

ISSUES – FIGURE SET

Ecology of Disturbance

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Controlled fire, © Konza Prairie LTER,
Manhattan, KS {[www.konza.ksu.edu/
gallery/hulbert.jpg](http://www.konza.ksu.edu/gallery/hulbert.jpg)}

Figure Set 2: Hubbard Brook Experiment

Purpose: To introduce students to the Hubbard Brook design and findings.

Teaching Approach: "take home/group"

Cognitive Skills: (see Bloom's Taxonomy) — comprehension, interpretation

Student Assessment: Pressing question; Diagram with essay quiz

BACKGROUND

The Hubbard Brook clear-cut experiment is probably the most quoted ecosystem-scale study, and students are often immediately impressed by the scale (both temporal and spatial) of its design. Herb Bormann and Gene Likens chose this region of the White Mountains in New Hampshire because the Hubbard Brook Experimental Forest could be partitioned into reasonably sized, discrete watersheds drained by obvious streams. Impermeable bedrock beneath the site allowed the researchers to conduct input/output measurements by sampling precipitation (plus dry deposition and nitrogen fixation) and stream water at the base of the watersheds. For the biogeochemical studies they monitored nutrient loss from the 6 watersheds by placing a V-notched weir across the stream exiting a watershed; the weir created a small dam and stream gauges continuously measured flow and water height. Water samples collected at the notch gave an integrated measure of nutrient loss from the watershed.

In the Watershed 2 study all vegetation was cut during fall and winter of 1965; the forest floor was little disturbed since the trees were felled onto snow and no wood was removed. Bromacil, a nonspecific woody herbicide, was broadcast sprayed over the watershed by helicopter in June 1966 to kill regrowth. For the next two summers, 2,4,5-T was sprayed from the ground on the persistent regrowing vegetation with backpack mist blowers. Beginning in 1969, vegetation was allowed to regrow.

Export exceeded input of most nutrients for 2 reasons. First, the absence of evapotranspiration led to a 40% increase in stream discharge and accelerated leaching of soil nutrients. The second phenomenon was decoupling of decomposition and plant nutrient uptake in the watersheds. Soil ammonium concentrations increased mainly due to decomposition of the pulse of organic matter (e.g. dead leaves, roots) and inhibition of plant uptake. Soil nitrifiers then oxidized the ammonium into nitrate, and the mobile nitrate leached into streams leaving the watershed. The dramatic result demonstrates the tight coupling of nitrogen cycle processes in this forest.

The researches link increased nitrate output with increased availability of hydrogen ions (as a result of nitrification) and subsequent leaching of cations from the system. In soil cations are mobilized as hydrogen ions replace them in soil exchange complexes.

According to Likens et al. (1970) "Our study shows that retention of nutrients within the ecosystem is dependent on constant and efficient cycling between the various components of the intrasystem cycle (i.e. organic, available nutrients, and soil and rock mineral compartments)...Blocking of the pathway of nutrient uptake by destruction of one subcomponent leads to greatly accelerated export of the nutrient capital of the ecosystem." This Ecological Monographs paper concludes with a very useful 11 point summary of the study.

For additional information (including photographs) see the Hubbard Brook ISSUES Data Set in this TIEE volume and <http://www.hubbardbrook.org/research/overview/hbguidebook.htm>.

Literature Cited

- Bormann, F. H., and G. E. Likens. 1970. The nutrient cycles of an ecosystem. Scientific American 223: 92-101.
- Bormann, F. H., and G. E. Likens. 1995. Biogeochemistry of a forested ecosystem. Springer-Verlag, New York.
- Likens, G. E., F. H. Bormann, R. S. Pierce, and W. A. Reiners. 1978. Recovery of a deforested ecosystem. Science 199: 492-496.
- Likens, G. E., F. H. Bormann, N. M. Johnson, D. W. Fisher, and R. S. Pierce. 1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed-ecosystem. Ecological Monographs 40:23-47.

STUDENT INSTRUCTIONS

For homework study the Hubbard Brook Experiment figure on your own*. In class you will work in pairs or small groups with other students to better understand the results and how/why the scientists did this research.

