# Hubbard Brook Experimental Forest
## Student Activities: Teacher's Manual

## Introduction

The activities contained in the HBEF Student Activities manual have been designed to introduce middle and high school students to the research program of the Hubbard Brook Experimental Forest (HBEF) and the Hubbard Brook Ecosystem Study (HBES). The manual is a component of the HBES Educational Resources website; more information may be found by clicking on the "educational resources" button of the **HBES website**: http://www.hubbardbrook.org/.

The manual contains three activities that may be used individually or in order as a group. While they work best when used together, there is no need to complete all of them in any particular order; for example, feel free to only use Activity 3 if you prefer. In the *first activity*, students read a brief introduction to and history of the HBES, and then take an online tour of the research facility. We have also designed handouts to help guide students through the tour. The *second activity* is centered on early deforestation research conducted in 1963, and allows students to graph and manipulate real data from the experiment. The *third activity* deals with basic forest ecology research, and outlines protocols for you and your students to take simple forest measurements in your schoolyard or nearby study area. We have also provided similar data from a long-term monitoring program at the HBEF for comparison.

*Standards*

In 1996, the National Research Council published the National Science Education Standards, a set of guidelines designed to direct the teaching of K-12 science. These standards move science education towards the teaching of science in schools as it is actually conducted: not with pre-set outcomes, but as a process that requires knowledge as well as reasoning and thinking skills. The activities in this book were designed to meet many aspects of the new standards, in the hopes that students will take an active part in learning through research, group discussions, and presentations. Table 1 and 2 show how each activity addresses these standards.

**Table 1**.
National Science Education Standards (9-12) addressed in the HBEF Student Activity Manual.

| National Standards | Activity 1 | Activity 2 | Activity 3 |
|---|---|---|---|
| **Unifying Concepts and Processes** | | | |
| • Systems, order, and organization | √ | √ | √ |
| • Evidence, models, and explanation | √ | √ | √ |
| • Change, constancy, and measurement | √ | √ | √ |
| • Evolution and equilibrium | √ | | |
| **Science as Inquiry** | | | |
| • Abilities necessary to do scientific inquiry | | √ | √ |
| • Understandings about scientific inquiry | √ | √ | √ |
| **Physical Science** | | | |
| • Chemical reactions | √ | | |
| **Life Science** | | | |
| • Interdependence of organisms | √ | √ | √ |
| • Matter, energy, and organization in living systems | √ | √ | √ |
| • Behavior of organisms | √ | | √ |
| **Earth and Space Science** | | | |
| • Geochemical cycles | √ | | |
| **Science and Technology** | | | |
| • Understandings about science and technology | √ | √ | √ |
| **Science in Personal and Social Perspectives** | | | |
| • Population growth | √ | | |
| • Natural resources | √ | √ | √ |
| • Environmental quality | √ | √ | √ |
| • Natural and human-induced hazards | √ | √ | |
| • Science and technology in local, national, and global challenges | √ | √ | |
| **History and Nature of Science** | | | |
| • Science as a human endeavor | √ | √ | √ |
| • Nature of scientific knowledge | √ | √ | √ |
| • Historical perspectives | √ | √ | √ |

