Forest in my Neighborhood: An Exercise Using Aerial Photos To Engage Students in Forest Ecology & Land Use History

GLENN R. MATLACK   RYAN W. MCEWAN

Human activity has profoundly altered the deciduous forest of the eastern United States. Modern forest is a patchwork of stands of varying ages, sizes, and shapes reflecting a complex history of land use (Williams, 1989). Much modern forest is nestled in and around human communities, and faces the threat of imminent clearance for residential and commercial development (Matlack 1997a,b; Hall et al., 2002). Such forest experiences a variety of human impacts, including edge effects (Matlack 1993a, 1994), invasion by nonnative plants and animals (Britton, 1997), overgrazing by white-tailed deer (Rooney & Waller, 2003), firewood gathering, and foot traffic (Matlack, 1993b).

Despite its highly disturbed character, modern suburban forest still preserves some of the biological diversity of the original forest ecosystem (Matlack, 2005). If diversity is to be maintained in developed regions, people who live next to forest fragments must have an appreciation of their structure and dynamics. Unlike forests of less-populated regions, isolation alone cannot be depended on to protect the Eastern forest ecosystem. To intelligently manage neighborhood forests, local residents and decision makers must have an awareness of forest ecology. Thus, education is at the core of forest conservation in the eastern United States.

We teach a lower-level undergraduate course in forest history aimed at non-majors. To give students an awareness of forest ecology at the rural/urban interface, we include an exercise based on aerial photos. Students are asked to examine photos of rural and suburban areas taken in the 1980s and record the occurrence of a variety of land uses. Sample points are relocated on photos taken 20 years later, and students tabulate transitions in land use over the interval.

GLENN R. MATLACK (matlack@ohio.edu) is a faculty member, and RYAN W. MCEWAN is a graduate assistant, both in Environmental and Plant Biology, Ohio University, Athens, OH 45701.

Our goals are:

- to illustrate modern trends in forest distribution, complementing our lectures on forest history
- to raise awareness of modern land use practices as threats to forest ecosystems in the eastern United States
- to generate interest in the course as a whole.

We hope that informed students will contribute to public debate after graduation, and become effective managers of private forests in the region.

Each student performs the exercise on the neighborhood of his/her childhood home, an approach that has several advantages. First, engaging a student's interest is a necessary prerequisite to effective teaching in any course. We have found that a novel perspective on the familiar neighborhood stimulates student interest and increases engagement in the exercise. Second, students already have a general impression of changes taking place in their home neighborhood, which can be tested by examination of land cover data. Finally, students are already familiar with the locations and land uses shown in the photos, reducing the time required to learn landuse pattern recognition.

The exercise can be described as a process of guided research in which impressions based on childhood experience are used as testable hypotheses. Active involvement of students in the research process has been shown to be the most effective approach to science learning (Warren, 1997; Barr, 1998), a finding that extends to environmental topics (Zelezney, 1999). Evaluations of science teaching effectiveness show that students who examine a concept through research receive a clearer understanding than those who only receive the concept passively in a lecture (SRI, 1997; Moss et al., 1998), especially if all the stages of Baconian science (hypothesis formation, inquiry design, data collection and analysis, evaluation, and hypothesis modification) are included in the exercise (Martin et al., 1997). The aerial photo exercise is designed to include each of the essential

Baconian stages, although its formal structure is not mentioned in the classroom. The exercise has worked well for us over several years. It is simple to use, holds student interest, and makes important points about forest conservation in a human-shaped landscape. In this article, we describe the exercise in detail and comment on its effectiveness as a teaching tool.

The Course & Students

The land use exercise is part of an undergraduate course in American Forest History presented in the Environmental and Plant Biology Department at Ohio University (Athens, Ohio, USA). The course presents forests in both cultural and biological contexts. It assumes no prior background in biology, and is often taken by non-majors to satisfy a General Education science requirement. Material is presented in a lecture/discussion format using a variety of pedagogical methods to encourage student participation. Students in the spring quarter of 2005 were typical. Most were juniors and seniors majoring in the humanities and social sciences. Natural science majors made up only 15% of the class. The class included 80 students, almost entirely from Ohio (95%). They came from all parts of the state and a variety of community types, but the rapidly growing suburbs of large cities (Columbus, Cleveland, and Cincinnati) were most common. Most home communities included at least a few forest fragments, and many students mentioned playing in the woods as children.

