



Measuring Biodiversity: Educator Handout

OVERVIEW

In this activity, students will learn about different measures of biodiversity: richness, Shannon diversity index, and evenness. Students will begin by calculating these indices by hand using a very small sample data set. Students will then read an overview of the Northern Lakes and Forests and Southern Wisconsin Till Plains, two different Wisconsin ecoregions, and use Google Sheets or Microsoft Excel to calculate and compare biodiversity from a Snapshot Wisconsin database.

KEY CONCEPTS

- Biodiversity is the variety of life and can be measured on multiple scales including genetic diversity, species diversity, and ecosystem diversity.
- Indices that measure species diversity include species richness (the number of species in a given area), the Shannon diversity index (accounting for richness and proportional abundance of species) and evenness (similarity in the abundances of species).
- The location and abundance of animals are determined by the availability of resources and community interactions, such as competition, predation, and human influences.
- An ecological niche is the role of an organism in its environment, which includes the conditions under which it can live, what resources it uses, and how it reproduces.
- The diversity of an ecosystem, including soil, plant, structural, topographic, and climatic diversity, can positively impact animal species diversity.

LEARNING OBJECTIVES

Students will be able to:

- Calculate diversity indices (richness, Shannon diversity index, and evenness) by hand and using Google Sheets or Microsoft Excel.
- Make predictions and use evidence to explain why certain ecoregions may have higher diversity than others.
- Explain the relationships between diversity indices.
- Predict how diversity could support ecosystem resilience.
- Explain how ecological niches relate to diversity.

CURRICULUM CONNECTIONS

Curriculum	Standards
NGSS (April 2013)	HS-LS2-2, HS-LS2-7, HS-LS4-6
AP Biology (2012–13)	4.A.5, 4.C.4
IB Biology (2016)	HL Option C.1, C.4
AP Environmental Science (April 2013)	II.A, II.C, VII.C
IB Environmental Systems & Societies (2010)	4.1.1, 4.1.5; 4.2.1, 4.2.7; 4.3.1, 4.3.2, 4.3.4, 4.3.5
Wisconsin's Standards for Science	SCI.CC2.h, SCI.LS2.A.h, SCI.LS2.C.h, SCI.LS4.D.h

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KEY TERMS

Ecosystem, ecoregion, community, diversity, richness, Shannon diversity index, evenness, species abundance, ecological niche

TIME REQUIREMENTS

2 (45-min) class periods depending prior experience with biodiversity and student capabilities with Google Sheets or Microsoft Excel and analyzing data.

SUGGESTED AUDIENCE

This activity is appropriate for high school biology (all levels including AP and IB), high school environmental science (all levels including AP and IB), and introductory college biology or ecology.

PRIOR KNOWLEDGE

Biodiversity, ecosystem, ecoregion, species abundance, data analysis, Google Sheets or Microsoft Excel, ecological niche

MATERIALS

Internet-connected computers with Google Sheets or Microsoft Excel, Student Handout, Google Sheets Tutorial, Microsoft Excel Tutorial, Ecoregion Appendix, calculators that include natural log (ln), overhead projector (*optional*)

TEACHING TIPS

- The activity is divided into four parts. The first part involves students making calculations by hand using a small sample data set. Part 3 involves calculations in Google Sheets or Microsoft Excel using the trail camera data set. If time is limited, Parts 2 - 4 can be done together as a standalone activity.
- Consider assigning Part 4 as homework after completing Parts 1 through 3 in class.
- It may be beneficial to review Part 1 as a class before moving on to Parts 2 - 4 to ensure the students understand the different biodiversity indices and calculations.

PROCEDURES

Prior to Class

1. Ensure that you have enough calculators and computers for students. Students can either work independently, or in small groups for this exercise.
2. Have the Ecoregion Appendix, Google Sheets or Microsoft Excel Tutorial, and Measuring Biodiversity Database in an accessible location for students, this could be on flash drives or sent via email.

