NATURE LAB Educator Resources

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 can also be found in this guide.

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 in interactive textbook and is full of multimedia experiences that help to explain the concepts. Student 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.

Themes:

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.

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)
- ***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
- Borneo Location Sounds Video – https://vimeo.com/195881253
- 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
- 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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Krause, Bernard L. *The Great Animal Orchestra: Finding the Origins of Music in the World's Wild Places*. New York: Little, Brown, 2012. Print.

Krause, Bernie L. "The Niche Hypothesis: How Animals Taught Us to Dance and Sing." (1987.): 1-6. *Http://xenopraxis.net/*. Web. 9 Feb. 2017. <http://xenopraxis.net/readings/krause_nichehypothesis.pdf>.

Purvis, Andy, and Andy Hector. "Getting the Measure of Biodiversity." *Nature.com*. Macmillan Publishers, 11 May 2000. Web. 25 Jan. 2017. <http://www.nature.com/nature/journal/v405/n6783/full/405212a0.html>.

Rasmussen, Carol. "NASA Finds Good News on Forests and Carbon Dioxide." *NASA*. NASA, 229 Dec. 2014. Web. 25 Jan. 2017. <https://www.nasa.gov/jpl/nasa-finds-good-news-on-forests-and-carbon-dioxide>.

Thompson, Christian. *Borneo's New World: Newly Discovered Species in the Heart of Borneo*. N.p.: World Wildlife Fund, n.d. PDF.

SYMPHONY OF THE RAINFOREST:

Part 1: Recording the Rainforest

Time: Two 45-minute class periods

Objectives:

The student will…

- 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.
- 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.

Materials:

- 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)
- ***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; shorter versions of rainforest sounds can be found here https://www.natureworkseverywhere.org/resources/recording-the-rainforest/ if SoundCloud is blocked at your school

Suggested Flow:

1. Open the class by giving students this entry task ***"Define biodiversity. Describe ways that human activity might impact biodiversity."*** Discuss student answers with the class.

2. Show ***Recording the Rainforest*** (8:02 min) (https://vimeo.com/200689436) to introduce the acoustic survey work that was conducted in Borneo. Ask students to briefly summarize the video and to write questions that arose while watching it. Explain that the questions should fall into one or both of the following categories:
    a. Something still unanswered or unknown
    b. Something that they know how to answer from watching the video and might be good review questions.

3. Discuss student questions and revisit the entry question—*describe ways that human activity might impact biodiversity*—by asking students what human impacts on the rainforest were portrayed in the video.

4. If you have access to computers, students can explore the Story Map (http://arcg.is/2gBeUJk) at their own pace. They should plan on using headphones as the Story Map has sounds. Alternatively, you can project the Story Map and use it in place of a PowerPoint presentation to guide students through the topics of the rainforest's ecological importance, rainforest threats, how sound can be visualized, and how scientists measure biodiversity through sound to help inform land management decisions.

5. The Story Map is interactive and has several sections that ask the viewer to complete a short activity or answer a question. Throughout the Story Map there are several URLs that are highlighted and underlined. Students may be directed to click on them to gather more information, however, some are there for students to look up words or explore in-depth as needed. As students move through the Story Map, the Part 1 Student Handout will guide them through the activities and provide a place to record answers to questions. Activities in the Story Map support the other parts of the lesson plan and provide context for the data activity in part 2.

6. When students have completed interacting with the Story Map, use the student handout to guide discussion. Specific points on which to focus might include:
    - Only animals that vocalize can be captured using acoustic surveys, what organisms aren't recorded and how can you account for them?
      Possible answers: Plants, some invertebrates, non-vocalizing organisms like fish, etc. would not be recorded. Visual surveys could be done, traditional methods (e.g. transects) could be used to take an inventory of non-vocalizing organisms to augment the audio data.

    - What considerations must be made in addition to biodiversity when making land management decisions?
      Possible answers: Human developments, sacred sites and cultural locations, the effect of development on water sources, land ownership, etc.

    - Let's pretend we are about to undertake an acoustic survey of the school or the environment we live in. What are some questions we could try investigate with audio recordings? What might audio recordings be able to tell us about our home? What are some things about soundscapes that you are curious about?
      Answer will vary.

7. The answer key to the student handout is on the next page. There are additional homework questions at the end.

Recording the Rainforest Part 1:
The Sounds of Borneo Story Map - TEACHER ANSWER KEY

Directions:

Go to The Sounds of Borneo Story Map at http://arcg.is/2gBeUJk . The following questions can be answered using information located in the Story Map text as well as through various hyperlinks located in the Story Map, which appear as blue text. The questions below follow the Story Map in chronological order.

1. Listen to a few minutes of the first and second movements of the rainforest symphony. Compare and contrast the soundscape you hear in each. How are they similar? How are they different? Speculate why they are different.
   Answers may vary: The first movement is more droning and high-pitched. There aren't as many bird sounds, but there are quite a few different high-pitched sounds that last for a long time. In the second movement, there is more variation in the sounds. There are still the high-pitched sounds, but there's also whooping and chirping. It sounds like there are more animals. They could have been recorded in different locations or at different times of day.

2. How old is the Bornean rainforest?
   Answer: Over 130 million years old.

3. Explore the IUCN website (http://www.iucnredlist.org/) to discover the status of the Bornean orangutan, proboscis monkey, Sumatran elephant (listed as a subspecies of Asian elephant), and Sunda clouded leopard and list below.
   Answer (as of Jan 2017): The Bornean orangutan is critically endangered, the proboscis monkey is endangered, the Sumatran elephant is endangered, and the Sunda clouded leopard is listed as vulnerable.

4. Define and give examples of ecosystem services.
   Answer: Ecosystem services are any positive benefits to humans provided by nature. They include recreation, tourism, clean air, clean water, food, etc.

5. Describe how trees sequester carbon.
   Answer: Trees take in carbon from the atmosphere and store, or sequester, it in their leaves, branches, trunks, and roots. Fallen leaves and branches add carbon to the soil.

6. List 3 types of medicines that have come from rainforest plants.
   *Answers will vary (find more at http://www.buzzle.com/articles/rainforest-plants-used-for-medicine.html): **Periwinkle** is used to make medicines for lymphocytic leukemia and other cancers. Quinine from the cinchona tree is used to treat malaria. The **cocoa tree** has high medicinal value and its extracts can be used to treat anxiety, fatigue, fever, coughs, and more. Extracts from **wild yams** are used in birth control pills and other steroidal products.*

7. Describe at least two local and/or global ecosystem services provided by rainforests.
   Answer: Rainforests provide a variety of ecosystem services including: filtration of water, regulation of climate, medicine and food, etc.

8. Using the swipe map, describe how Borneo's forest cover has changed over time.
   Answer: The general trend is forest cover decrease over time. Forest cover is greatest toward the interior of the island, while the loss of forest cover is greatest near the coasts and cities.

9. Using the legend to the left of the map, note some of the main land cover types that have replaced intact or old-growth forest in the period from 1973 to 2015.
   Answer: Oil palm plantations, logged forest, and non-forest have replaced large sections of old-growth forest.

10. The legend contains a category called "non-forest". What do you think might exist in these areas? You can consult more maps at http://bit.ly/2khlqud to enhance your answer.
    Answer: These areas could be villages, other agricultural uses, and mining areas.

11. Describe the impacts of ecosystem threats like mining, acacia and oil palm plantations, and logging on Borneo's landscape.
    Answer: Mining activities strip the land of forests and can lower the water table. With forests removed, there is increased risk of flooding and increase in sedimentation in rivers. Harmful chemicals are also used in mining and these can leak into watersheds. Acacia and oil palm plantations also cause massive deforestation because forests are removed entirely and replaced with a single species. These plantations completely transform the landscape. All three activities can affect habitats leading to a loss of biodiversity.

> **Teacher Note:** Consider having students explore these threats in more detail beyond the Story Map. Consider using the jigsaw technique to have students research one area and then share with other students.

12. List three products you use that contain palm oil.
    Answers will vary: Chocolate, soap, cosmetics, etc.

13. Describe some of the ways to measure biodiversity. What are the benefits and limitations of each?
    Answer: Biodiversity can be measured with transects and quadrats – these methods are better at capturing organisms that don't move around much and don't make sounds. The limitations are that these types of studies are time consuming and the scientists must be able to identify all of the species they find or take samples and key them out later. These studies can also miss animals that move around. Camera traps are another option, but they only capture animals that move and come within range. Remote-sensing with satellite data can be easier than sending scientists out to do a field study, but there still needs to be some ground-truthing and it's better for looking at large-scale landscape vegetation patterns or productivity than looking at invertebrates. The advantage is that satellite data is able to capture global changes.

14. Describe the difference between alpha and beta-diversity.
    Answer: Alpha-diversity is the count of the number of species in an area. It's also known as species richness. Beta-diversity compares the biodiversity across different areas.

15. Why is knowing the beta-diversity of a landscape critical to the development of conservation strategies and land management plans?
    Answer: It's important to know the beta-diversity when making landscape plans so you understand where the greatest diversity exists across a landscape. If you knew only the species richness of individual areas, but not how they compare or which species overlap, it would be hard to make decisions to, for example, protect the greatest amount of diversity.

16. Measuring and protecting biodiversity might be one goal in a land management strategy. What are other things that must be considered when deciding how to manage land?

Answer: The following are other considerations when creating a land management strategy: human inhabitants and what they use the forest for (food, medicines, sacred and cultural spaces), how water will be affected by development, government, laws, etc.

17. Use the online tone generator (http://onlinetonegenerator.com/hearingtest.html) to determine the highest frequency you can hear and record it here.
    Answers will vary: The human hearing range is 20-20,000 Hz so it's unlikely students could hear higher than that.

18. Audio recordings in a rainforest can capture a variety of organisms, but what are some of the organisms they can't capture and how could you account for them in a study of biodiversity?
    Answer: Animals that don't vocalize will not be captured. Plants and fungus will not be captured. These organisms could be measured using other studies like traditional ground surveys, camera traps, or satellite data depending on the organisms.

19. Describe the acoustic niche hypothesis.
    Answer: Acoustic niche hypothesis is the idea that animals have evolved to communicate at different frequencies so they can hear each other above other organisms.

20. How have animals evolved in response to competition for space in the soundscape?
    Answer: They communicate at different frequencies or in between the sounds of others.

21. What happens to soundscape saturation when a habitat is disturbed?
    Answer: As habitats become disturbed, the soundscape becomes less saturated with sound. In other words, as animals disappear from the habitat, the bandwidths that were occupied with their vocalizations are now empty.

22. Describe the three types of sounds in an environment.
    Answer: Biophony is the term for sounds in the environment produced by animals—like bird calls and monkey howls. Geophony is the term for sounds produced by wind, water, and rain. Anthrophony is the term for sounds produced by humans.

23. List all of the animals you can think of in the rainforest environment that can vocalize or produce sounds.
    Answer: Birds, amphibians, insects, monkeys, orangutans, squirrels, bats, other mammals, etc.

24. Can you hear anthrophony, geophony, and biophony in the sound clip? Describe the sounds you heard and categorize them.
    Answer: Anthrophony – a chainsaw; biophony – an insect chirp and a bird call; geophony – rainfall

25. Answer the following questions about the spectrogram example shown in the Story Map (and below):

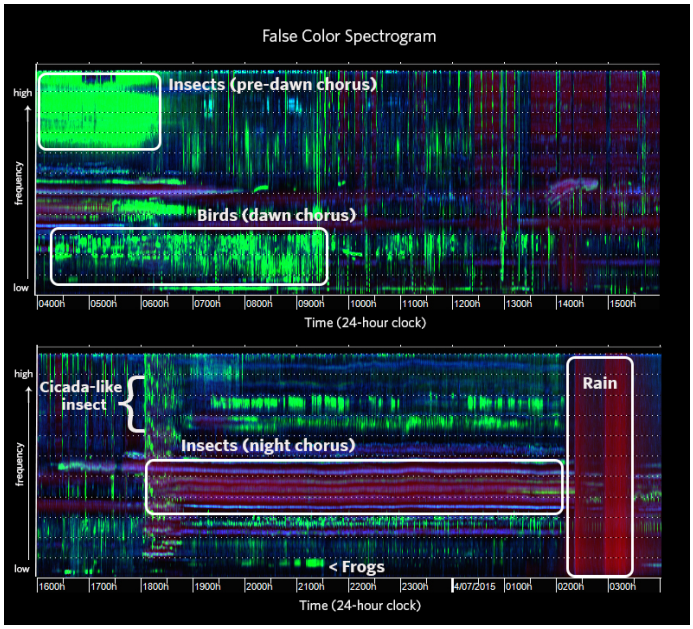


Image credit: Michael Towsey and Anthony Truskinger,
Queensland University of Technology

a. What time of day appears to be the loudest and with most frequencies filled with sound?
Answer: The early morning hours between 400h (4:00 AM) and 630h (6:30 AM) appear to have the most frequencies filled with sound. The insects at the highest frequencies appear to be very loud.

b. What type of geophony is depicted in this spectrogram and what time did it occur?
Answer: The geophony depicted in the spectrogram is rain and it began around 200h and ended at 330h (2:00 AM-3:30 AM).

c. Using frequency information from the spectrogram, describe how the sounds of the rainstorm differ from those of the animals.
Answer: The rain sounds fill the spectrogram from top to bottom, so the sounds occupy every frequency, whereas the animal sounds fill specific frequency bands.