**Table 2**. New Hampshire Science Standards addressed in Activity 1: The HBEF Virtual Tour.

| New Hampshire Standards | Activity 1 | Activity 2 | Activity 3 |
|---|---|---|---|
| **Science as Inquiry** | | | |
| • ...understanding of how the scientific enterprise operates | √ | √ | √ |
| **Science, Technology, and Society** | | | |
| • ...use measuring instruments to gather accurate and/or precise information | | | √ |
| • ...use technology to observe nature | √ | | √ |
| • ...to understand that science and technology can affect individuals...can affect science and technology | √ | √ | √ |
| • ...to understand that progress in science and technology is controlled by societal attitudes and beliefs | √ | √ | |
| **Life Science** | | | |
| • ...ability to recognize patterns and products of evolution, including...specialization, adaptation, and natural selection | √ | | |
| • ...to understand how environmental factors affect all living systems... | √ | √ | √ |
| • ...to understand that organisms are linked to one another and to their physical setting by the transfer of matter and energy to maintain a dynamic equilibrium | √ | √ | √ |
| • ...to understand fundamental structures, functions...found in microorganisms, fungi...plants, and animals | √ | | |
| **Earth/Space Science** | | | |
| • ...to understand that the Earth is a complex planet with five interacting systems... | √ | √ | √ |
| • ...to understand that the Earth contains a variety of renewable and non-renewable resources | √ | √ | √ |
| **Unifying Themes and Concepts** | | | |
| • ...to recognize parts of any object or systems, and understand how the parts interrelate in the operation... | √ | √ | √ |
| • ...quantify their interactions with phenomena in the natural world... | √ | √ | √ |

# Activity 1
## Introduction to the Hubbard Brook Experimental Forest

In this activity, your students will first read a brief history of the research program at the Hubbard Brook Experimental Forest (HBEF). After reading this background material, students will then take a virtual tour of the HBEF. One possibility is to have the students read the introduction as a homework assignment the night before taking the tour in class. The virtual tour can be found on the student's homepage of the **Educational Resources** section of the Hubbard Brook Ecosystem Study's website: http://www.hubbardbrook.org/. When finished with the tour, students may complete any of several accompanying handouts we have developed. The handouts contain questions of varying difficulty about the HBEF and the tour, and are located on the teacher's homepage of this website.

# Activity 2
## Watershed Experiments at the Hubbard Brook Experimental Forest

In this activity, students will compare a treatment watershed (tree cutting followed by herbicide application in Watershed 2) with the reference watershed (uncut forest in Watershed 3). Students will manipulate the data to determine whether the treatment produced the desired result: less water taken up by vegetation and more water running off into streams. (Another way to present this would be that students are testing the hypothesis that clearcutting reduces streamflow.) Students will compare the results suggested by a few years of data to the conclusions that can be drawn from a long-term study. To improve the quality of interpretation, students will look at a supplemental data set containing annual rainfall amounts.

In each Hubbard Brook watershed, scientists collected streamflow data on a daily basis as instantaneous flow rates: liters of water per second. They then integrated these values over time and standardized them for the area of the watershed. The results are reported as millimeters per day per standard area. This conversion makes it possible to conveniently compare streamflow to precipitation, and to compare streamflow in watersheds of different sizes. For example, in 1958 in Watershed 2, a value of 645.15 is listed in the data files. This means that during 1958, 645.15 mm of water (for any given area – for example, 1 square meter or 100 square meters) flowed out of Watershed 2.

In this activity, students will be working with streamflow and precipitation data collected from Watersheds 2 and 3 at the HBEF. The student procedure indicates that they will receive either printed spreadsheets or computer files containing these data. We have provided the data in formats suitable for either option. Students may work in small groups or as individuals. These data files may be found on the teacher's homepage of the **Educational Resources** section of the HBES website: http://www.hubbardbrook.org/.

The file containing easily printable spreadsheets is an MS Word file, and is located adjacent to the Activity 2 link ("Teacher Data file: MS Word"). It contains annual streamflow and precipitation data for both Watersheds 2 and 3 in a handout for students. There is also a teacher's section that includes another data column containing the difference between Watershed

2 and Watershed 3 (i.e., WS2 – WS3). The teacher's file also contains several graphs of precipitation and streamflow, for your reference.

There are two MS Excel computer files: one for teachers, and for students. Both are also adjacent to the Activity 2 link. The teacher's file contains annual precipitation, streamflow, and streamflow difference in Watersheds 2 and 3, and also includes graphs for your reference. The student version does not contain graphs or streamflow difference values.

