WORCESTER POLYTECHNIC INSTITUTE

CREATING LESSON PLANS

Supplemental Materials

AIDEN JOHNSON

JEREMIAH MAYLUM

JAMES NICOLL

WILLIAM SMITH

WHITE MOUNTAINS PROJECT CENTER, NEW HAMPSHIRE, UNITED STATES

Table of Contents

List of Tables and Figures

List of Tables

List of Figures

Appendix A: Authorship Page

Chapter/Section	Primary Author	Primary Editors
Abstract	All	All
Introduction	Jeremiah M.	All
Background	-	-
1. Environmental Issues	All	Aiden J.
2. Education	James N.	Aiden J.
2.1 Outdoor Lessons	Jeremiah M.	William S.
2.2 Experiential Learning	Jeremiah M.	William S.
2.3 Scientific Sources and Partnerships	Aiden J.	James N.
3. Hubbard Brook	William S.	James N.
Methodology	-	-
Goal	William S.	All
O1: Asses Hubbard Brook's Approach to Education	Jeremiah M.	William S.
O2: Investigate Other Approaches and Factors for Developing Science and Nature Lessons	Jeremiah M.	Aiden J.
O3: Draft and Pilot Lesson Plans	Jeremiah M.	Aiden J.
O4: Create Final Deliverables	William S.	Aiden J.

Appendix A: Authorship Page

Chapter/Section	Primary Author	Primary Editors
Findings	-	-
1. Lesson Plan Topics	William S.	James N.
2. Learning Outcomes	William S.	James N.
3. Teaching Methods	Jeremiah M.	William S.
Recommendations	-	-
1. Student and Teacher Feedback	Jeremiah M.	Aiden J.
2. Travel Logistics	Jeremiah M.	William S.
3. Lesson Plan Alterations	Jeremiah M.	James N.
Conclusion	-	-
Conclusion	James N.	Jeremiah M.
Acknowledgements	William S.	Jeremiah M.
References	All	All

Appendix A: Authorship Page

Chapter/Section	Primary Author	Primary Editors
Appendices	--	-
A Draft Focus Group Direction	Jeremiah M.	William S.
B Interview Questions	All	All
C Interviewees	Jeremiah M.	Aiden J.
D Informed Consent	All	All
E Post-Tour Survey Questions	Jeremiah M.	James N.
F Systematic Observation Tools	William S.	James N.
G Glossary	James N.	Aiden J.

Appendix B: Focus Group Questions

Appendix B: Focus Group Questions With HBRF Employees

- To introduce ourselves, could you please say your name and describe your role at Hubbard Brook?
- Can you tell us about the current research projects or programs that are being conducted at the Hubbard Brook Research Foundation? What are the key objectives, methods, and findings of these initiatives?
- Do you face any challenges or barriers that you encounter in implementing education programs at the HBRF? How do you address these challenges and ensure the success of your initiatives?
- Can you tell us about your experience engaging with local communities to raise awareness about environmental issues and promote environmental literacy?
- Have you experienced any difficulties teaching about climate change?
- We've heard from a previous interview about the use of role play and also competition to gets kids to engage. Do you think these methods could be effective?
- How does the age of students affect your approach?

Appendix C: Interview Questions

C.1 SCIENCE TEACHERS AND EDUCATORS

- Thanks for taking the time to meet us. this is xyz, and I'm abc. So, you are a science teacher here. What do you love about teaching science to (middle/high school) kids?
- As the preamble mentioned, we are working with Hubbard Brook to make lesson plans for students who go on tours through the Experimental Forest. We are hoping to get your insight on education so that we can make effective and enjoyable post-tour lesson plans.
- What science topics do your students seem to enjoy the most? Why?
  - What activities do you do with students that they enjoy the most?
  - What information do they find most interesting?
  - What is it about the lessons and activities that make them engaging?
- Are there ways that the tour or post-tour activities can be connected to the material you cover in classes with the students? (Give context to teacher)
- How do you assess whether students enjoy a lesson?
- How do you assess whether students were engaged?
- How do you assess what students learned?
- Have you ever worked with long-term recurring data? For example, using and building upon data from a previous class with a new group of students.
  - If so, what has been your experience?
  - If not, what do you think about using it for your lessons?
- What tips and tricks have you personally found helpful for keeping student interest?
- What kind of feedback from students is most helpful to you?
  - What would you like to learn from the students about their experience with the tour?
- Have you ever brought your students outside for a lesson?
  - If so, how effective was that for teaching?
- Is there anybody you might recommend us to talk to?
- Are there any questions you think we missed, and should ask in the future?

C.2 Brendan Leonardi

- What role do you fill for the Hubbard Brook Foundation?
- How have some of Hubbard Brook's previous educational projects been most successful?
- What do you feel are some of the most important topics to teach?
- What financial or material support will our team be provided?
- What can we expect as the settings that the lesson plans will be conducted in?
- What are activity expectations (refinement to the research plot? Tour length? Activities outside of the research plot?)
- Are there any handouts that are handed to tour groups?
- How has the local community been incorporated into previous projects?
- How have the Next Generation Science Standards Affected your research and education programs?
- Who are some other Hubbard Brook staff that would be helpful to talk to?
- Are there any Hubbard Brook stakeholders you could help us get connected with?
- What individual aspects of the Hubbard Brook Experimental Forest do you think could be improved upon?
- Has your organization run into any notable challenges when running educational programs?
- How do you handle challenges like poor weather or unusually large or small class sizes?
- What are some financial, weather, or other constraints you've found restrict lesson plans?

Appendix D: Interviewees

Appendix D.1: Public School Teachers

- Rose Dedam (St Johnsbury Academy-AP Bio Teacher)
- Leslie Houghton (Lisbon Regional School-Middle School Science Teacher)
- Melissa Jellison (Lisbon Regional School-High School Science Teacher)
- Jen Weatherbee (Plymouth Elementary School-Elementary School Teacher)

Appendix D.2: Environmental Educators

- Kayla Croteau (Watershed Education Specialist)
- Stuart Hickey (Coos County Education Coordinator)
- Amanda Carron (Associate Director of Programs)
- Jen Weatherbee (Plymouth Middle School-Middle School Teacher)

Appendix D.3: HBRF Staff

- Brendan Leonardi (Young Voices of Science and Education manager)
- Amey Bailey (Forestry Tech)
- Hannah Vollemer (Technician)

Appendix E: Preambles

Appendix E.1: Science Teacher and Educator Interview Preamble

We are students from Worcester Polytechnic Institute in Massachusetts. We are working with the Hubbard Brook Research Foundation at Hubbard Brook Experimental Forest to develop lesson plans for students in grades 4-12. We would be grateful for your insight on teaching methods. Participation in this hour-long interview is completely voluntary, and you may withdraw at any time. If you prefer, anything you say can be kept confidential. Otherwise, we may note that the information comes from a local school teacher. However, no additional identifying information will be associated with your responses. If you would like, we are happy to provide you with a copy of our project report prior to its publication. If you have any questions, you can reach us at HB.ResearchPlot@gmail.com. You can also reach our faculty advisors, Corey Dehner and Seth Tuler at cdehner@wpi.edu and stuler@wpi.edu. Thank you for your participation.

Appendix E.2: Hubbard Brook Staff Interview Preamble

We are students from Worcester Polytechnic Institute in Massachusetts. We are working with the Hubbard Brook Research Foundation at Hubbard Brook Experimental Forest to develop lesson plans for students. We would be grateful for your insight on what aspects of Hubbard Brook's work you think students may find most intriguing. Participation in this hour-long interview is completely voluntary, and you may withdraw at any time. If you agree, we would like to include some of your responses in our final report which is published on the WPI library database. We are happy to send you our report for your review prior to publication. Alternatively, we are happy to keep your identity confidential and refrain from putting any identifying information in the final report or any accompanying documents. Rather, we will simply note that the information came from a Hubbard Brook employee. If you have any questions, you can reach us at HB.ResearchPlot@gmail.com. You can also reach our faculty advisors, Corey Dehner and Seth Tuler at cdehner@wpi.edu and stuler@wpi.edu. Thank you for your participation.

Appendix E.3: Environmental Educator Interview Preamble

We are students from Worcester Polytechnic Institute in Massachusetts. We are working with the Hubbard Brook Research Foundation at Hubbard Brook Experimental Forest to develop lesson plans for students. We would be grateful for your insight on environmental education. Participation in this hour-long interview is completely voluntary, and you may withdraw at any time. If you agree, we would like to include some of your responses in our final report which is published on the WPI library database. We are happy to send you our report for your review prior to publication. Alternatively, we are happy to keep your identity confidential and refrain from putting any identifying information in the final report or any accompanying documents and will simply note that the information comes from an education organization member. If you have any questions, you can reach us at HB.ResearchPlot@gmail.com. You can also reach our faculty advisors, Corey Dehner and Seth Tuler at cdehner@wpi.edu and stuler@wpi.edu. Thank you for your participation.

Appendix E.4: Systematic Observation Consent Preamble

Hubbard Brook will add a section to the waivers sent to teachers and parents, prior to tours. This added section will ask for permission for Worcester Polytechnic students to observe and take notes of the tour group for the purpose of improving future educational experiences. At the beginning of tours, the tour-guide will point out and mention the team member taking notes.

This way, teachers will be aware and consenting to having non-Hubbard Brook staff conduct their tour group.

Appendix E: Preambles

Appendix E.5: Pilot Lesson Plan Consent

Hubbard Brook will add a section to the waivers sent to teachers and parents, prior to tours. This added section will ask for permission for Worcester Polytechnic students to conduct the tour group, using new lesson plans for the purpose of improving future educational experiences.

This way, teachers will be aware and consenting to having non-Hubbard Brook staff conduct their tour group.

Appendix E.6: Focus Group Consent Preamble

We are students from Worcester Polytechnic Institute in Massachusetts. We are working with the Hubbard Brook Research Foundation at the Hubbard Brook Experimental Forest to develop lesson plans for students. We would be grateful for your insight on environmental education. Participation in this focus group is completely voluntary, and you may withdraw at any time. If you agree, we would like to include a record of notes taken during the focus group in our final report which is published on the WPI library database. We are happy to send you our report for your review prior to publication. Alternatively, we are happy to keep your identity confidential and refrain from putting any identifying information in the final report or any accompanying documents and will simply note that the information comes from a local school teacher. If you have any questions, you can reach us at HB.ResearchPlot@gmail.com. You can also reach our faculty advisors, Corey Dehner and Seth Tuler at cdehner@wpi.edu and stuler@wpi.edu. Thank you for your participation.

Appendix E.7 Principal Outreach Preamble

Dear Principal….,

We are students from Worcester Polytechnic Institute in Massachusetts. We are working with the Hubbard Brook Experimental Forest, specifically Brendan Leonardi, title, to develop hands-on lessons for students in grades 4-12. We would be grateful for the opportunity to speak with your teachers, particularly those who teach science, to learn what sorts of lessons they would find most beneficial. We are happy to accommodate their schedule and come to your school to conduct the interviews. Please feel free to reply to this email. Regardless, we will follow up with a phone call in a couple of days. If you have any questions, you can reach us at HB.ResearchPlot@gmail.com. You can also reach our faculty advisors, Corey Dehner and Seth Tuler at cdehner@wpi.edu and stuler@wpi.edu. Thank you for your consideration.

Best wishes,

Appendix F: Post Activity Questions

Appendix F.1: For Brendan Leonardi After Pilot

- How do you feel we could have made some of the activities more engaging
- What changes might make the lesson plan easier to conduct?
- Are there any methods we used in the lesson plan procedure that felt unnecessary?
- Did you think the lesson helped students achieve the desired learning outcome?