26. Listen again to a few minutes of the first and second movements of the rainforest symphony. Based on what you've learned by looking at a false-color spectrogram of rainforest sounds, when do you think they were recorded?
Answers will vary: They could have been recorded at different times of day or in different locations. The sounds in movement one were very different than those in movement two. Movement one seemed noisier than movement 2, so it's more likely that 1 was recorded earlier in the morning since the rainforest spectrogram indicates that there is more sound in the pre-dawn to dawn hours.

Teacher Note: Movement 1was recorded just before sunrise and movement 2 was recorded just after sunrise – a ½ hour later. Extended versions of the sounds are available on SoundCloud https://soundcloud.com/user-638717367/sets/borneo-the-symphony-of-the-rainforest

27. How can acoustic data inform land management decisions?
    Answer: Acoustic data can help establish the beta-diversity across locations. If the false-color spectrograms and sounds help determine which areas are more similar and which areas have more varied biodiversity, it may help scientists determine which areas can be developed and which areas should be protected (if the goal is to try and preserve the most biodiversity). It can also help scientists to look at changes in alpha-diversity overtime in order to assess which strategies are effective.

28. Conduct an Internet search to find one example of another use of acoustic technology in conservation and describe it briefly.
    Answers will vary, some examples include:
    - *The impacts of anthropogenic noise on marine communities (https://serc.si.edu/research/projects/bioacoustics-and-biodiversity)*
    - *Coral reef health around Moorea Island (http://www.nature.com/articles/srep33326)*

Homework Questions:

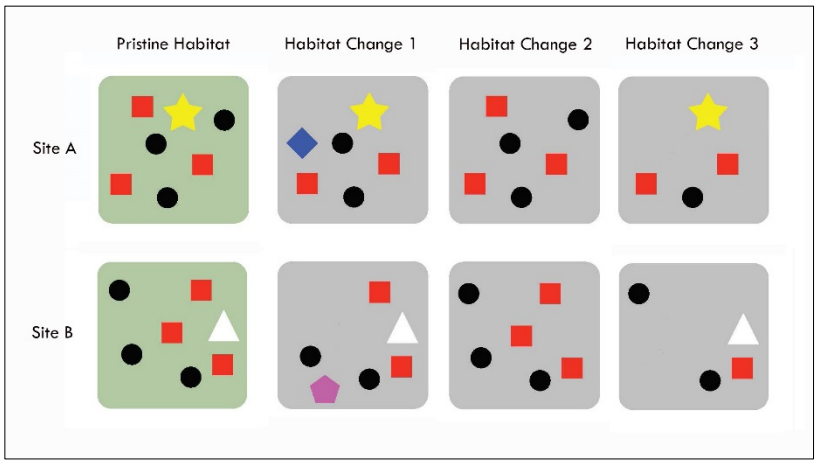
> **Teacher Note:** Students do not need to see the Story Map to answer these questions.

29. Imagine you want to do an acoustic survey of your own. What would you record? How could you capture the sounds of your life in order to compare them? What might you want to investigate? How might you compare and contrast the differences between locations?
    Answers will vary. Depending on what students want to do, consider doing Part 3 of this lesson.

30. If you recorded the sounds of your school for 24-hours (e.g. the gym, cafeteria, library, etc.), what might you learn about the inhabitants? What sounds do you think you would hear? Is there a dawn chorus? A night chorus? What are the noisiest and quietist times of day? Is there anything unexpected you might hear?
    Answer: There would be a morning chorus as the building opens and the students start arriving. It's likely that the noisiest times would be in the morning during arrival, during passing periods, and at the end of the day. Then after school the sounds would change and include teachers talking or working, custodians cleaning, and after school activities. The sounds would be different in classrooms than in the gym, theater, or cafeteria. There might be an orchestra or band practice. Perhaps the school is used for night school or some other activities and there will be a second round of sound in the evening. The wee hours of the night are most likely the quietest. Surprises might include mice or other animals that come out when everyone is gone!

A conservation organization was working with a community to determine how different habitat changes affected the alpha and beta-diversity at two different locations—sites A and B. Refer to the images below to answer questions 31-36. In these images, different shapes represent species. The number of shapes corresponds to the number of a particular species. For example, there are three species living in the pristine version of site A (red square, black circle, and yellow star). The red square and black circle are more abundant, numbering three individuals each, while there is only one yellow star.

Remember that alpha-diversity (α) is a count of the number of species in an area and beta-diversity (β) is a measure of how different the species are between the two locations. If the two sites have the same species, then beta diversity is low, if the two sites have very different species then beta diversity is high.



31. Describe what happens to the alpha-diversity (α) of sites A and B for habitat changes 1, 2, and 3? (Hint: does it increase or decrease?)
Answer: For habit change 1 α increases, for 2 α decreases, for 3 α remains the same.

32. How does the beta-diversity (β) **between sites A and B** change when habitat changes 1, 2, and 3 are implemented? (Hint: does it increase or decrease?)
Answer: For habitat change 1 β increases, for 2 β decreases, for 3 β stays the same.

33. In which of the habitat changes are individuals lost, resulting in smaller populations, but the overall species richness remains the same compared to the pristine habitat?
Answer: Habitat change 3

Teacher Note: The following questions introduce the topic of invasive species.
For more information, see http://www.nature.org/ourinitiatives/habitats/forests/explore/explore-invasive-species.xml.

34. Is an increase in alpha-diversity always a good thing? Can you imagine a scenario in which increased alpha-diversity is not a desirable change?
Answer: Alpha-diversity is just the number of species in an area. It doesn't take into account whether these species are native or invasive. Disturbances can often lead to the introduction of invasive species, which would increase alpha-diversity, but not necessarily in a desirable way.

35. In which habit change scenario is there a possibility that the increase in alpha-diversity is not a positive change?
    Answer: Habitat change 1 led to both an increase in alpha and beta-diversity. In each site, a new species (blue diamond in site A and purple polygon in site B) arrived. It's possible that these new species are invasive.

36. Let's assume that the habitat changes pictured are due to different selective logging strategies in a forest. **If the conservation organization's goal is to find the land management strategy that best preserves biodiversity across the two sites, <u>which of the habitat changes in this scenario best meets that goal?</u>** In this example, all of the shapes represent native species, except the blue diamond and the purple pentagon, which are invasive species.
    Answer: Habitat change 3 best meets the goal of preserving biodiversity. While the population size decreases, the alpha-diversity and beta-diversity remain unchanged. In habitat change 1, the alpha and beta-diversity both increase, but this is due to the arrival of invasive species, which is not a positive change for the habitat overall. However, there are questions that still need to be addressed regarding the decrease in population abundance, especially if this is a downward trend.

SYMPHONY OF THE RAINFOREST
Part 2: Soundscape Saturation

Time: One to two 45-minute class periods with homework.

Objectives:
The student will…

- 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.

Materials:

- Teacher – computer, projector, and speakers
- Internet connection
- Borneo Location Sounds Video – https://vimeo.com/195881253
- 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/

Suggested Flow:

1. This part of the lesson allows students to examine real data from the Borneo acoustic survey that is being used to determine variance in biodiversity between different locations in the study.

2. To begin the lesson, play this video with 30 second sound clips from four different locations in Borneo (https://vimeo.com/195881253).

3. Pause after each location and have students record what they think they hear. After all of the clips have played, ask students if they can tell which location was the most disturbed landscape based on the sounds they heard. They can rate them from least to most disturbed.

4. Now tell students that the clips include sounds recorded in an oil palm plantation, an acacia plantation, a selectively logged forest, and the Wehea Protected Forest. Ask them which landscapes they believe are the most disturbed. Play the sounds again and have them guess if they can tell which sounds belong to which landscape. Have them explain why they guessed the way they did.

5. Share the sounds answer key with students and have them check how they did (https://vimeo.com/203880913). Explain that it's hard to just listen to the sounds and determine what the level of biodiversity is, which is why spectrograms and other types of data analysis are useful. This activity will introduce students to one way of trying to examine sound data to learn about different landscapes.

   Answers as shown in the video:

   - Clip 1: Oil Palm Plantation
   - Clip 2: Wehea Protected Forest

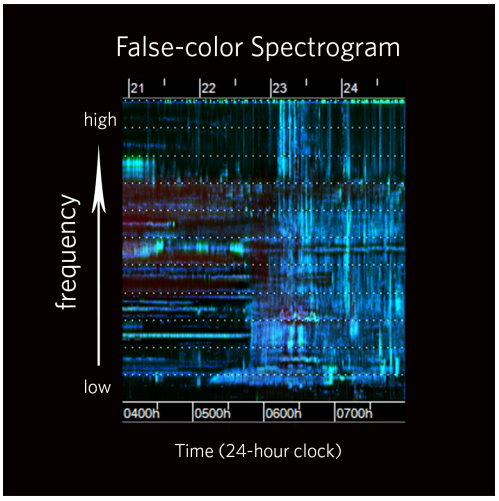
- Clip 3: Acacia Plantation
- Clip 4: Selectively Logged Forest

6. Provide students with the Copies of Part 2: Soundscape Saturation Student Handout (https://www.natureworkseverywhere.org/resources/recording-the-rainforest/). The answer key is on the next page. After students work through the activity, have a class discussion using any of the follow prompts:
    - What are the differences between false-color spectrograms and soundscape saturation graphs?
    - Why would one be more useful than another?
    - What do scientists need to think about when they decide how to analyze and portray their results?
    - Do you think the data in this activity help to support Krause's acoustic niche hypothesis? Why or why not?
    - What are the limitations of acoustic data?
    - Is there anything that surprised you when you thought through some of the challenges of experimental design?
    - What factors beyond biodiversity are important when considering different land management strategies?
    - Can you think of any current events where stakeholder concerns were not addressed with regard to land development and management? If so, what were the impacts of this lack of consideration for all stakeholders?

Part 2: Soundscape Saturation Student Handout

Teacher Answer Key

Soundscape Saturation



False-color spectrograms visualize the bandwidths of sound filled over time while also showing a variety of sound characteristics like complexity, loudness, and number of sound events.

In contrast, a soundscape saturation graph displays when there is sound present and the percent of bandwidths or frequencies filled with sound. Each point on the graph represents one unique minute of sound captured by a recorder. This is another way of visualizing the soundscape and is one step towards determining how sound can be used to assess biodiversity and landscape health in a quantifiable way.

