A Field-Based Technique for Teaching about Habitat Fragmentation and Edge Effects

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ABSTRACT

This article presents a field technique that exposes students to the indirect effects of habitat fragmentation on plant distributions through studying edge effects. This assignment, suited for students in an introductory biogeography or resource geography class, increases students' knowledge of basic biogeographic concepts such as environmental gradients and disturbance in addition to formulating research questions and design. In this exercise, fieldwork can be implemented with simple tools that are easily obtainable and found in most physical geography labs. In this example, student response to the exercise was positive; they indicated that the exercise was a fun and interactive way to learn fundamental biogeographic concepts.

Key Words: *active learning, fieldwork, biogeography, habitat fragmentation*

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INTRODUCTION

This article discusses a problem-based fieldwork exercise in which undergraduate students examine the effects of habitat fragmentation by examining the biogeography of vegetation along the edge of a jeep road in a local recreation area, while identifying limitations and potential improvements to the approach. Other studies have illustrated the importance of fieldwork in undergraduate geography education (e.g., Wheeler 1985; Kent, Gilbertson, and Hunt 1997; Butler and Wilkerson 2000); in this article, we stress the importance of combining fieldwork with research process and design education in geography classes.

Understanding the effects of disturbance on the composition and distribution of plants and animals is a critical issue in biogeography. Habitat fragmentation changes the functioning of an ecosystem by increasing the amount of edge habitat and reducing the area of functional interior habitat. Anthropogenic (i.e., road building) and geomorphic (i.e., landslides) disturbances that fragment a landscape increase the amount of edge habitat. Edges, analogous to ecotones, are recognized by biogeographers, foresters, and landscape ecologists as a unique peripheral landscape component within which environmental conditions and species composition may differ from interior habitat (Turner, Gardner, and O'Neill 2001). Edges are important to consider in biogeographic instruction in the context of biodiversity, energy flow of plants, animals, and environmental variables, and resource management (Fraver 1994; Malanson and Cairns 1995; Zheng and Chen 2000). The collective quality of edges has inspired both applied and basic interest in the attempt to understand the resultant spatial structure, and distribution of plants and animals that result from the creation of edges.

We demonstrate that the field project, linking research design and data collection and analysis through fieldwork, increases students' understanding of both research design and biogeographic concepts. We begin with an overview of edge effects, the biogeographic concept examined by students in the project. Next we discuss the rationale for the pedagogical approach—problem-based learning—and we then outline an application of the approach to a biogeography course in which students are active in the research plan from start to finish by conducting fieldwork and analyzing the collected data. We conclude with an evaluation of the exercise based on student input, and potential limitations of problem-based learning.

BIOGEOGRAPHIC EFFECTS OF EDGES

A recent trend in literature that addresses edge effects from an applied perspective emphasizes boundaries of anthropogenic influence, such as those created by clear-cuts (Chen, Franklin, and Spies 1992, 1995; Chen, Franklin, and Lowe 1996), agriculture (Fraver 1994), and roads (Spellerberg 1998; Develey and Stouffer 2001). These studies are significant to land managers because anthropogenic disturbance patterns often result in isolated patches too small to preserve an interior forest environment (Chen, Franklin, and Spies 1992). Edges are also important from a geomorphic perspective. For example, Kupfer and Malanson (1993a, 1993b) examined riparian cutbank edges for their biogeographic significance, and suggest there is much to be learned about edges that are continuously recreated and maintained by fluvial processes. Avalanches are an additional landscape process that affects the local environment through a disturbance regime (Malanson and Butler 1984). Studies from both basic and applied perspectives have shown directional changes in species composition found along edges, including the potential for edges to act as a conduit for the dispersal of invasive species (e.g., Bolger *et al.* 2000; Cadenasso and Pickett 2001).

Stable edges generate indirect effects on the surrounding landscape by creating a microclimate that manifests itself in altered plant composition and structure (Fraver 1994). For example, in western forests, avalanche paths reflect a local microclimatic regime with different plant assemblages than adjacent landscape elements (Malanson and Butler 1984). In eastern forests, disturbance may affect the abundance of conifer versus deciduous trees found along edge to interior gradients.

