TIEE

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ISSUES – FIGURE SET

What Are the Impacts of Introduced Species?

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Brown tree snake, *Boiga irregularis*
photo © G. H. Rodda, USGS
{biology.usgs.gov/s+t/
imagefiles/x181w02.htm}

Figure Set 5: Gypsy Moth Invasion and Links to Outbreaks of Lyme Disease

Purpose: To allow students to piece together the 3-way interaction of gypsy months, mice, and Lyme disease.
Teaching Approach: "jigsaw"
Cognitive Skills: (see Bloom's Taxonomy) — comprehension, interpretation, synthesis
Student Assessment: diagram quiz

BACKGROUND

This study by Jones et al. (1998) involves an introduced insect, the gypsy moth (*Lymantria dispar*). The moth was intentionally introduced into Massachusetts for potential silk production in the 1880’s. By 1987 the moth was established throughout the Northeast. It has now spread south to the Virginias and west to Michigan and to numerous other states throughout the U.S. It has become a serious pest on native and ornamental trees in the U.S. In parts of New England, defoliation of oaks in particular has occurred numerous times due to gypsy moth outbreaks.

Since 1980 gypsy moths have defoliated about a million acres of forest a year. In 1981 roughly 13 million acres were defoliated - an area larger than Massachusetts and Connecticut combined. Gypsy moth larvae prefer hard woods but feed on hundreds of tree and shrub species. When populations are dense they eat almost any vegetation. Trees are killed when they have been greatly defoliated (more than 50% of summer foliage) several times, or when stressed by other factors such as drought.

The life cycle of gypsy moths involves 4 stages: eggs larvae, pupae, and adult moths. Only the larvae damage vegetation. The moth lays egg masses on tree trunk, and branches and hatching coincides with leaf budding of hardwoods in the spring. Larval dispersal happens via silken threads on the winds or human transportation of wood and other objects. Larvae molt numerous times; these stages are called instars. In mid-summer larvae enter the pupae stage when they morph into adult moths. Moths mate in mid—late summer; eggs don't hatch until the following spring.

This Issue is based on a *Science* paper by Jones et al. (1998) that links heavy oak acorn production with degrees of gypsy moths outbreaks and Lyme disease. The data supports the idea that acorn biomass determine populations of white-footed mice and white-tailed deer in oak forests. Since mice eat gypsy moth larvae, they can decrease moth outbreaks.

In addition to eating moth larvae, those mice harbor the Lyme disease bacterium. Lyme disease is very serious in the northeast U.S.; if untreated it leads to severe joint and nervous system problems. Therefore this paper suggests that Lyme disease infection is higher in summers fallowing oak mast years (high acorn productions) and that acorn biomass could be used to predict Lyme disease risk.

The Jones et al. paper is a terrific example of the complex interactions between organisms in an ecosystem — and the surprising effects of these interactions on people.

In this 3-way jigsaw the first set of groups work on Figures 5a, 5b, and 5c, respectively, and they become “experts” on their figure. In the second grouping, students explain the 3 figures to each other and attempt to put the whole acorn-mouse-deer-tick-lyme disease puzzle together.

Web Resources

- http://www.fs.fed.us/ne/morgantown/4557/gmoth/ USDA site
- http://www.fs.fed.us/na/morgantown/fhp/gm/gmhb.htm Dept. of Agriculture
- http://www.gmsts.org/operations/ Slow the Spread
- http://lucas.osu.edu/gm/gmhome.htm Ohio State
- http://www.na.fs.fed.us/spfo/pubs/fidls/gypsymoth/gypsy.htm US Dept Agriculture, Forest Service
- http://www.vermontcf.org/pdfs/deerticks.pdf
- http://www.canr.uconn.edu/ces/forest/lyme.htm Links Between Acorns, Gypsy Moths, and Lyme Disease

STUDENT INSTRUCTIONS

Jigsaw Group A (Figure 5A)

To begin, someone in your group should volunteer to read the following individual and groupwork directions.