Appendix F.2: For Teachers (sent in an email)

- Was there any information the students learned today that you think you'd be able to use in classes?
- Are there any aspects of the tour/activities that you think were unnecessary?
- Please list 1-3 things that you think the students found most engaging, and 1-3 things that the students seemed bored with. (These things can include conversation topics, sights or areas on the tour, activities, etc.)
- What do you think could improve the student's experience on future tours?
- What is one thing we could do better to improve your experience as a teacher?
- Which stop(s) on the tour did you think the students found most interesting? Why?

Appendix F.3: Written Handout Questionnaire (Middle School)

- What emotion best describes your experience on our tour?
- What part of the tour did you find most exciting from today? Why?
- What is the coolest thing you learned today?
- Was there any point you felt bored?
- What would make you feel more engaged?
- Do you have anything else to share with the staff?

Appendix F.4: Written Handout Questionnaire (High School)

- What mood best describes your experience on our tour?
- What part of the tour did you find most exciting from today?
- What is the most interesting thing you learned today?
- What would make you feel more engaged?
- Was there any point you felt bored?
- Do you have anything else to share with the staff?

Appendix F.5: Verbal Questions For Whole Tour-Group

- What's one thing you all learned today? (pick anybody who raises their hand)
- What did you find really cool? (pick anybody who raises their hand) - (if they don’t explain, follow up by asking) “what did you learn from that?”

Appendix G: Glossary

Appendix G.1: Lesson Plan

A lesson plan is a framework for a lesson; including the goal of what students should learn, the procedure to achieve that goal, required resources, and a way to evaluate how successfully the goal was achieved (FutureLearn, n.d.).

Appendix G.2: Traditional education

Traditional education is the systematic instruction for a group of students, including discussions, presentations, and handouts (Law Insider, n.d.).

Appendix G.3: Hands-on Learning

Hands-on learning uses experiments where students use manipulatives to learn content and build skills (IGI Global, n.d.).

Appendix G.4: Experiential Learning

Experiential Learning uses activities, which utilize direct experiences to gain knowledge and skills (Gross & Rutland, 2017).

Appendix G.5: Content Analysis

Content analysis is a method for processing and categorizing data into groupings (Given, 2008).

Appendix G.6: Systematic Observation

Systematic observation is the collection of data according to a set of procedures (Given, 2008).

Appendix G.7: Snowball Sampling

Snowball sampling is the process of relying on initial interviewees to identify additional interviewees (Given, 2008).

Appendix G.8: Next Generation Science Standards

Next Generation Science Standards are a set of research-based standards for scientific knowledge and understanding for students K-12, with the goal of giving teachers the flexibility to design their curriculum based on their own classroom (Next Generation Science Standards, n.d.)

Appendix H: Systematic Observations

Appendix H.1: Systematic Observation Note-Taking Sheet

Group1: St. Johnsbury Academy AP Bio, Sep 6th

Group2: Lin-Wood Middle School, Sep 15th

	Notes
Overall mood	• Attentive, quiet, little tired, positive mood • Goofy, hyper, some interested, some not, excited to be in the woods
How much did students seem to already know?	• Familiar with acid rain, environmental competition • Trees soaking in water, deciduous vs coniferous, Heater in watershed 4
What information was new to them?	• Salamander lifespans • Beech bark disease • Emerald ash borer, acid rain
Did students show interest in particular topics?	• Wildlife (Birds, bears) • Forest health and biodiversity and the effects of invasive species • Beech bark disease impacts • Picture of moths • Woodpeckers and their impact • Calcium reintroduction • Rain meter caught more attention than initial discussion • Experimental procedures • New technology / uses for AI • Picture of moths • Invasive species • Dead animals • Japanese salamanders • Caterpillar on tree • Water cleanliness • Ph • Mushrooms

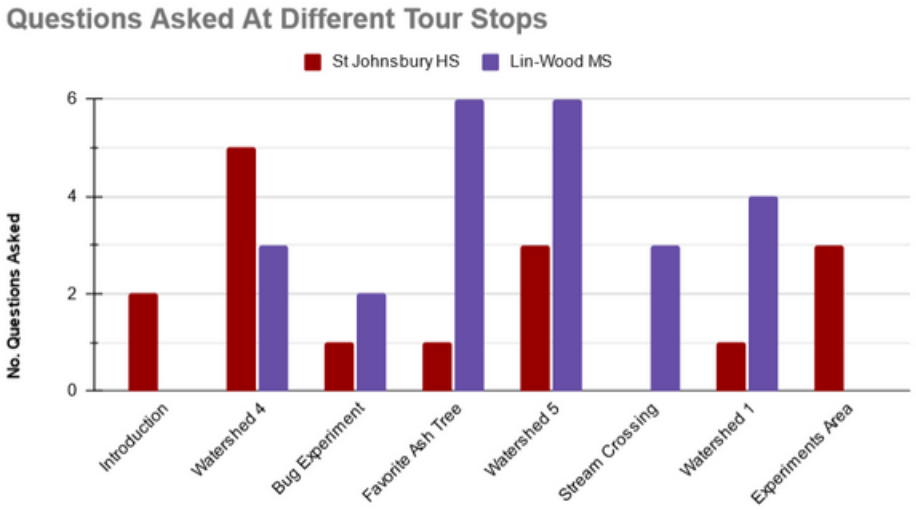
Student-asked questions	• Do you see a lot of bears? • Is hunting allowed in the forest? • What happens at a watershed when it rains a lot? • Are there any fish? • Can running water become eutrophic? (too many nutrients) • Have any watersheds cut trees along the stream? • What does oligotrophic mean? • Do you observe bats? • What are these berries? • Can a clear-cut forest recover? • Does HB plan on cutting more? • What are the yellow tags? (sticky tags) • Are trees tapped for sap? • Are the workers mostly college students? • What's your (Brendan's) favorite project you've worked on? • What's the floatie in Weir 4? • Is there chaga in the forest? • What's this caterpillar? And the cocoon? • Why do the insects live if their lifespan is so short? • Ever seen a dead body? Deer? Bear? • What is the fencing in Weir 5? • Where was acid rain first found? • Can you drink stream water? • Are there fish? • Longest-living salamander ever?
Student distractedness	• Were highly distracted when first off bus getting introduction in zero-shade prior to heading to forest • Students were consistently distracted for roughly 30 sec at each weir stop (even longer at Weir 4) • Overall very attentive: no phones and very little side-chatter while Brendan spoke • Easily distracted • After Brendan asked a question, side-chatter and distractedness increased • Some were collecting walking sticks, some had their heads down
Other Notes	• A few students asked the majority of questions • High variety among kids, seems like a representative sample • Took them longer to get focused, but they did listen closely at some stops • A group of girls was in the back not paying attention

Appendix H: Systematic Observations

Appendix H.2: Questions Asked at Different Tour Stops

Group1: St. Johnsbury Academy AP Bio, Sep 6th
Group2: Lin-Wood Middle School, Sep 15th

We used the student engagement, measured by the number of questions asked at different stops along the tour, to analyze what topics students showed more or less interest in. While unable to make a lesson plan that incorporates the water sheds, we see that students held a lot of interest in them, as was also noted by Rose Dedam, one of the teachers we interviewed. The exact number of questions asked, and the tour stop they were asked at, are displayed in Figure



Appendix H.3: Time Spent and Student Engagement at Tour Stops

Group1: St. Johnsbury Academy AP Bio, Sep 6th
Group2: Lin-Wood Middle School, Sep 15th

TOUR STOPS	TIME SPENT (not including walking time)	START ATTENTION	END ATTENTION
First Entering Forest	> 5:49 > 5:00	> 10/10 > 4/10	> 9/10 > 9/10
Weir 4	> 16:13 > 6:00	> 6/10 > 8/10	> 9/10 > 9/10
Bug Experiment	> 4:21 > 4:00	> 10/10 > 5/10	> 10/10 > 10/10
Favorite Ash Tree	> 10:21 > 9:00	> 8/10 > 3/10	> 6/10 > 9/10
Weir 5	> 6:48 > 10:00	> 8/10 > 8/10	> 10/10 > 10/10
Stream Crossing	> 2:04 > 5:00	> 10/10 > 7/10	> 9/10 > 7/10
Weir 1	> 11:05 > 7:00	> 6/10 > 6/10	> 7/10 > 9/10
Ground Warming (Post-Tour)	> 15:12 > N/A	> 10/10 > N/A	> 8/10 > N/A
Total	> 1:11:53 > 46:00	N/A	N/A

Appendix I: Lesson Plans

Appendix I.1: Water Quality Handout (MS)

HUBBARD BROOK RESEARCH FOUNDATION

Stream Water Quality

Today you will be acting as a scientist studying water quality in a stream flowing from a forested ecosystem. You will be measuring a few parameters of water such as pH, which is a measure of how acidic or basic the water is, temperature, and the total dissolved solids in the water. These qualities are an important part of measuring how clean the water is. All these qualities need to be within a certain range or else it can cause damage to trees and plants, as well as creatures that live in or near the water, and can be unusable for humans who need the water to drink. Forests act as filters for water and provide many benefits that result in higher water quality. Trees create shade to keep water from getting too hot, they filter out harmful solids and pollutants, and they filter the air and provide nutrients to regulate the pH of water. If forests get damaged or cut down, what effect could that have on the streamwater and consequently on people who use the water flowing from the forest?

MATERIALS

- 3 Flags
- Data Collection Sheet
- Meter Tape
- 1 Clipboard
- pH strips
- Nets
- 2 Pencils
- Water Testing Tool
- Ziploc Bag for pH strips and other trash

PROCEDURE

1. Site Setup

- Find an open area of stream
- Place one flag next to the stream
- Starting at the flag, run the meter tape out 10m along the stream and **lay the meter tape on the ground**.
- Place a flag at 5m and at 10m along your meter tape

Figure 1: Stream Setup

2. Preparing to Take Measurements

- One student records measurements in the datasheet
- Other students will be assigned roles for measurements

3. Taking your Measurements

- At all three flags, **take pH, total dissolved solids and temperature measurements**.
- **pH**
  - Dip the colored end of the strip into the stream for 1 second then remove it, and shake excess water off of the pH strip
  - **Immediately** compare the colors on your strip with the provided reference table. Record the pH in the **pH column of the data table**
  - Dispose of your pH strip in the Ziploc bag
- **Water Temperature**
  - Press the **Mode** button until it shows **degrees Fahrenheit**
  - Dip the testing end into the water until the **temperature stabilizes**. This could **take about a minute**
  - Record Temperature in the **Temperature column of the data table**
- **Total Dissolved Solids**
  - Press the **Mode** button until it says **0ppm**
  - **Dip the testing end** into the water for **5 seconds**
  - Press the **Clear** button between measurements
  - Record Total Dissolved Solids in the **Total Dissolved Solids column of the data table**

Figure 2: pH strips and reference table

- Before moving on to Step 4, make sure you've taken measurements at all three flags and filled out the datasheet.

