W 331-A

Environmental Science — Biodiversity Counts!

Project Area: Environmental Science

Skill Level: Intermediate-Advanced

Learner Outcomes:
- -Define biodiversity
- -Be able to count and calculate diversity metrics
- -Understand why biodiversity is important

Tennessee Science Curriculum Standard GLEs:

S1. Embedded Inquiry 0607.Inq.1-5, 0707.Inq.1-5, 0807.Inq.1-5

S5. Biodiversity & Change 0807.5.1, 0807.5.5

TNCore Math:
7.NS. 2-3
7.EE.1-4

Science Skills: Develop hypothesis, observe, collect data, interpret

Math Skills: Solve real-world problems using numerical and algebraic equations; apply multiple operations on rational numbers (add, subtract, multiply, divide)

Life Skills: Observing, Reasoning, Communicating

Tags: Biodiversity, communities

Time Needed:
Set up: 5 minutes
In class: 30 minutes

Materials:
- -Small items that can be sorted by color, size, shape, etc. (e.g., animal counters, Lego blocks, beads, cards with pictures of animals, etc.), approximately 20 per group of students
- -Chalkboard or large writing pad for recording observations

In this activity, students will learn about biodiversity — how we measure it and why it matters!

Set up

This activity can be done with either natural communities (e.g., insects collected from a pond or field, plant specimens collected from a field — see EXTENSIONS for more ideas), or can be done with an artificial community consisting of at least four different things (e.g., beads, animal figures, legos, cards with pictures of the animals — anything that can be sorted by a characteristic).

Students will work in small groups, with four or five groups in a class. Before class, create four to five "communities" of approximately 20 individuals. Make some that are more diverse (equal representation of all types) and some that are less diverse (mostly one type of thing). Here's an example setup with insects:

Community	Pillbug	Monarch butterfly	Lady beetle	Honey bee	Stink bug
1 (more richness, more evenness)	4	4	3	5	4
2 (less richness, more evenness)	6	0	7	0	7
3 (more richness, less evenness)	15	1	2	1	1
4 (less richness and less evenness)	0	15	0	4	1

Introducing the Activity

Ask your students: What do you think biodiversity means?

Possible answers: Diversity of life on earth, all the different species in a community, all the genetic differences in a population or community.

Show your students pictures of various biomes. First, show a tundra (arctic) biome and a rain forest. **ASK: Where do you think we find the most biodiversity?** (Answer: rain forest) **Ask your students why they think that is.** (Answers: Warmer temperatures mean greater plant productivity which can support a bigger food web, warmer temperatures mean nutrients are recycled quickly, lots of different niches and habitats, etc. If you think of a food pyramid, the rain forest has a broader base.)

Now show pictures of two temperate biomes: a grassland and a temperate deciduous forest. **ASK: Which has a greater biodiversity?** This should be difficult to answer, because it is hard to tell from simply looking at them.

Explain that because we cannot always tell what the diversity of an area is, we need ways to quantify and describe biodiversity. In this lesson, students will learn how to do just that.

Have your students work in four to five small groups for this activity. Give each group an artificial community (see setup) or have them collect a natural community (see Extensions). They should be sitting so that they can see all the other groups' communities. As you work through this activity, record the answers for all groups on a large chart.

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Part 1. Calculating biodiversity

Predict: Ask your students to look at the different communities. **Have them make two predictions:**

1. **Which community has the highest diversity?**
2. **Which community has the lowest diversity?**

Investigate: Explain that one way we can quantify diversity is by counting **richness**: This is the number of types of species in your community. Have students count the number of species and record their observations. (In the example data set, richness = 5, because there are five different species present.)

Now explain that diversity takes into account both richness and **evenness**: This is the relative abundance of each species (or how they are distributed). The highest evenness occurs when every species has equal representation in the community. Have students rate each community as **high**, **medium** or **low** evenness.

Have them look at the richness and evenness scores and determine the **diversity** of each community.

Have your students calculate Simpsons diversity index.[1]

D = Simpsons Index of Diversity

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

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

Example dataset and calculation:

First, calculate the numerator (top):

Species	Number of individuals
Pillbug	1
Monarch butterfly	9
Lady beetle	2
Honey bee	4
Stink bug	5

= (1(1-1) + 9(9-1) + 2(2-1) + 4(4-1) + 5(5-1))
= 1(0)+9(8)+2(1)+4(3)+5(4)
= 0 + 72 + 2 + 12 + 20 **= 106**

Then, calculate the denominator (bottom):
N = 1 + 9 + 2 + 4 + 5 = 21
N(N-1) = 21(20) = **420**

Then, put it all together:
D = 1 - (106 / 420)
D = 1 - (0.25) **= 0.75**

This equation shows that if you randomly pick two species, you have a 75 percent chance of those two individuals being different species. We can say the diversity is HIGH (the closer to 1, the higher the diversity). **Have your students record the diversity on their data sheets.**

***Revisit the hypothesis*: Were their original predictions correct? Who had the most diverse and who had the least diverse community?**

[1]Simpson, Edward H. (1949). Measurement of diversity. Nature, 163, 688

Part 2: Disaster Strikes!