Edges created by natural or anthropogenic disturbance form altered microclimatic regimes that extend into the interior forest (Chen, Franklin, and Spies 1992; Kupfer and Malanson 1993a, 1993b; Fraver 1994; Malanson and Cairns 1995). Fraver (1994) and Chen, Franklin, and Spies (1995) found that in general, forest edges have lower humidity, higher air temperatures, higher soil temperatures, increased solar radiation (Chen, Franklin, and Spies 1995; Malanson and Cairns 1995), and lower soil moisture (Chen, Franklin, and Spies 1992) than interior sites. These landscape alterations make the functional area of interior forest smaller than its actual area (Kupfer and Malanson 1993a, 1993b; Fraver 1994). Fraver (1994) argues that perhaps the most important variable in increasing biodiversity at an edge is an increase in shortwave radiation, due to his finding that several light tolerant species were unique to edge sites. Study variables, edge orientation, time of day, and topography define the extent of edge influences (Chen, Franklin, and Spies 1995).

Microclimatic edge effects have a bearing on vegetation species richness and composition. Abiotic factors of edges are important to consider because they penetrate into the interior forest to varying degrees, beginning new competition regimes (Fraver 1994) that alter biotic features of plants. For example, Chen, Franklin, and Spies (1995) found changes in canopy cover, stems per hectare, basal area, and mean diameter at breast height to be associated with edges. Kupfer and Malanson (1993a) report marked differences in species composition and plant assemblages, and basal area of plants on edge and interior sites. Directional changes associated with late successional species were found in the interior, and secondary successional species were found along the edges, indicating that site dynamics imitate a retrograde succession controlled by chronic stress rather than abrupt disturbance (Kupfer and Malanson 1993a, 1993b). The authors' finding indicates that site dynamics may be controlled differently in landscapes where sites are progressively created and destroyed.

In the context of the classroom, edges are often presented from a landscape scale, through analysis of aerial photographs. However, grasping the physical implications of habitat fragmentation may be difficult for students to understand without observing the spatial patterns firsthand. Field projects make the idea of habitat fragmentation easier for students to understand, and enable students to grasp the significance of habitat fragmentation from numerous scales of analysis.

PEDAGOGICAL APPROACH

Fieldwork is a fun and an effective avenue for introducing students to methods in biogeography. Fieldwork has been recognized as in integral part of geographic education, and it is argued that "the principal training of the geographer should come, whenever possible, by doing fieldwork" (Sauer 1956, 296). With observational and analytical abilities as important keys in the growth of a geographer (Sauer 1956), fieldwork should be "an integral part of every geography program" (Miller 1981, 235). While fieldwork has been used successfully in human geography courses (Wheeler 1985; Jennings 1993; Pawson and Teather 2002), the application presented here is applicable for physical geography courses.

Given increasing class size and challenges with respect to budget constraints, some have noted that field experience is generally on the decline in undergraduate geography education (de Blij 1990; Bradbeer 1996; Butler and Wilkerson 2000). It has been noted that virtual reality fieldwork is increasing, as some instructors have replaced traditional field experiences with computer simulations and models within the classroom (Maxfield 1991; Kent, Gilbertson, and Hunt 1997). However, simulation models do not necessarily stimulate students' learning and many processes are best understand through field observation (Luft 1990), and the increase in virtual fieldwork does not have to—and should not—replace traditional fieldwork (Kent and Foskett 2000). We suggest that it is possible to give undergraduate students field experience within the challenging context of contemporary academia and present an application for an undergraduate biogeography class.

Simply taking students into the field does not always achieve the intended goals, which may include independent learning and active participation in research design. For that reason, we chose to implement a problem-based learning approach in the design of the field exercise. The potential utility of problem-based learning within the field of geography, particularly with applications involving fieldwork, has been recognized (Bradbeer 1996). With roots in medical education, problem-based learning seeks to develop critical thinking skills in students and give students the opportunity to apply new knowledge on their way to becoming "self-directed" learners (Bradbeer 1996; Kent and Foskett 2000). As a core component of geography, research should not be taught "piecemeal," and combining empirical fieldwork with the development of a research plan from hypothesis generation through data analysis allows students to create or establish knowledge themselves instead of relying on lectures or readings (Welch and Panelli 2003). In fact, it has been argued that teaching research process and design should be promoted as a vital part of geography courses (Welch and Panelli 2003).