- Individually look at Figures 5A; take your time to first describe the figure (parameters and scale on each axis, the symbols, the overall pattern) and then attempt to interpret them. Be sure to read through the “explanations of the graphs” below. When each person in your group has finished doing this, carefully discuss each figure together. Make sure that each person truly understands the data, the axes, the symbols, the pattern, your interpretations. Now figure out how to explain these graphs to other students who will not have seen them before. What confused you at first? Show and explain these. What are the most important points you need to make? Make sure you can explain these clearly. Anticipate problems and questions they may have. Don’t finish until each person in your group feel comfortable teaching this material in the next grouping.
- Your figure is part of the data in a paper by Jones et al. published in the journal *Science* in 1998. The researchers put together an ecological puzzle that involves an introduced insect, the gypsy moth. The moth was intentionally introduced into Massachusetts for potential silk production in the 1880’s. That failed, but gypsy moth larvae became a serious pest on native and ornamental trees in the U.S. In parts of New England defoliation of oaks in particular has occurred numerous times due to gypsy moth outbreaks; when that happens forests in summer look like they do in winter. Trees that have been defoliated several times often die. Tree defoliations by gypsy moths happen now periodically in the northeast. In 1981 an area the size of Massachusetts and Connecticut was defoliated by the moth.
- Gypsy moths have 4 life stages — eggs, larvae, pupae, and adults. Only the larvae damage vegetation. Dispersal of larvae happens via silken threads caught by the wind and unintentionally by people. More and more states now have gypsy moths including the Virginias and Michigan.
- Jones et al. studied interactions between a number of seemingly unrelated organisms — gypsy moths, oak trees (their acorns), white-footed mice, ticks, deer, and the bacterium that causes a serious disease in humans called Lyme disease. People with serious cases have painful joints and brain disorders. Figure 5A shows the density (mice per hectare) of white-footed mice in a New England forest. Masting large production of acorns by oaks in the fall takes place every 2-5 years in New England and when that happens more mice survive the winter and breed in spring. Part of this experiment involved acorn addition; the scientists added acorns to reach a density of about 60 acorns per square meter (similar to a big acorn crop). Your job is to understand this graph as well as you can and explain it to students in the second grouping of the jigsaw. With this information and that from 2 other figures from this study, you should be able to piece together a fascinating story of how gypsy moth introduction has seriously affected the health of many people in New England.

Jigsaw Group B (Figure 5B)

To begin, someone in your group should volunteer to read the following individual and groupwork directions.

- Individually look at Figures 5b; take your time to first describe the figure (parameters and scale on each axis, the symbols, the overall pattern) and then attempt to interpret them. Be sure to read through the "explanations of the graphs" below. When each person in your group has finished doing this, carefully discuss each figure together. Make sure that each person truly understands the data, the axes, the symbols, the pattern, your interpretations. Now figure out how to explain these graphs to other students who will not have seen them before. What confused you at first? Show and explain these. What are the most important points you need to make? Make sure you can explain these clearly. Anticipate problems and questions they may have. Don't finish until each person in your group feel comfortable teaching this material in the next grouping.
- Your figure is part of the data in a paper by Jones et al. published in the journal *Science* in 1998. The researchers put together an ecological puzzle that involves an introduced insect, the gypsy moth. The moth was intentionally introduced into Massachusetts for potential silk production in the 1880's. That failed, but gypsy moth larvae became a serious pest on native and ornamental trees in the U.S.. In parts of New England defoliation of oaks in particular has occurred numerous times due to gypsy moth outbreaks; when that happens forests in summer look like they do in winter.
- Gypsy moths have 4 life stages — eggs, larvae, pupae, and adults. Only the larvae damage vegetation. Dispersal of larvae happens via silken threads caught by the wind and unintentionally by people. More and more states now have gypsy moths including the Virginias and Michigan.
- Jones et al. studied interactions between a number of seemingly unrelated organisms — gypsy moths, oak trees (their acorns), white-footed mice, ticks, deer, and the bacterium that causes a serious disease in humans called Lyme disease. Figure 5B shows the densities of various life stages of the gypsy moth in the study area. Part of the study involved effects of mice on gypsy moths. The scientists removed mice by continuously trapping them in the experimental areas. Your job is to understand this graph as well as you can and explain it to students in the second grouping of the jigsaw. With this information and that from 2 other figures from this study, you should be able to piece together a fascinating story of how gypsy moth introduction has seriously affected the health of many people in New England.
- Figure 5B shows the densities of various life stages of the gypsy moth in the study area. Part of the study involved effects of mice on gypsy moths. Your job is to understand this graph as well as you can and explain it to students in the second grouping of the jigsaw. With this information and that from 2 other figures from this study, you should be able to piece together a fascinating story of how gypsy moth introduction has seriously affected the health of many people in New England.

