Using Probability and Limits to Investigate Biodiversity

Suzanne Lenhart, Associate Director for Education & Outreach

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Activity I: An introduction to quantifying biodiversity?

Goals:

1. Be able to define biodiversity
2. Be able to define species richness and species evenness
3. Use probability to derive Simpson's Index
4. Be able to use this index to explain probability and biodiversity in an area

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Activity I: Connect with Common Core Standards

1. See structure in expressions (algebra)
2. Building functions (functions, modeling)
3. Conditional probability and rules of probability (statistics and probability, modeling)

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Biodiversity

- Biodiversity is a measure of the different kinds of organisms in a specific region or defined area.
- Biodiversity includes the number of species and their range of *adaptations* which are traits that can be behavioral, physical, or physiological. These traits enhance an organisms' fitness (ability to pass on its genes to another generation through reproduction)

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Biodiversity

- Biodiversity takes into account species richness and evenness
- Species richness is represented by the number of species in a region
- Species evenness is 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.

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Let's look at two samples:

A biologist goes out into the field and collects information on two separate types of plots that are the same size but with one main difference. Sample one is in the woods and sample two is in a pasture. The biologist is interested in the types of insects that are found in the plots and whether there is a difference between the two plots. The data are shown on the next page…..What do you think?

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Hypothesis

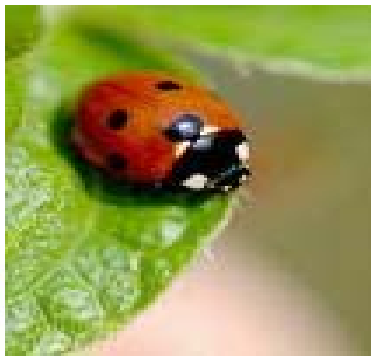
- A Hypothesis is an educated guess based on knowledge
- A Hypothesis can be either accepted or rejected based on the collected of data and data analysis
- Based on the hypothesis predictions can be made about answers to biological questions.

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

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?

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Answers:

- Plot 1, the woods, has more species richness because in plot 2, the pasture, there are no butterflies. Plot 1 has 5 species while Plot 2 only has 4 species present.
- Plot 1 also has more species evenness, there is close to the same amount 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

To quantify biodiversity, let's do some probability!

Work on handout….

To quantify biodiversity, let's do some probability!

- Suppose you had an area with 10 honey bees and 50 spotted lady beetles.
- You select an individual and then select another individual without replacing the first individual.
- What is the probability that the selected individuals are both honey bees?

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

To quantify biodiversity, let's do some probability!

- Suppose you had an area with 10 honey bees and 50 spotted lady beetles.
- You select an individual and then select another individual without replacing the first individual.
- What is the probability that the selected individuals are both honey bees?
- (10/60)(9/59)

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Continuing with probability!

- In our area with 10 honey bees and 50 spotted lady beetles, what is the probability that the selected individuals are both lady beetles?
- Again multiply the probabilities

(50/60)(49/59)

What is the probability that the two selected individuals are from different species?

$1 - \{ (10/60)(9/59) + (50/60)(49/59) \}$

$1 - \{(10)(9) + (50)(49)\}/ \{(60)(59)\}$

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Simpson's Index

Continuing in this way, we can derive Simpson's index, which gives a way to express how diverse a sample is based on a probability.

If you select an individual from an area (at random) and then you Select another individual from that area without replacing the first individual, 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 different species.

You would have high diversity in your sample.

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

Work on a model of biodiversity

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

D= Simpsons Index of Diversity

Σ = summation
(this notation not used with middle school students)

S= number of species
n_i= number of individuals within the i^{th} species
N= total number of individuals within the sample

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

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

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

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

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

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

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.

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

ON YOUR OWN:

Can you calculate Simpsons Diversity Index for Plot 2?

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

Remember to start with the numerator
Then calculate the denominator
Then divide the numerator by denominator
Then subtract your fraction from 1

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

Which plot is more diverse based on your calculations?

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

ON YOUR OWN:
Can you calculate Simpsons Diversity Index for your insects?

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF

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

NIMBioS
National Institute for Mathematical and Biological Synthesis

NSF