Introduce: **ASK: Why do you think biodiversity is important?**

Possible answers: Aesthetics (looks nice), recreation (e.g., bird watching, fishing, hunting), source of new products (e.g., pharmaceuticals), resists invading species or diseases, important for other organisms in the food web, other ecosystem services (e.g., clean water, air, soil, clean up pollutants).

***Predict*: When disaster strikes (like disease or natural disasters) which communities do you think will be more affected?**

***Investigate*:** Pick a species and explain that it has a very important function in the community. For example, flowers depend on honey bees to pollinate. These flowering plants can't reproduce without the help of honey bees.

Tell your students there's been a terrible disaster (e.g., hurricane, disease, hunters) which has killed off almost all the honey bees. Go around the classroom and randomly remove two honey bees from each group. If they only have one honey bee, remove that one.

ASK: Do you have any bees left in your community?

Students with more diverse communities should still have some bees; the less diverse communities may have no bees.

ASK: What do you think will happen to the flowering plants in your area?

Possible answers: If several bees are left, the plants are unlikely to be affected. If no bees are present, then the flowers won't get pollinated and the plant species might die off.

Get your students to recalculate the richness, evenness and diversity of their new communities, just as they did for part 1. If short on time, then just re-calculate richness. Record the data and share it with the class.

***Revisit the hypothesis*: Which communities were more affected by the disaster?** (**Answer:** Least diverse)

***Discuss and Apply*:**

What happened to the diversity in the more diverse communities? Answer: The richness/diversity stayed about the same.

What will be the effect of the disaster on the plants in these more diverse communities? Answer: Bees will still be there to spread seeds and will probably have little effect on the plants.

What happened to the diversity in the least diverse communities? Answer: The richness/diversity was lower.

What will be the effect of the disaster on the blueberry plants in the least diverse communities? Answer: The bees will be gone (or reduced), so flowers won't get pollinated and won't be able to reproduce.

What else might have happened as a result of this loss of biodiversity? Possible answers: No honey is made, so bears and other animals might lose a food source; birds that eat bees might also lose a food source.

What are some ways humans cause losses in biodiversity? Possible answers: Habitat destruction due to civilization or climate change, spread diseases, spread invasive species, forest fires, pollution, over hunting, over fishing, etc.

Extension and Variations:

1. Use a natural community. Instead of using toys, get your students outside to sample their own community! Try to pick at least two sites, one which is impacted by human activity (e.g., an urban area) and one that is more natural. Use a bucket to collect sediments from a creek and collect the larvae that live there. On land, use a hula hoop to designate an area in a field or forest and collect different plants or insects that live there. Students can use a key to identify the organisms. For example, use the activities in the "Life Beneath Your Feet" module on soil biology to collect organisms and preserve them in isopropanol. Then carry out the diversity exercises here.

2. Small samples (Activity 3 in student handout). Since scientists usually can't count ALL the species in a given area, they must use small subsamples to estimate biodiversity. In this activity, students randomly pull five and then 10 individuals from their community, then recalculate richness and/or diversity as for part 1. They should find that for less biodiverse communities, a small sample is fairly accurate, but for more biodiverse communities, they need a larger sample to estimate richness or diversity.

> **Was the small sample more accurate for more diverse or less diverse communities?** (**Answer:** less diverse)
>
> **How do you know if you have a big enough sample to estimate biodiversity?** (**Possible answers:** If you have the same richness in your small and large samples, then it's probably pretty accurate; keep sampling more and more until the richness stays the same.)

3. Biodiversity as a function of scale. Biodiversity can depend on the size of the area you are measuring. Typically, we expect higher richness if we take a larger area into account. If your students are working in small groups, tell them each group is a different patch of forest. Now ask them to predict whether the biodiversity would be higher or lower for the entire forest (i.e., the whole class). Then, pool all the communities and have your students calculate richness and/or diversity.

Resources

Project Learning Tree: "Exploring Environmental Issues: Biodiversity." Available at www.plt.org

Duncan, S.I., Lenhart, S.L., and K.K. Sturner. 2014. Measuring biodiversity with probability. The Mathematics Teacher 107(7): 547-552

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Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development. University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and county governments cooperating. UT Extension provides equal opportunities in programs and employment.

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Environmental Science — Biodiversity Counts!

Words to Explore

Biodiversity

Richness

Evenness

Community

Species

Keystone species

Did You Know?

Tennessee is the most biodiverse inland state in the United States!

Did You Know?

Each year, about 15,000 NEW species are discovered!

Our planet is filled with life. Do you know how to count It?

Biodiversity, or biological diversity, is the variety of life on our planet. It includes everything from a tiny microbe to a giant blue whale, and everything in between!

In many parts of the world, human actions result in a loss of biodiversity — species can die off because of habitat degradation, loss of a food source, new diseases, or introduction of an exotic species.

Why should we protect biodiversity?