Jigsaw Group C (Figure 5C)

To begin, someone in your group should volunteer to read the following individual and groupwork directions.

- Individually look at Figures 5C; take your time to first describe the figure (parameters and scale on each axis, the symbols, the overall pattern) and then attempt to interpret them. Be sure to read through the "explanations of the graphs" below. When each person in your group has finished doing this, carefully discuss each figure together. Make sure that each person truly understands the data, the axes, the symbols, the pattern, your interpretations. Now figure out how to explain these graphs to other students who will not have seen them before. What confused you at first? Show and explain these. What are the most important points you need to make? Make sure you can explain these clearly. Anticipate problems and questions they may have. Don't finish until each person in your group feel comfortable teaching this material in the next grouping.

- Your figure is part of the data in a paper by Jones et al. published in the journal *Science* in 1998. The researchers put together an ecological puzzle that involves an introduced insect, the gypsy moth. The moth was intentionally introduced into Massachusetts for potential silk production in the 1880's. That failed, but gypsy moth larvae became a serious pest on native and ornamental trees in the U.S. In parts of New England defoliation of oaks in particular has occurred numerous times due to gypsy moth outbreaks; when that happens forests in summer look like they do in winter.

- Jones et al. studied interactions between a number of seemingly unrelated organisms — gypsy moths, oak trees (their acorns), white-footed mice, deer, ticks, and the bacterium that causes Lyme disease. Your figure focuses on the black-legged tick which is a vector the bacterium for Lyme disease. This is a serious disease that was first detected in Lyme, Massachusetts and if left untreated causes severe joint problems and neurological effects in people. It can be treated with heavy doses of antibiotics but is often is not because it is confused with the flu. The disease is transmitted to humans by ticks infested with the Lyme disease bacterium. Adults ticks feed and mate on deer before they drop to the ground in the fall. The following spring and summer tick "offspring" feed on mice (for blood) and in this way pick up the bacterium. A later life stage seeks more blood meals from vertebrate hosts, which can be humans.

- Figure 5C shows the densities of ticks that carry the bacterium for Lyme disease in the study area. Part of the study involved affects acorn addition on mouse densities. Your job is to understand this graph as well as you can and explain it to students in the second grouping of the jigsaw. With this information and that from 2 other figures from this study, you should be able to piece together a fascinating story of how gypsy moth introduction has seriously affected the health of many people in New England.

Questions for Second Jigsaw Group (all groups have one A, B, and C person)

Each A, B, and C person should take a few minutes and explain your figure(s) to your other group members. Patiently teach them what your data show. Finally, your group should use your combined knowledge to explain the phenomena.