Furthermore, a problem-based approach is in accord with the National Geography Standards, which suggest that "a geographically informed person" can ask, acquire, organize, and analyze geographic information while answering geographic questions (Geography Education Standards Project 1994, 29).

As an approach that strongly encourages students to become active learners, problem-based learning meshes very well with fieldwork and can actually help limit passive learning in the field (Bradbeer 1996). Participation in a field exercise does not guarantee active learning, as fieldwork can vary greatly in the level of contribution by students depending on the particular pedagogical approach. In their review of fieldwork in geography, Kent, Gilbertson, and Hunt (1997) outline two continua in fieldwork based on the level of autonomy and participation. Fieldwork can range from a project that is completely dependent on instructors and considered to be staff-led to an autonomous project in which decisions are in the hands of the students from hypothesis generation through data collection and analysis (Kent, Gilbertson, and Hunt 1997). Similarly, a field experience can range from the simple observation of phenomena to active, hands-on participation (Kent, Gilbertson, and Hunt 1997). Kent, Gilbertson, and Hunt's (1997) review of previous work shows that students prefer approaching fieldwork through active participation rather than observational tours, and this active participation in experiments fosters students' feelings of ownership in the learning process (Finn, Maxwell, and Calver 2002; Pawson and Teather 2002; Jennings and Huber 2003). Finally, through a problem-based learning approach, students understand the relationship between the research process and the acquisition of primary data, and also learn to work in unfamiliar environments while developing an appreciation for place-specific problems (Marotz and Rundstrom 1986).

Applying a problem-based learning approach to fieldwork provides students with additional benefits. Not only do students become active learners who gain an understanding for the research process, but during and following fieldwork supported by problem-based learning students have an improved understanding of lecture discussions (Fuller, Rawlinson, and Bevan 2000) and are better trained for future employment in their field. In their review of field-based education, Lonergan and Andresen (1988) outline the benefits of acquiring subject knowledge from the field. They state that knowledge learned during readings and lectures is "demystified," and concepts learned from the classroom can be integrated with knowledge gained during fieldwork (Longergan and Andresen 1988, 65). In addition, during fieldwork "original" knowledge can be gained in a holistic fashion by students without it being explicitly imparted on them by instructors (Longergan and Andresen 1988). A problem-based approach to teaching research design, used as a supplement to traditional lecture instruction, challenges students and gives them the skills and confidence to conduct independent research (Simm and David 2002). Field experience also can serve to make students more marketable to potential employers as students develop skills that can be transferred to future careers while making themselves more competitive (Simm and David 2002; Jennings and Huber 2003). Sauer (1956, 296) argues that fieldwork is "the best apprenticeship," while de Blij (1990) stresses the importance of beginning independent research, including fieldwork, as an undergraduate in order to jumpstart a career in geography.

CLASS CONTEXT

This field project was a required component of an introductory biogeography course. The course introduces both ecological biogeography and historical biogeography. Students are taught to think critically and analytically about global and local distributions of plants and animals, and question why certain plants and animals are found in some places, and not others.

Because the course is introductory, it does not have prerequisites. However, many students in the class have taken introductory physical geography, and/or biology. Because there are no prerequisites, the class is designed to appeal to a diverse student body. During the semester we performed this project, a total of six majors were represented: geography, wildlife science, chemistry, political science, biology, and interdisciplinary studies. All twenty-four students in the class were either juniors or seniors. Only two of the students had previously conducted fieldwork, so this assignment added another important learning dimension to our class.

METHODS

This field exercise actively involves students in the research process, from hypothesis generation, through presentation of results. Table 1 outlines the steps taken for the implementation of this exercise. This project not only increases students understanding of how fragmentation may indirectly affect the environment around them, but it gives them the opportunity of simple and fundamental observations of the landscape from a spatial perspective, which was the emphasis of the project. The advantage of this exercise is that the procedures may be applied to edges in almost any location, depending on the type of edges found in the local environment. For example, roads, avalanche paths (Malanson and Cairns 1995), trails, and agricultural field edges can all be examined by students through a simple fieldwork design.