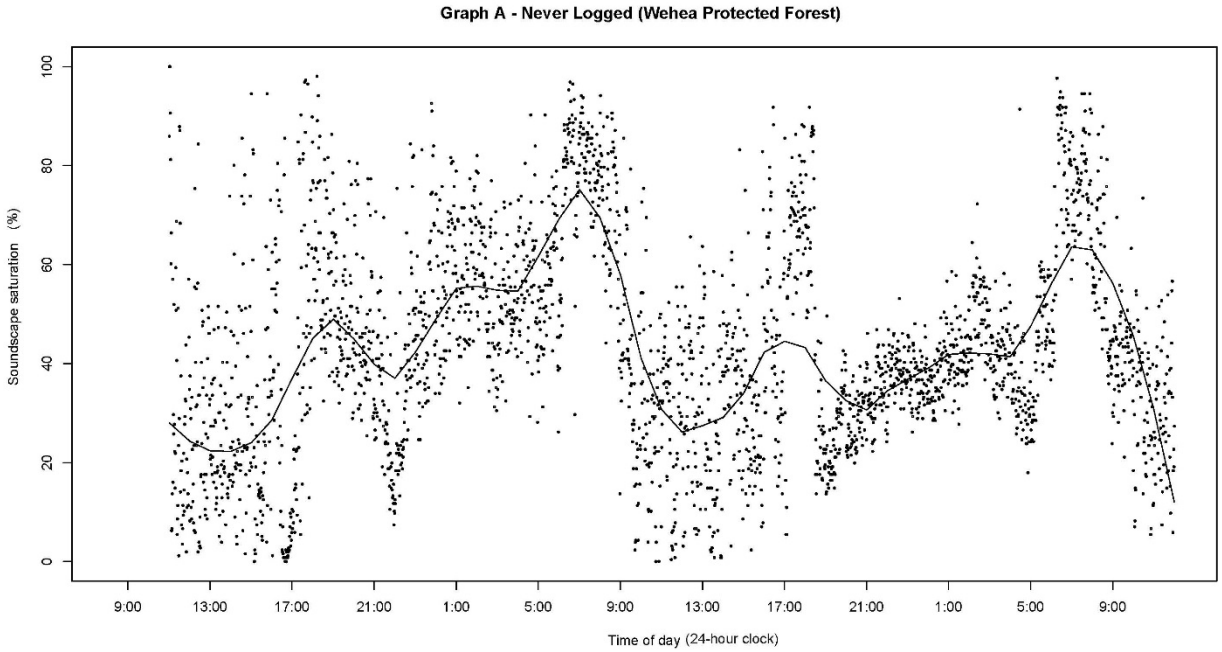
In the graphs on the following pages, the y-axis represents the percent soundscape saturation. The x-axis represents the time scale using the 24-hour clock (also known as military time).

Soundscape saturation means a percentage of bandwidths that are filled with sound at any given minute. The higher the percent, the more sound-saturated the landscape. If the saturation is 50%, then half the bandwidths are filled with sound at that moment. In other words, if there is a point on the graph at 9:00 AM at 20%, it means that at that moment, 20% of the bandwidths or frequencies are filled with sound. If at 9:01 AM there is a point at 40%, then 40% of the bandwidths were filled with sound.

The solid line or trend line in these graphs was created through a mathematical method (called local regression or LOESS smoothing). It represents the general trend in the data or the average sound saturation across time.

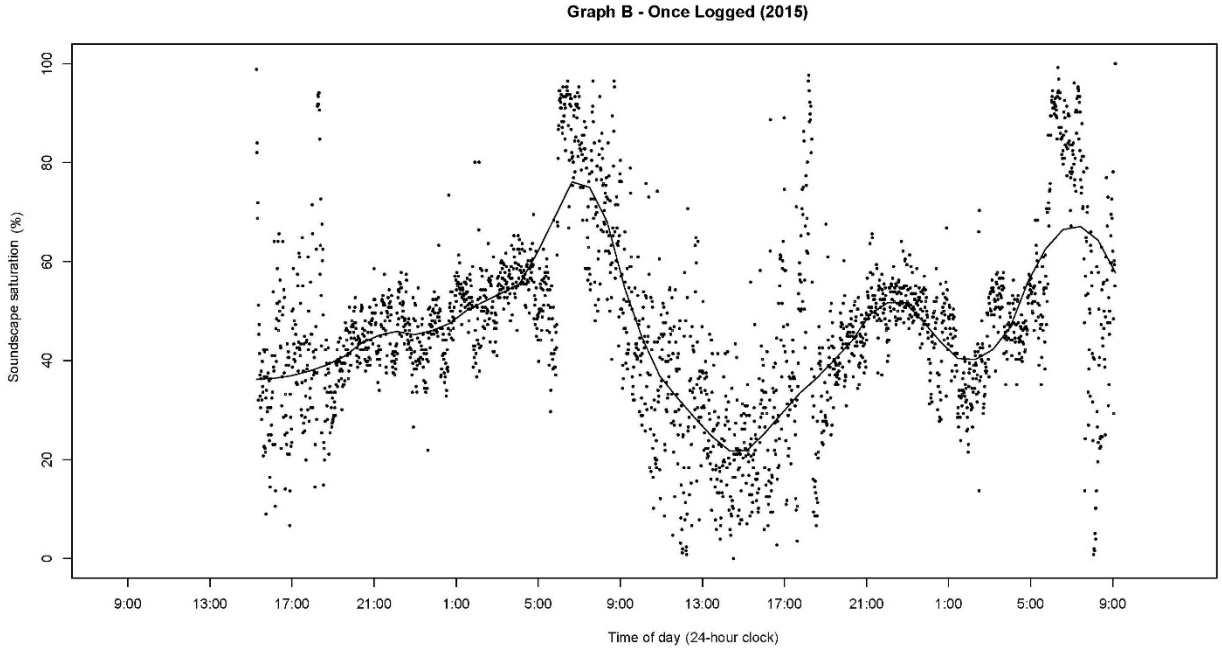
Use graphs A, B, C, D, and E to answer the questions 1-14. The questions refer to the trend line.

Teacher note: The trend line was created by taking an average of number bandwidths filled every 10 minutes, but doing this for every minute. So for example, the averages are from 9:00 to 9:10 AM, from 9:01 to 9:11 AM, and for every minute thereafter.



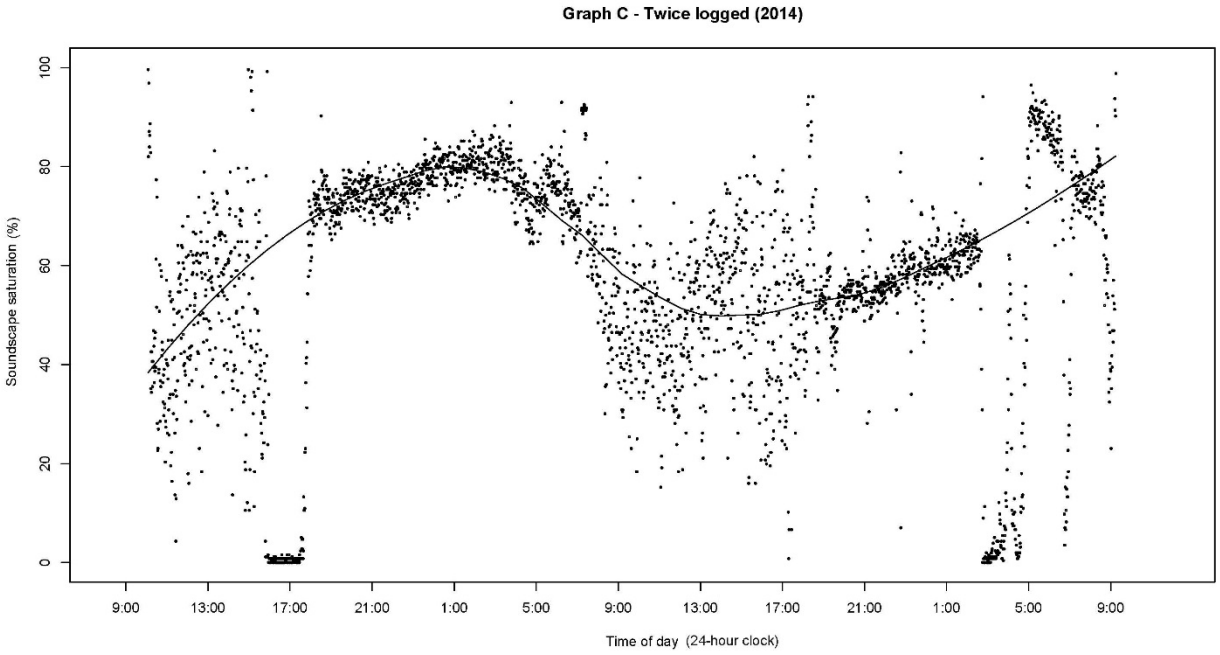
1. Look at graph A – Never Logged. Using the trend line as a guide, describe the change in soundscape saturation throughout a day. Looking at the trend line, describe the times of day the **average soundscape saturation** is the highest and lowest. Include percent soundscape saturation in your answer. Note that this graph covers a period of two days of data collection.

   Answer: Soundscape saturation is variable throughout the day. The highest average saturation is 75% and occurs around 7:00 AM. The lowest average saturation is around noon (the second noon at the end of the graph) and is about 10%. The second lowest average saturation is slightly less than 30%, occurs around noon on the first day.



2. Look at graph B – Once Logged. Compare and contrast graphs A and B in terms of the change in soundscape saturation throughout a day. Using the trend line as a guide, indicate the time of day with the highest and lowest **average soundscape saturation** for graph B. Include percent soundscape saturation in your answer. Note that this graph covers just under two days of data collection.

   Answer: Compared to graph A, graph B has fewer peaks in soundscape saturation overall. However, it still has the two highest average saturation points occurring around 7:00 AM on both days (75% for day 1 and 65% for day 2). The lowest average saturation point of 20% is at around 15:00 hours or 3:00 PM, which differs from graph A where the lowest point was at noon.



3. Look at graph C – Twice logged. Describe the trend in **average soundscape saturation** in this graph. What time(s) of day represent peak average soundscape saturation? Describe the overall trend in soundscape saturation for this location. Note that this graph covers a period of two days of data collection.
   Answer: On graph C one of the highest average soundscape saturations, 80%, occurs around 1:00 AM and one of the lowest, 50%, occurs around 14:00 hours or 2:00 PM. Because the other peaks and valleys occur outside of the data collection period, it's hard to say what the other low/high points would be. Interestingly, between the first period from 5:00-9:00, there is a downward trend in saturation and during the second period from 5:00-9:00 there is an upward trend.

4. Compare and contrast graphs A, B, and C. What are the major similarities and differences in the **average soundscape saturation**? Are there any differences in the number of peak periods or the duration of peak periods?
   Answer: Between graphs A, B, and C there is a definite difference in the times of day with variation in average soundscape saturation. They are similar in that the peak average soundscape saturation percentages are between 75% and 80%. Interestingly, the protected forest and the once-logged areas have the lowest levels of soundscape saturation at 20% whereas the twice-logged area only goes as low as about 50%. The animals vocalizing in location C only have one peak period per day compared to areas A and B, but the peak period in C lasts longer.

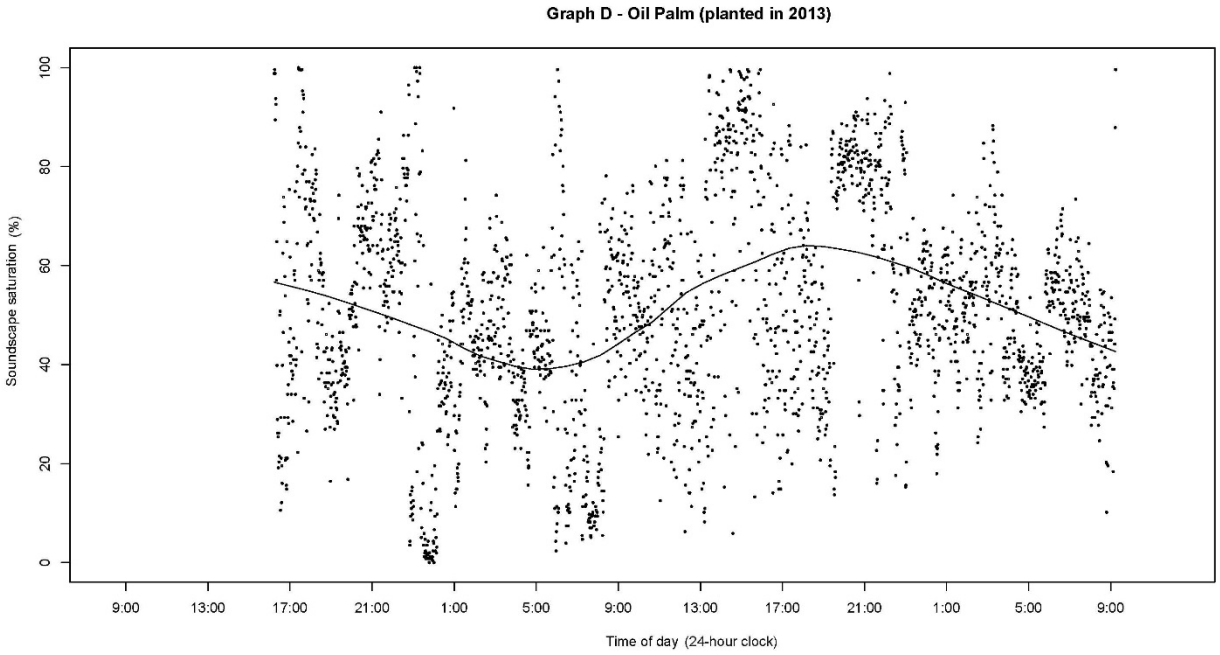
5. The locations for graphs B and C indicate that they there were once logged (2015) and twice logged (2014) respectively. The years indicate the last time they were logged. So even though the area for graph C was twice-logged, more time has passed since the disturbances than the location for graph B. Graph C shows a markedly different soundscape saturation than graphs A and B, which might imply that logging (especially two incidences of logging) has had an effect on the soundscape. However, there are several extenuating circumstances outside of logging activity. What kinds of questions do you need to answer before you can attribute the soundscape change in graph C to logging?
   Answer: It would be important to know where these locations are in relation to each other and what other elements are in the landscape. Are they near a river? Are they at the same elevation? How close are they to human habitation? Are they near roads/houses? What other kinds of activities might be taking place (like hunting)?