Figure 3: Water Testing Tool

4. Stream Animal Observations

- Explore the stream! Use the nets to find animals that live there between your flags
- These could be bugs, frogs, salamanders, spiders or anything else you may encounter
- **We are not "catching" animals, we are observing them. Release anything from your net after recording it and avoid using the net for frogs or salamanders as they are large enough to be observed from a distance.**
- Record what you find in the **Stream Animal Observations Table**
- Once you've explored your research area,feel free to **spread out and look around the surrounding stream area** for other organisms

5. Clean up all your materials at the end of the activity.

DATA COLLECTION

Streamwater Data Table

Location	pH	Temperature	Total Dissolved Solids
0m			
5m			
10m			

Stream Animal Observations

	Take notes on what you find (how many, color, size, location, etc.)
Water Skimmers	
Spiders	
Caterpillars	
Other Bugs	
Slugs Snails Worms	
Frogs Salamanders	
Other (Try to identify what you found)	

Appendix I: Lesson Plans

Appendix I.2: Water Quality Handout (HS)

HUBBARD BROOK RESEARCH FOUNDATION

Stream Water Quality

Today you will be acting as a scientist studying water quality in a stream flowing from a forested ecosystem. You will be measuring a few parameters of water such as pH, which is a measure of how acidic or basic the water is, temperature, and the total dissolved solids in the water. These qualities are an important part of measuring how clean the water is. All these qualities need to be within a certain range or else it can cause damage to trees and plants, as well as creatures that live in or near the water, and can be unusable for humans who need the water to drink. Forests act as filters for water and provide many benefits that result in higher water quality. Trees create shade to keep water from getting too hot, they filter out harmful solids and pollutants, and they filter the air and provide nutrients to regulate the pH of water. If forests get damaged or cut down, what effect could that have on the streamwater and consequently on people who use the water flowing from the forest?

MATERIALS

- 3 Flags
- Data Collection Sheet
- Meter Tape
- 1 Clipboard
- pH strips
- Nets
- 2 Pencils
- Water Testing Tool
- Ziploc Bag for pH strips and other trash

PROCEDURE

1. Site Setup

- Find an open area of stream
- Place one flag next to the stream
- Starting at the flag, run the meter tape out 10m along the stream and **lay the meter tape on the ground**.
- Place a flag at 5m and at 10m along your meter tape

Figure 1: Stream Setup

2. Preparing to Take Measurements

- One student records measurements in the datasheet
- Other students split up and rotate taking measurements

3. Taking your Measurements

- At all three flags, **take pH, total dissolved solids and temperature measurements**.
  - **pH**
    - Dip the colored end of the strip into the stream for 1 second then remove it, and shake excess water off of the pH strip
    - **Immediately** compare the colors on your strip with the provided reference table. Record the pH on your datasheet
    - Dispose of your pH strip in the Ziploc bag
  - **Water Temperature**
    - Press the **Mode** button until it shows **degrees Fahrenheit**
    - Dip the testing end into the water until the **temperature stabilizes**. This could **take about a minute**
    - Record Temperature on your datasheet
  - **Total Dissolved Solids**
    - Press the **Mode** button until it says **0ppm**
    - **Dip the testing end** into the water for **5 seconds**
    - Press the **Clear** button between measurements
    - Record Total Dissolved Solids on your datasheet

Figure 2: pH Table

- Before moving on to Step 4, make sure you've taken measurements at all three flags and filled out the datasheet.

Figure 3: Water Testing Tool

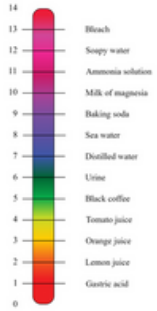
4. Stream Animal Observations

- Explore the stream! Use the nets to find animals that live there between your flags
- These could be bugs, frogs, salamanders, spiders or anything else you may encounter
- **We are not "catching" animals, we are observing them. Release anything from your net after recording it and avoid using the net for frogs or salamanders as they are large enough to be observed from a distance.**
- Record what you find in the provided table.
- Once you've explored your research area,feel free to **spread out and look around the surrounding stream area** for other organisms

5. Move to the second site

- Find a new spot with differing characteristics than your previous area. For example:
  a. In the sun vs In the shade
  b. Fast moving vs Stagnant water
  c. Deep vs Shallow
- Repeat steps 1-4 at this new site

What stream characteristics could have caused differences in your measurements?



6. Discussion

- **Your teacher will now lead your group through some discussion questions**
  a. 7 is the neutral pH of water. Lower than 7 means it is more acidic and higher than 7 means more basic. Lemon juice has a pH of 2, while bleach has a pH of 13. If the water had the same pH as lemon juice or bleach, what do you think would happen to the creatures that live in the water? What might happen to the trees that take up the water through their roots?
  b. If stream water temperature is too hot, the creatures in the stream will be unhealthy and likely die. What could cause temperature changes in the water?
  c. Water acts as the blood of a forest, moving around needed nutrients such as minerals, dead plant matter, and animal matter. When water quality changes, many plants and animals suffer and some may die. Why do changes in water quality affect the trees and animals?
  d. Reflect on the differences in your measurements between your two research areas. Was the pH different? Was the temperature different? Was the Total Dissolved Solids different? What might have caused these differences?
  e. Why is studying water quality important? Think about where your water comes from at home, how much water plants and trees need, and how fresh water is used by human society.

7. Clean up all your materials at the end of the activity.

DATA COLLECTION Site 1

Streamwater Data Table: Site 1

Location	pH	Temperature	Total Dissolved Solids
0m			
5m			
10m			

Stream Animal Observations: Site 1

	Take notes on what you find (how many, color, size, location, etc.)
Water Skimmers	
Spiders	
Caterpillars	
Other Bugs	

Appendix I: Lesson Plans

Slugs Snails Worms	
Frogs Salamanders	
Other (try to identify what you found)	

DATA COLLECTION Site 2

Streamwater Data Table: Site 2

Location	pH	Temperature	Total Dissolved Solids
0m			
5m			
10m			

Stream Animal Observations: Site 2

	Take notes on what you find (how many, color, size, location, etc.)
Water Skimmers	
Spiders	
Caterpillars	
Other Bugs	
Slugs Snails Worms	
Frogs Salamanders	
Other (try to identify what you found)	

Appendix I.3: Water Quality Organizer Notes (MS)

Streamwater Quality Organizer Notes

Age Group: 6th-8th grade
Time Estimate: 45 minutes

Background to tell students:

Today you will be acting as a scientist studying water quality in a stream flowing from a forested ecosystem. You will be measuring a few parameters of water such as pH, which is a measure of how acidic or basic the water is, temperature, and the total dissolved solids in the water. These qualities are an important part of measuring how clean the water is. All these qualities need to be within a certain range or else it can cause damage to trees and plants, as well as creatures that live in or near the water, and can be unusable for humans who need the water to drink. Forests act as filters for water and provide many benefits that result in higher water quality. Trees create shade to keep water from getting too hot, they filter out harmful solids and pollutants, and they filter the air and provide nutrients to regulate the pH of water. If forests get damaged or cut down, what effect could that have on the streamwater and consequently on people who use the water flowing from the forest?

MATERIALS

- 3 Flags
- Data sheet
- Meter tape
- 1 Clipboard
- pH tape
- Net
- 2 Pencils
- Water testing tool
- Ziploc bag for pH tapes and other trash

Notes by Section

1. Site Setup

- Double check that you have all materials listed in the materials list
- Bring students to the stream to set up a research site. It is good to have a spot picked out before bringing out students for the activity
- Give the students a rough overview of what they will be doing, for example tell them that they will be:
    a. Marking a research area with flags
    b. Taking measurements next to each of the flags
        i. Give a demo of all three measurements outside of their marked area
        ii. Show them that they should dip the pH paper in the water then immediately compare with the table on the bottle
        iii. Show how to change the mode of the water testing tool
        iv. Take one example Temperature measurement
        v. Take one example Total dissolved solids measurement
        vi. Show students which spots they will record each data point

2. Preparing to Take Measurements

- We will need one student to volunteer to record measurements using the datasheet provided
    - Give this student the datasheet and instructions on the clipboard
- The other students should be assigned roles, multiple students can be given the same role if need be for a large group:
    - Measuring pH
        - pH tape
    - Measuring temperature
        - Water testing tool
    - Measuring total dissolved solids
        - This student will also need the water testing tool, they will need to wait until the student measuring temperature finishes
- Ensure the students know where their data table is located and that they read the instructions in order

3. Taking your Measurements

- When taking pH measurements, talk about the Hubbard Brook Acid Rain experiment. Try to naturally bring it up in response to their measurements:
    - A neutral pH of water is 7. Water at Hubbard Brook was found with a pH of 2 in the mid-1900's, the same as lemon juice, due to the effects of acid rain pollution on

Appendix I: Lesson Plans

the landscape. To mitigate the effects of acid rain, scientists added calcium, which is a basic element, to the ecosystem to increase the pH and make the ecosystem less acidic

- Before moving on to step 4, make sure the students have taken measurements at all three flags and filled out the datasheet.

4. Stream Animal Observations

- Set a timer for 15 minutes as the limit for how long they can search
- Let students know they can look outside of the stream if they are having a hard time finding anything

5. Discussion

Read out these discussion questions and facilitate conversation between the students

a. **7 is the neutral pH of water. Lower than 7 means it is more acidic and higher than 7 means more basic. Lemon juice has a pH of 2, while bleach has a pH of 13. If the water had the same pH as lemon juice or bleach, what do you think would happen to the creatures that live in the water? What might happen to the trees that take up the water through their roots?**
(Show students picture of pH spectrum below)
   i. *Creatures in the water might have to move to a different area which could disrupt the food web*
   ii. *Creatures in the water and the trees around it might die if the pH reaches these extremes*

b. **If stream water temperature is too hot, the creatures in the stream will be unhealthy and likely die. What could cause temperature changes in the water?**
   i. *Global warming*
   ii. *Trees die and that gives direct sunlight*
   iii. *Changes in the water that could affect its conductivity which affects how quickly temperature changes (pollution, animal waste, etc.)*

c. **Water acts as the blood of a forest, moving around needed nutrients such as minerals, dead plant matter, and animal matter. When water quality changes, many plants and animals suffer and some may die. Why do changes in water quality affect the trees and animals?**
   i. *Some species can't adapt quick enough*
   ii. *Some species require specific conditions that they cant live without (i.e. a certain range of pH/temperature/Total Dissolved Solids)*
   iii. *If water is unusable by certain animals or trees then those species will die without a way to get the water or nutrients they need*
   iv. *Animals are affected indirectly when plants die due to low water quality*

d. **Why is studying water quality important? Think about where your water comes from at home, how much water plants and trees need, and how fresh water is used by human society.**
   i. *Studying water quality helps us protect our forests and our own drinking water*
   ii. Studying water quality helps us understand the interactions between air, water and the landscape, and how changes in one can affect the others

7. Ensure students clean up all their materials at the end of the activity.

GENERAL TOPIC

- Effects of water quality
  - Example: the water at Hubbard Brook has a pH closer to 7, which is good for the trees and for people who use the water down the line. If it had a pH of 2 it would be as acidic as lemon juice which would be bad for the trees and the people who drink the water.

LEARNING OUTCOME

- Value of clean water and the effects of the forest on water quality.

CONNECTIONS

- Next Gen Science Standard: MS-ESS3-3 Earth and Human Activity
  - Studying pH can help students understand human effects on water quality. Additionally, students can discuss and explain why more acidic or more basic water is bad for humans and the environment.

CONSTRAINTS

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES

- If short on time: Shorten animal observation to 5-10 minutes

Appendix I: Lesson Plans

Appendix I.4: Water Quality Organizer Notes (HS)

Streamwater Quality Organizer Notes

Age Group: 9th-12th grade
Time Estimate: 45 minutes

Background to tell students:

Today you will be acting as a scientist studying water quality in a stream flowing from a forested ecosystem. You will be measuring a few parameters of water such as pH, which is a measure of how acidic or basic the water is, temperature, and the total dissolved solids in the water. These qualities are an important part of measuring how clean the water is. All these qualities need to be within a certain range or else it can cause damage to trees and plants, as well as creatures that live in or near the water, and can be unusable for humans who need the water to drink. Forests act as filters for water and provide many benefits that result in higher water quality. Trees create shade to keep water from getting too hot, they filter out harmful solids and pollutants, and they filter the air and provide nutrients to regulate the pH of water. If forests get damaged or cut down, what effect could that have on the streamwater and consequently on people who use the water flowing from the forest?