Classroom Preparation

One benefit of approaching fieldwork using problem-based learning is that students learn through hands-on experience. Still, adequate preparation, guidance, and wrap-up is necessary for an effective exercise (Longergan and Andresen 1988; Kent, Gilbertson, and Hunt 1997). Classroom preparation for fieldwork consisted of a lecture on edge effects. This lecture was part of a larger module on concepts in landscape biogeography. First, students

Table 1. General steps to implement biogeographic edge study.

Step	Method
1	Classroom preparation and background. Show aerial photographs of habitat fragmentation in multiple environments to get students thinking about the landscape scale implications of habitat fragmentation. Give classroom lecture on edges and edge effects. Introduce the study site through maps and background on land use history. Have students generate hypotheses about how edge environments might differ from interior environments. Lecture on forest dominants (if applicable).
2	Fieldwork: Individual landscape observation.
3	Fieldwork: Divided the class into groups of five, data collection, and recording.
4	Data entry and plot construction.
5	Students create and present group posters to class; debriefing.

were exposed to habitat fragmentation from a landscape scale by looking at satellite imagery of deforestation, development, and avalanche and debris slides. Following this introduction, we specifically addressed the indirect impacts of edges on a fine scale. Topics addressed in this lecture were soil moisture, light, species composition, and diameter at breast height (DBH), and how each can vary across edges, producing edge effects. Students were asked to think about various processes that could create landscape edges, and the effect of these processes on landscapes in several locations, such as arid and humid environments.

Because of the diverse student background in the course, primary emphasis of the field component was placed on the spatial pattern of life forms and fundamental biogeographic concepts, rather than the identification of specific taxa. However, forest dominants were discussed in the classroom setting so that students could subsequently identify these taxa in the field with the aid of guidebooks. This aspect of the project, however, may be easily modified for courses that wish to spend considerable time with the interpretation of specific taxa. If so, classroom preparation should include species-specific information on forest dominants and wildlife species; such information for North American species could be easily accessed using the two volume, USDA Forest Service, *Silvics of North America*, (Burns and Honkala 1990), available online. By providing such background, students can associate life history traits with the effects of disturbance. Integration of this material could include a framework that uses species "vital attributes" (Noble and Slatyer 1980) so that species-disturbance condition interactions could be adapted for any ecosystem.

Presentation of the study site followed the lecture on edge effects. Our study location was the Pandapas Pond Recreation Area located in Jefferson National Forest, approximately five miles outside of Blacksburg, Virginia. In our exercise, the specific field site was introduced to students before visiting the location. While Bradbeer (1996, 12) argues that in many field exercises "the actual field location becomes almost an irrelevance" to students, we contend with our specific application that the particular place selected for fieldwork can hold significance for the students.

Most students who participated in the exercise were very familiar with Pandapas Pond Recreation Area given its amenities for hiking, fishing, mountain biking, and horseback riding, and its proximity to campus, but few students have examined the landscape with a scientific eye. In this case, the location specifically drew students in and made them more excited about their work. For example, one student volunteered to produce a map of the area to practice geographic information systems (GIS) techniques. His map was subsequently used in our preparatory class discussions.

The recreation area is dissected by numerous hiking and mountain biking trails, jeep roads, and forest service roads. We selected a site along a double track jeep road, with a southerly aspect (Fig. 1). The class instructor and assistant reviewed land use history of the site prior to the fieldwork day so students would have an understanding of how fire history and logging could potentially influence plant distributions. At this particular site, there had been no logging or fires within the last seventy-five years (United States Forest Service, personal communication 2004).

Following the edge effects lecture, students were asked to generate two hypotheses about what we might see at our particular study site. Examples of hypotheses that the students generated were, "herbaceous cover will decrease with distance from edge of the jeep road," and "density of conifers will be higher closer to the edge of the jeep road." These student-generated hypotheses guided the creation of a data collection sheet to be used for field data collection. For classes that identify taxa, species-specific hypotheses should be encouraged based on dominant taxa.