We as humans are part of the planet's food webs. We are dependent on life around us!

- Many drugs and helpful products have come from nature; if we lose species we would lose these products.
- Keystone species perform special functions. For example, a plant might depend on a certain species of insect for pollination.
- More biodiverse communities are more stable, so when disasters or an invading species comes along, it can resist the change.

How do we measure biodiversity?

Diversity is a measure of the different kinds of organisms in a region or other defined area. It includes the number of species and the distribution of individuals among the species.

Richness is the number of species in a region or specified area.

Evenness is how equally the species are distributed. Maximum evenness is when all types of species have the same number of individuals.

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Simpson's Diversity Index

Scientists need a universally recognized way to communicate how biodiverse a community is. In 1949, a British statistician named **Edward Simpson** came up with an idea: We could use **probability** to express how diverse an area is.[1] Probability is a way of expressing the likelihood that an event will occur.

How it works:
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 percent chance of picking out different species so you have high diversity in your sample.

Here's how you calculate Simpsons Diversity Index for this insect community:

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

Species	Number of
Pillbug	1
Monarch	9
Lady beetle	2
Honey bee	4
Stink bug	5

D = Simpsons Index of Diversity
Σ = summation
S = number of species
ni = number of individuals within the ith species
N = total number of individuals within the sample

First, calculate the numerator (top):
= (1 (1-1) + 9(9-1) + 2(2-1) + 4(4-1) + 5(5-1))
= 1(0)+9(8)+2(1)+4(3)+5(4)
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Then, calculate the denominator (bottom):
N = 1 + 9 + 2 + 4 + 5 = 21
N(N-1) = 21(20) = **420**

Then, put it all together:
D = 1 - (106 / 420)
D = 1 - (0.25) = **0.75**

So what does it mean?
If you randomly pick two species you have a 75 percent chance of those two individuals being different species. We can say the diversity is HIGH (the closer to 1, the higher the diversity.)

[1]Simpson, Edward H. (1949). Measurement of diversity. Nature, 163, 688

Activity 1: Calculating Diversity

Your leader will give you a community of different species. Take a look at your community, compare it to the other communities in the class and make a prediction.

Predict:

Which community do you think is the *most* biodiverse? ___________________

Which community do you think is the *least* biodiverse? ___________________

Investigate: Find out how diverse your community is.

1. Determine the RICHNESS of your community. Richness is the number of species present. List the names of the species in the first column and write the richness in the "richness" row.
2. Count the number of each species and enter your numbers into the table.
3. Determine the EVENNESS. How evenly are the species distributed? Remember that the highest evenness is when all species have close to the same number. Score each community as high, medium or low evenness.

	Community				
Species	**1**	**2**	**3**	**4**	**5**
RICHNESS (number)					
EVENNESS (high, medium, or low)					
DIVERSITY (high, medium, or low)					
DIVERSITY (calculated)					

1. Which community was the most biodiverse? ____

2. Which community was the least biodiverse? ____

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Activity 2: DISASTER STRIKES!!!

Biodiversity is very important in helping a community withstand change. This change could be habitat destruction, disease or invasion by another species. That's because different species perform different "jobs," and more species means you're more likely to have a species there to perform that job!

Your leader will present you with a disastrous scenario where some biodiversity is LOST.

Predict: What do you think will happen...

...to the most biodiverse community? ____

...to the least biodiverse community? ____

Investigate: After the disaster, look at your new communities and recalculate richness and diversity. Compare it to the numbers from Activity 1. Compare your data with the rest of the class.

	Community				
	1	2	3	4	5
RICHNESS					
EVENNESS					
DIVERSITY					

1. What happened to the biodiversity in the more diverse communities?

____

2. What will be the effect of the disaster on the more diverse communities?

____

3. What happened to the biodiversity in the least diverse communities?

____

4. What will be the effect of the disaster on the least diverse communities?

____

5. What else might have happened as a result of this loss of biodiversity?

____

6. What are some ways humans cause losses in biodiversity?

____________________________________ ____________________________________

____________________________________ ____________________________________

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Activity 3: Small Samples

There are often so many species in an area that a scientist can't sample them all! They must rely on small samples and try to estimate richness. Could you estimate the diversity from a small sample?

Predict:

If you were to only sample five individuals, would you see the same richness as for the whole community?

____

Investigate:

Step 1. Put your community back into the bag. Now, randomly draw *5* individuals. What is the richness of your subsample? Record your data below.

Step 2. Return your community to the bag. Mix them well, then randomly draw *10* individuals. Record your data below.

Step 3. Compare your community with the others in the class.

	Community				
	1	**2**	**3**	**4**	**5**
Actual RICHNESS (from Activity 1)					
RICHNESS (for 5 individuals)					
RICHNESS (for 10 individuals)					

1. Was 5 individuals a big enough sample to accurately measure richness?

____

2. Was 10 individuals a big enough sample to accurately measure richness?

____

3. Was a small sample more accurate for more diverse or less diverse communities?

____

4. How do you know if you have a big enough sample to estimate biodiversity?

____

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