FIGURES

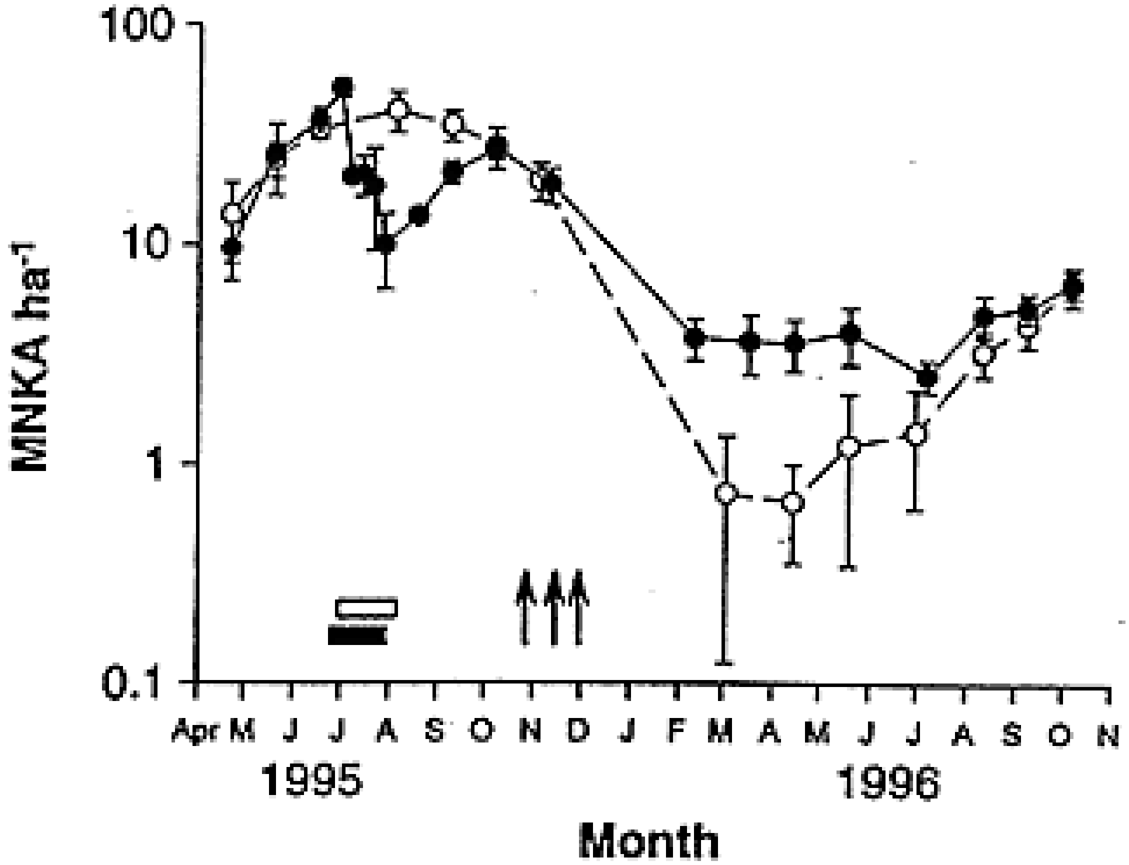

Figure 5A. Average density per hectare (2.2 acres) of white-footed mice in 3 control (open circles) and 3 experimental (closed circles) areas. The vertical lines are standard errors, which are a statistical measure of the range of the 3 replicates. The data show (1) 1995 mouse densities before, during, and after mouse removal from the experimental areas (black bar) from experimental areas during the time when gypsy moths pupate (become larvae; white bar); (2) 1995 mouse densities before and during addition of oak acorns (black arrows) to experimental areas in October-November 1995 when there were naturally few acorns produced by trees in the control areas, and (3) 1996 mouse densities after acorn additions to experimental areas in 1995. Mouse densities typically go up when oaks produce more acorns and they naturally decline in the winter (from Jones, C. G., R. S. Ostfeld, M. P. Richard, E. M. Schauber, and J. O. Wolff. 1998. Chain reactions linking acorns to gypsy moth outbreaks and Lyme disease risks. Science 279: 1023-1026).