6. Sunrise happens around 6:00 AM in these locations and is often a time of abundant animal activity in the rainforest. Describe the soundscape saturation with respect to this time of day in graphs A, B, and C.
   Answer: Both graphs A and B (protected forest and once logged) show a trend toward increased soundscape saturation around sunrise – peaking at about 7:00 AM. Graph C (twice logged) does not reflect this trend. As mentioned previously, there is both an increasing and decreasing trend between the two days of data collection during the 5:00-9:00 period. However, in each case, the sound is not at its peak around sunrise.

7. Do you think the same animals inhabit locations A, B, and C? Why or why not? What more information do you need to know to determine this?
   Answer: You can't tell from these data whether or not the same animals inhabit these locations. The graphs simply show how saturated the environment is with sound. You would have to go back to the original audio recordings and spectrograms and do a more detailed analysis of what lives there to be sure.

8. What kind of research might you need to do to answer the following questions?
   a. Does one species always vocalize at the same time of day regardless of the habitat or location?
   b. Does one species always vocalize at the same frequency regardless of the habitat or location?

   Answer: For both a. and b., you would need to go back to the audio recordings and spectrograms to determine this by examining the vocalization frequency and time of day across different habitats or locations.



9. Now examine graph D – Oil Palm. Describe the trend in **average soundscape saturation** for this graph. When is peak average soundscape saturation? Compare this graph to A, B, and C. Which of these graphs does graph D most closely resemble? How is it similar and how is it different?
Answer: The peak average soundscape saturation for graph D occurs around 18:00, or 6:00 PM, and is about 60%. The lowest average soundscape saturation is at about 5:00 and is around 40%.

Graph D somewhat resembles graph C in that it has fewer peaks and valleys and instead has one broader, longer peak period. However, the longer peak period of saturation in graph C is much higher than that of graph D.

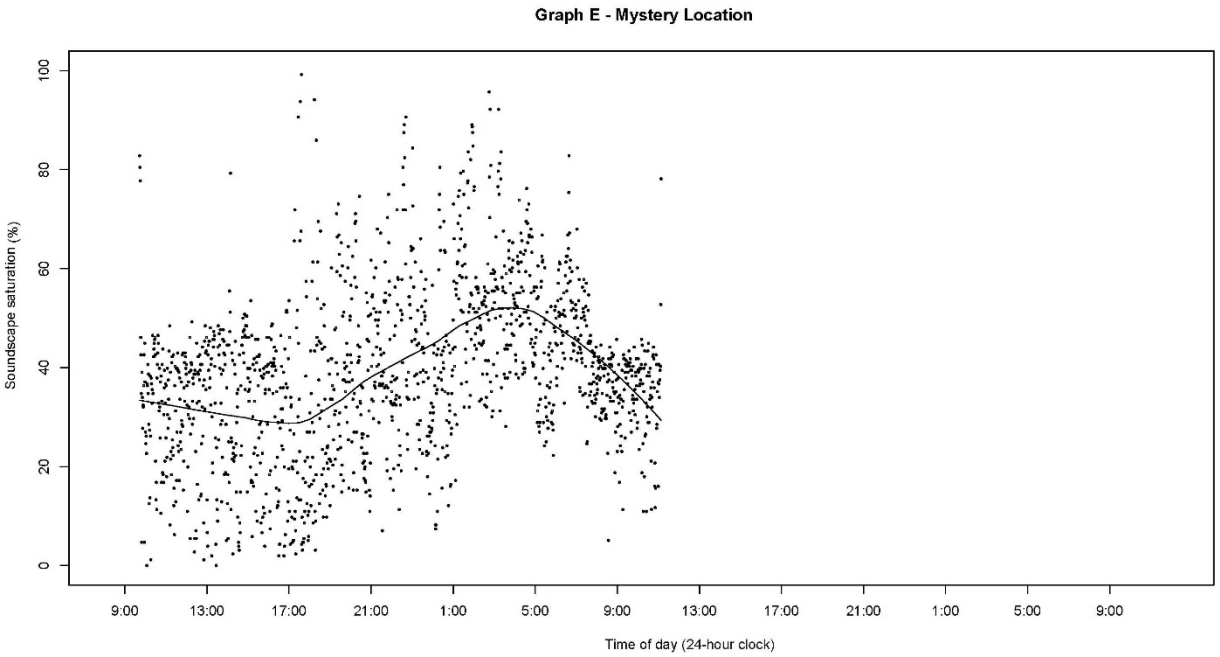
Graph D is also missing that peak average soundscape saturation around sunrise as found in graphs A and B. Similar to graph C, its lowest average soundscape saturation is 40%.

10. Based on your examination of graphs A, B, C, and D what conclusions can you draw about landscape type and sound saturation?
    Answer: Different landscapes do have different soundscape saturation patterns. Graphs A and B are fairly similar in their general trends and are likely the most similar landscape types among the four locations. Graphs C and D represent a more disturbed habitat (C) and a completely different habitat in terms of vegetation (D) and the soundscape saturation patterns appear to reflect those differences. Both are missing the distinct period in the morning where there is high soundscape saturation between 5:00-9:00 AM. That could indicate that some of those key morning animals are absent.

11. As stated in the story map, Bernie Krause introduced the concept of an acoustic niche. This states that every animal species occupies its own acoustic niche in a soundscape to avoid competition for sound space with other species. This hypothesis supports the idea that the healthier and more biodiverse an ecosystem is, the fuller the soundscape will be. Based on this idea, can you assess the relative health or comparative level of biodiversity of the landscapes represented in graphs A, B, C, and D or you need more information than soundscape saturation to determine ecosystem health? If so, what can you determine with the soundscape saturation graphs and what can't you determine?

    Answer: From the soundscape saturation graphs, it is clear that with the change of vegetation or habitat that the time and duration of when animals vocalize is different. This could imply that the animals vocalizing are different animals or that something about the habitat has changed their schedule. In order to determine if they were the same animals, you would have to listen to the recordings. Comparing all of these graphs does allow you to see how different vegetation types impact the organisms that live there (or don't), but only in a very general way.

    You can't determine exactly which animals live in an area, or which bandwidths their sounds occupy, from the soundscape saturation graphs. The graphs only inform you what percentage of the bandwidths are full of sound at different moments. In order to determine which animals are represented in the soundscape and which bandwidths have sound, you'd have to listen to the recordings and look at the spectrograms.



12. Now examine graph E – Mystery Location. You have just 24-hours of data from this location. Describe all of the similarities and differences, noting the maximum and/or minimum **average soundscape saturations** and times of day. Based on the soundscape saturation information from the other graphs, from what type of landscape do you think these data were obtained? Is it the same or different than the landscape represented in graphs A, B, C, and D. Describe the biodiversity of this site relative to the other locations. Use evidence to defend your reasoning.

Possible student answer: Graph E is very similar to both graphs C and D in that it has fewer peaks and valleys on the trend line. This means that it has less variety in soundscape saturation throughout the day. If soundscape saturation is correlated to biodiversity, then this landscape is less biodiverse. Graphs C (twice logged) and D (oil palm) represent more disturbed habitats than Graph A (protected forest). Because of the similarities between the overall trend of soundscape saturation between graphs C, D, and E this leads me to believe that Graph E comes from a disturbed habitat as well.

The time of day when the soundscape saturation is greatest is around 4:00 in graph E. The times of day when soundscape saturation is greatest in graph C are 1:00 and 9:00 and in graph D 17:00 and 18:00. This leads me to believe that maybe the species composition in location E is different because the animals vocalize at different times. This could mean the habitat/vegetation is different.

Across all of the graphs, peak sound saturation levels are lowest in graph E, not even reaching 50%, whereas in graph A for the protected forest, the highest sound saturation is over 70%. The peak soundscape saturation is nearly 80% in graph C and over 60% in graph D. This could indicate that the area is very disturbed since it appears to have fewer animals vocalizing across time.

Note for teacher: this graph comes from an acacia plantation – so it is indeed a disturbed habitat, and it is a different type of vegetation than the other landscapes. It is also a monoculture, so it's likely that there is fairly low biodiversity here. The oil palm plantation is also a monoculture and its peak soundscape saturation levels are the lowest among graphs A, B, C, and D.

Applications of Acoustic Data

13. If you ran an ecotourism outfit and wanted to make sure you took tourists to the rainforest to see birds and other animals, when would you arrange your tours? How could you use acoustic data to determine this?
    Answer: In habitats like the Wehea protected forest, it appears from graph A that animals vocalize most during 5:00-9:00 AM, with the peak occurring around 7:00 AM. I would make sure that we are well within the forest no later than 7:00 AM.

14. In what are other ways do you think acoustic data could be useful?
    Answers may vary. Students may suggest that acoustic data provides a record of what lives in a place at a certain time and these data can be compared across years to see if there has been a shift in species composition. It can also help capture the sounds of animals that have yet to be discovered. Once these animals are discovered, the acoustic record may help to identify the range of the species.

Study Limitations and Experimental Design Choices

15. Does acoustic data capture all of the organisms in an ecosystem?
    Answer: No it does not. Not all animals vocalize, so it excludes these organisms. Plants, fungi, bacteria, etc. are also not represented in soundscape data.

16. For this acoustic survey in Borneo, the acoustic recorders were strapped to trees at chest height. Describe the advantages and disadvantages of this experimental design.
    Answer: The advantage of this design are that chest height is accessible without additional equipment, so the recorders are easy to place and remove. The disadvantage is that they only capture sound at that height and may exclude sounds higher in the canopy or closer to the ground.

17. In this particular study, due to time limitations, the number of recorders available, and the number of sites visited, recorders where only placed on trees for 1-2 days at a time. How could this impact the data that was collected and how would you solve for that impact in future investigations?
    Answers may vary. Students may suggest that there could have been a weather event like a rainstorm that caused some animals to vocalize less (or more). Once a preliminary study like this was conducted, areas of concern could be retested.

    Students might also suggest that if there was any seasonality (as in temperate forests in the USA), we might see different patterns throughout the years. For example, in a temperate forest, a lot of birds are not there in the winter due to migration. There may also be differences due to rainy seasons vs dry seasons, etc.