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In the Watershed 2 study, all vegetation was cut during fall and winter of 1965; herbicide (Bromacil) applied for 3 years inhibited regrowth. They measured concentration of major ions in stream water before and after deforestation, including the years when herbicide was used. See the figure legend for more details about their methods.

- * Use the step one-step two approach we have practiced in class. In step one you first figure out how the figure or table is set up (e.g. what the labels on the axes mean). You also need to have a pretty good idea of the experimental design — how the scientists set up the experiments — and the hypotheses they addressed. In step two you can continue on and interpret the data. For both steps write down any questions you have.

FIGURES

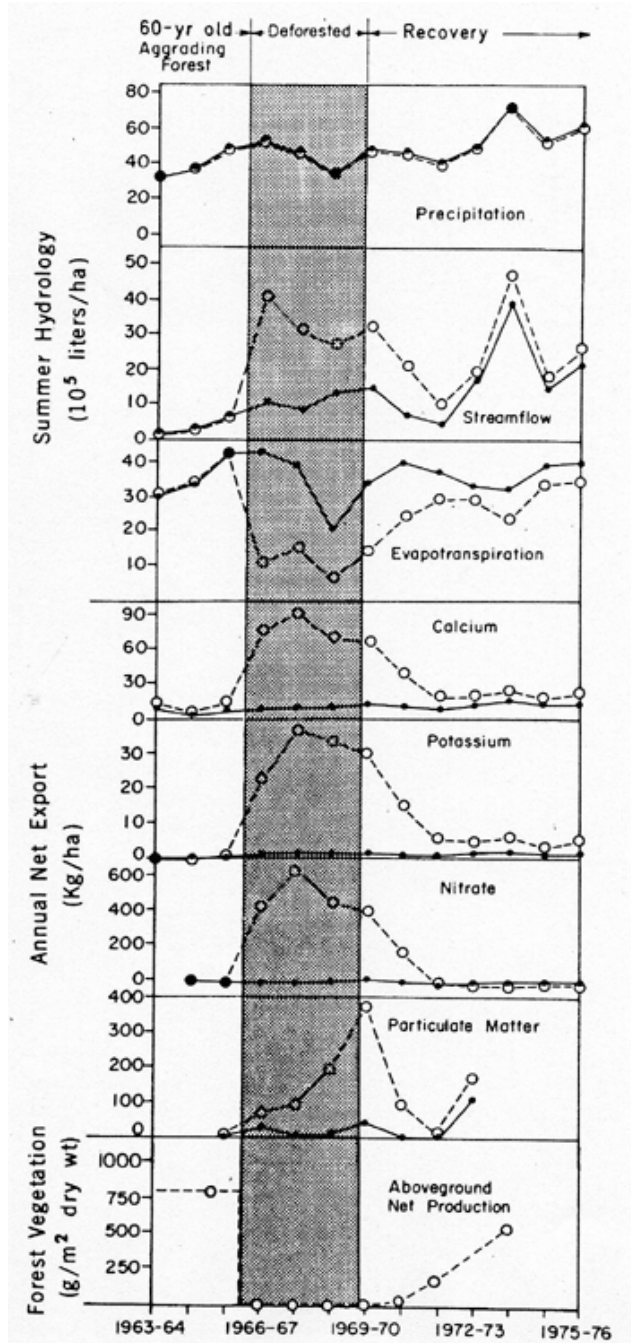


Figure 2. Precipitation, stream flow, net export of nutrients and particulate matter, and aboveground production in 2 watersheds in the Hubbard Brook Experimental Forest. Watershed 2 (open circle) was clearcut in 1966 and herbicides were applied monthly from fall of 1966 to winter 1969. Watershed 6 (closed circles) remained unaltered. Nutrients and particulates were measured in a stream draining the watershed. Data are a composite of (From Bormann and Likens 1978. Recovery of a deforested ecosystem. *Science* 199: 492-496).

