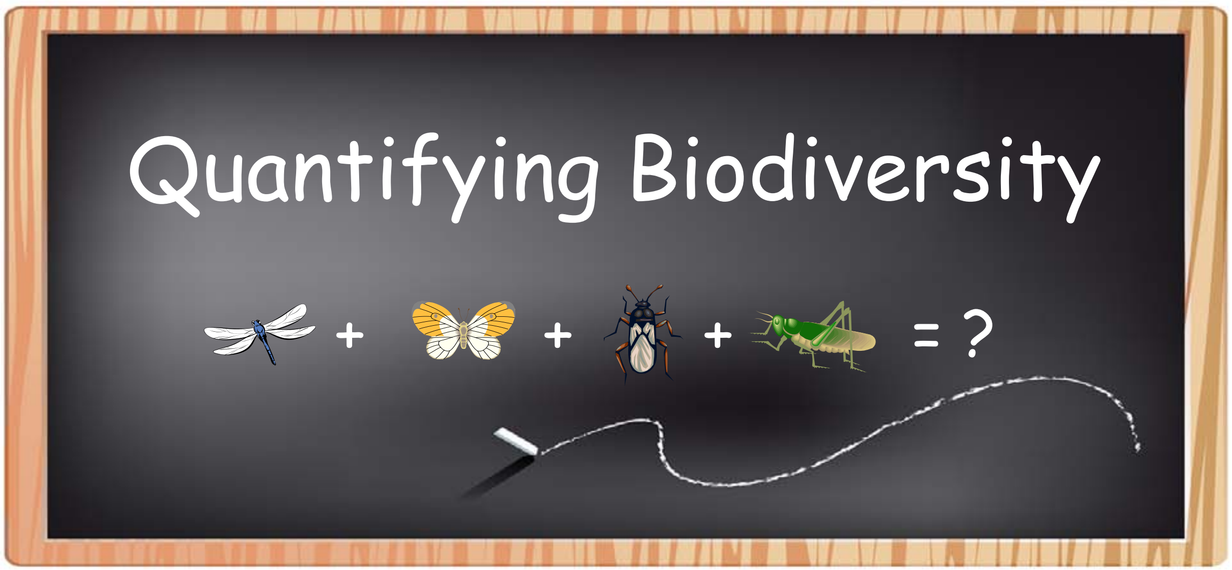
Biology Meets Math



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Goals:

1. Be able to define **biodiversity**
2. Be able to define **species richness** and **species evenness**
3. Be able to use the equation called **Simpson's Index of Biodiversity** to explain biodiversity in an area, and relate this index to probability

What does biodiversity mean to you

?

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What is **Biodiversity** to an Ecologist?

- Biodiversity is a **measure** of the different kinds of organisms in a region or other defined area.

- Biodiversity includes the **number of species** and the **distribution of individuals** among the species.

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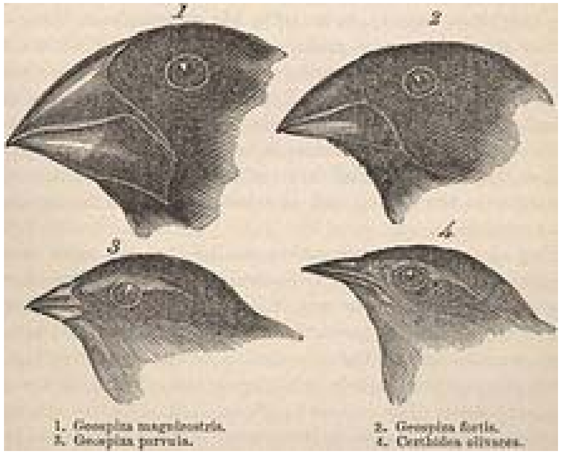
What is **Biodiversity** to an Ecologist?