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Part 1: Introduction to Diversity Indices

1. Distribute the Student Handout. Ask your students to read the introduction and Part 1 of the worksheet.
2. Instruct your students to work through questions 1 through 5 using a calculator.
3. *Optional step: go over answers as a class to ensure all students understand the different biodiversity indices and calculations.*

Part 2: Diversity by Ecoregion

1. Ask your students to read the Ecoregion Appendix handout.
2. Instruct your students to complete question 6.

Part 3: Measuring Biodiversity using Snapshot Wisconsin Data

1. Ask your students to read Part 3 of their worksheet.
2. Instruct your students to refer to Google Sheets or Microsoft Excel Tutorial for steps to open Measuring Biodiversity file and begin analyzing the data. *Optional step: use an overhead projection to work through the initial steps (or as many as you deem necessary).*
3. Instruct your students to complete questions 7 through 12.

Part 4: Interpreting Diversity Indices

1. Instruct students to complete questions 13 through 20.

ANSWER KEY

1. Based on the species list below, what is the richness of this community?

Species: Deer, Deer, Deer, Deer, Deer, Badger, Elk, Elk, Elk, Squirrel, Squirrel, Squirrel, Squirrel, Wolf, Wolf, Red Fox, Sandhill Crane, Sandhill Crane, Sandhill Crane, Porcupine, Porcupine, Bald Eagle, Snowshoe Hare, Snowshoe Hare, Snowshoe Hare

S = 10, this number reflects the number of species present in the list.



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2. Using the table below, calculate the total abundance in the community and the P_i value for each species. Next, calculate the natural log of P_i for each species ($\ln(P_i)$) and then multiply the two columns to calculate $P_i * \ln(P_i)$. Limit your numbers to 3 decimal places.

Species	Abundance	P_i	$\ln(P_i)$	$P_i * \ln(P_i)$
Deer	5	.2	-1.609	-.322
Badger	1	.04	-3.219	-.129
Elk	3	.12	-2.120	-.254
Squirrel	4	.16	-1.832	-.293
Wolf	2	.08	-2.526	-.202
Red Fox	1	.04	-3.219	-.129
Sandhill Crane	3	.12	-2.120	-.254
Porcupine	2	.08	-2.526	-.202
Bald Eagle	1	.04	-3.219	-.129
Snowshoe Hare	3	.12	-2.120	-.254
Total Abundance	25			

3. Calculate H by adding each of the values in the $P_i * \ln(P_i)$ column of the table above and taking the negative of that value.

$$H = 2.168$$

4. Use the richness value you calculated in question 1 to calculate H_{MAX} .

$$H_{MAX} = \ln(\text{richness}) = 2.302$$

5. Use the Shannon diversity index value you calculated in question 3 and the H_{MAX} value you calculated in question 4 to calculate E .

$$E = H/H_{MAX} = .942$$

Part 2: Diversity by Ecoregion

6. Read about the Northern Lakes and Forests and Southern Wisconsin Till Plains, two ecoregions of Wisconsin. Predict which has the greatest biodiversity? What information did you use to make that prediction?

Answers will vary. Diversity in the ecoregion should increase animal species diversity; therefore, ecoregions with greater diversity of plant species and vertical structure (combination of grass, shrubs, and trees of varying heights) should have greater animal diversity. Following this logic, the Northern Lakes and Forests should show a greater diversity than Southern Wisconsin Till Plains. Additionally,

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students may add that human population is likely higher and more dense in the farmlands of Southern Wisconsin Till Plains than the forested Northern Lakes and Forests.

Part 3: Measuring Biodiversity using Snapshot Wisconsin Data

7. Calculate the species **richness** for each ecoregion. Record the values below.

Ecoregion	Richness
Northern Lakes and Forests	23
Southern Wisconsin Till Plains	15

8. Which ecoregion has the greatest species richness? Propose an explanation for differences in species richness from one ecoregion to another.

Northern Lakes and Forests has greater species diversity than Southern Wisconsin Till Plains. Answers will vary, but could reflect the smaller human population up north, or the fact that the southeastern Wisconsin was converted for agriculture causing an ecological disturbance on native communities.