The Exercise

Phase I: Land Use in the 1980s

Land use change is assessed by comparing aerial photos from the 1980s and 2000s (Figure 1) in an extended project running eight weeks of the ten-week course. Aerial photos taken in the National High Altitude Photography program (NHAP) in the early 1980s are kept as digital files in the University library at a scale of 1:20,000. Photos from the early 2000s are purchased by students as a text for the course. The two sets of photos roughly bracket the lifespans of most students. The "Photofinder" software at the U.S. Geological Survey Web site (USGS, 2006) allows a student's home to be located quickly and precisely without assistance. Students use Photofinder to order photos directly from the USGS. Photos are delivered to individual students as TIFF data files.

Early in the course we introduce students to aerial photos with a PowerPoint (MicroSoft Inc., Redmond, Washington) presentation featuring scanned photos of many landscape features they are likely to encounter, followed by a discussion (presentation and discussion together consume about 30 minutes of class time). In particular, we discuss vegetation signatures differentiating various types of forest and rural land use. Students enjoy recognizing features such as airports, golf courses, and stadiums, and the shore of Lake Erie. The presentation is posted on the course Web site for students' later reference (readers can view it at: http://www.plantbio.ohiou.edu/archival/matlack/A_field guide_to_aerial_photos.pdf).

Students are then asked to describe land use around their homes in the early-1980s photo using a point-sampling method. Points are located with ImageJ image-processing software, developed by the NIH (downloadable free at http://rsb.info.nih.gov/ij/). Each student loads the photo file into the software, specifies the scale, and imposes a grid, with a 500 m interval on the aerial photos. In a classroom presentation lasting about 15 minutes, we show students how to anchor one grid point on their house and another on a long-established recognizable point (e.g., a road intersection) at a distance from their house (reiterated in a handout viewable at: http://www.plantbio.ohiou.edu/archival/matlack/A&TF_Aerials_I.pdf). This fixes the grid in space and allows grid points to be precisely relocated on the early-2000s aerial, which is specified at the same scale. Students record for future reference the grid points they used for anchors, and the objects in the photo used for alignment. They then examine the vegetation at each of the 100 points in a 10 X 10-point square, classifying points as urban/paved, pasture/lawn, row-crop agriculture, disturbed soil, young deciduous forest (fine-textured canopy), old deciduous (course canopy), coniferous forest, regenerating old field, water, or "other." At each forested point, the closest distance to a forest edge is measured with the ruler tool in ImageJ. The greatest straight-line length of the forest patch is recorded. At each nonforested point, distance is measured to the nearest forest patch. Data are collected in a work sheet, which is provided (viewable at: http://www.plantbio.ohiou.edu/archival/matlack/A&TF_ Aerials_I.pdf). Students seem comfortable collecting data outside of class without supervision, although assistance is always available if they request it.

Data analysis consists of tabulating the number of grid points in each of the land use categories. Distance from the forest edge is summarized as the average distance among all forested points, providing an index of the degree of edge exposure in forest stands. Average distance to the nearest forest summarizes the isolation of forest fragments. Average stand length provides a crude measure of patch size. Although these summary statistics miss much of the subtlety of pattern in a heterogeneous landscape (Gustafson, 1998), they capture the essential aspects of stand frequency, size, and isolation. They can be calculated by most of the class without assistance –– an important consideration given that most class members have no college-level experience with numerical analysis. Although the method of data collection and presentation is specified, there is no single correct answer in these results.