Your students will use either graph paper or spreadsheet software to generate a figure that shows streamflow changes over time in the treatment and reference watersheds. Begin the activity by having the entire class review the data set and discuss the best approach for data analysis. Students should create two separate graphs: annual streamflow in WS2 and annual streamflow in WS3, or one graph containing both. One interesting way to compare the treatment and reference watersheds is to transfer the graph for WS3 (reference) to a transparency, so that it can be superimposed on the graph for WS2 (treatment). It is also instructive to graph the annual average precipitation for each watershed on transparencies and superimpose it on the two streamflow graphs.

Students will first graph results from the five years immediately following the clear-cut, and will then look at the remaining 18 years. Through comparing the short-term and long-term data, students should gain an understanding of how short-term trends can be misleading in ecology. One option for the activity's classroom organization would be to have your students graph the baseline data individually or in small groups, and then gather as an entire class to discuss what the data indicate (using the questions in the Procedure). Repeat this for the second data section (the five years after the clear-cut) and again for the third section (the final 18 years). In addition to graphing changes in the two watersheds over time, students can use the annual streamflow values to calculate the difference in streamflow (WS2 - WS3) between the watersheds. They will observe a pre-treatment difference between WS2 and WS3. Then they will see that in the years immediately after the treatment, the difference between WS2 and WS3 increases dramatically. Streamflow in WS2 increased an average 32 % in the three years after clearcutting.

With time, however, the difference between the two watersheds returns to baseline values. And then, something very interesting happens. Streamflow in WS2 becomes even smaller than it was before the treatment. Thirteen to 23 years after treatment, the average streamflow in WS2 is 7% less than it had been BEFORE treatment.

What's going on? For three years after the trees were cut, herbicides were applied to prevent any vegetation from re-growing. But once the herbicide treatments stopped and the vegetation was allowed to grow back, water yields declined rapidly. The original forest had been composed of mature hardwood species such as sugar maple, American beech, and yellow birch. But when the scientists stopped applying herbicides, the regenerating forest had a different composition. Most of the trees were pin cherry and paper birch. Studies at Hubbard Brook have demonstrated that these two species transpire more, and thus take up more water from the soil, than the original mature forest species. Data on total vegetative biomass in WS2 can be found on the Hubbard Brook website (see "Suggestions for Further Study").

The story is not over, however, because pin cherry trees do not live very long — usually only about 30 years. The data set provided only goes through 1988, 23 years after treatment. As pin cherry trees die off at Hubbard Brook, they should be replaced by the original hardwood species — maple, beech, and yellow birch. So the trend in water yield could change again.

Table 1. Hubbard Brook Watershed Treatments.

| Watershed | Size (hectares) | Treatment |
|---|---|---|
| 2 | 15.6 | Clearcut in winter 1965-66. Trees left on the ground. Herbicides applied in 1966, 1967, and 1968. |
| 3 | 42.4 | Reference (no treatment). |
| 4 | 36.1 | Strip-cut in 3 phases, in 1970, 1972, 1974. Trees removed from watershed. |
| 5 | 21.9 | Whole-tree harvested during the dormant season of 1983-1984. |

For students who would like to carry out an additional activity, data from a second treatment (strip cutting in Watershed 4) can be located on the Hubbard Brook website. This activity is in “Suggestions for Further Study,” in the student manual. Watershed 4 was divided into 49 strips, each strip 25 meters wide. In autumn of 1970, every third strip of forest was cut. A second set of strips was cut in 1972. In 1974, the third and final set of strips was cut. In contrast to WS2, where all the felled trees were left in place, on WS4 the trees were removed. However, no herbicide was applied to prevent vegetation regrowth.