- Biodiversity can also refer to species' range of ***adaptations***, which are traits that can be behavioral, physical, or physiological. These traits enhance an organism's fitness (ability to pass on its genes to another generation through reproduction)



Darwin's Finches

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Biodiversity

Biodiversity takes into account:

- Species richness: the number of species in a region or specified area

Species	Number of Individuals
E. Redbud	3
Black Oak	4
Post Oak	5
White Pine	3
Honey Locust	1

Biodiversity

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- Species richness: the number of species in a region or specified area

- Species evenness: the degree of equitability in the distribution of individuals among a group of species. Maximum evenness is the same number of individuals among all species.

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Species	Number of Individuals
E. Redbud	5
Black Oak	5
Post Oak	5
White Pine	5
Honey Locust	5

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Okay, Ecologists … Get ready for data!

An ecologist goes out into the field and collects information from two separate plots of the same size but with one big difference: Plot 1 is in the woods and Plot 2 is in a pasture. The ecologist is interested in the types of insects that are found in the plots and whether there is a difference between the two plots.

What will we find out?

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First! Make Your **Hypothesis**

- A hypothesis is an educated guess based on knowledge
- A hypothesis can be either accepted or rejected based on the collected data and data analysis
- Based on the hypothesis, predictions can be made about answers to biological questions.

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Examples of **Hypotheses**

There is water on Mars.

The global temperature of our planet has risen.

More people in this room like Justin Bieber than do not like him.

What would be a good hypothesis for our ecologist?

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Examples of **Hypotheses**

There is water on Mars. **True! Almost all of it is ice. Source: NASA**

The global temperature of our planet has risen. **True! Between 1906 and 2007, the global surface temperature has risen 0.74ºC [±.18]. Source: IPCC**

More people in this room like Justin Bieber than do not like him. **Test it out – what did you find?**

What would be a good hypothesis for our ecologist?

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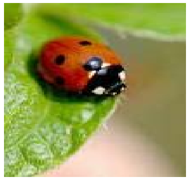
Field Data

Species	Plot 1 Woods	Plot 2 field
Centipedes	50	10
Millipedes	36	50
Butterflies	35	0
Lady bugs	55	39




Based on the data:

- Which plot has more species richness?
- Which plot has more species evenness?
- Which plot has more biodiversity?

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Answers:

- Plot 1, the woods, has more species richness. In plot 2, the pasture, there are no butterflies. Plot 1 has 4 species while Plot 2 only has 3 species present.
- Plot 1 also has more species evenness. There is close to the same number of individuals in each group.
- Therefore, plot 1 is more diverse than plot 2 because species richness is higher and the species are more evenly distributed

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What if your data looked like this?

Species	Plot 1 Woods	Plot 2 field
Centipedes	50	1
Millipedes	36	1
Butterflies	35	30
Lady bugs	55	39
Grasshoppers	0	40




What if your data were more complicated?

Species	Plot 1 Woods	Plot 2 field
Centipedes	50	1
Millipedes	36	1
Butterflies	35	30
Lady bugs	55	39
Grasshoppers	0	40

Maybe more evenness?

Maybe more richness?

Which one has more biodiversity now?




Edward Hugh Simpson's Idea

- Scientists needed a universally recognized method of comparison.
- In 1949, a British statistician came up with an idea he published in the journal *Nature*:

    In order to understand how diverse an area is we can do a math problem that shows us in terms of a **probability** how diverse the area is!

Plot 1!

Plot 2!

Let's Review Probability:

Probability is a way of expressing likelihood that an event will occur
For example: If I toss a coin how what is the probability of the coin landing on heads?

- Heads

- Tails

One side of the quarter is heads and the other side of the quarter is tails, so we can say you have a half or ½ or 0.5 or 50% chance of the quarter landing on the heads side. Another way you can say this is you are about 50% sure the quarter will land on the side with the head.