Students record their calculations in a for-credit worksheet and answer short essay questions designed to promote thinking about trends in land use and changes in forest frequency and fragmentation (viewable at: http://www.plantbio.ohiou.edu/archival/matlack/A&TF_Aerials_I.pdf). They are asked to predict which land uses will increase and decrease during their lifetimes, and to suggest causes. This phase is equivalent to the "explanation" phase of Martin et al. (1997) science learning model, asking the student to form hypotheses on the basis of initial observations. Worksheets are collected, graded, and returned with written comments by the fifth week of the ten-week course. An early deadline for Phase I has the benefit of reducing procrastination; students are obliged to start work on the project early in the course! We grade worksheets solely for completion of all parts of the assignment; the goal is the experience of collecting and considering the data rather than the assimilation of a testable set of facts.

Phase II: Land Use in the 2000s

The second phase of the project asks students to repeat the data collection and analysis using the early-2000s aerial photos. Students use the same anchor points to align the grid points on the 2000s photo, allowing them to precisely relocate each grid point examined in the 1980s' photo. Land uses at each point are recorded and summary statistics are calculated as before. In addition, students do a point-by-point comparison of land use between the two sampling dates and construct a 1980-2000 transition matrix. This consists of tallying the frequency with which each land use observed in the 1980s changes to each of the land uses in the 2000s. A matrix worksheet is provided to guide this phase (viewable at: http://www.plantbio.ohiou.edu/archival/matlack/A&TF_Aerials_II.pdf), and students seem to have little difficulty using it.

Change is calculated in the average distance to the forest edge, average distance to the nearest forest, and average stand length. These findings are reported on the worksheet, followed by essay questions probing the nature of land use change. Students are asked to reconsider their initial predictions in light of the second data set, and asked about the consequences of such change for forest organisms. The assignment is handed in during the eighth week of the quarter, just before lectures on forest regeneration and the expansion of suburbia in the twentieth century. Having formed their own opinions about forest fragmentation from direct observation, the students are now equipped to think critically about the interpretations we present in lecture.

The work schedule could easily be altered to fit a different course format. Although we use the exercise with undergraduates, there is no reason it couldn't be used with upper-level high school students. Because collection and analysis of data take only two to three hours in each phase, photo handling could be compressed into two supervised lab sessions. The whole exercise would be completed in a week.

What Do Students Learn?

Most students observe a loss of forest caused by suburban encroachment over the interval (Figure 1). Students generally anticipate this finding because most have observed real estate

Figure 1. Aerial photos of a section of Fairfield, Ohio from 1981 (above) and 2000 (below) showing the spread of residential neighborhoods and regeneration of forest on agricultural land. A student would orient himself/herself using the principal roads and then navigate along roads to his/her home. In addition to the proliferation of tract housing, he/she would probably comment on the linear structure of forest along streams (left center), the isolation of small forest fragments (bottom left), several ball fields, a divided highway (bottom right), and disturbed soil portending future development.

development in their home neighborhoods. Many also note an increase in the amount of young forest as agricultural land is abandoned – an unexpected result for most of them. Forested points are generally closer to a forest edge in the 2000s than they were in the 1980s, and nonforested points are more distant from forests. Most students find that average stand length has decreased as forest is cleared, but there is substantial variation in each of these landscape measures. Students from rural parts of the state sometimes find a net increase in forest cover. Different parts of the state experience different land use dynamics – an important teaching point that we make when summarizing the exercise.

The exercise clearly taps into personal experiences of the students. Their final reports often take the form of a personal narrative about land use change in the neighborhood, frequently mentioning clearance of a particular tract of forest for a shopping center or residential development. Students often pull in observations about topics outside the course, such as traffic patterns, wildlife biology, or water quality. At an emotional level, many students lament the loss of forests they played in as children. These events are placed in the context of local-community debates involving conservation, employment, or the future of agriculture. Students often take the opportunity to speak out strongly against commercial and residential development.

In spring 2005 we used a before-and-after questionnaire to see what students had learned from the exercise. The exercise apparently succeeded in giving the class a more accurate understanding of the amount of forest in their home neighborhoods. Before the exercise, there was no correspondence between actual forest cover and students' estimates of cover (a regression of estimated cover on cover actually observed in the photo was not significant; $P > 0.05$). Students tended to over-estimate cover relative to what is actually shown in the photos. After the exercise, actual cover significantly predicted students' estimates of cover (estimated cover regressed on observed cover; F = 24.12, 52 df, $P < 0.0001$, $R^2 = 0.321$) although they still tended to overestimate cover (Figure 2). Before the exercise students' estimates of change in forest cover were unrelated to real rates of change, but rates were significantly correlated after the exercise (Spearman $R_{after} = 0.37$; $P = 0.003$).

