



SYMPHONY OF THE RAINFOREST: How Sounds Can Help Measure Biodiversity

This teacher's guide gives an overview of the three lessons associated with the Symphony of the Rainforest materials. Background information, essential questions, standards, objectives, vocabulary, materials, and additional resources can be found in this guide. Instructions for each activity and answer keys are included in the lesson documents for Part 1, 2, and 3 found here:

<https://www.natureworkseverywhere.org/resources/recording-the-rainforest/>

Subject Areas: Biology, Environmental Science, Ecology

Grade Levels: 9-12

Time:

- Part 1: Two 45-minute class periods.
- Part 2: One to two 45-minute class period with homework.
- Part 3: Multiple class periods based on study design and procedure.

Essential Questions:

- What can acoustic recordings of the rainforest tell us about biodiversity?
- Why is biodiversity important?
- How can you measure biodiversity?
- What are ecosystem services?
- What ecosystem services do rainforests provide globally and locally?
- How have animals evolved in response to competition for space in the soundscape?
- What are the threats to Borneo's rainforests?
- How can soundscapes inform land management and conservation decisions?
- What issues and questions in addition to biodiversity must be addressed when considering different land management scenarios?
- How can you use sound to investigate your own environment?

Purpose and Overview:

It is recommended that Part 1 be taught first, with Parts 2 and 3 being optional and independent of each other.

Part 1: This lesson introduces students to the acoustic niche hypothesis and how animals have evolved to fill different acoustic niches to avoid competing for space in the soundscape. Through the use of a short video (8:02 min) and an interactive story map, students explore the science behind using soundscapes to measure biodiversity and determine land management strategies. The story map acts as an interactive textbook and is full of multimedia experiences that help to explain the concepts. Students use a worksheet as a guide while they explore everything from Borneo's ecosystem, to the concepts of alpha-diversity and beta-diversity, to the future use of acoustic technology in science.

Part 2: This lesson gives students an in-depth experience using real acoustic survey data from the field to learn about different land-use scenarios and their impacts on the soundscape and biodiversity. Students explore actual sounds from different landscapes in Borneo to qualitatively assess the differences and then

examine a variety of soundscape saturation graphs to visualize the differences and make inferences. Students also explore the limitations of these data and are given the opportunity to suggest different types of investigations. Students will also be exposed to the factors beyond biodiversity, like human habitations and hydrology, that must be considered when creating land management strategies.

Part 3: In this lesson, students come up with their own ideas for investigations using sounds from their community. Instructions for using cell phones as recorders and for creating spectrograms in Audacity are included. Additionally, there are instructions for sharing student data using interactive maps from Esri and Google.



Rainforests act as natural water filters. The trees also slow rainwater and send it into underground reserves, which decreases flooding and preserves our freshwater supply.



Rainforests are the lungs of the planet—they produce more than 20% of the planet's oxygen. They also absorb greenhouse gases, which helps to stabilize the climate.

Nature Works Everywhere Themes:

Introduction:

Borneo is an island in Southeast Asia comprised of three different countries—Indonesia, Malaysia, and Brunei. It is the third largest island on the planet after Greenland and New Guinea. The island consists mainly of dense rainforest, and is likely one of the oldest rainforests in the world—over 130 million years old. The coastal areas are fringed with mangrove forests and many rivers provide access deep into the forest.

Borneo is among the most biologically diverse habitats on the planet and is home to many endemic mammal species, including the Bornean Orangutan, proboscis monkey, and the Borneo pygmy elephant. Borneo is home to such a multitude of invertebrates that in some places you can find as many as 1,000 different invertebrate species on one tree. There more than 15,000 plant species, 420 bird species, 200 reptiles and amphibians, and over 200 mammal species on the island. Globally, rainforests are home to over 50% of the terrestrial organisms on this planet.

Though seemingly far away from students in the United States, rainforests play an important role in the lives of all of Earth's inhabitants. Rainforests around the world supply the Earth with over 20% of its oxygen. All types of forests around the world absorb up to 30%, or 2.5 billion metric tons, of human carbon dioxide emissions, with tropical rainforests estimated to absorb over half of that total—more than the boreal forests of Siberia, Canada, and other northern regions combined

(<https://www.nasa.gov/jpl/nasa-finds-good-news-on-forests-and-carbon-dioxide/>)!

Additionally, the rich biodiversity of the rainforests provides a source of ingredients for many of our modern medicines. Twenty-five percent of all modern medicines are derived from rainforest plants and, of the plants used for treating cancer, 70% are only found in rainforests. The Bornean forests are also a source of wood products used around the world. Local people benefit from the food, clean water, and medicinal plants that the forests provide. Borneo's indigenous people, the Dayak, view the forests as sacred spaces that support life.