Field Methods

Observation. The class conducted fieldwork on a Saturday morning. The fieldwork date was announced early in the semester to allow students ample time for adjusting schedules. Data collection took approximately three hours to complete with twenty-two people. An on-site introduction to the field equipment was provided upon our arrival (Table 3). The first step in the fieldwork component consisted of simple observation; the intent of this activity was to allow time for student reconnaissance. Before group work began, students were asked to individually observe the landscape surroundings. Questions included the following: "What kinds of changes can you anticipate about differences in living conditions from edge to interior?" and "Where do

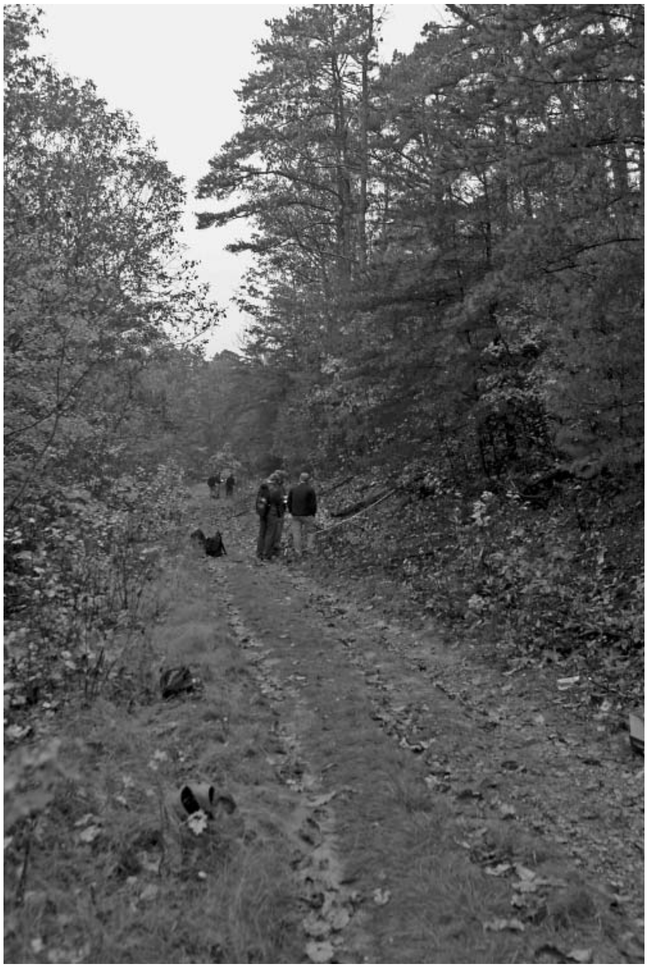

Figure 1. Snakeroot jeep trail, Pandapas Pond Recreation Area.

you see the most conifers?" For undergraduate classes, the observation component will be a very important step in learning to observe and interpret a landscape from a biogeographic perspective. Even though the area was familiar to most students, these general observation questions encourage students to focus on particular aspects of their environment they may not have previously considered in past visits.

Group data collection followed individual observations. Because many students had a broad geography background, or no geography or biology background at all, our data collection focused only on the spatial attributes of general categories of deciduous and coniferous trees rather than specific species of trees or herbaceous understory. However, students were required to practice species identification in the field using guidebooks for the purpose of becoming familiar with forest dominants of southern Appalachia. Our fieldwork plan involved the use of 1 meter by 1 meter quadrats placed at 5 m intervals along edge (0 meters) transects and interior transects. Four 25-meter edge transects and four 25-meter interior transects defined the data collection boundaries for this study (Fig. 2). Students collected data for the variables outlined in Table 2 at each quadrat. Students used the data collection form shown in Figure 3.

Table 2. Frequency of stems found with specific DBH plotted along distance to edge (0 = beginning of transect).

Distance to edge (m)	0	5	10	15	20	25
0–0.5	6	4	19	10	6	12
0.5–1	0	2	0	0	3	0
1–1.5	0	3	0	0	1	1
1.6–2	0	2	0	0	0	0
2.1–2.5	0	1	0	3	1	0
>2.5	0	0	0	2	2	2

Alternately, a continuous belt transect could be used to demonstrate changes in space, with the width of the belt transects dependent upon the density of the plants on the chosen landscape. The study could be adjusted to include collection of additional variables including species, diameter of dead trees (to understand competitive effects), and evidence of natural disturbances (such as insect infestations and fire) and observations of fauna. Depending upon the local situation, these data could provide for a richer set of learning opportunities and can be easily integrated into the exercise.