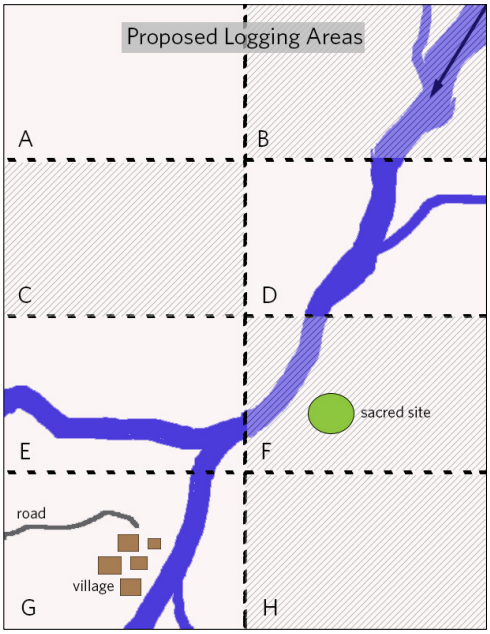
18. Ultimately, when designing an experiment, scientists must balance cost and feasibility with their investigation objectives. Time, money, weather, equipment cost, and access (getting permission from logging companies, communities, government, etc. to do research on location) are all factors that must be addressed in experimental design. In a remote forest setting, scientists must even consider how they get to the locations, where they will sleep, and how they will eat and have access to clean water. Even battery life is a concern when using high-tech equipment in a remote location.

    Because of these factors, scientists must make careful decisions in order to get the most out of their investigations. If you were part of a team who was invited back to the rainforests of Borneo to continue to investigate biodiversity as it relates to land management – what would you like to investigate and how would your investigation compliment the acoustic survey described in this lesson? Describe any limitations or possible barriers to your proposal that you would have to overcome.

    Answers may vary. Students may suggest placing recorders higher in the trees. They would have to figure out way to get in the trees (equipment) and how to carry this equipment in the forest. They may wish to add a survey that incorporates animals that don't vocalize. In order to do this, they would have to come up with a survey method to collect these data.

From Biodiversity Study to Land Management

19. Examining the biodiversity of a landscape can help scientists determine which areas are critical habitats that need to be protected. This information can aid in the determination of land management strategies that support conservation while allowing for development activities like agriculture and logging. However, knowing the biodiversity of an area is only part of the picture. The landscape pictured to the right has been surveyed for biodiversity and the portions of land on the map marked A, D, E, and G have been shown to support extremely high biodiversity. The recommendation from ecologists is to protect these areas. The recommendation also states that shaded areas (B, C, F, H) on the map are most suitable for logging or other development activities because they have lower biodiversity. Note that the arrow indicates the direction of river flow.



What are all of the factors that should be considered before implementing a land management strategy and who should be at the table to have these discussions? In other words, who are the stakeholders? Are some considerations more important than others?

Answer:

Factors

- *The proposed development areas are patchy and disconnected, meaning there is no corridor for animals to travel between the protected areas. (Teacher note: as noted in the video, animals like the orangutan need large habitats.)*
- *While the village itself is not in a proposed development area, these areas are upstream from the village and development activities may contaminate water.*
- *All of the proposed areas are far from the road, which means new roads will have to be established to reach the areas, which will further impact the ecosystem.*
- *One of the proposed areas (F) is the location of a sacred site and development activities may adversely affect this site.*

Stakeholders

- *The villagers – to comment on how they will be affected by proposed development activities. They may have sacred sites, use the land for hunting or farming, and their water may be affected by development.*
- *Government officials – to ensure who has rights to the lands in question.*
- *Other scientists (e.g. hydrologists, carbon scientists) – to ensure that waterways won't be affected by proposed logging activities and that the logging will be conducted in a way that has the least impact.*

Which considerations are most important?

There is no uniform or "right" answer to what is more important. There are many trade-offs that need to be addressed whether the aim is biodiversity conservation, protecting human wellbeing, or conservation of land that can provide important ecosystem services globally, etc.

Teacher note: These topics are great content for further exploration a class debate!

SYMPHONY OF THE RAINFOREST

Part 3: Community Soundscapes

Time: Multiple class periods based on study design and procedure.

Objectives:

The student will…

- 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:

- 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

Suggested Flow:

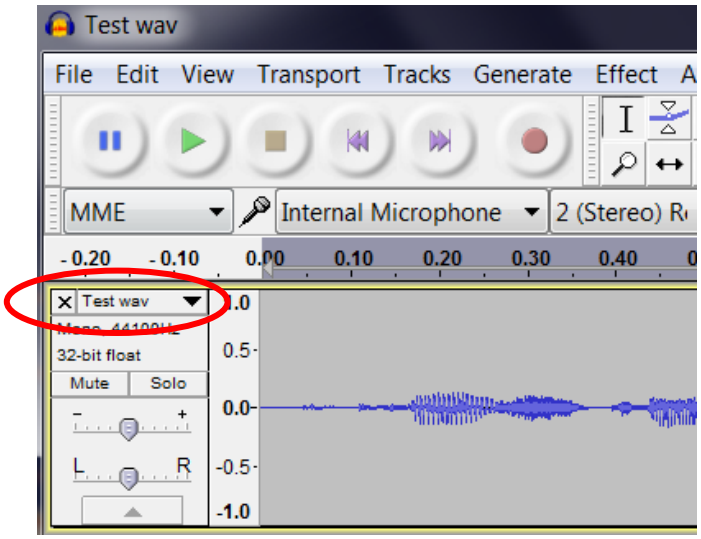
1. Students can conduct their own local version of an acoustic survey to map out sounds across the urban areas they inhabit. Possible uses of this information:
    a. Record sounds of the school environment.
    b. Compare urban sound spectrograms to tropical rainforest spectrograms.
    c. Create and view spectrograms of the sounds and try to pinpoint areas of highest "acoustic biodiversity", or times of day with the richest urban soundscapes, or urban areas that have the most anthrophony, etc.
    d. Record and map urban sounds and create a catalog of the community.

2. How to do it:

    To record sounds:
    Use a cell phone or other recording device. If using the native voice recording apps on iPhone or Android, students will need to convert the sounds into MP3 or WAV format. This can be done using the free VLC player or other software. A VLC player can be downloaded here: http://www.videolan.org/vlc/index.html. Alternatively, there are many free apps that can be downloaded to phones that will record sound and let you specify the file format. For the next step, the audio files will need to be in WAV or MP3 format. Once the sounds are recorded, students can email them to themselves, save in a folder, and open in Audacity.

    To use Audacity to view spectrograms:
    Download Audacity http://www.audacityteam.org/ (free) if you don't already have it. Go to file>open and choose the appropriate file.

    The click on the dropdown menu for your sound file. In the example below, the sound file is called "Test wav". Then select "Spectrogram".


Test wav
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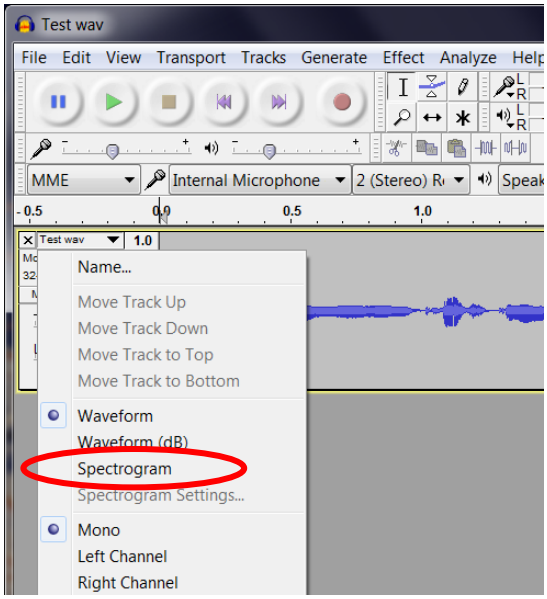
Test wav
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Internal Microphone
2 (Stereo) R
- 0.5 0.0 0.5 1.0
Test wav
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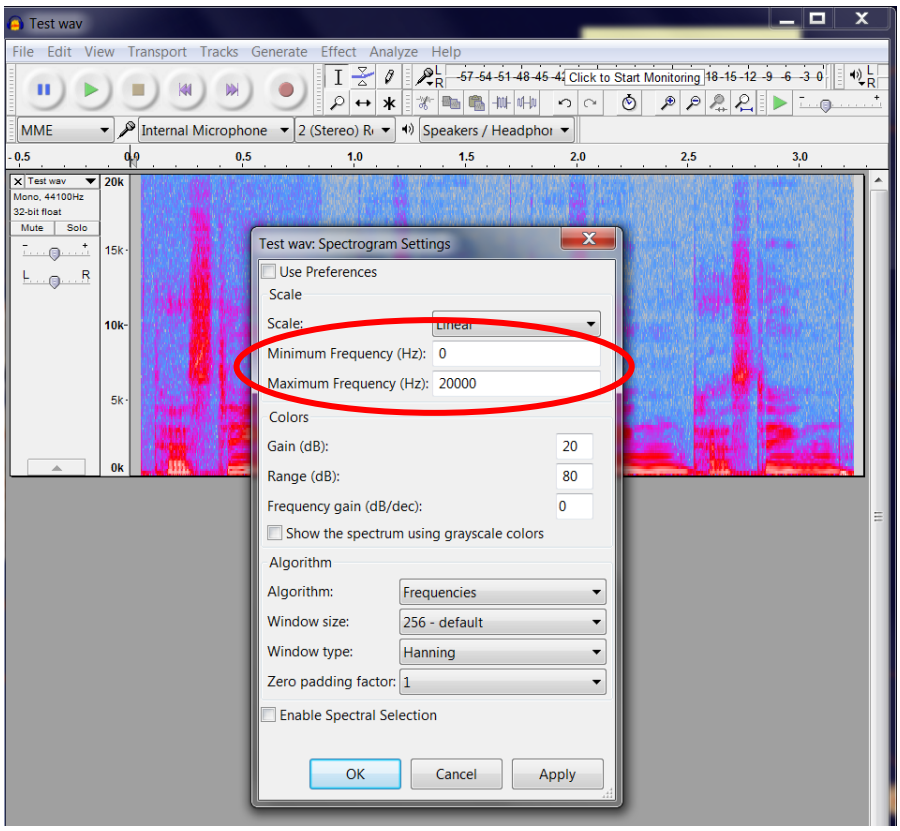
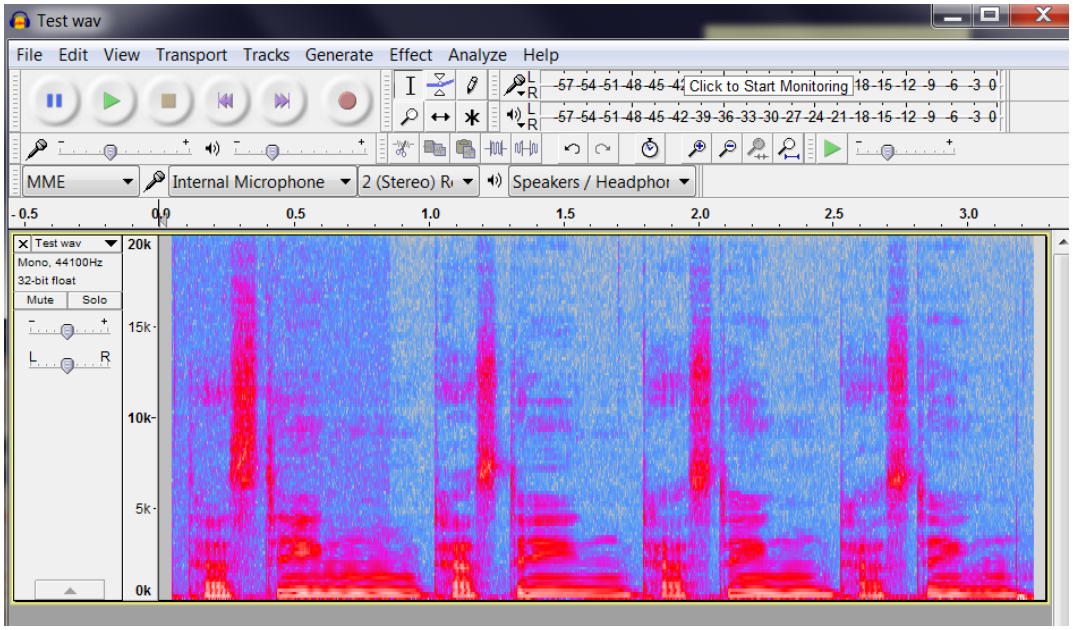
Move Track to Top
Move Track to Bottom
Waveform
Waveform (dB)
Spectrogram
Spectrogram Settings...
Mono
Left Channel
Right Channel

Once in spectrogram view, you can go back to this same menu and change the frequency range viewable. Since the limit of human hearing is 20,000 Hertz, you may want to adjust the upper limit to 20,000 Hz. You can also adjust the color range or show in grayscale.