These forests are currently under threat from widespread deforestation. The Nature Conservancy is working in East Kalimantan on the island of Borneo to help protect these biologically rich forests and to enrich local communities. This set of activities introduces students to the issues at hand and describes one innovative method—acoustic surveying—that is being used to measure biodiversity across different landscapes in East Kalimantan. The goal of these surveys is to use the recorded soundscape to measure the

biodiversity of the area and to ultimately determine the health of the ecosystem. This information can then be used to inform land management and conservation decisions throughout the landscape. These decisions may include determining which locations are the most critical to protect because they contain the greatest biodiversity. Alternatively, an already degraded ecosystem might be a better location for logging or other development activities like housing or agriculture. Scientists may also be able to determine which type of logging practices are less harmful to the ecosystem. For example, acoustic survey data might be able to compare the effects on biodiversity of reduced-impact logging activities (removal of one specific tree species at a time) vs. clear cutting activities.

Objectives:

The student will...

Part 1

- Describe ways that humans can impact biodiversity.
- Utilize an online story map to explore sounds, videos, interactive maps to gain a better understanding of the ecosystem services, biodiversity, threats, research, and land management strategies as they pertain to The Nature Conservancy’s work in Borneo.
- Investigate deforestation using an interactive map based on satellite data.
- Describe the ecosystem threats in Borneo posed by development activities like logging, agriculture, and mining.
- Differentiate between alpha-diversity and beta-diversity and describe the applications of each with regard to land management scenarios.
- Describe the acoustic niche hypothesis and explain how animals have evolved to occupy different spaces in the soundscape.
- Describe the different types of sound in an environment, including biophony, anthrophony, and geophony.
- Explore how acoustic surveys can be used to assess biodiversity across different landscapes.
- Discuss ways to implement an acoustic survey at school or in the community and describe their ideas for possible investigations.

Part 2

- Analyze graphical soundscape saturation data to determine the difference in soundscapes between pristine and disturbed environments.
- Describe the limitations of a particular dataset and determine additional information needed for decision-making and further analysis.
- Make inferences about the impact of time of day on animal vocalizations.
- Use known habitat data to guess the type of habitat represented by a mystery location’s dataset.
- Explore limitations and constraints in the experimental design process.
- Evaluate the multiple factors that must be considered when making land management decisions.

Part 3

- Design and conduct an investigation of a local “habitat” using an acoustic survey.
- Generate spectrograms in Audacity or other software for analysis.
- Compare and contrast soundscapes.
- Communicate and share data and study results visually using a story map, Google map, or other means.

Materials:

Part 1:

- Teacher – computer and projector
- Internet connection
- Headphones and/or speakers (for video and story map)
- Computers (1-2 students per computer or teacher can project Story Map to class if there are not enough computers)
- **Nature Works Everywhere** video – **Recording the Rainforest** <https://vimeo.com/200689436>
- Copies of Part 1 Recording the Rainforest Student Handout – <https://www.natureworkseverywhere.org/resources/recording-the-rainforest/>
- Story Map – **The Sounds of Borneo** <http://arcg.is/2gBeUJk>
- Optional – full length rainforest sounds <https://soundcloud.com/user-638717367/sets/borneo-the-symphony-of-the-rainforest>; 6-minute versions of rainforest sounds can be found here <https://www.natureworkseverywhere.org/resources/recording-the-rainforest/> if SoundCloud is blocked at your school

Part 2:

- Teacher – computer, projector, and speakers
- Internet connection
- **Nature Works Everywhere** Borneo Location Sounds Video – <https://vimeo.com/195881253>
- **Nature Works Everywhere** Borneo Location Sounds Video Answer Key – <https://vimeo.com/203880913>
- Copies of Part 2 Soundscape Saturation Student Handout – <https://www.natureworkseverywhere.org/resources/recording-the-rainforest/>

Part 3:

- Materials may vary based on the project that students choose
- Recording devices or cell phones
- Computers, internet, headphones
- Audacity (free audio software)
- VLC Player or other file conversion software (free)
- Google My Maps Account or Esri Free Education ArcGIS accounts

Standards:

Next Generation Science Standards – High School

Disciplinary Core Ideas

- LS2.A Interdependent Relationships in Ecosystems
- LS2.C Ecosystem Dynamics, Functioning, and Resilience
- LS4.D Biodiversity and Humans
- LS4.B Natural Selection
- LS4.C Adaptation
- ETS1.A Defining and Delimiting Engineering Problems
- ETS1.B Developing Possible Solutions

Science and Engineering Practices

- Analyzing and Interpreting Data
- Constructing Explanations and Designing Solutions

- Engaging in an Argument from Evidence
- Asking Questions and Defining Problems
- Using Mathematics and Computational Thinking
- Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts

- Scale, Proportion, and Quantity
- Stability and Change
- Cause and Effect
- Patterns

Performance Expectations

- HS-LS2-2 Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems at different scales. (average, determining trends, comparisons of multiple data sets)
- HS-LS2-7 Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from four factors: 1) the potential for species to increase in number, 2) the heritable genetic variation of individuals in a species due to mutation and sexual reproduction, 3) competition for limited resources, and 4) the proliferation of those organisms that are better able to survive and reproduce in the environment.
- HS-LS4-4 Construct an explanation based on evidence for how natural selection leads to adaptation of populations.
- HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