9. Calculate the **Shannon diversity index** for the three vegetation types. Record the values in the table below.

Ecoregion	Shannon diversity index
Northern Lakes and Forests	1.577
Southern Wisconsin Till Plains	1.425

10. Is there a relationship between the Shannon diversity index and the richness for each ecoregion? Explain your reasoning.

The Shannon diversity index is calculated by taking the sum of $P_i * \ln(P_i)$ for each species. If more numbers are added based on the number of species present (or richness), then higher richness should increase the Shannon diversity index if the relative species abundance remains the same.

11. Calculate the **evenness** for each ecoregion. Record the values in the table below.

Ecoregion	Evenness
Northern Lakes and Forests	.503
Southern Wisconsin Till Plains	.443

12. Is there a relationship between the evenness and richness for each ecoregion? Explain your reasoning.



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Richness does not impact the evenness of an ecosystem. Evenness is calculated by dividing the Shannon diversity index (H) by the natural log of the richness (H_{\max}). If the species abundance within a community are completely proportional (even), then H would be the same as H_{\max} , so evenness (E) would be equal to 1. If two communities have even species abundances but richness is higher in one than the other, then evenness (E) would still be equal to 1 for each community.

Part 4: Interpreting Diversity Indices

13. Based on the calculations you performed, which ecoregion has the overall greatest diversity? Use evidence from the data to support your claim.

Northern Lakes and Forests should have shown overall greater diversity. Students should summarize findings from analyzing different biodiversity measures to support their statement.

14. Values for Shannon diversity index typically fall between the ranges of 1.5 and 3.5, did the analyzed data fall between these values? What could be a possible explanation?

Students should acknowledge that the values were low for the Shannon diversity index range. Possible explanations could include the use of trail cameras for collecting the data, or that Wisconsin is home to less diverse species and habitats compared to more tropical regions.

15. What are some advantages of using trail camera data for calculating biodiversity? Disadvantages?

Some advantages may include that the technique is noninvasive, the ability to gather long term data if the cameras are left in place, and potential cost saving for long term usage. Some disadvantages may include missing smaller species, biases for where the trail cameras are placed, and the time and effort of classifying the trail camera photos.

16. What additional information would be valuable for analyzing the diversity of the different ecoregions that can't be captured in trail camera photos?

Answers will vary, for example trail camera photos do not capture all species, especially very small species. They are biased towards larger animals, such as large mammals. To calculate more accurately, you would need abundance data for all taxa.

17. In ecology, resilience is defined as the ability of an ecosystem to resist change or recover from a disturbance quickly. Which ecoregion do you predict would have the greatest resilience? What evidence supports this claim?

Answers will vary. The ecoregion with the highest diversity should have the highest resilience. When there are more species interacting and competing in a community, the average interactions that any one species experiences are likely to be weaker than in a simpler, less diverse community. When there are environmental fluctuations among a community some species will inherently do better than others



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depending on the disturbance, and having a greater diversity of species should result in more species being able to withstand such disturbances.

18. An ecological niche is the function of an organism in its environment, which includes the conditions under which it can live, what resources it uses, and how it reproduces. Use the concept of ecological niche to explain the difference in richness from the Northern Lakes and Forests and Southern Wisconsin Till Plains ecoregions.

An ecological niche is the function of an organism in its environment, which includes the conditions under which it can live, what resources it uses, and how it reproduces. Different species can coexist in the same habitat by occupying different niches. An ecoregion in Wisconsin that has greater soil, plant, structural, and microclimate diversity is likely to have high diversity of available niches, and thus a higher number of species to occupy those niches.

19. Think about the human population in the Northern Lakes and Forests versus Southern Wisconsin Till Plains. How might human activities influence the biodiversity of these ecoregions?

The presence of humans can cause some species to avoid the area and other species to be attracted to the area. The human impact on species diversity also depends on the type of human activity and how disruptive it is to wildlife – such as the large scale farming that occurs in south eastern Wisconsin.

20. How might biologists use the diversity indices you calculated to inform their restoration efforts?

Biologists may use diversity indices to prioritize their conservation and restoration efforts. Areas with the highest levels of biodiversity may get more resources allocated to them. Also, biodiversity can be monitored over time to detect changes that may signal an issue that needs to be remedied.