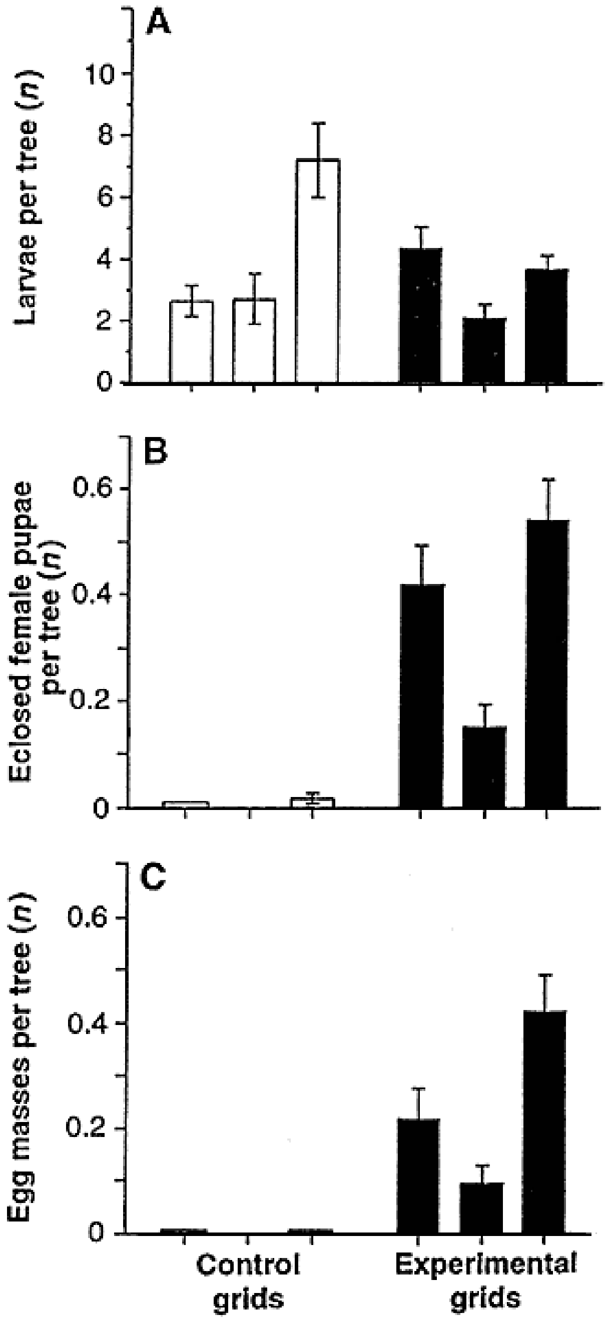

Figure 5B. Densities of gypsy moth life stages on or under burlap bands placed around trees in control areas (open bars) and experimental areas (solid bars) where white-footed mice were removed. The bars show averages and the vertical lines standard errors, which are a statistical measure of the range of the replicates within each area.

A is the number of living late-stage moths per tree just before mouse removal.

B is the number of female pupae per tree successfully changing into adults after mouse removal.

C is the number of moth egg masses per tree after mouse removal

(from Jones, C. G., R. S Ostfeld, M. P. Richard, E. M. Schauber, and J. O. Wolff. 1998. Chain reactions linking acorns to gypsy moth outbreaks and Lyme disease risk. Science 279: 1023-1026).