DATA ENTRY AND ANALYSIS

Upon completion of fieldwork, students were responsible for entering the data gathered by their group in Excel. Data entry was performed per quadrat, with the variable of interest on the y-axis, and the distance from edge on the x-axis, as depicted in Table 2. Once each group entered their data, the instructor combined each set into one large database that was made available to all students. Students entered the data into a spreadsheet, generated averages for their data, and produced a minimum of three bivariate plots that

Table 3. Recommended field equipment.

Measuring tapes (at least 25 meters)
Soil penetrometer
Compass
Diameter tape
Diameter card, for small plants
Stake flags
GPS
Species charts
Camera
Field notebook/metal clipboard

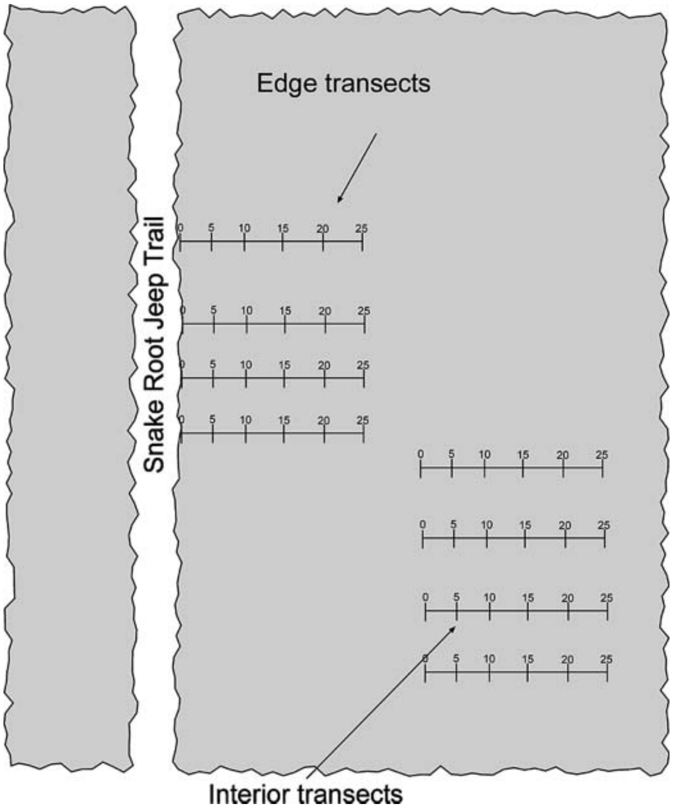

Figure 2. Data collection plan for edge and interior sites.

depicted the data. The graphs chosen by students related to at least three hypotheses that they generated, such as, "we hypothesize that mean DBH of conifers increases with distance from edge." Students compared plots that showed how variables change with distance from edge, and plots that compared the results among the control site and the edge site. Students were encouraged to generate additional statistics to depict their data (for example, ANOVA, t-tests, regressions, etc.). However, since statistical backgrounds of the students varied greatly, statistical analysis was not made a mandatory part of the analysis. Simple visual inspection of plots and discussion of general patterns observed was a basic way for all students to understand which variables were sensitive to edge effects at this particular location. Through examination of simple plots, where variables are plotted along the distance from edge, students were able to make simple observations regarding how variables change with distance to edge. Students were able to find which variables were sensitive to edge effects and which variables were not influenced by the altered environmental condition created by the presence of the jeep road.

Debriefing also is an important part of fieldwork using a problem-based learning approach, and should follow the field experience as soon as possible in a two-way manner in which students and instructors interact with one another (Kent, Gilbertson, and Hunt 1997). The debriefing session is used to reinforce the connections between knowledge gained in the field with concepts presented during lectures and readings, and can serve to transition to the next topic presented in class. During debriefing, students created a group poster to present their results to the class. The creation of this poster enabled all students to summarize and present their results in a qualitative and quantitative manner, to carry out a complete research project, and to provide an avenue for class discussion of findings and limitations of our research process. To ensure that all students contributed in the completion of the project, each group was required to hand in an activity report, signed by each member of the group, outlining the specific contributions of each group member.