The exercise appeared to give students a more accurate view of other land uses as well. More realistic estimates of the frequency of lawn, suburban, urban, and agricultural areas are consistent with a broadening of the students' viewpoint from the scale of a residential street to the scale of the wider landscape. An increase in the number of causes students listed for forest clearance suggests that the exercise produced a more complex understanding of the mechanisms of forest change. Forest regeneration, a gradual but important process in our region, was apparently unanticipated by most students before they discovered it in their photos. We don't know how our students will translate their understanding of landscape dynamics into actual behavior later in life (we have only used the exercise for five years), but our hope is that a more precise understanding of forest dynamics will lead to environmentally sensitive choices in their personal lives, and more enlightened public policy debates.

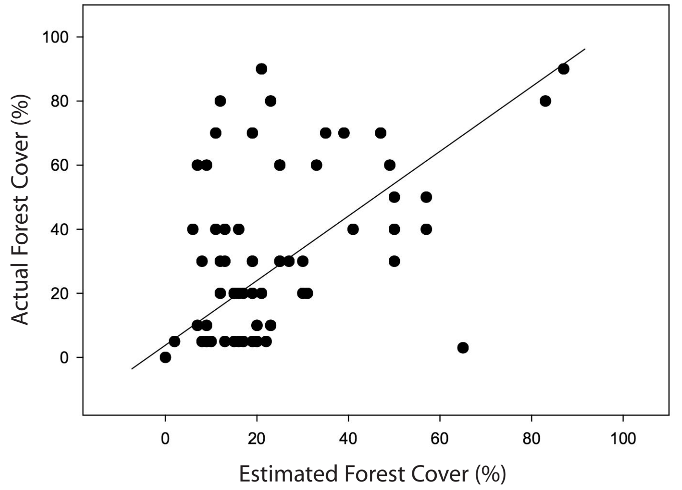

Figure 2. Student estimates of forest cover plotted against actual cover in their home neighborhoods after participating in the aerial photo exercise. Each point represents a single student. The diagonal line indicates perfect prediction of actual forest cover (observed = predicted) . Although many students still overestimate cover after the exercise, the relationship is measurably stronger than before the exercise.

Conclusion

Biographies of famous environmentalists repeatedly trace their ecological awareness to childhood experience of the natural environment, and to contact with mentors or teachers at critical phases (Tanner, 1980; Chawla, 1998, 1999). We work on the premise that *all* people have some form of early environmental experience which can be recalled profitably in their later education. Our students come to the aerial photo exercise with well-developed attitudes toward land use in their childhood communities and a passing familiarity with important environmental issues, attitudes which are obvious in their reports. Comparisons of environmental literacy among groups of college students suggest much valuable insight is acquired through informal experience rather than classroom exposure (Robinson & Crowther, 2001). Thus, the student's whole personal experience has value, and should not be disregarded in formal teaching exercises (AAAS, 1993; Lloyd, 1996). Indeed, the most effective science teaching may be that which can take advantage of existing knowledge (Nadkarni, 2004). Although we know little about the specific life experiences of our students, such experience has generated considerable personal interest in the exercise, has given students novel and original perspectives in its interpretation, and has almost certainly contributed to its success. Effective teaching requires that we acknowledge this experience and work with it constructively.

The exercise appears to have broadened the students' landscape perspective within their communities both by exposing them to new information, and by providing a context to use previous information about the environment. As such, it has satisfied our teaching goals. We recommend the exercise to our colleagues, and we welcome inquiries.

Acknowledgments

We thank the hundreds of students in PBIO 109 who have participated in the aerial photo exercise and provided feedback. We are grateful to Carol Brewer and three anonymous reviewers for thoughtful comments on the manuscript. Peggy Sattler and her staff have provided invaluable assistance in handling photos.