The final spectrogram for the "Test wav" can be seen below. Students can take a screenshot (printscreen) of their image, open MS Paint, Photoshop or any other photo editing software and save as a JPEG for later use.



3. Considerations:
    - Students should record at the same time of day depending on the goal. You may wish have them record at dawn or dusk.
    - Consider having students take a photo of the area where they record to document the landscape.
    - Students could be assigned to record sounds in various parts of an urban area. Be sure to be specific on what time and where they should record. You could turn this into a GPS activity by having them record their GPS coordinates.

4. There are a variety of ways your students can tell the story of their sounds and display and share their sounds, spectrograms, and photos. If students are going to map and share their sound information publicly on the internet, you should avoid having them map and label their personal residences due to issues of privacy and safety of minors. A few examples of ways to share sounds are included below.

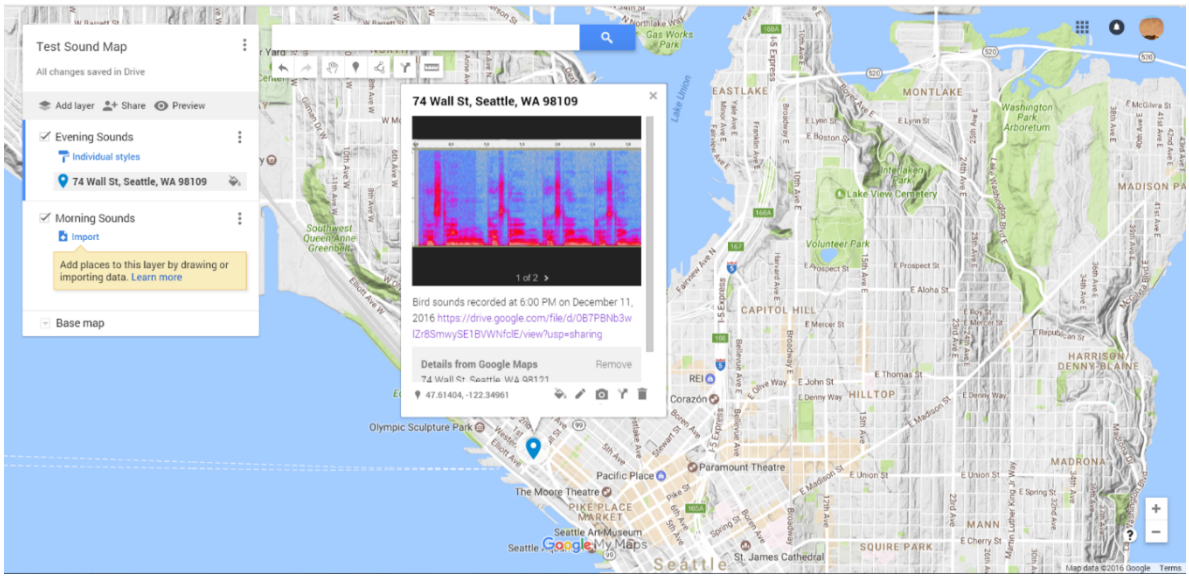
    Podcasting

    Students could create a sound story about their community and turn it into a podcast. For more information on podcasting in the classroom, check out the blogs below:

    - Podcasting – Using Podcasts in the Classroom, by EdTechTeacher http://edtechteacher.org/tools/multimedia/podcasting/
    - Podcasts: The Nuts and Bolts of Creating Podcasts, on ReadWriteThink by NCTE http://www.readwritethink.org/classroom-resources/printouts/podcasts-nuts-bolts-creating-30311.html

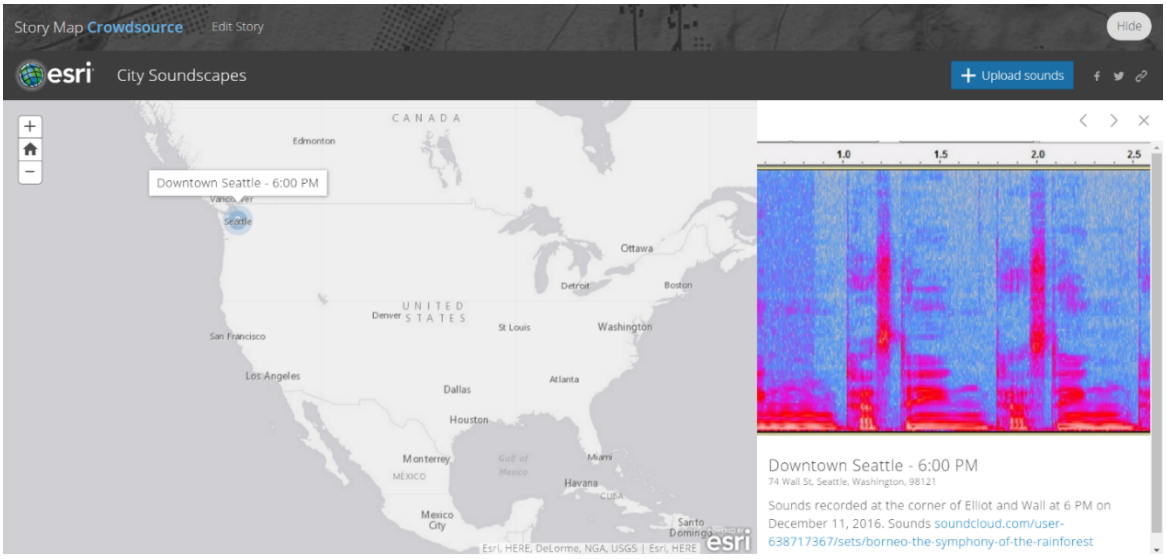
    Google My Maps (https://www.google.com/maps/about/mymaps/)

    a. You can create a Google My Map with multiple layers for time of day or type of sound (anthrophony, geophony, biophony).
    b. If you make the map link available (and editable) by your students, they can upload their information on their own.
    c. They can find their location by entering the street address or by locating it on the map. When there, they can drop a pin, give it a title, description, and upload photos. They can upload there sounds to a sound hosting site like SoundCloud and then include the URL. Alternatively, it's easy to upload MP3 files to a Google Drive. You could have a class folder where students drop their sounds and then paste the share link in the description (it will appear as a hyperlink). An example of what this might look like is below.



Esri Story Maps – Crowdsource or Other (https://storymaps.arcgis.com/en/)

a. Esri offers free educator accounts – you can find out more by visiting this site: http://www.esri.com/industries/education/schools
b. There are many forms of Story Maps available, but the Crowdsource Story Map (https://storymaps.arcgis.com/en/app-list/crowdsource/) might prove to be a useful template for hosting this type of information.
c. In the Crowdsource Story Map, you can quickly build the platform that students can go to using a link and click a button to upload information. Once on the Crowsdsource Story Map, they find their location and share their spectrogram, photo, description of location to the map. Similar to above, they can host their recorded sounds in Google Drive or a site like SoundCloud. They can past the URL for the sound in to the description text in the Story Map. An example Crowdsource Story Map is below.



STUDENT HANDOUT

Recording the Rainforest Part 1:
The Sounds of Borneo Story Map Student Handout

Directions:

Go to The Sounds of Borneo Story Map at http://arcg.is/2gBeUJk. The following questions can be answered using information located in the Story Map text as well as through various hyperlinks located in the Story Map, which appear as blue text. The questions below follow the Story Map in chronological order.

37. Listen to a few minutes of the first and second movements of the rainforest symphony. Compare and contrast the soundscape you hear in each. How are they similar? How are they different? Speculate why they are different.

38. How old is the Bornean rainforest?

39. Explore the IUCN website (http://www.iucnredlist.org/) to discover the status of the Bornean orangutan, proboscis monkey, Sumatran elephant (listed as a subspecies of Asian elephant), and Sunda clouded leopard and list below.

40. Define and give examples of ecosystem services.

41. Describe how trees sequester carbon.

42. List 3 types of medicines that have come from rainforest plants.

43. Describe at least two local and/or global ecosystem services provided by rainforests.

44. Using the swipe map, describe how Borneo's forest cover has changed over time.

45. Using the legend to the left of the map, note some of the main land cover types that have replaced intact or old-growth forest in the period from 1973 to 2015.

46. The legend contains a category called "non-forest". What do you think might exist in these areas? You can consult more maps at http://bit.ly/2khlqud to enhance your answer.

47. Describe the impacts of ecosystem threats like mining, acacia and oil palm plantations, and logging on Borneo's landscape.

48. List three products you use that contain palm oil.

49. Describe some of the ways to measure biodiversity. What are the benefits and limitations of each?

50. Describe the difference between alpha and beta-diversity.

51. Why is knowing the beta-diversity of a landscape critical to the development of conservation strategies and land management plans?

52. Measuring and protecting biodiversity might be one goal in a land management strategy. What are other things that must be considered when deciding how to manage land?

53. Use the online tone generator (http://onlinetonegenerator.com/hearingtest.html) to determine the highest frequency you can hear and record it here.

54. Audio recordings in a rainforest can capture a variety of organisms, but what are some of the organisms they can't capture and how could you account for them in a study of biodiversity?

55. Describe the acoustic niche hypothesis.

56. How have animals evolved in response to competition for space in the soundscape?

57. What happens to soundscape saturation when a habitat is disturbed?

58. Describe the three types of sounds in an environment.

59. List all of the animals you can think of in the rainforest environment that can vocalize or produce sounds.

60. Can you hear anthrophony, geophony, and biophony in the sound clip? Describe the sounds you heard and categorize them.

61. Answer the following questions about the spectrogram example shown in the Story Map (and below):

d. What time of day appears to be the loudest and with most frequencies filled with sound?

e. What type of geophony is depicted in this spectrogram and what time did it occur?

f. Using frequency information from the spectrogram, describe how the sounds of the rainstorm differ from those of the animals.

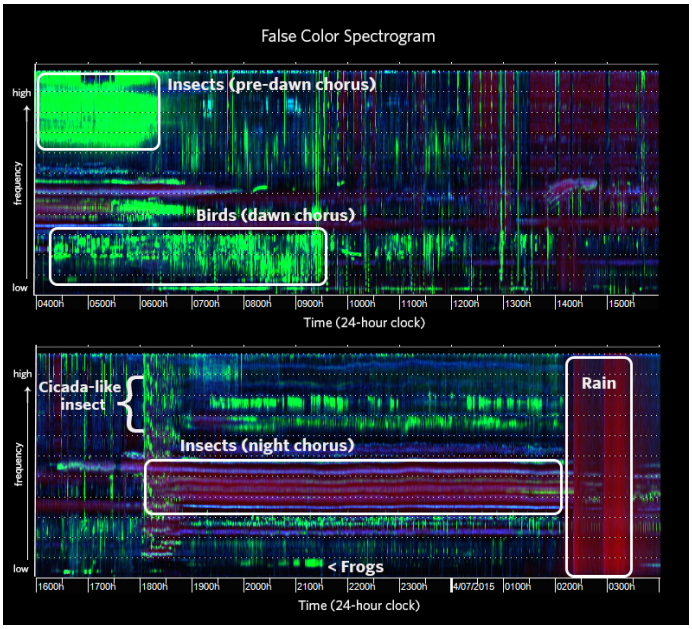


Image credit: Michael Towsey and Anthony Truskinger,
Queensland University of Technology

62. Listen again to a few minutes of the first and second movements of the rainforest symphony. Based on what you've learned by looking at a false-color spectrogram of rainforest sounds, when do you think they were recorded?