Data Sheet for Snakeroot Trail

Group Name:___________________________

Date:________ Time:________ Transect location (C/E) _____

Quadrat measure (m): _____

Soil pentrability (kg/cm²): 1)_____ 2)_____ 3) _____

% Bare ground or rock: _____ % Herbaceous cover: _____

Total Number of tree species per quadrat _____

CONIFEROUS

Number of dead coniferous trees: _____

Number of coniferous stems: _____

_____	_____	_____	_____	_____
0.0 – 0.5 cm	0.6 -1.0 cm	1.1 -1.5 cm	1.6 - 2.0 cm	2.1 - 2.5 cm

(Number in each class)

DBH Measurements for Coniferous Trees > 2.5 cm:

DECIDUOUS

Number of dead deciduous trees: _____

Number of deciduous stems: _____

_____	_____	_____	_____	_____
0.0 – 0.5 cm	0.6 -1.0 cm	1.1 -1.5 cm	1.6 - 2.0 cm	2.1 - 2.5 cm

(Number in each class)

DBH Measurements for Coniferous Trees > 2.5 cm:

Figure 3. Data sheet used for field collection.

LEARNING OUTCOMES

The major learning outcomes of this project were threefold. First, the students learned to use the scientific method to conduct a research project. Given the spatial nature of edges, they did so thinking and seeing like a geographer. Second, the students gained an understanding of sampling, and the importance of scale and resolution in data collection. For example, the 1 meter by 1 meter quadrats in the original study design proved effective to capture a sufficient sample size in the plots closer to the edge, but insufficient for stem counts in interior plots because of how widely spaced trees were in the interior forest. The fact that the 1 meter quadrats were sufficient to capture stems on the edge, but not in the interior, illustrated to students there was indeed an edge effect in the case of stem density. One student observed quite correctly, that "the one meter by one meter quadrats weren't big enough to provide a fair representation of trees in the [interior] area . . . ." Such observations gave students a lesson in the importance of scale, the necessity of field improvisation, and reconnaissance fieldwork. We found that the students were excited to work together to problem solve in the field by altering their study plan to include additional data collection. The success of this project was grounded in the freedom students had to think for themselves, with little guided assistance.

Additionally, students reported discrepancies in the measured data from their initial observations. For example, another student observed:

> . . . the data collection differed a bit from the pre-measured observations. It did initially appear that there were more species at the edge and that the canopy cover appeared to increase as you move further into the interior.

However, as the student reported, this observation was not supported by the data.

Finally, this project increased the students' understanding of fundamental biogeographic concepts such as spatial scale, distribution of plants and animals, ecotones, biodiversity, and influence of human activities on pattern and process. For example, a student reported in their poster:

> Overall, the research is about the micro-environment created by the edge and how it pertains to various tree species in the area.

Another student said:

> The experience was very beneficial in helping me understand research methods in biogeography (I had no previous experience). It was good in that it helped 'bring to life' many of the concepts we learned in class. It is one thing to learn something in a classroom; it's another to experience it first-hand.

The broader implications of this project are that it can be adapted to many types of environments and habitat types. The influence of agriculture could be examined by studying agricultural plot edges, for example. Recreation impacts could be examined through analysis of different trail types, with associated edge effects. Additional modification of this project could include an analysis of invasive species found along edge habitat, examining the edge as a conduit for their dispersal. Finally, a comparison of edge effects across different environmental gradients (such as elevation), or comparing two different aspects would be a project that could increase student understanding of environmental gradients.

The practical challenges often associated with large biogeography classes could become an advantage in a study such as ours, as several manageably sized groups could gather data at different locations simultaneously. If a class lacks a teaching assistant, the instructor could recruit help from graduate students, other instructors, or undergraduate students who have previously taken the course; also, advanced students enrolled in the class could serve as group leaders. The outcome could be a more thorough understanding of edge effects across a variety of environments.

Though examination of edge effects in conjunction with classroom learning is not necessarily novel to the biogeographic classroom, we have encountered instances throughout our careers when instructors of physical geography and similarly broad courses are in need of including a biogeography lab in their course, though they lack the background to develop such an exercise; the project we describe could readily serve such a purpose. Additionally, it provides an easily adaptable, tried-and-true, field example for current biogeography instructors seeking to expand their instruction beyond the classroom.

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