MATERIALS

- 3 Flags
- Data sheet
- Meter tape
- 1 Clipboard
- pH tape
- Net
- 2 Pencils
- Water testing tool
- Ziploc bag for pH tapes and other trash

Notes by Section

1. Site Setup

- Double check that you have all materials listed in the materials list
- Bring students to the stream to set up a research site. Try to find an open area of stream free of large rocks or other hazards that will block you from the stream. It is good to have a spot picked out before bringing out students for the activity
- Give the students a rough overview of what they will be doing, for example tell them that they will be:
    a. Marking a research area with flags
    b. Taking measurements next to each of the flags
        i. Give a demo of all three measurements outside of their marked area
        ii. Show them that they should dip the pH paper in the water then immediately compare with the table on the bottle
        iii. Show how to change the mode of the water testing tool
        iv. Take one example Temperature measurement
        v. Take one example Total dissolved solids measurement

2. Preparing to Take Measurements

- We will need one student to volunteer to record measurements using the datasheet provided
- The other students should split up and rotate taking measurements on pH, temperature and total dissolved solids
- Ensure the students know where their data table is located and that they read the instructions in order

3. Taking your Measurements

- When taking pH measurements, talk about the Hubbard Brook Acid Rain experiment. Try to naturally bring it up in response to their measurements:
    - A neutral pH of water is 7. Water at Hubbard Brook was found with a pH of 2 in the mid-1900's, the same as lemon juice, due to the effects of acid rain pollution on the landscape. To mitigate the effects of acid rain, scientists added calcium, which is a basic element, to the ecosystem to increase the pH and make the ecosystem less acidic
- Before moving on to step 4, make sure the students have taken measurements at all three flags and filled out the datasheet.

4. Stream Animal Observations

- Set a timer for 10 minutes as the limit for how long they can search
- Let students know they can look outside of the stream if they are having a hard time finding anything

5. Move to the second site

- Have students repeat their site setup, measurements, and observations at the second site
- Remind them to use the Site 2 datasheet
- Another 10 minute timer for the stream animal observations at the second site

6. Discussion

Read out these discussion questions and facilitate conversation between the students

a. **7 is the neutral pH of water. Lower than 7 means it is more acidic and higher than 7 means more basic. Lemon juice has a pH of 2, while bleach has a pH of 13. If the water had the same pH as lemon juice or bleach, what do you think would happen to the creatures that live in the water? What might happen to the trees that take up the water through their roots?**
(Show students picture of pH spectrum below)
    i. *Creatures in the water might have to move to a different area which could disrupt the food web*
    ii. *Creatures in the water and the trees around it might die if the pH reaches these extremes*

b. **If stream water temperature is too hot, the creatures in the stream will be unhealthy and likely die. What could cause temperature changes in the water?**
    i. *Global warming*
    ii. *Trees die and that gives direct sunlight*
    iii. *Changes in the water that could affect its conductivity which affects how quickly temperature changes (pollution, animal waste, etc.)*

c. **Water acts as the blood of a forest, moving around needed nutrients such as minerals, dead plant matter, and animal matter. When water quality changes, many plants and animals suffer and some may die. Why do changes in water quality affect the trees and animals?**
    i. *Some species can't adapt quick enough*
    ii. *Some species require specific conditions that they can't live without (i.e. a certain range of pH/temperature/Total Dissolved Solids)*
    iii. *If water is unusable by certain animals or trees then those species will die without a way to get the water or nutrients they need*
    iv. *Animals are affected indirectly when plants die due to low water quality*

d. **Reflect on the differences in your measurements between your two research areas. Was the pH different? Was the temperature different? Was the Total Dissolved Solids different? What might have caused these differences?**
    i. *These answers will vary depending on the spots students pick*

e. **Why is studying water quality important? Think about where your water comes from at home, how much water plants and trees need, and how fresh water is used by human society.**
    i. *Studying water quality helps us protect our forests and our own drinking water*
    ii. Studying water quality helps us understand the interactions between air, water and the landscape, and how changes in one can affect the others

7. Ensure students clean up all their materials at the end of the activity.

Appendix I: Lesson Plans

GENERAL TOPIC

- Effects of water quality
  - Example: the water at Hubbard Brook has a pH of 7, which is good for the trees and for people who use the water down the line. If it had a pH of 2 it would be as acidic as lemon juice which would be bad for the trees and the people who drink the water.

LEARNING OUTCOME

- Value of clean water and the effects of the forest on water quality.

CONNECTIONS

- Next Gen Science Standard: HS-LS2-7 Ecosystems: Interactions, Energy, and Dynamics
  - Studying water quality can help students understand human effects on water quality and how that in turn affects the forest and humans. Additionally, students can discuss and explain why acidic water is bad for people and the environment.

CONSTRAINTS

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES

- If short on time: Shorten animal observation to 5-10 minutes

Appendix I.5: Tree Survey Handout (MS)

Tree Health Survey

Today you will be a scientist studying tree health. You will be measuring tree diameter, identifying tree species, and determining tree health. These measurements are vital for determining the overall composition of the forest and how the forest is doing as far as health and function. It is important to study tree health over time so the impact of climate change and invasive species can be monitored in forest ecosystems.

MATERIALS

- 2 Pencils
- 1 Clipboard
- Tree Identification Guide
- Beech Bark Disease Rating Reference Sheet
- Tree Survey Datasheet
- Diameter Pole (1.37m long)
- Diameter Tape

PROCEDURE

1. Create Teams

- Split students into groups of 3-5. Each group should have one student who records the data collected by the team.
- Teams can divide roles or they can all work together on each task.
- The roles are:
  - Measuring **diameter**,
  - Determining **tree species**
  - Evaluating **tree health**
  - Evaluating **beech bark disease severity**.
- When any data is collected, the recorder should repeat it back out loud to avoid errors.

2. Take Measurements

- Starting in the center of the plot, move outward and find the first tagged tree in your plot. Record this tree tag number on your data sheet.
- For each tagged tree you will collect a few pieces of information
  - **Measuring Diameter**
    - Set up the diameter pole next to the tree, on the side of the tree with the tree tag.
    - **Wrap the diameter tape around the tree**. Make sure to measure using the side of the tape labeled "Diameter: Inches to 100ths". Record the diameter measurement in inches. Write the diameter in the "diameter" column in your data sheet. Refer to Figure 1 below for the correct side of the tape

Figure 1: Diameter Tape

    - If the tree is larger than the tape, record it as the largest measurement on the tape.
    - Refer to Figure 2 below for help using a diameter pole and diameter tape.

Figure 2: Taking Tree Measurements

- **Identifying Tree Species**
  - Using the tree identification guide for reference, work as a team to **determine the species** of your tree.
  - Keep in mind the color and texture of the bark as well as the shape of the leaves. If it is hard to tell which leaves go to which tree, smaller trees can be shaken to help identify those leaves.
  - Once you have identified your tree, **record the tree name** in the "tree species" column. Tree names can be found on the reference sheets.
  - Don't hesitate to ask for help if you have trouble identifying a tree.
- **Determining Tree Health**
  - 1: Alive and healthy
    - The tree does not show any signs of damage on the bark or in the crown, and there are no obvious dead branches at the top.
  - 2: Alive but small signs of damage/decline
    - The tree does show small signs of damage on the bark or in the crown and/or there are a few dead branches at the top.
  - 3: Alive but dying
    - The tree shows obvious signs of damage and decay on the bark or in the crown. There are many dead branches at the top, but still has a limited number of green leaves. Signs of an unhealthy tree can be lichen, fungus and/or slugs on your tree bark.
  - 4: Standing dead
    - This tree shows very obvious signs of damage and decay on the bark and in the crown. The entire top of the tree is dead, with no leaves and sometimes large portions of the top are missing. The majority of standing dead trees will have lichen and fungus growing on the bark, and may be decomposing at the base.
- **Rating Beech Bark Disease Severity**
  - If you identify an American Beech tree, you will also evaluate the severity of Beech Bark Disease on this tree.
  - Use the Beech Bark Disease reference sheet to help rate the severity.
  - Record the rating in the column labeled "Beech Bark Disease" in the data sheet.

- **Before moving on to Step 3, make sure you have taken all measurements for the current tree and recorded them on your data sheet.**

3. Repeat Step 2 for Each Tree in Your Plot

- Move on to the next closest tagged tree and repeat all the same measurements for this tree.
  - Tree ID Number
  - Diameter
  - Tree Species
  - Tree Health
  - Beech Bark Disease (if applicable)
- For every team that successfully completes three tree evaluations they will receive a prize!

Appendix I.6: Tree Survey Handout (HS)

Tree Health Survey

Today you will be acting as a scientist evaluating tree health. You will be measuring tree diameter, identifying tree species, and determining tree health. These measurements are vital for determining the overall composition of the forest and how the forest is doing as far as health and function. It is important to study tree health over time so the impact of climate change and invasive species can be monitored in forest ecosystems.

MATERIALS

- 2 Pencils
- 1 Clipboard
- Tree Identification Guide
- Beech Bark Disease Rating Reference Sheet
- Tree Survey Datasheet
- Diameter Pole (1.37m long)
- Diameter Tape

PROCEDURE

1. Create Teams

- Split students into groups of 3-5. Each group should have one student who records the data collected by the team.
- Teams can divide roles or they can all work together on each task. Students will be measuring **diameter**, determining **tree species**, and evaluating **tree health** and **beech bark disease severity**. When any data is collected, the recorder should repeat it back out loud to avoid errors.

2. Take Measurements

Starting in the center of the plot, move outward and find the first tagged tree in your plot. Record this tree tag number on your data sheet.
For each tagged tree you will collect a few pieces of information

- **Measuring Diameter**
  - Set up the diameter pole next to the tree, on the side of the tree with the tree tag. We use a diameter pole to keep the measurement height on the tree consistent.
  - **Wrap the diameter tape around the tree**. Make sure to measure using the side of the tape labeled "Diameter: Inches to 100ths". Record the diameter measurement in inches. Refer to Figure 1 below for the correct

Figure 1: Diameter Tape

  - If the tree is larger than the tape, record it as the largest measurement on the tape.
  - Refer to Figure 2 below for help using a diameter pole and diameter tape.

Figure 2: taking tree measurements

- **Identifying Tree Species**
  - Using the tree identification guide for reference, work as a team to **determine the species** of your tree.
  - Keep in mind the color and texture of the bark as well as the shape of the leaves. If it is hard to tell which leaves go to which tree, smaller trees can be shaken to help identify those leaves.
  - Once you have identified your tree, **record the four letter abbreviation**. Tree abbreviations can be found on the reference sheets, see Figure 3 below.

    Red maple *Acer rubrum* = **ACRU**

  Figure 3: Tree Name Example
  - Don't hesitate to ask for help if you have trouble identifying a tree.