63. How can acoustic data inform land management decisions?

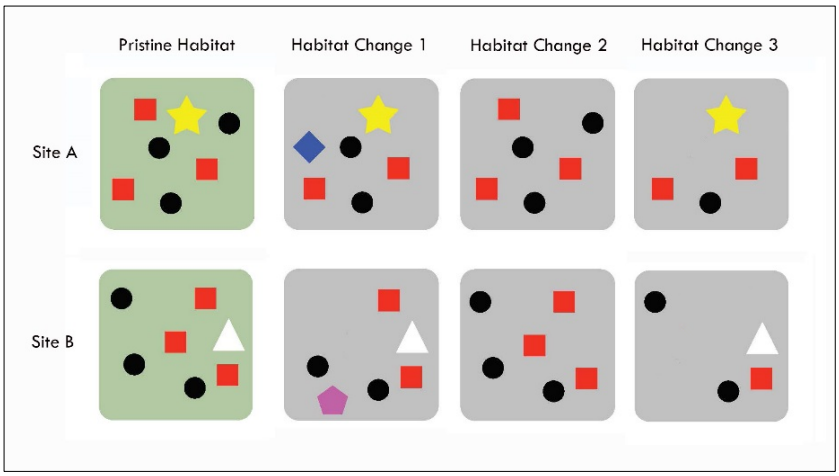
64. Conduct an Internet search to find one example of another use of acoustic technology in conservation and describe it briefly.

Homework Questions:

65. Imagine you want to do an acoustic survey of your own. What would you record? How could you capture the sounds of your life in order to compare them? What might you want to investigate? How might you compare and contrast the differences between locations?

66. If you recorded the sounds of your school for 24-hours (e.g. the gym, cafeteria, library, etc.), what might you learn about the inhabitants? What sounds do you think you would hear? Is there a dawn chorus? A night chorus? What are the noisiest and quietist times of day? Is there anything unexpected you might hear?

A conservation organization was working with a community to determine how different habitat changes affected the alpha and beta-diversity at two different locations—sites A and B.



Refer to the images to the right to answer questions 31-36. In these images, different shapes represent species. The number of shapes corresponds to the number of a particular species. For example, there are three species living in the pristine version of site A (red square, black circle, and yellow star). The red square and black circle are more abundant, numbering three individuals each, while there is only one yellow star.

Remember that alpha-diversity (α) is a count of the number of species in an area and beta-diversity (β) is a measure of how different the species are between the two locations. If the two sites have the same species, then beta diversity is low, if the two sites have very different species then beta diversity is high.

67. Describe what happens to the alpha-diversity (α) of sites A and B for habitat changes 1, 2, and 3? (Hint: does it increase or decrease?)

68. How does the beta-diversity (β) **between sites A and B** change when habitat changes 1, 2, and 3 are implemented? (Hint: does it increase or decrease?)

69. In which of the habitat changes are individuals lost, resulting in smaller populations, but the overall species richness remains the same compared to the pristine habitat?

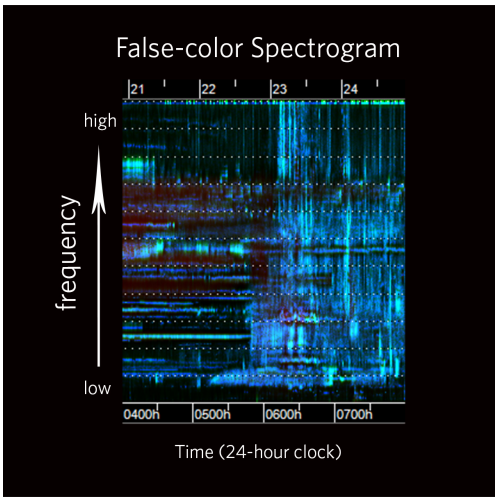
70. Is an increase in alpha-diversity always a good thing? Can you imagine a scenario in which increased alpha-diversity is not a desirable change?

71. In which habit change scenario is there a possibility that the increase in alpha-diversity is not a positive change?

72. Let's assume that the habitat changes pictured are due to different selective logging strategies in a forest. **If the conservation organization's goal is to find the land management strategy that best preserves biodiversity across the two sites, <u>which of the habitat changes in this scenario best meets that goal?</u>** In this example, all of the shapes represent native species, except the blue diamond and the purple pentagon, which are invasive species.

SYMPHONY OF THE RAINFOREST
Part 2: Soundscape Saturation Student Handout

Soundscape Saturation



False-color spectrograms visualize the bandwidths of sound filled over time while also showing a variety of sound characteristics like complexity, loudness, and number of sound events.

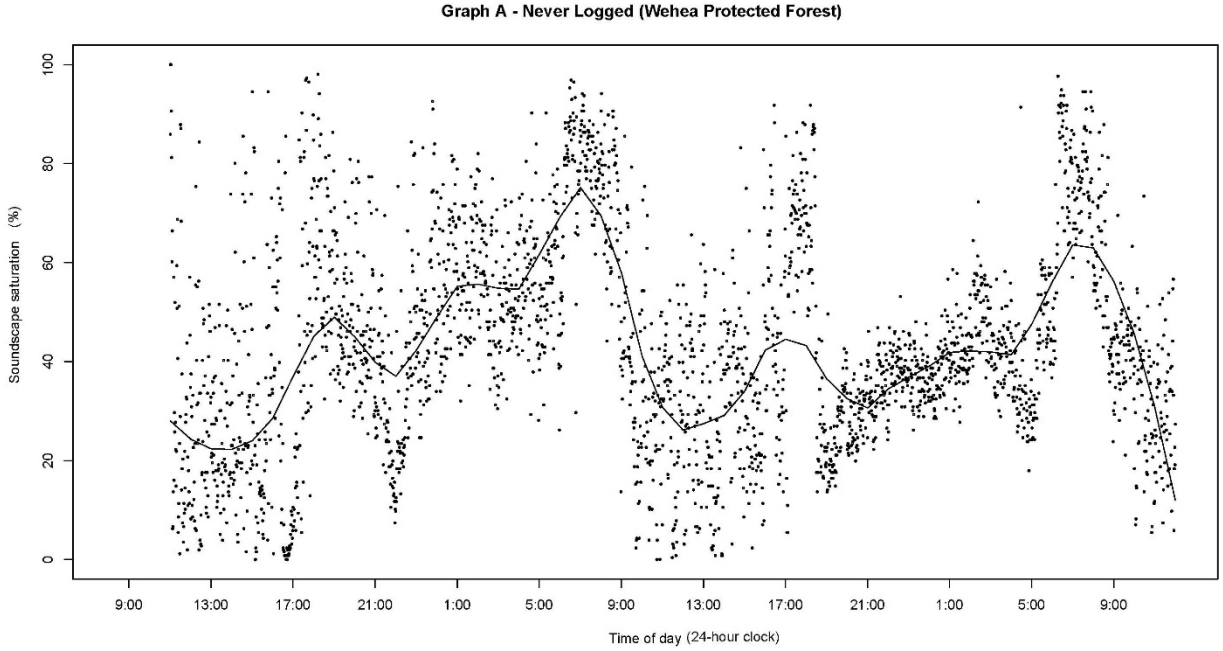
In contrast, a soundscape saturation graph displays when there is sound present and the percent of bandwidths or frequencies filled with sound. Each point on the graph represents one unique minute of sound captured by a recorder. This is another way of visualizing the soundscape and is one step towards determining how sound can be used to assess biodiversity and landscape health in a quantifiable way.

In the graphs on the following pages, the y-axis represents the percent soundscape saturation. The x-axis represents the time scale using the 24-hour clock (also known as military time).

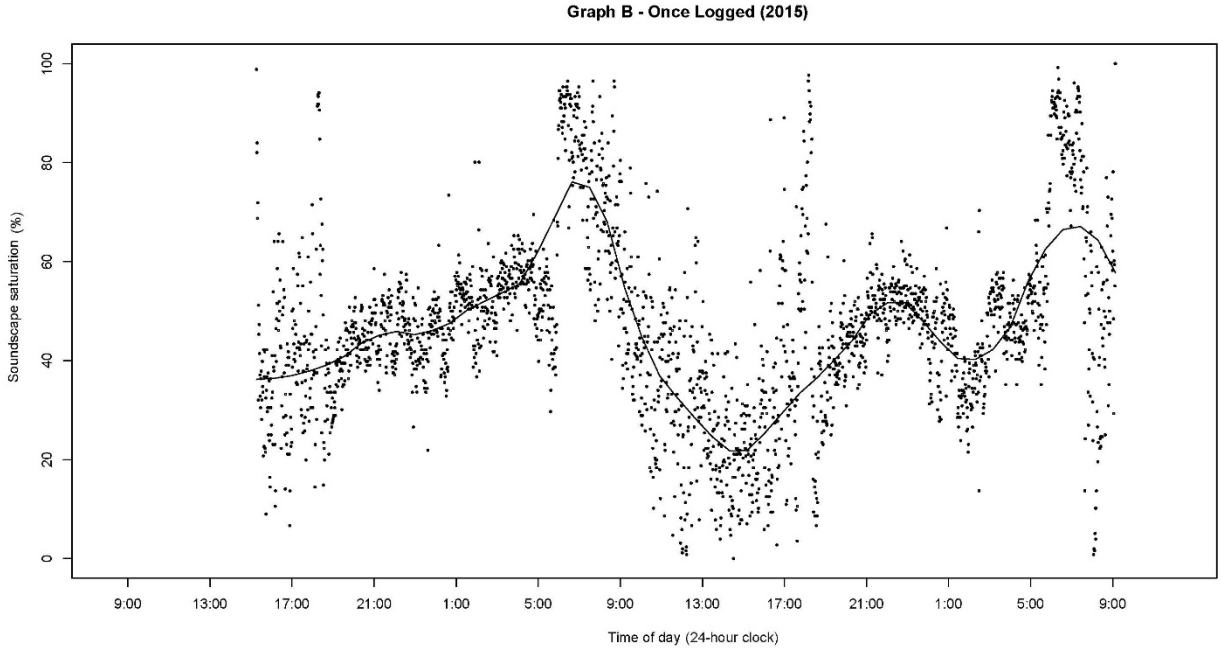
Soundscape saturation means a percentage of bandwidths that are filled with sound at any given minute. The higher the percent, the more sound-saturated the landscape. If the saturation is 50%, then half the bandwidths are filled with sound at that moment. In other words, if there is a point on the graph at 9:00 AM at 20%, it means that at that moment, 20% of the bandwidths or frequencies are filled with sound. If at 9:01 AM there is a point at 40%, then 40% of the bandwidths were filled with sound.

The solid line or trend line in these graphs was created through a mathematical method (called local regression or LOESS smoothing). It represents the general trend in the data or the average sound saturation across time.

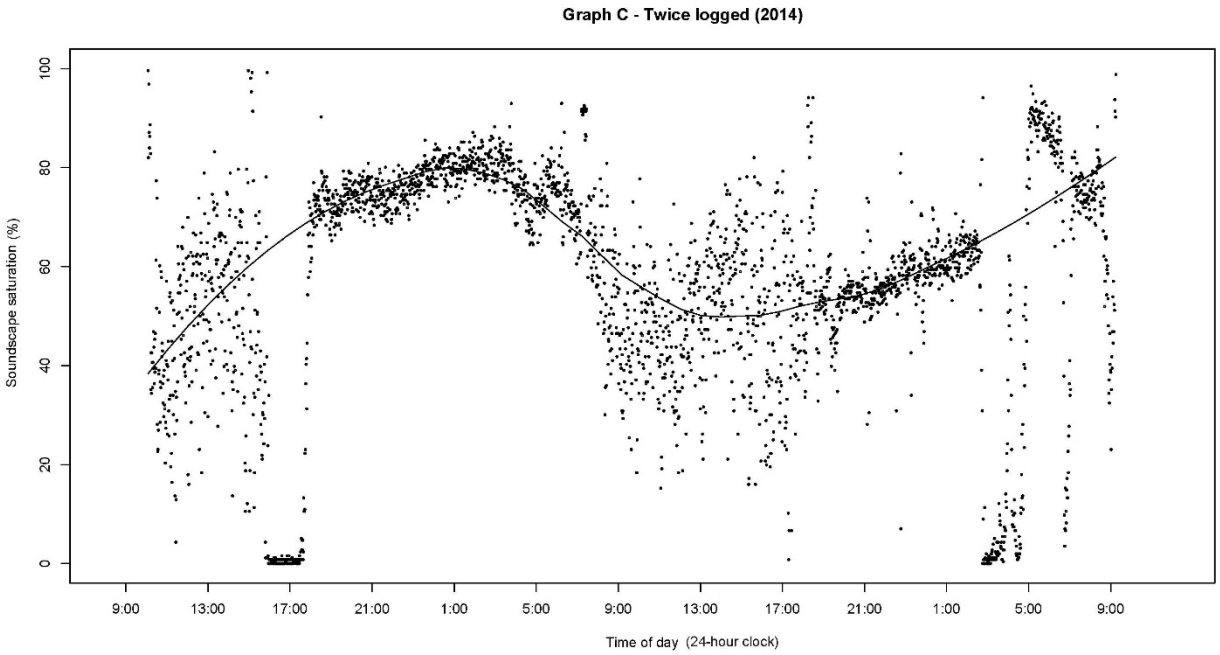
Use graphs A, B, C, D, and E to answer the questions 1-14. The questions refer to the trend line.