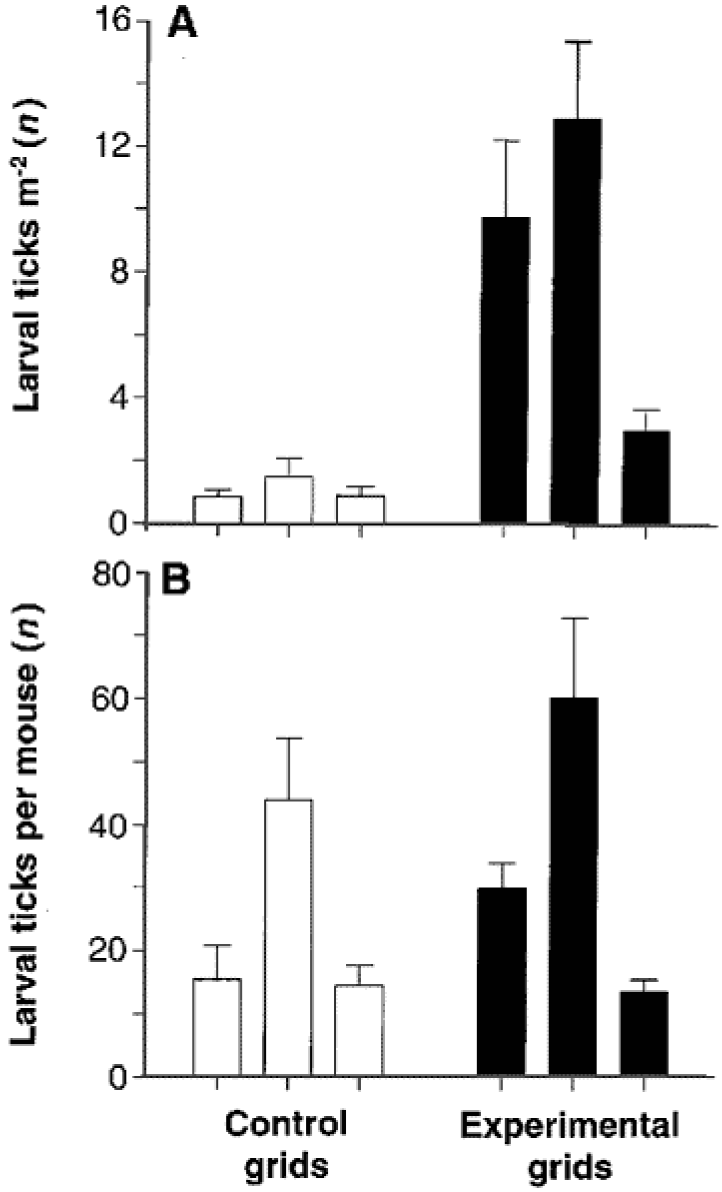

Figure 5C. Lyme disease tick densities on control areas (open bars) and experimental areas (solid bars) in August 1995 after acorn additions to experimental grids in October-November 1995. The bars show averages and the vertical lines are standard errors, which are a statistical measure of the range of the replicates within each area. A is the number of host-seeking larval ticks per square meter. B is the number of larval ticks per mouse (from Jones, C. G., R. S Ostfeld, M. P. Richard, E. M. Schauber, and J. O. Wolff. 1998. Chain reactions linking acorns to gypsy moth outbreaks and Lyme disease risk. Science 279: 1023-1026).

FACULTY NOTES

The jigsaw is a type of cooperative groupwork in which students teach each other and then put together pieces of a puzzle. Done well, it is a very effective method, but it does take a fair amount of time. In this jigsaw there are 3 subsets of information. Using a class of 30 as an example, divide the class into 6 subgroups of 5 students. Give 2 groups Figure 5A plus accompanying information (below), 2 groups 5B, and 2 groups 5C. Allow these students enough time to look at their figures and background information individually and then with their team members. The goal is for each student to understand their topic clearly enough so that they can teach it to another student. Then, rearrange the groups so that there are 10 groups with an A, B, and C student in each one. Again, give the second grouping time so that students can explain their figure and questions they may have without feeling rushed. The final question for this group is to use their combined knowledge to explain the phenomena. That's what makes it a "jigsaw" - the pieces are reassembled to solve the puzzle.

This will be a challenging but fun puzzle for ecology students. You will need to decide how much time they will need for the first and second grouping of the jigsaw. The first groups will need a good amount of time just to read through all the information. You can of course use the figures in class discussion and skip the jigsaw.

Jones et al. conclude that their data "… provide strong support for the idea that a chain of events links acorns to gypsy moth outbreaks and Lyme disease risk. The experiments demonstrate first that acorns determine overwinter survival, reproduction, and the resulting density of mice. Second, that high or low mouse density, at low gypsy moth population density, can respectively suppress or release moth populations through altered pupae predation. Third, that acorns determine larval tick densities by affecting the use of oak forests by deer, resulting in high densities of both host-seeking uninfected ticks and ticks parasitizing mice at the time when spirochaete-infected mice are most abundant…. Our studies clearly demonstrate that both gypsy moth dynamics and Lyme disease risk have contingent outcomes arising from a complex chain of strong pairwise interactions among taxonomically diverse species that are all interconnected within an ecosystem." Said more simply 1) more acorns results in more mice (Figure 5A), 2) more mice results in fewer gypsy moths (Figure 5B), and 3) more acorns lead to higher tick densities (as a result of higher numbers of mice and deer). Therefore lower numbers of gypsy moths may be a predictor of greater Lyme disease risk. Quite a set of interactions for an introduced species!

Student Assessment: Diagram Quiz

Make a clear drawing or sketch of the interactions between gypsy moths, acorns, mice, deer, deer ticks, and Lyme disease. Label each component. Between components write a phrase or sentence that clearly describes the interaction.

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

On-going (also called formative) evaluation of the approaches your 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/) 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.