# Activity 3
## Forest Ecology

In this activity, we introduce students to forest ecology research at the HBEF. The introductory section contains information about experiments vs. monitoring; treatments, controls, and references; plot sampling and design; and how scientists actually conduct long-term forest research and monitoring. The next section consists of five protocols that direct students in measuring trees in their schoolyard. The final section allows students to use real data collected in the HBEF to make comparisons between years and different areas. We also provide suggestions for how your students can use their collected data, and how they may make comparisons between your schoolyard and Hubbard Brook. The different sections are designed to be used individually or together – for example, you can work with the data without completing the protocols, or you can just complete a few of the protocols.

***Protocols***

This section is designed to get your students out in your schoolyard or nearby study area (e.g., park, forest, etc) to measure trees and other environmental variables. We have provided a few protocols that guide students through collecting data on species composition, tree diameter, tree height, and more; however, you should feel free to adapt this activity to fit the needs of your class. The protocols vary in the time they require for completion. While there is certainly always a benefit to having your students explore natural areas, you will be the best judge of whether or not a protocol is too time-consuming for your class. If one or all of the protocols will take too long, the activity will still be useful even if you skip them. Measuring real trees and study plots will likely make the HBEF data (next section) more tangible to your students, but the data activity (below) is useful by itself.

You should first have your class read through the introduction and the beginning of the protocols. Then have your class (as groups, individuals, or together) brainstorm what questions could be answered by measuring trees in your study area. Next, your students should select several plots in the study area (or many study areas, if you prefer), map the plots, and make note of environmental variables within those plots (Protocol 1). Then they may quantitatively measure the trees in each of the plots, recording such variables as species composition and density, as well as tree height, diameter, and basal area. Their questions will determine what variables are measured and which protocols are used.

At the end of the activity we make several suggestions and provide examples of how they might use their data to answer questions about their study area(s). The goal of this activity is not to have students do specific things with specific data; instead, we encourage students to propose questions and chose scientific protocols to collect data that might be useful for (partially or completely) answering those questions. This is an open-ended activity designed to give students exposure to collecting data in a standard fashion.

*Modifying Protocol 5: using a clinometer to measure tree height.*

Please note that Protocol 5 only works when measuring the tree height of straight (i.e., not leaning) trees growing on relatively flat surfaces (i.e., not on sloping land or hillsides). If your class is only able to locate plots on sloping land or with leaning trees, you can either 1) not use Protocol 5 to measure tree heights (skip this protocol) or 2) modify Protocol 5 to include basic trigonometry, a topic that is beyond the scope of this activity.

Modifying Protocol 5 to include trigonometry is fairly straightforward. Have your class build a clinometer as described in the first section of the protocol. Then update the diagram in Figure 5 to include the angle of the ground, thus modifying other measurements as shown on the next page. Students can measure the slope of the ground using the clinometer. The rest of the measurements of the "triangle" in the diagram can be determined using trigonometry.

***Hubbard Brook Ecosystem Study Data***

In the next section, we have provided two datasets from the HBES. Both datasets contain information about the HBEF reference area (Watershed 6); the first is from 1977, and the second is from 1997. We include suggestions for using these data to examine how the northern hardwood forest biome has been growing in the past few decades, and how different sections of a reference area look compared to each other (e.g., what types of trees are present at the top of the watershed, compared to the bottom). You may want to have your students develop reports or presentations that explain these data and what questions could be answered by them. Many example questions are at the end of the activity.

We also indicate that students can potentially compare HBES and their own schoolyard data. However, it's important that you tell them they can't make very accurate, direct comparisons unless they collect a great deal of information about their site and Hubbard Brook. Without knowing a great number of environmental variables (e.g., annual rainfall, latitude/longitude, solar radiation, max/mean temperatures), comparison between sites would not be very useful or accurate. However, if you or your students are interested in setting up simple long-term monitoring plots in your schoolyard, you could certainly collect these types of data, go online and download similar data from the HBES website, and then make comparisons.

The data files can be found on the activity page of the teacher's section of the HBES website (http://www.hubbardbrook.org/). Click on the **Educational Resources** button and follow the link to the "Teacher's Homepage".

**Alternate Figure 5.**