AP Environmental Science

- II The Living World (A. Ecosystem structure, C. Ecosystem diversity, D. Natural ecosystem change)
- IV Land and Water Use (A. Agriculture, B. Forestry, D. Other land use)
- VII Global Change (C. Loss of biodiversity)

AP Biology

- Big Idea 1: The process of evolution drives the diversity and unity of life.
 - Essential Knowledge
 - 1.A.1 Natural selection is a major mechanism of evolution.
- Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.
 - Essential Knowledge
 - 4.A.5 Communities are composed of populations of organisms that interact in complex ways.
 - 4.C.4. Diversity of species within an ecosystem may influence the stability of the ecosystem.
- Science Practices
 - 5: The student can perform data analysis and evaluation of evidence.
 - 6: The student can work with scientific explanations and theories.

Common Core Standards – Science and Technical Subjects

Grades 9-10

- CCSS.ELA-LITERACY.RST.9-10.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
- CCSS.ELA-LITERACY.RST.9-10.2 Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
- CCSS.ELA-LITERACY.RST.9-10.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- CCSS.ELA-LITERACY.RST.9-10.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9-10 texts and topics*.
- CCSS.ELA-LITERACY.RST.9-10.7
Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Grades 11-12

- CCSS.ELA-LITERACY.RST.11-12.1 Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
- CCSS.ELA-LITERACY.RST.11-12.2 Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
- CCSS.ELA-LITERACY.RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.
- CCSS.ELA-LITERACY.RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.
- CCSS.ELA-LITERACY.RST.11-12.7 Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

Vocabulary:

- **Acoustic niche hypothesis:** the partitioning of vocalizations across frequency and time that occurs in habitats. This is the result of competition for space in the soundscape wherein vocalizing animals have evolved to time-shift or adjust their vocalization bandwidths so that they occupy a unique niche in the soundscape and can be heard among all other sounds.
- **Bandwidth:** the range of frequencies within a given band.
- **Biodiversity:** the variety of life in the world or in a particular habitat or ecosystem.
- **Ecosystem:** a biological community of interacting organisms and their physical environment.
- **False-color spectrogram:** a visual representation of sound including frequency, time, and a third dimension represented by color. The third dimension can include loudness, repetition, and other characteristics.
- **Frequency:** the number of occurrences of a repeating event per unit time; in this case, frequency is a measure of sound.
- **Hertz:** the number of cycles per second (Hertz or Hz); the unit for the measurement of sound frequency.
- **Spectrogram:** a visual representation of a spectrum; in this case the frequency of sound over time.
- **Soundscape:** the sounds heard in a particular location.

Additional Resources:

Soundscapes and Bioacoustics

- The Voice of the Natural World, TED Talk by Bernie Krause
https://www.ted.com/talks/bernie_krause_the_voice_of_the_natural_world?language=en
- Listening to Wild Soundscapes, Science Friday interview with Ecologist Bryan Pijanowski and Bioacoustician Bernie Krause
<http://www.npr.org/2011/04/22/135634388/listening-to-wild-soundscapes>
- Wild Sanctuary – Bernie Krause’s website of sounds and other work.
<http://www.wildsanctuary.com/>
- AI Experiments – in a collaboration between ornithologists and computer scientists, applied machine learning or artificial intelligence was used to group bird sounds by their similarities. Learn more and explore the experiment.
<https://aiexperiments.withgoogle.com/bird-sounds>
- Xeno-canto – spectrograms and audio recordings from birds around the world.
<http://www.xeno-canto.org/>
- The Macaulay Library – audio recordings, images, and videos of birds from around the world.
<http://macaulaylibrary.org/>
- The Cornell Lab of Ornithology – learn more about birds, Project Feeder Watch, and eBird
<http://www.birds.cornell.edu/Page.aspx?pid=1478>
- A list of sound-oriented websites from around the world from The Acoustic Ecology Institute.
<http://www.acousticecology.org/soundscapelinks.html>

Biodiversity

- Why is biodiversity so important? TED-Ed by Kim Preshoff
<http://ed.ted.com/lessons/why-is-biodiversity-so-important-kim-preshoff>
- Why Measure Biodiversity? Module, by University of Idaho
[http://www.webpages.uidaho.edu/veg_measure/Modules/Lessons/Module%209\(Composition&Diversity\)/9_2_Biodiversity.htm](http://www.webpages.uidaho.edu/veg_measure/Modules/Lessons/Module%209(Composition&Diversity)/9_2_Biodiversity.htm)
- California Academy of Sciences Biodiversity Course
<https://www.calacademy.org/biodiversity-course>

Deforestation

- Tropical Deforestation – Advanced Environmental Science Geoinquiry where students can explore deforestation trends and patterns using a map of South America
<http://education.maps.arcgis.com/home/item.html?id=2364362d205142039f6be19f19b008d9>

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