References

American Association for the Advancement of Science (AAAS). (1993). *Benchmarks for Science Literacy*. New York: Oxford University Press.

Barr, R.B. (1998). Obstacles to implementing the learning paradigm – what it takes to overcome them. *About Campus*, September 18-25.

Britton, K.O. (Editor). (1997). Exotic pests of eastern forests. Proceedings of the Exotic Pests of Eastern Forests Conference, April 8-10, 1997. Nashville, Tennessee: Tennessee Exotic Pest Plant Council.

Chawla, L. (1998). Significant life experiences revisited, a review of research on sources of environmental sensitivity. *Journal of Environmental Education*, *29*, 11-21.

Chawla, L. (1999). Life paths into effective environmental action. *Journal of Environmental Education*, *31*, 15-26.

Gustafson, E.J. (1998). Quantifying landscape spatial pattern, What is the state of the art? *Ecosystems, 1*, 143-156.

Hall, B., Motzkin, G., Foster, D.R., Syfert, M. & Burk, J. (2002). Three hundred years of forest and land use change in Massachusetts, USA. *Journal of Biogeography*, *29*, 1319-1335.

Lloyd, C.V. (1996). Scientific literacy in two high school biology classrooms: Considering literacy as a social process. *Journal of Classroom Interactions*, *31*, 21-27.

Martin, R., Sexton, C., Wagner, K. & Gerlovich, J. (1997). *Teaching Science for all Children, Second Edition*. Boston: Allyn and Bacon.

Matlack, G.R. (1993a). Microclimate variation within and among forest edge sites in the eastern United States. *Biological Conservation*, *66*, 185-194.

Matlack, G.R. (1993b). Sociological edge effects, the spatial distribution of human activity in suburban forest fragments. *Environmental Management*, *17*, 829-835.

Matlack, G.R. (1994). Vegetation dynamics of the forest edge, trends in space and successional time. *Journal of Ecology*, *82*, 113-124.

Matlack, G.R. (1997a). Land use and forest distribution in the hinterland of a large city. *Journal of Biogeography*, *24*, 281-296.

Matlack, G.R. (1997b). Four centuries of forest clearance and regeneration in the hinterland of a large city. *Journal of Biogeography*, *24*, 297-308.

Matlack, G.R. (2005). Slow plants in a fast forest: Local dispersal as a predictor of species frequencies in a dynamic landscape. *Journal of Ecology*, *93*, 50-59.

Moss, D.M., Abrams, E.D. & Kull, J.A. (1998). Can we be scientists too? Secondary students' perceptions of scientific research from a project-based classroom. *Journal of Science Education and Technology*, *7*, 149-161.

Nadkarni, N. (2004). Not preaching to the choir, Communicating the importance of forest conservation to non-traditional audiences. *Conservation Biology*, *18*, 602-606.

Robinson, M. & Crowther, D. (2001). Environmental science literacy in science education, biology, and chemistry majors. *The American Biology Teacher*, *63*(1), 9-14.

Rooney, T.P. & Waller, D.M. (2003). Direct and indirect effects of white-tailed deer in forest ecosystems. *Forest Ecology and Management, 181,* 165-176.

SRI International. (1997). Globe year 2. Evaluation, implementation and progress. Available online at: http://www.globe.gov/fsl/evals/y2full.pdf.

Tanner, T. (1980). Significant life experiences. *The Journal of Environmental Education*, *11*, 20-24.

U.S. Geological Survey. (2006). PhotoFinder photo locating software. Available online at: http://edcsns17.cr.usgs.gov/finder/finder_main.pl?dataset_name=NAPP.

Warren, R.G. (1997). Engaging students in active learning. *About Campus 2*, 16-20.

Williams, M. (1989). *Americans and Their Forests, A Historical Geography*. Cambridge: Cambridge University Press.

Zelezny, L.C. (1999). Educational interventions that improve environmental behaviors, a meta-analysis. *Journal of Environmental Education*, *31*, 5-14.