- **Determining Tree Health**
  - 1: Alive and healthy
    - The tree does not show any signs of damage on the bark or in the crown, and there are no obvious dead branches at the top.
  - 2: Alive but small signs of damage/decline
    - The tree does show small signs of damage on the bark or in the crown and/or there are a few dead branches at the top.
  - 3: Alive but dying
    - The tree shows obvious signs of damage and decay on the bark or in the crown. There are many dead branches at the top, but still has a limited number of green leaves. Signs of an unhealthy tree can be lichen, fungus and/or slugs on your tree bark.
  - 4: Standing dead
    - This tree shows very obvious signs of damage and decay on the bark and in the crown. The entire top of the tree is dead, with no leaves and sometimes large portions of the top are missing. The majority of standing dead trees will have lichen and fungus growing on the bark, and may be decomposing at the base.
- **Rating Beech Bark Disease Severity**
  - If you identify an American Beech tree, you will also evaluate the severity of Beech Bark Disease on this tree.
  - Use the Beech Bark Disease reference sheet to help rate the severity.
  - Record the rating in the column labeled "Beech Bark Disease" in the data sheet.

Before moving on to Step 3, make sure you have taken all measurements for the current tree and recorded them on your data sheet.

3. Repeat Step 2 for Each Tree in Your Plot

- Move on to the next closest tagged tree and repeat all the same measurements for this tree.
  - Tree ID Number
  - Diameter
  - Tree Species
  - Tree Health
  - Beech Bark Disease (if applicable)
- For every team that successfully completes five tree evaluations they will receive a prize!

Discussion Questions

I. **Why is it important to study trees and forests?**

II. **What sort of services do you get from trees and forests, even if you are not in a forest or do not live near one?**

III. **Why is it important to identify and study invasive species?**

Appendix I.7: Tree Survey Organizer Notes (MS)

HUBBARD BROOK RESEARCH FOUNDATION

Tree Health Survey Organizer Notes

Age Group: 6th-8th grade
Time Estimate: 45 minutes

Background to tell students:

Today you will be a scientist studying tree health. You will be measuring tree diameter, identifying tree species, and determining tree health. These measurements are vital for determining the overall composition of the forest and how the forest is doing as far as health and function. It is important to study tree health over time so the impact of climate change and invasive species can be monitored in forest ecosystems.

MATERIALS

- 2 Pencils
- 1 Clipboard
- Tree Identification Guide
- Beech Bark Disease Rating Reference Sheet
- Tree Survey Datasheet
- Diameter Pole (1.37m long)
- Diameter Tape

PROCEDURE

1. Create Teams

- Split students into groups of 3-5. Each group should have one student who records the data collected by the team.
- Teams can divide roles or they can all work together on each task.
- The roles are:
  - Measuring **diameter**,
  - Determining **tree species**
  - Evaluating **tree health**
  - Evaluating **beech bark disease severity**.
- When any data is collected, the recorder should repeat it back out loud to avoid errors.

2. Take Measurements

- Starting in the center of the plot, move outward and find the first tagged tree in your plot. Record this tree tag number on your data sheet.
- For each tagged tree you will collect a few pieces of information
  - **Measuring Diameter**
    - Set up the diameter pole next to the tree, on the side of the tree with the tree tag.
    - **Wrap the diameter tape around the tree**. Make sure to measure using the side of the tape labeled "Diameter: Inches to 100ths". Record the diameter measurement in inches. Write the diameter in the "diameter" column in your data sheet. Refer to Figure 1 below for the correct side of the tape

Figure 1: Diameter Tape

    - If the tree is larger than the tape, record it as the largest measurement on the tape.
    - Refer to Figure 2 below for help using a diameter pole and diameter tape.

Appendix I: Lesson Plans

Figure 2: Taking Tree Measurements

- **Identifying Tree Species**
  - Using the tree identification guide for reference, work as a team to **determine the species** of your tree.
  - Keep in mind the color and texture of the bark as well as the shape of the leaves. If it is hard to tell which leaves go to which tree, smaller trees can be shaken to help identify those leaves.
  - Once you have identified your tree, **record the tree name** in the "tree species" column. Tree names can be found on the reference sheets.
  - Don't hesitate to ask for help if you have trouble identifying a tree.
- **Determining Tree Health**
  - 1: Alive and healthy
    - The tree does not show any signs of damage on the bark or in the crown, and there are no obvious dead branches at the top.
  - 2: Alive but small signs of damage/decline
    - The tree does show small signs of damage on the bark or in the crown and/or there are a few dead branches at the top.
  - 3: Alive but dying
    - The tree shows obvious signs of damage and decay on the bark or in the crown. There are many dead branches at the top, but still has a limited number of green leaves. Signs of an unhealthy tree can be lichen, fungus and/or slugs on your tree bark.
  - 4: Standing dead
    - This tree shows very obvious signs of damage and decay on the bark and in the crown. The entire top of the tree is dead, with no leaves and sometimes large portions of the top are missing. The majority of standing dead trees will have lichen and fungus growing on the bark, and may be decomposing at the base.
- **Rating Beech Bark Disease Severity**
  - If you identify an American Beech tree, you will also evaluate the severity of Beech Bark Disease on this tree.
  - Use the Beech Bark Disease reference sheet to help rate the severity.
  - Record the rating in the column labeled "Beech Bark Disease" in the data sheet.

- **Before moving on to Step 3, make sure you have taken all measurements for the current tree and recorded them on your data sheet.**

3. Repeat Step 2 for Each Tree in Your Plot

- Move on to the next closest tagged tree and repeat all the same measurements for this tree.
- For every team that successfully completes three tree evaluations they will receive a prize!

Read out these discussion questions and facilitate conversation between the students

I. **Why is it important to study trees and forests?**
   A. *Forests provide essential resources such as drinking water and timber*
   B. *Forests provide home for a multitude of organisms, supporting local and regional biodiversity*
   C. *Forests clean the air by sequestering carbon and filter harmful compounds from the water*
   D. *Forests provide shade for soils and streams, regulating local climate*
   E. *Forests provide outdoor spaces for recreation, including camping, hiking, biking, fishing, hunting and more.*

II. **What sort of services do you get from trees and forests, even if you are not in a forest or do not live near one?**
   A. *Think ecosystem services (clean air, sequester CO2, clean filtered water, storm water/flooding mitigation, habitat for animals and plants, climate control via shade, much of the same reasons it is important to study forests in general)*

III. **Why is it important to identify and study invasive species?**
   A. *Manage impact they have on the environment*
   B. *Mitigate the environmental and economic consequences*

GENERAL TOPIC:

- Tree species and health identification

LEARNING OUTCOME:

- Learn data collection methods used by scientists and researchers in the field
- Learn to identify and evaluate trees accurately

CONNECTIONS:

- Next Gen Science Standard: **HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics**

Appendix I.8: Tree Survey Organizer Notes (HS)

HUBBARD BROOK RESEARCH FOUNDATION

Tree Health Survey Organizer Notes

Age Group: 9th-12th grade
Time Estimate: 45 minutes

Background to tell students:

Today you will be a scientist studying tree health. You will be measuring tree diameter, identifying tree species, and determining tree health. These measurements are vital for determining the overall composition of the forest and how the forest is doing as far as health and function. It is important to study tree health over time so the impact of climate change and invasive species can be monitored in forest ecosystems.

MATERIALS

- 2 Pencils
- 1 Clipboard
- Tree Identification Guide
- Beech Bark Disease Rating Reference Sheet
- Tree Survey Datasheet
- Diameter Pole (1.37m long)
- Diameter Tape

PROCEDURE

1. Create Teams

- Split students into groups of 3-5. Each group should have one student who records the data collected by the team.
- Teams can divide roles or they can all work together on each task. Students will be measuring **diameter**, determining **tree species**, and evaluating **tree health** and **beech bark disease severity**. When any data is collected, the recorder should repeat it back out loud to avoid errors.

2. Take Measurements

Appendix I: Lesson Plans

Starting in the center of the plot, move outward and find the first tagged tree in your plot. Record this tree tag number on your data sheet.
For each tagged tree you will collect a few pieces of information

- **Measuring Diameter**
  - Set up the diameter pole next to the tree, on the side of the tree with the tree tag. We use a diameter pole to keep the measurement height on the tree consistent.
  - **Wrap the diameter tape around the tree**. Make sure to measure using the side of the tape labeled "Diameter: Inches to 100ths". Record the diameter measurement in inches. Refer to Figure 1 below for the correct side of the tape

Figure 1: Diameter Tape

  - If the tree is larger than the tape, record it as the largest measurement on the tape.
  - Refer to Figure 2 below for help using a diameter pole and diameter tape.

- **Identifying Tree Species**
  - Using the tree identification guide for reference, work as a team to **determine the species** of your tree.
  - Keep in mind the color and texture of the bark as well as the shape of the leaves. If it is hard to tell which leaves go to which tree, smaller trees can be shaken to help identify those leaves.
  - Once you have identified your tree, **record the four letter abbreviation**. Tree abbreviations can be found on the reference sheets, see Figure 3 below.

Red maple *Acer rubrum* = **ACRU**

Figure 3: Tree Name Example

  - Don't hesitate to ask for help if you have trouble identifying a tree.

- **Determining Tree Health**
  - 1: Alive and healthy
    - The tree does not show any signs of damage on the bark or in the crown, and there are no obvious dead branches at the top.
  - 2: Alive but small signs of damage/decline
    - The tree does show small signs of damage on the bark or in the crown and/or there are a few dead branches at the top.
  - 3: Alive but dying
    - The tree shows obvious signs of damage and decay on the bark or in the crown. There are many dead branches at the top, but still has a limited number of green leaves. Signs of an unhealthy tree can be lichen, fungus and/or slugs on your tree bark.
  - 4: Standing dead
    - This tree shows very obvious signs of damage and decay on the bark and in the crown. The entire top of the tree is dead, with no leaves and sometimes large portions of the top are missing. The majority of standing dead trees will have lichen and fungus growing on the bark, and may be decomposing at the base.
- **Rating Beech Bark Disease Severity**
  - If you identify an American Beech tree, you will also evaluate the severity of Beech Bark Disease on this tree.
  - Use the Beech Bark Disease reference sheet to help rate the severity.
  - Record the rating in the column labeled "Beech Bark Disease" in the data sheet.

Before moving on to Step 3, make sure you have taken all measurements for the current tree and recorded them on your data sheet.

3. Repeat Step 2 for Each Tree in Your Plot

- Move on to the next closest tagged tree and repeat all the same measurements for this tree.
  - Tree ID Number
  - Diameter
  - Tree Species
  - Tree Health
  - Beech Bark Disease (if applicable)
- For every team that successfully completes five tree evaluations they will receive a prize!

Read out these discussion questions and facilitate conversation between the students

I. **Why is it important to study trees and forests?**
   - A. *Forests provide essential resources such as drinking water and timber*
   - B. *Forests provide home for a multitude of organisms, supporting local and regional biodiversity*
   - C. *Forests clean the air by sequestering carbon and filter harmful compounds from the water*
   - D. *Forests provide shade for soils and streams, regulating local climate*
   - E. *Forests provide outdoor spaces for recreation, including camping, hiking, biking, fishing, hunting and more.*

II. **What sort of services do you get from trees and forests, even if you are not in a forest or do not live near one?**
   - A. *Think ecosystem services (clean air, sequester CO2, clean filtered water, storm water/flooding mitigation, habitat for animals and plants, climate control via shade, much of the same reasons it is important to study forests in general)*

III. **Why is it important to identify and study invasive species?**
   - A. *Manage impact they have on the environment*
   - B. *Mitigate the environmental and economic consequences*

GENERAL TOPIC:

- Tree species and health identification

LEARNING OUTCOME:

- Learn data collection methods used by scientists and researchers in the field
- Learn to identify and evaluate trees accurately

CONNECTIONS:

- Next Gen Science Standard: **HS-LS2-2 Ecosystems: Interactions, Energy, and Dynamics**

CONSTRAINTS

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES

- If short on time: reduce the number of trees observed

Appendix I: Lesson Plans

Appendix I.9: Insect Food Web Handout (MS)

Insects and the Food Web

Today, you will be studying the food web, with a focus on insects. The food web shows all the connections of how energy moves through an ecosystem. Like how plants get energy from the sun, insects get energy from eating plants, and birds get energy from eating the insects, all the way up to the top predators in the ecosystem. Every member of an ecosystem, big and small, plays an important role in the stability of the system. Insects, while small in size, are a major part of forest ecosystems because they eat plants and are eaten by almost all animals, therefore regulating plant growth and providing food for the entire forest. Larger predators control populations of herbivores like deer or moose. A stable, complex food web is a good indicator of a healthy functioning environment. Forest ecologists use a variety of techniques to measure insects as a metric of food availability, one of which is the sticky trap. Sticky traps allow scientists to measure diversity and abundance of insects in an ecosystem.