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Simpson's Index of Biodiversity

Simpson's Index is a way to express how diverse a sample is based on a probability. The probability can be explained as follows:

If you close your eyes and pick out an individual organism from a sample and then you repeat by closing your eyes and picking out another individual from your sample, what is the probability that the organisms will be different species?

If the probability is high, for example 0.8 then you have an 80% chance of picking out different species so you have high diversity in your sample.

Same or Different?

Simpson's Index of Biodiversity

$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$

Let's define the variables:

D= Simpsons Index of Diversity

Σ = summation

S= number of species

n_i= number of individuals within the i^{th} species

N= total number of individuals within the sample

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Sigma What?

- Let's say you wanted to sum up a series of numbers:

$$\text{species}_1 + \text{species}_2 + \text{species}_3 + \ldots + n_i + \ldots + n_S$$

- What mathematical notation would you use to make it easier to write that?

Sigma What?

- Let's say you wanted to sum up a series of numbers:

$$species_1 + species_2 + species_3 + \ldots + n_i + \ldots + n_S$$

- What mathematical notation would you use to make it easier to write that? Summation Notation

$$\sum_{i=1}^{S} n_i$$

- Read it: "the sum of n_i, from $i = 1$ to S, where S is the total number of species"

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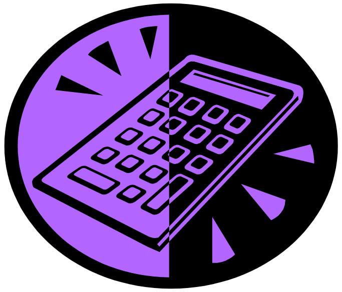
$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$



D= Simpsons Index of Diversity
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Species	Plot 1 Woods	Plot 2 field
Centipedes	50	10
Millipedes	36	50
Butterflies	35	0
Lady bugs	55	39

Let's calculate D for plot 1:
First do the numerator (top part):

*Use each observation to get count n, then multiply it by (n-1) and add those products together.

=(50(50-1)+36(36-1)+35(35-1)+55(55-1))

=50(49)+36(35)+35(34)+55(54)

=2450+1260+1190+2970

=7870

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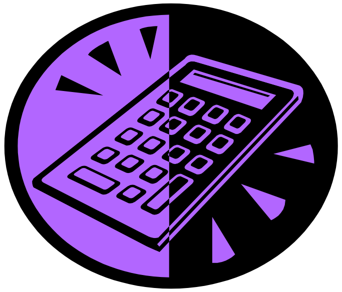
$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$



Next, let's calculate the denominator:
Remember N = total number of individuals counting all species in your plot.
In plot 1:

50+36+35+55=176=N

For the denominator we have to calculate:

N(N-1) = 176(175)=30,800

Species	Plot 1 Woods	Plot 2 field
Centipedes	50	10
Millipedes	36	50
Butterflies	35	0
Lady bugs	55	39

Next let's put it all together:

$$D = 1 - \frac{7870}{30800}$$

D **= 1 - (0.256)**

D **= 0.744**

So what does this mean? If you randomly pick two individuals in plot 1 you have a 74.4% chance of those two individuals being different species. We can say the diversity in the plot is high.

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ON YOUR OWN:
Can you calculate Simpson's Index for Plot 2?

$$D = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$

Species	Plot 1 Woods	Plot 2 field
Centipedes	50	10
Millipedes	36	50
Butterflies	35	0
Lady bugs	55	39

Remember:
Start with the numerator
Then calculate the denominator
Then divide the numerator by denominator
Then subtract your fraction from 1

Which plot is more diverse based on your calculations?
Does this support or refute your hypothesis?

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Looking for More?

- Check out our second biodiversity module on real salamander data!
- Look up on your own: Shannon's Index of Biodiversity
- Real datasets to compare available at www.handsontheland.org

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For The Biodiversity Module & More:

- Website: www.nimbios.org
- See what we’re all about
- Sign up for our bimonthly email newsletter
- Check our blog

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