More figures and photographs can be found at the Hubbard Brook Case Study: http://www.cnr.umn.edu/forestecology/lecture40_ppt.pdf or at <http://links.jstor.org/sici?sici=0036-8075%2819780203%293%3A199%3A4328%3C492%3AROADE%3E2.0.CO%3B2-D>.

FACULTY NOTES

For "take home/group" students first work on the figure and accompanying explanation of the experiment on their own as a homework assignment. In class they work in small groups (or pairs), explain the figure to each other, and then discuss it together. After this you project the data and go into a class discussion.

This figure could also be used in a think-pair-share exercise in class. I suggest the take home component because there is a good deal of information both in the figure and implied by the findings, and a thoughtful analysis will require a fair amount of time for students. Also most inexperienced ecology students are especially challenged by ecosystem approaches such as input/output comparisons; they have little or no familiarity with these ideas.

Discussion Questions:

- Why did the researchers use herbicides to inhibit plant growth for 2 years following deforestation?
- Streamflow increased in streams exiting the deforested watershed. Why? Where did the water come from?
- The Hubbard Brook researchers selected a site with impermeable bedrock. Why was this critical to their experiments?
- This is an ecosystem-scale watershed study. If you were to design an input/output ecosystem study such as this what would you need to think about in selecting a location and habitat type (e.g. grassland, lake).
- Ecologists who do manipulative field experiments should consider the ethical aspects of their actions. Some manipulations are quite minor (e.g. removing some leaves from a tree) while others are major (applying herbicide to an entire watershed). If you were considering using an herbicide in a field investigation (and even the very environmentally conscious Audubon Sanctuary researchers do this on occasion), what would you want to know about the herbicide and its effects?
- What are some of the implications of the Hubbard Brook research for conservation and pollution research and policy?

Student Assessment: 1) Diagram with essay quiz.

Ask students to write a brief essay (define approximate length) to address the following question. One striking result of the Hubbard Brook Experiment on watershed 2 was the large increase in nitrate in stream water exiting the watershed. Use a simple drawing to show the source of this nitrogen (e.g. where did it mainly come from?) and how this nitrogen is converted into nitrate which ends up in the stream water. Be sure to use these terms; organic nitrogen, ammonium, nitrate, leaching, bacteria. Write a brief explanation of your drawing.

Student Assessment: 2) Pressing question.

Students write 3 "pressing questions" about the experiment or figure on a 3x5 card which they hand in as they walk into class (this is also an easy way to take attendance). You select some of the cards, read a few questions, and ask students to discuss or answer them.

Evaluating an Issue: How do you know whether it is working?

On-going (also called formative) evaluation of the approaches you are using is critical to the success of student-active teaching. Why try out new ideas if you don't know whether or not they are working? This is a brief overview of formative evaluation. For more information, go to the Formative Evaluation essay in the Teaching Section.

Course Goals:

Formative evaluation only works if you have clearly described your course goals - because the purpose of the evaluation is to assess whether a particular technique is helping students reach these goals. For instance, most of us have "learn important ecological concepts and information" as a course goal. If I reviewed the nitrogen cycle in a class, for evaluation I might ask students to sketch out a nitrogen cycle for a particular habitat or system. Each student could work alone in class. Alternatively, I might ask students to work in groups of 3 and give each group a different situation (e.g. a pond receiving nitrate from septic systems, an organic agricultural field, an agricultural field receiving synthetic fertilizer). The students could draw their flows on a large sheet of paper (or an overhead transparency) and present this to the rest of the class.

The Minute Paper:

Minute papers are very useful evaluative tools. If done well they give you good feedback quickly. Minute papers are done at the end of a class. The students are asked to respond anonymously to a short question that you ask. They take a minute or so to write their response in a 3x5 card or a piece of paper. You collect these and learn from common themes. In the next class it is important that you refer to one or two of these points so that students recognize that their input matters to you. The [UW - FLAG site \(www.wcer.wisc.edu/nise/cl1/flag/\)](http://www.wcer.wisc.edu/nise/cl1/flag/) gives a good deal of information about using minute papers including their limitations, how to phrase your question, step-by-step instructions, modifications, and the theory and research behind their use.