MATERIALS

- 2 Animal Observation Sheets
- Food Web Cards
- 2 Pencils
- 2 Clipboards
- 5 Different Colored Spools of Yarn
- Scissors

PROCEDURE

Animal Observations

- Divide into groups of **3-5** students
- Visit your first sticky trap
- Write down what you find on the trap in the observation sheet
  - Column 2: Total number of insects (abundance)
  - Column 3: How many insects of each type (diversity)
- Move to the next sticky trap and build upon your observations
- Discuss as a group to fill in the Food Web Diagram
- **Observe your surroundings** for signs of animals that might eat insects (predators), and **record your findings**
  - Could be larger insects, chipmunks, birds, frogs or salamanders
  - Examples of animal signs are woodpecker holes or moose poop
- When you finish, gather as a class with your teacher to go through a food web game

Figure 1: Sticky Trap

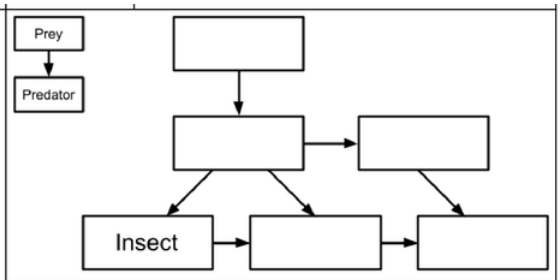
DATA COLLECTION

Animal Observation Sheet

Sticky Trap	Total Number of Insects	Type (ex. 3 mosquitoes, 4 moths, 1 beetle, etc)
#1		
#2		
#3		

Food Web Diagram

Word Bank:
Sun
Plant
Bird
Moose
Coyote



Animal Observations

Example:
- Chipmunk climbing a tree
- Woodpecker holes

Appendix I.10: Insect Food Web Handout (HS)

Insects and the Food Web

Today, you will be studying the food web, with a focus on insects. The food web shows all the connections of how energy moves through an ecosystem. Like how plants get energy from the sun, insects get energy from eating plants, and birds get energy from eating the insects, all the way up to the top predators in the ecosystem. Every member of an ecosystem, big and small, plays an important role in the stability of the system. Insects, while small in size, are a major part of forest ecosystems because they eat plants and are eaten by almost all animals, therefore regulating plant growth and providing food for the entire forest. Larger predators control populations of herbivores like deer or moose. A stable, complex food web is a good indicator of a healthy functioning environment. Forest ecologists use a variety of techniques to measure insects as a metric of food availability, one of which is the sticky trap. Sticky traps allow scientists to measure diversity and abundance of insects in an ecosystem.

MATERIALS

- 2 Animal Observation Sheets
- Food Web Cards
- 2 Pencils
- 2 Clipboards
- 5 Different Colored Spools of Yarn
- Scissors

PROCEDURE

Animal Observations

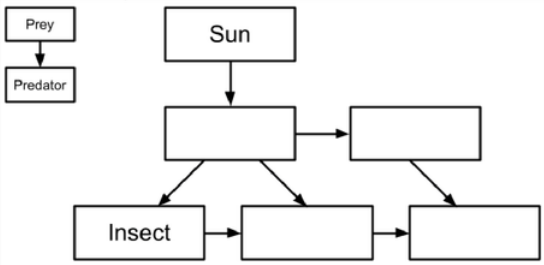
- Divide into groups of **3-5** students
- Visit your first sticky trap
- Write down what you find on the trap in the observation sheet
  - Column 2: Total number of insects (abundance)
  - Column 3: How many insects of each type (diversity)
- Look for the next sticky trap and build upon your observations
- Discuss as a group to fill in the Food Web Diagram
- **Observe your surroundings** for signs of animals that might eat insects (predators), and **record your findings**
  - Could be larger insects, chipmunks, birds, frogs or salamanders
  - Examples of animal signs are woodpecker holes or moose poop
- When you finish, gather as a class with your teacher to go through a food web game

Figure 1: Sticky Trap

Appendix I: Lesson Plans

DATA COLLECTION

Animal Observation Sheet

Sticky Trap	Total Number of Insects	Type (ex. 3 mosquitoes, 4 moths, 1 beetle, etc)
#1		
#2		
#3		
Food Web Diagram		
Animal Observations	Example: - Chipmunk climbing a tree - Woodpecker holes	

Appendix I.11: Insect Food Web Organizer Notes (MS)

Insects and the Food Web Organizer Notes

Age Group: 6th-8th grade
Time Estimate: 30-45 minutes

Background to Tell Students:

Today, you will be studying the food web, with a focus on insects. The food web shows all the connections of how energy moves through an ecosystem. Like how plants get energy from the sun, insects get energy from eating plants, and birds get energy from eating the insects, all the way up to the top predators in the ecosystem. Every member of an ecosystem, big and small, plays an important role in the stability of the system. Insects, while small in size, are a major part of forest ecosystems because they eat plants and are eaten by almost all animals, therefore regulating plant growth and providing food for the entire forest. Larger predators control populations of herbivores like deer or moose. A stable, complex food web is a good indicator of a healthy functioning environment. Forest ecologists use a variety of techniques to measure insects as a metric of food availability, one of which is the sticky trap. Sticky traps allow scientists to measure diversity and abundance of insects in an ecosystem.

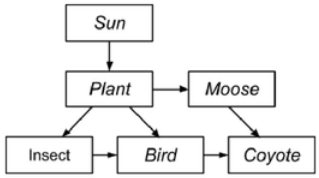
MATERIALS

- 2 Animal Observation Sheets
- Food Web Cards
  - Reference the list below for which set to use
- 2 Pencils
- 2 Clipboards
- 5 Different Colored Spools of Yarn
- Scissors

PROCEDURE NOTES

1. Animal Observations

- Divide into groups of **3-5** students
- Visit the first sticky trap
- Write down insect findings in the Animal Observation Sheet
  - Column 2: Total number of insects (abundance)
  - Column 3: How many insects of each type (diversity)
- Move to the next sticky trap and build upon the observations
- Have the students discuss as a group to fill in the Food Web Diagram. The completed diagram should like this:



- **Observe the surroundings** for signs of animals that might eat insects (predators) and **record findings**
  - Could be larger insects, chipmunks, birds, frogs or salamanders
  - Examples of animal signs are woodpecker holes or moose poop
- Connect student observations to a story about humans meddling with the food web at Yellowstone in the early 20th century: "As an example of how humans can disrupt the food web, in the past people wanted to try to control the food web at Yellowstone National Park. They thought they would make the park safer and happier by getting rid of all the wolves. However, removing the wolves led to a massive increase in the populations of grazing animals like elk or deer, which destroyed much of the natural beauty of the park."
- Let observations continue until about 15 minutes have passed or until students show signs of boredom or distractedness

Appendix I: Lesson Plans

Appendix I.12: Insect Food Web Organizer Notes (HS)

Insects and the Food Web Organizer Notes

Age Group: 9th-12th grade
Time Estimate: 30-45 minutes

Background to Tell Students:

Today, you will be studying the food web, with a focus on insects. The food web shows all the connections of how energy moves through an ecosystem. Like how plants get energy from the sun, insects get energy from eating plants, and birds get energy from eating the insects, all the way up to the top predators in the ecosystem. Every member of an ecosystem, big and small, plays an important role in the stability of the system. Insects, while small in size, are a major part of forest ecosystems because they eat plants and are eaten by almost all animals, therefore regulating plant growth and providing food for the entire forest. Larger predators control populations of herbivores like deer or moose. A stable, complex food web is a good indicator of a healthy functioning environment. Forest ecologists use a variety of techniques to measure insects as a metric of food availability, one of which is the sticky trap. Sticky traps allow scientists to measure diversity and abundance of insects in an ecosystem.

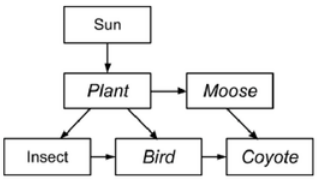
MATERIALS

- 2 Animal Observation Sheets
- Food Web Cards
  - Reference the list below for which set
- 2 Pencils
- 2 Clipboards
- 5 Different Colored Spools of Yarn
- Scissors

PROCEDURE NOTES

1. Animal Observations

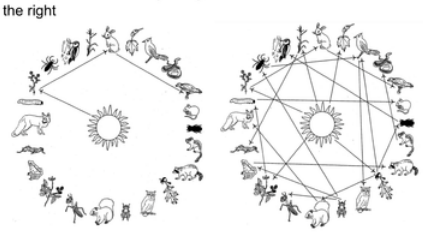
- Divide into groups of **3-5** students
- Visit the first sticky trap
- Write down insect findings in the Animal Observation Sheet
  - Column 2: Total number of insects (abundance)
  - Column 3: How many insects of each type (diversity)
- Move to the next sticky trap and build upon the observations
- Have the students discuss as a group to fill in the Food Web Diagram. The completed diagram should like similar to this:



- **Observe the surroundings** for signs of animals that might eat insects (predators) and **record findings**
  - Could be larger insects, chipmunks, birds, frogs or salamanders
  - Examples of animal signs are woodpecker holes or moose poop
- Connect student observations to a story about humans meddling with the food web at Yellowstone in the early 20th century: "As an example of how humans can disrupt the food web, in the past people wanted to try to control the food web at Yellowstone National Park. They thought they would make the park safer and happier by getting rid of all the wolves. However, removing the wolves led to a massive increase in the populations of grazing animals like elk or deer, which destroyed much of the natural beauty of the park."
- Let observations continue until about 15 minutes have passed or until students show signs of boredom or distractedness

2. Food Web

- Bring the groups of students together
  - For classes larger than 16 students, break up into two groups
- **Give ONE Food Web Card** to each student, and **gather students into a circle**
- The student with the **Sun** card goes in the middle, with the first spool of yarn
- The student with the spool asks **who gets energy from them**
  - Plants get energy from the Sun, bugs eat plants, birds and other animals eat insects or plants, and predators get energy from their prey
- Then the student **while holding onto the string**, tosses the spool to a student who gets energy from them
- Repeat the previous two steps until students reach what seems to be an appropriate end of the food chain
- Cut the string at the end of the food chain, but don't have the students let go of the string
- Repeat the process (at least 3 chains) with a different colored string (starting at the Sun card) until every student is holding string, and the web should look similar to the image below on the right



3. Discussion

- After all food chains have been made, ask the following questions:
  - ***Why do you think it's called a food "web"?***
    - *The food web is made up of many different food chains, all which are interconnected to make up the ecosystem food web*
  - ***Who is holding the most strings? Why?***
    - *The student with the sun card is holding the most strings, because the food web starts with primary producers getting energy from the sun, which is transferred to herbivores and omnivores, and subsequently to the carnivores and other top level predators*
- Cut the string that all bug card students are holding and have them sit down (Bug, Beetle, Moth, Spider). Have all students with cut food chains also sit
  - Example: Beetle sits down. If Woodpecker was connected to Beetle, Woodpecker sits down. If Hawk was connected to Woodpecker, Hawk also sits down
- Encourage students to look around the circle and see how the food web is affected by the loss of insects in the ecosystem (almost every chain will be affected in some way)
- Have the remaining students sit down and continue Discussion
  - ***What happens if insects are removed from the food web?***
    - *When insects are removed from the food web, individual food chains begin to breakdown, causing a massive collapse of the web as whole*
  - ***Which groups in the food web have the most influence on the ecosystem?***
    - *Primary producers have a disproportionately large influence on the food web, as they make up a large part of the base of the web, providing energy for numerous herbivores and omnivores that are subsequently prey for larger predators. Predators at the top of the food chain can also have a disproportionate effect on the ecosystem, if their populations are*

Appendix I: Lesson Plans

numerous they can have a serious top down effect on the food web and ecosystem as a whole.