1. Look at graph A – Never Logged. Using the trend line as a guide, describe the change in soundscape saturation throughout a day. Looking at the trend line, describe the times of day the **average soundscape saturation** is the highest and lowest. Include percent soundscape saturation in your answer. Note that this graph covers a period of two days of data collection.



2. Look at graph B – Once Logged. Compare and contrast graphs A and B in terms of the change in soundscape saturation throughout a day. Using the trend line as a guide, indicate the time of day with the highest and lowest **average soundscape saturation** for graph B. Include percent soundscape saturation in your answer. Note that this graph covers just under two days of data collection.



3. Look at graph C – Twice logged. Describe the trend in **average soundscape saturation** in this graph. What time(s) of day represent peak average soundscape saturation? Describe the overall trend in soundscape saturation for this location. Note that this graph covers a period of two days of data collection.

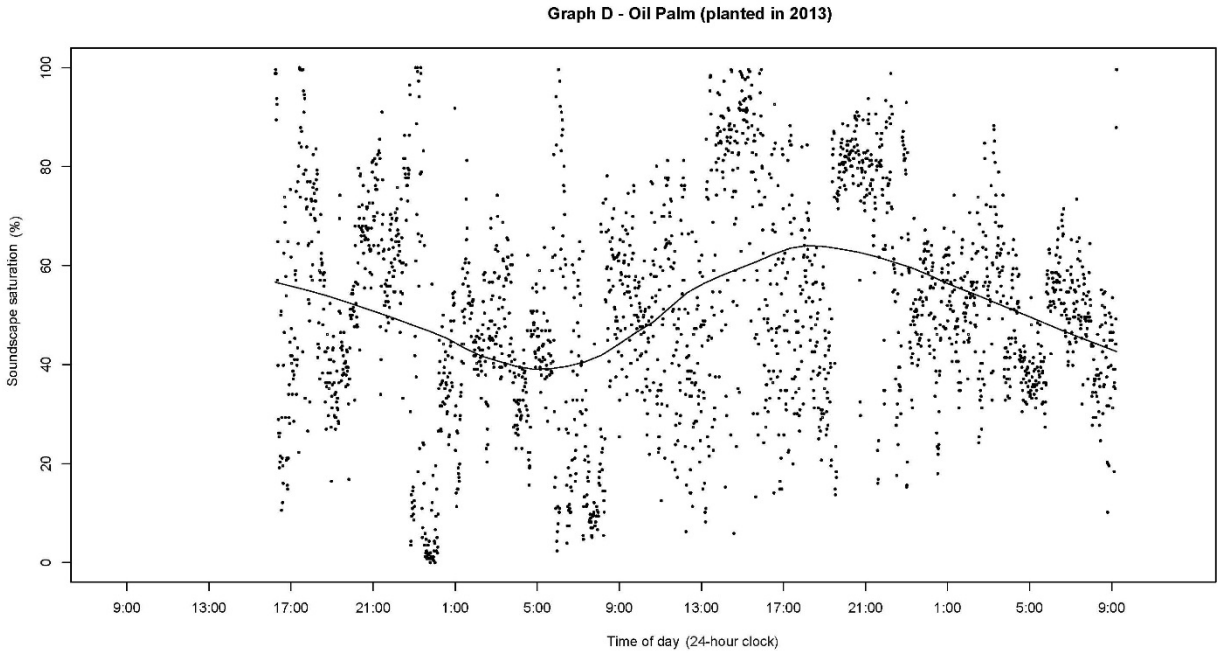
4. Compare and contrast graphs A, B, and C. What are the major similarities and differences in the **average soundscape saturation**? Are there any differences in the number of peak periods or the duration of peak periods?

5. The locations for graphs B and C indicate that they there were once logged (2015) and twice logged (2014) respectively. The years indicate the last time they were logged. So even though the area for graph C was twice-logged, more time has passed since the disturbances than the location for graph B. Graph C shows a markedly different soundscape saturation than graphs A and B, which might imply that logging (especially two incidences of logging) has had an effect on the soundscape. However, there are several extenuating circumstances outside of logging activity. What kinds of questions do you need to answer before you can attribute the soundscape change in graph C to logging?

6. Sunrise happens around 6:00 AM in these locations and is often a time of abundant animal activity in the rainforest. Describe the soundscape saturation with respect to this time of day in graphs A, B, and C.

7. Do you think the same animals inhabit locations A, B, and C? Why or why not? What more information do you need to know to determine this?

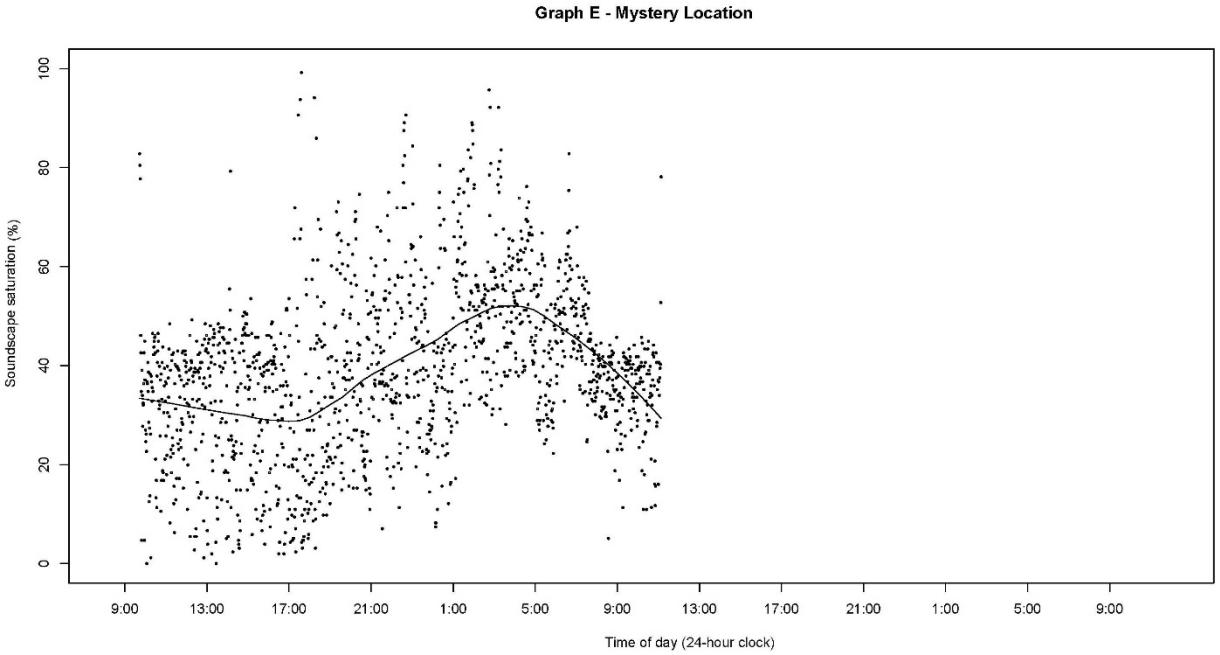
8. What kind of research might you need to do to answer the following questions?
    a. Does one species always vocalize at the same time of day regardless of the habitat or location?
    b. Does one species always vocalize at the same frequency regardless of the habitat or location?



9. Now examine graph D – Oil Palm. Describe the trend in **average soundscape saturation** for this graph. When is peak average soundscape saturation? Compare this graph to A, B, and C. Which of these graphs does graph D most closely resemble? How is it similar and how is it different?

10. Based on your examination of graphs A, B, C, and D what conclusions can you draw about landscape type and sound saturation?

11. As stated in the story map, Bernie Krause introduced the concept of an acoustic niche. This states that every animal species occupies its own acoustic niche in a soundscape to avoid competition for sound space with other species. This hypothesis supports the idea that the healthier and more biodiverse an ecosystem is, the fuller the soundscape will be. Based on this idea, can you assess the relative health or comparative level of biodiversity of the landscapes represented in graphs A, B, C, and D or you need more information than soundscape saturation to determine ecosystem health? If so, what can you determine with the soundscape saturation graphs and what can't you determine?



12. Now examine graph E – Mystery Location. You have just 24-hours of data from this location. Describe all of the similarities and differences, noting the maximum and/or minimum **average soundscape saturations** and times of day. Based on the soundscape saturation information from the other graphs, from what type of landscape do you think these data were obtained? Is it the same or different than the landscape represented in graphs A, B, C, and D. Describe the biodiversity of this site relative to the other locations. Use evidence to defend your reasoning.

Applications of Acoustic Data

13. If you ran an ecotourism outfit and wanted to make sure you took tourists to the rainforest to see birds and other animals, when would you arrange your tours? How could you use acoustic data to determine this?

14. In what are other ways do you think acoustic data could be useful?

Study Limitations and Experimental Design Choices

15. Does acoustic data capture all of the organisms in an ecosystem?

16. For this acoustic survey in Borneo, the acoustic recorders were strapped to trees at chest height. Describe the advantages and disadvantages of this experimental design.

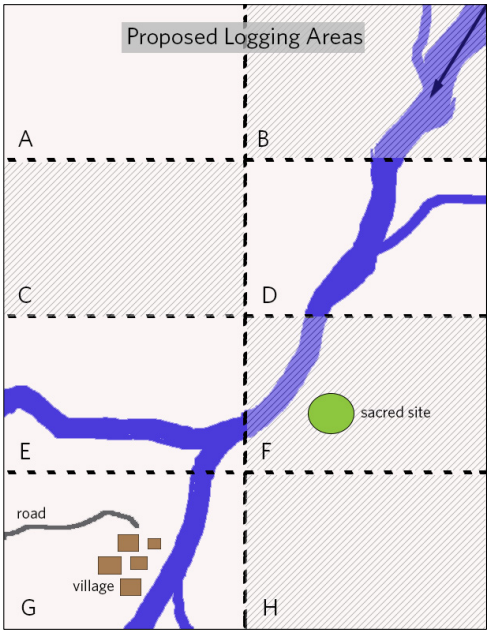
17. In this particular study, due to time limitations, the number of recorders available, and the number of sites visited, recorders where only placed on trees for 1-2 days at a time. How could this impact the data that was collected and how would you solve for that impact in future investigations?

18. Ultimately, when designing an experiment, scientists must balance cost and feasibility with their investigation objectives. Time, money, weather, equipment cost, and access (getting permission from logging companies, communities, government, etc. to do research on location) are all factors that must be addressed in experimental design. In a remote forest setting, scientists must even consider how they get to the locations, where they will sleep, and how they will eat and have access to clean water. Even battery life is a concern when using high-tech equipment in a remote location.

    Because of these factors, scientists must make careful decisions in order to get the most out of their investigations. If you were part of a team who was invited back to the rainforests of Borneo to continue to investigate biodiversity as it relates to land management – what would you like to investigate and how would your investigation compliment the acoustic survey described in this lesson? Describe any limitations or possible barriers to your proposal that you would have to overcome.

From Biodiversity Study to Land Management

19. Examining the biodiversity of a landscape can help scientists determine which areas are critical habitats that need to be protected. This information can aid in the determination of land management strategies that support conservation while allowing for development activities like agriculture and logging. However, knowing the biodiversity of an area is only part of the picture. The landscape pictured to the right has been surveyed for biodiversity and the portions of land on the map marked A, D, E, and G have been shown to support extremely high biodiversity. The recommendation from ecologists is to protect these areas. The recommendation also states that shaded areas (B, C, F, H) on the map are most suitable for logging or other development activities because they have lower biodiversity. Note that the arrow indicates the direction of river flow.



What are all of the factors that should be considered before implementing a land management strategy and who should be at the table to have these discussions? In other words, who are the stakeholders? Are some considerations more important than others?