- ***What would happen if we removed the top predators from the food web? Which organisms would be affected and how?***
  - *If the top predators were removed from the ecosystem, the second level of the web would be affected, including herbivores and other animals that are eaten by the predators. These herbivore populations would flourish, and consequently the plant communities would be rapidly consumed by the increase in herbivore populations and reduce the available plant material in the ecosystem.*
- ***What would happen if we added a 'Human' card? Where would they fit in the web?***
  - *If a human card was added to the food web, it would likely be put at the top of each and every food chain. Humans can be eaten by top predators, but as our society has progressed, this occurrence is less and less likely. With technology and innovation, Humans sit almost resoundingly at the top of the food web and can have a massive impact on every ecosystem they encounter.*

- To wrap up the lesson, have the students line up to hand in their cars. As they hand in their cards, ask each student what group their organism falls in (producer, consumer, and herbivore, carnivore, omnivore) and why their specific organism is important for the food web as a whole.

- **Clean up** the strings

GENERAL TOPIC:

- The Food Web
  - "As an example of how humans can disrupt the food web, in the past people wanted to try to control the food web at Yellowstone National Park. They thought they would make the park safer and happier by getting rid of all the wolves. However, by removing the wolves, this led to a massive increase in the populations of grazing animals like elk or deer, which destroyed much of the natural beauty of the park."

LEARNING OUTCOME:

- Understanding the importance of insects and how all members of an ecosystem are important to maintain balance in the food web

CONNECTIONS:

- Next Gen Science Standard: MS-LS2-4 Ecosystems: Interactions, Energy, and Dynamics
  - Disruptions to any physical or biological component of an ecosystem can lead to shifts in all of its populations.

CONSTRAINTS:

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES:

- Change the set of Food Web Cards per the number of students, according to the reference list

FOUNDATION

Food Web Cards For Different Sized Groups:

Six students (minimum that can work)
{ Sun, Plant, Bug, Bird, Moose, Coyote }

Seven students (replace Bug with Mosquito and Beetle)
{ Sun, Plant, Mosquito, Beetle, Bird, Moose, Coyote }

Eight students (replace Plant with Tree and Grass)
{ Sun, Tree, Grass, Mosquito, Beetle, Bird, Moose, Coyote }

Nine students (replace Bird with Woodpecker and Hawk)
{ Sun, Tree, Grass, Mosquito, Beetle, Moose, Coyote, Woodpecker, Hawk }

Ten to sixteen students (adding organisms in the order they're written)
{ Sun, Tree, Grass, Mosquito, Beetle, Moose, Coyote, Woodpecker, Hawk, Moth, Mushroom, Fox, Rabbit, Flower, Chipmunk, Frog }

Ecosystem Elements:

- Sun
- Plants
  - Tree, Grass, Flower, Fungi
- Bugs
  - Mosquito, Beetle, Moth, Spider, Caterpillar, Butterfly
- Small Birds
  - Woodpecker, Robin, Chickadee
- Herbivores
  - Moose, Rabbit, Deer
- Omnivores
  - Chipmunk, Squirrel, Bear, Salamander
- Carnivores
  - Coyote, Fox, Snake, Hawk, Owl

Appendix I.13: Phenology Handout (Fall)

HUBBARD BROOK RESEARCH FOUNDATION

Fall Phenology

The season is changing before your very eyes! The trees and animals are preparing for winter using strategies they've evolved over tens of thousands of years. One of the most obvious changes in the fall is colorful foliage displayed by common trees. Tree leaves change color and drop every fall but when does this process begin and how long does it last, and does this transition period vary from year to year?

We're going to begin to address some of these questions in this lesson. Phenology is the study of seasonal changes in the life of an organism due to changes in its environment.

Let's get outside, find some deciduous trees and make observations!

MATERIALS

- Tree Color Data Sheets
- Tree Color Reference Sheets
- Leaf Measurement Sheets
- Pencils
- Clipboards
- Ruler or Measuring Tape

PROCEDURE

1. Observations

- Divide into groups of **2-5** students
- Choose **2 species** of trees to study. You will observe 5 trees of each species
- On the Tree Color **Data Sheet**, fill in the following information:
  - Today's date
  - Tree Species
  - Tag Number
  - Leaf Color Classification
- Use your best judgment to classify them according to the Tree Color **Reference Sheet**
  - Are the leaves mostly still green? Then they are 1-25% changed, but if they're mostly colored, they are 75-100% changed
- If possible, find a leaf from each of the two tree species you selected and **outline them**
- Measure and record the **length and width** of the leaves you are drawing

2. Graphing

- Consider the graph below and where your trees may belong

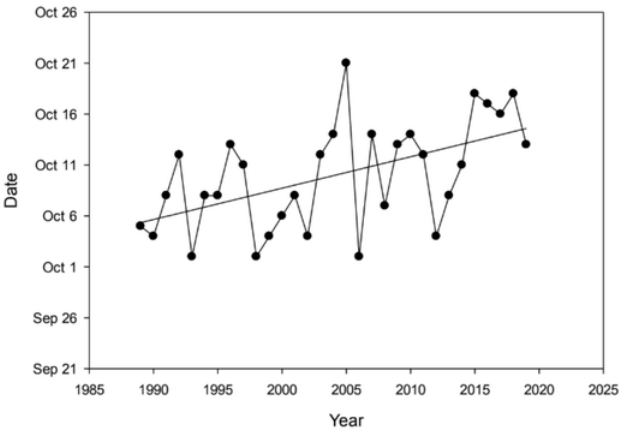


Figure 1: Peak Foliage of sugar maples at the bottom of Watershed 1 in the Hubbard Brook Experimental Forest

3. Discussion

- What differences do you notice between individuals of the same species?
- What differences do you notice between the two different species?
- Does it seem like trees of the same species transition at the same time?
- Do you see any trends, and do the trees you observed fit those trends?

DATA COLLECTION

Tree Color Data Sheet

Date: _____

Species 1:

Tag Number	123					
Summer Condition						
1-25% Leaf Color						
26-50% Leaf Color	X					
51-75% Leaf Color						
76-100% Leaf Color						

Species 2:

Tag Number	124					
Summer Condition	X					
1-25% Leaf Color						
26-50% Leaf Color						
51-75% Leaf Color						
76-100% Leaf Color						

Leaf Measurement Sheet

Date: _____

Species:	Length:	Width:

Appendix I: Lesson Plans

Appendix I.14: Phenology Handout (Spring)

Spring Phenology

Phenology is the study of seasonal changes in the life of an organism due to changes in its environment. Understanding seasonal changes helps scientists assess the health of ecosystems, and advise conservation efforts. In forested ecosystems, trees undergo various seasonal changes throughout the year. In springtime, trees put out their leaf buds for the year, which begin to swell and burst, leading into a full summer canopy. The timing of leaf out in spring is closely linked to insect emergence and the emergence of herbivores from winter hibernation. If the timing of spring leaf out is shifted due to climate change, the timing of insect and herbivore emergence could be impacted, further affecting organisms such as birds and amphibians which rely on these as their primary food source. Tracking the timing of leaf out in spring can help scientists understand how the timing of spring is shifting, and how this shift affects the ecosystem as a whole.

Let's get outside, find some deciduous trees and make observations!

MATERIALS

- Tree Bud Data Sheets
- Tree Bud Reference Sheets
- Pencils
- Clipboards
- Clothespins

PROCEDURE

1. Observations

- Divide into groups of **2-5** students
- Choose **2 species** of trees to study. You will observe 5 trees of each species
- On the Tree Bud **Data Sheet**, fill in the following information:
  - Today's date
  - Tree Species
  - Tag Number
  - Bud Classification
- Use your best judgment to classify them according to the Tree Bud **Reference Sheet**

Do you notice any differences between individuals of the same species or between the different species?

2. Discussion

- What differences do you notice between individuals of the same species?
- What differences do you notice between the two different species?
- Does it seem like trees of the same species bud at the same time?

DATA COLLECTION

Tree Bud Data Sheet

Date: _____

Species 1:

Tag Number	123					
Bud Burst						
Leaf Elongation						
Flowering	X					
Fruit Ripening						

Species 2:

Tag Number	124					
Bud Burst	X					
Leaf Elongation						
Flowering						
Fruit Ripening						

Appendix I.15: Phenology Organizer Notes (Fall)

Fall Phenology Organizer Notes

Age Group: 6th-12th grade
Time Estimate: 30-45 minutes

Background to tell students:

The season is changing before your very eyes! The trees and animals are preparing for winter using strategies they've evolved over tens of thousands of years. One of the most obvious changes in the fall is colorful foliage displayed by common trees. Tree leaves change color and drop every fall but when does this process begin and how long does it last, and does this transition period vary from year to year?

We're going to begin to address some of these questions in this lesson. Phenology is the study of seasonal changes in the life of an organism due to changes in its environment.

Let's get outside, find some deciduous trees and make observations!

MATERIALS

- Tree Color Data Sheets
- Tree Color Reference Sheets
- Leaf Measurement Sheets, enough for each student
- Pencils
- Clipboards
- Ruler or Measuring Tape

PROCEDURE NOTES

1. Observations

- Divide into groups of **2-5** students
- Students choose **2 species** of trees to study. They will observe 5 trees of each species
- On the Tree Color **Data Sheet**, fill in the following information:
  - Today's date
  - Tree Species
  - Tag Number
  - Leaf Color Classification
- Use your best judgment to classify them according to the Tree Color **Reference Sheet**
  - Are the leaves mostly still green? Then they are 1-25% changed, but if they're mostly colored, they are 75-100% changed
- If possible, find a leaf from each of the two selected tree species and **outline them**
- Measure and record the **length and width** of the leaves they draw

Appendix I: Lesson Plans

2. Graphing

- Consider the graph below and where the observed trees may belong

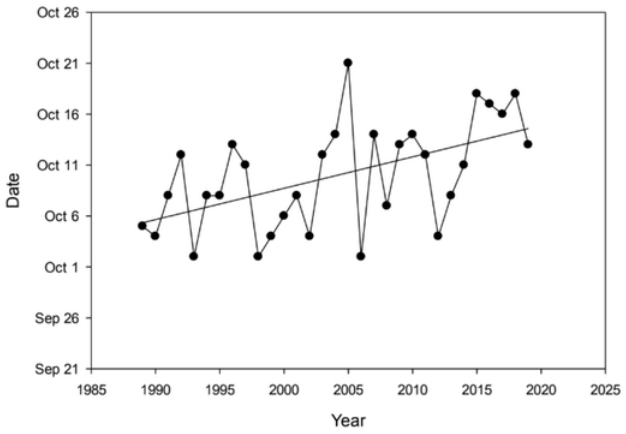


Figure 1: Peak Foliage of sugar maples at the bottom of Watershed 1 in the Hubbard Brook Experimental Forest

3. Discussion

- **What differences do you notice between individuals of the same species?**
  - *Trees of the same species change mostly all together*
- **What differences do you notice between the two different species?**
  - *Their leaf colors can have different gradients over time*
  - *Their leaves change colors at different rates*
  - *Some species of trees are less affected by climate change, not changing their winter preparations over time*
- **Does it seem like trees of the same species transition at the same time?**
  - *Not at the exact same time, but very within a similar time frame*
- **Do you see any trends, and do the trees you observed fit those trends?**
  - *Leaves seem to be changing colors, on average, earlier in year over time*

GENERAL TOPIC:

- Phenology
  - The study of seasonal changes in the life of an organism due to changes in its environment

LEARNING OUTCOME:

- Learn about how the forest reacts to the changing of seasons and compare data to long-term records

CONNECTIONS:

- Next Gen Science Standard: MS-ESS3-5 Earth and Human Activity
  - Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

CONSTRAINTS:

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES:

If short on time, give the teacher the discussion questions to go over in the classroom.

Appendix I.16: Phenology Organizer Notes (Spring)

HUBBARD BROOK RESEARCH FOUNDATION

Spring Phenology Organizer Notes

Age Group: 6th-12th grade
Time Estimate: 30-45 minutes

Phenology is the study of seasonal changes in the life of an organism due to changes in its environment. Understanding seasonal changes helps scientists assess the health of ecosystems, and advise conservation efforts. In forested ecosystems, trees undergo various seasonal changes throughout the year. In springtime, trees put out their leaf buds for the year, which begin to swell and burst, leading into a full summer canopy. The timing of leaf out in spring is closely linked to insect emergence and the emergence of herbivores from winter hibernation. If the timing of spring leaf out is shifted due to climate change, the timing of insect and herbivore emergence could be impacted, further affecting organisms such as birds and amphibians which rely on these as their primary food source. Tracking the timing of leaf out in spring can help scientists understand how the timing of spring is shifting, and how this shift affects the ecosystem as a whole.

Let's get outside, find some deciduous trees and make observations!

MATERIALS

- Tree Bud Data Sheets
- Tree Bud Reference Sheets
- Pencils
- Clipboards

PROCEDURE NOTES

1. Observations

- Divide into groups of **2-5** students
- Students choose **2 species** of trees to study. They will observe 5 trees of each species
- On the Tree Bud **Data Sheet**, fill in the following information:
  - Today's date
  - Tree Species
  - Tag Number
  - Bud Classification
- Use your best judgment to classify them according to the Tree Bud **Reference Sheet**

Discuss as a group: Do you notice any difference between individuals of the same species or between the different species?

2. Discussion

- **What differences do you notice between individuals of the same species?**
  - *Trees of the same species change mostly all together*
- **What differences do you notice between the two different species?**
  - *Their leaf colors can have different gradients over time*
  - *Their leaves change colors at different rates*
  - *Some species of trees are less affected by climate change, not changing their winter preparations over time*
- **Does it seem like trees of the same species bud at the same time?**
  - *Not at the exact same time, but very within a similar time frame*

Appendix I: Lesson Plans

GENERAL TOPIC:

- Phenology
  - The study of seasonal changes in the life of an organism due to changes in its environment

LEARNING OUTCOME:

- Learn about how the forest reacts to the changing of seasons and compare data to long-term records

CONNECTIONS:

- Next Gen Science Standard: MS-ESS3-5 Earth and Human Activity
  - Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.

CONSTRAINTS:

- For your safety in the forest, it is advisable to bring the following items in a backpack or bag of some sort: map of the research site (if far from school or roads), compass, cell phone, food/snacks, water, extra clothing (layers, raingear), bug repellent for ticks and flying insects and a basic first aid kit. These activities may require students to work in one area of the forest for a length of time, so biting insects may catch up to them. Also, walking off trail or "bushwhacking" requires much attention to where your feet are being placed and whether you are about to get a branch in the face. If possible, try to accomplish forest activities in groups, or with at least one other person. In most cases, we will be working in small groups, close to buildings and or roadways, so no one will be conducting field work alone deep in the forest, unless otherwise specified. If weather conditions are unfavorable (heavy rain, thunderstorms, etc.) please seek shelter and return at another time to continue the work.

ADJUSTABLES:

If short on time, give the teacher the discussion questions to go over in the classroom.

Appendix J: Reference Sheets

Appendix J.1: Tree Health Survey Datasheet

Tag Number	Diameter (In)	Species	Tree Health (1-4)	Beech Bark Disease (0-4)	Notes/Observations

Appendix J.2: Beech Bark Disease Rating Reference Sheet

Beech Bark Disease Rating Reference Sheet

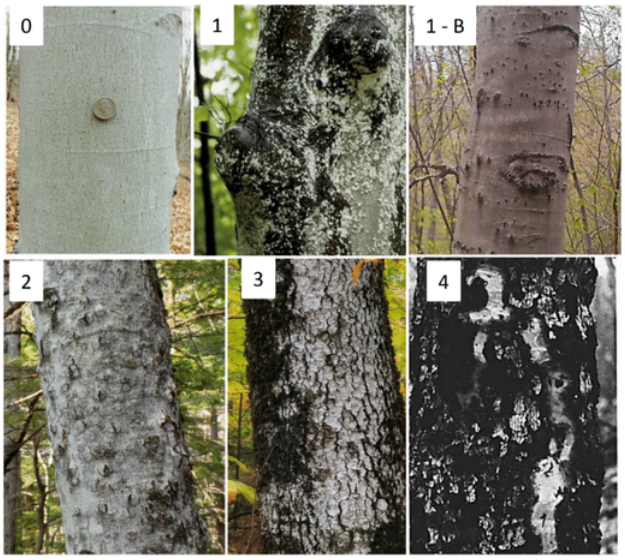


Figure 1. Beech bark disease reference photos above. Note that reference photo 1-B has Beech Bark Disease bumps, but also has old bear claw marks, giving a comparison of disease damage to other natural damages.

Beech Bark Disease Rating Codes

- **0:** no signs of disease, bark smooth and gray without any bumps. It is very unlikely you will find a beech tree with a rating of 0.
- **1:** disease is present but in small quantities. Small bumps are seen on the trunk but do not overlap with one another
- **2:** disease is more present on the trunk. Bumps and breaks in the bark are larger and more apparent, with some overlapping
- **3:** disease is very present on the trunk of the tree: Bumps and breaks in the bark are mostly overlapping and the trunk starts to look disfigured
- **4:** disease has spread to the entire tree. Bumps and breaks have all overlapped and the trunk is completely disfigured; usually with dead branches at top, or on a completely dead tree.

Background on Beech Bark Disease

Beech bark disease (BBD) is a disease involving a non-native scale insect in our forests. The scale insects burrow into the beech trees, leaving openings in the trunk for fungus to grow, causing bumps to erupt on the surface of the tree. These bumps are harmful to the overall health and function of these trees. For all beech trees in our plots, we record a Beech Bark Disease rating that reflects the severity of the disease that we can observe on the trunk.

Appendix J: Reference Sheets

Appendix J.3: Tree Reference Sheet

Sugar maple-Acer saccharum = ACSA

Sugar maple leaf and bark.

-Broad leaves with three lobes and U-shaped sinuses, smooth edges
-Opposite branching
-Seeds are in fruit (samara): two connected winged fruits
-Bark: gray to brown-gray, cracks deepen with age; corky to touch with fingernail
-Often with abundant moss and lichens

Red maple-Acer rubrum = ACRU

Red maple leaves and bark

-3-lobed serrated (pointed edges) leaves and V-shaped sinuses
-Opposite branching
-Bark: gray to gray brown and peeling in strips with age; much thinner and looser outer bark than sugar maple
-Fungus often forms a "bull's eye" pattern of cracks in the bark

Paper birch-Betula papyrifera = BEPA

Paper birch leaf and bark

-Doubly-serrate (big and little points on leaf edge) leaves that are broadly triangular
-Alternate branching
-Bark: white to peach; graying near tree base with age
-Large peels much thicker than the in yellow birch
-Note: Paper birch and gray birch have many hybrids that we will not be able to distinguish between

American beech-Fagus grandifolia = FAGR

American beech with cankers from beech bark disease.

-Broad, long, oval leaves that are wavy on the edges
-Alternate branching
-Seeds are a nut, 2 per cupule
-Bark: smooth gray even with age EXCEPT for diseased trees with cankers. Most beech trees will have some level of BBD
-See BBD rating and reference sheet to give your tree a BBD rating

Striped maple-Acer pensylvanicum = ACPE

Striped maple leaf and bark, though tree is wet and harder to see the stripes of green.

-Large, thin, 3-lobed broad and finely serrate leaves; resembling a duck's foot (Think large, wide maple leaf)
-Opposite branching
-Distinctive green or green-gray striped bark; very smooth when young
-Often with wounds from moose rubs
-Usually an understory tree and tree gap opportunist

Yellow birch-Betula allegheniensis = BEAL

Yellow birch leaf and bark of younger tree.

-Broad, oval leaves with a doubly pointed (serrate) edge
-Alternate branching
-Seeds are in winged seeds held in bunches (catkins)
-Bark: golden to yellow-gray with age
-Peeling strips are very thin and often tightly curled
-Long, obvious lenticels (horizontal lines)

White ash-Fraxinus americana = FRAM

White ash compound leaf and bark

-Compound leaves made up of 5-9 leaflets; usually 7
-Opposite branching
-Bark: Tan to light tan-gray, intersecting ridges make pattern of diamond-shaped furrows
-Bark is very corky and easily penetrated with your fingernails
-Ash trees typically grow straight up, with branches only at the top

Black cherry-Prunus serotina = PRSE

Black cherry bark often likened to "burnt potato chips". Photo by S. Thorne.

-Scaly bark, burnt chip bark
-Lenticels (horizontal lines) strong
-Leaves linear
-Alternate branching
-Underside of leaf with orange fuzz on mid-vein

Appendix J: Reference Sheets

Northern red oak-Quercus rubra = QURU

Red oak leaf and bark. Photo by S. Thorne.

-Long ridges of bark often with reddish valleys
-Younger trees have smoother bark
-Alternate branching
-Lobed leaves with pointed lobe tips

Eastern white pine-Pinus strobus = PIST

Eastern white pine bark and needles with close-up of one group of five needles (fascicle) on the right.

-5 needle pine with long, slender needles
-Bark in purplish plates, lighter color than hemlock
-White Pines can grow very large around and very tall
-White pine cones are the largest cones of all our conifers

Red spruce-Picea rubens = PIRU

Red spruce bark and sharp-pointed needles

-Pointy needles that develop in groups of three and so are triangular in cross-section
-Scaly bark, most similar to black cherry but with scales thicker and tighter to the trunk and lacking horizontal lenticels (horizontal lines)

Eastern hemlock-Tsuga canadensis = TSCA

Eastern hemlock bark and needles above and close-up of top and bottom sides of needles and cone on bottom.

-Shorter (< 2.5 cm long) flat needles growing from each side of the twig
-Two white lines on the underside of needles.
-Cones are very small (≤ 1cm) long and hang down on the branch
-Bark: reddish-gray to purplish brown and more deeply furrowed with age