LEARNING LANDSCAPE ECOLOGY

A Practical Guide to Concepts and Techniques

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Editors

2002

Springer

CHAPTER 14

Landscape Context

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OBJECTIVES

Ecological processes at a particular site are the result of both local dynamics and processes acting at the broader scale of the surrounding landscape. Thus, local characteristics and processes are linked to those of broader scales. The potential influence of the surrounding landscape includes effects on community composition, habitat quality, metapopulation dynamics, and local population persistence. Moreover, because landscapes are dynamic, we cannot expect processes and characteristics within habitat patches to remain static if the surrounding landscape is altered by natural or anthropogenic forces. Therefore, understanding the effects of landscape context on habitat patches is an important issue for basic ecological research and for conservation management. The objectives of this exercise are to help students

1. learn to quantitatively describe the "landscape neighborhood" surrounding a specific site;
2. conduct statistical tests to determine if characteristics of the landscape neighborhood are correlated with local community structure; and
3. *consider why landscape-level effects may vary among species.*

Here, you will determine if the surrounding landscape affects local community structure. Specifically, you will test whether the amount of mature forest in the broader landscape neighborhood affects either the diversity or the occurrence of certain plant species in a patch. In Exercise 1, you will measure the amount of old forest in the landscape surrounding a set of study sites to quantify the landscape neighborhood so that you understand the methods used to gather the data used in Exercise 2. Exercise 2 is an analysis of the effects of landscape context on species diversity using a larger set of data that has been assembled for you. Exercise 3 uses the same data set to test for landscape effects on individual species. The larger data set for Exercises 2 and 3 is available in tabular format in Table 14.3 (a pdf file readable using Adobe Acrobat Reader) in a spreadsheet entitled **context.xls** on the CD.

INTRODUCTION

A growing number of studies have demonstrated that local ecological processes are influenced by patterns and phenomena taking place at broader scales. For example, Gibbs (1998) found that some amphibian species disappeared from forest patches when the percentage of forest in the surrounding landscape dropped below 50%. Similar landscape effects on populations of wintering (Pearson, 1993) and breeding birds (Robinson, 1992) have been documented. The diversity and abundance of wintering birds can depend on the availability of resources in adjacent habitat patches, which are used by local birds for foraging or roosting. Nesting success of some breeding forest birds of North America has been correlated with the rate of brood parasitism by the brown-headed cowbird. The abundance of cowbirds (and resulting parasitism rates) depend on the amount of farmland in the surrounding landscape (Robinson et al., 1995). The spatial pattern of suitable habitat has been shown to affect the local density and sex ratio of small mammals. Collins and Barrett (1997) experimentally fragmented portions of habitat used by meadow voles. In fragmented habitats, the sex ratio was more skewed toward females as compared to unfragmented habitats. Similar effects on population persistence and density exist for plants (Bergelson et al., 1993; Matlack, 1994; Fischer and Stocklin, 1997; Pearson et al., 1998) and insects. The abundance of suitable habitat in the surrounding landscape can affect the persistence of local populations and the chance that a suitable site will be colonized. The surrounding landscape may also influence the probability that a site is disturbed (Turner et al., 1989; O'Neill et al., 1992). Thus, local populations and ecosystem processes exist within the context of the broader landscape.

In this exercise, you will test hypotheses related to herbaceous species diversity and the landscape context of forested sites supporting these species. The abundance of mature forest surrounding an early successional patch may be important because mature forest may affect the colonization of plant species into early successional patches. This exercise will involve quantifying characteristics of the surrounding landscape from land-cover maps and relating these features to plot-level vegetation data. The specific working hypothesis for the data collection was: *Species richness in young forest is correlated with the proportion of old forest in the surrounding landscape.* Data were collected from a series of plots in early successional forest that were similar with respect to within-site characteristics (e.g., soils, topography, elevation, land-use history) but varied with respect to landscape context. You will test whether the amount of old forest in the landscape affects (1) species richness for the entire plot and (2) the presence/absence of four individual plant species: *Galium aparine*, *Arisaema triphyllum*, *Viola canadensis*, and *Disporum lanuginosum*.

Study Area

The geographic setting is Madison County in western North Carolina, a landscape that has experienced a period of deforestation due to agricultural expansion, followed by a period of reforestation due to the abandonment of agricultural fields. These temperate deciduous forests are characterized by relatively high alpha diversity (i.e., within-patch diversity) in both woody and herbaceous plants. A land-cover map (derived from a 1991 Thematic Mapper satellite image) shows a portion of this landscape (Figure 14.1), including

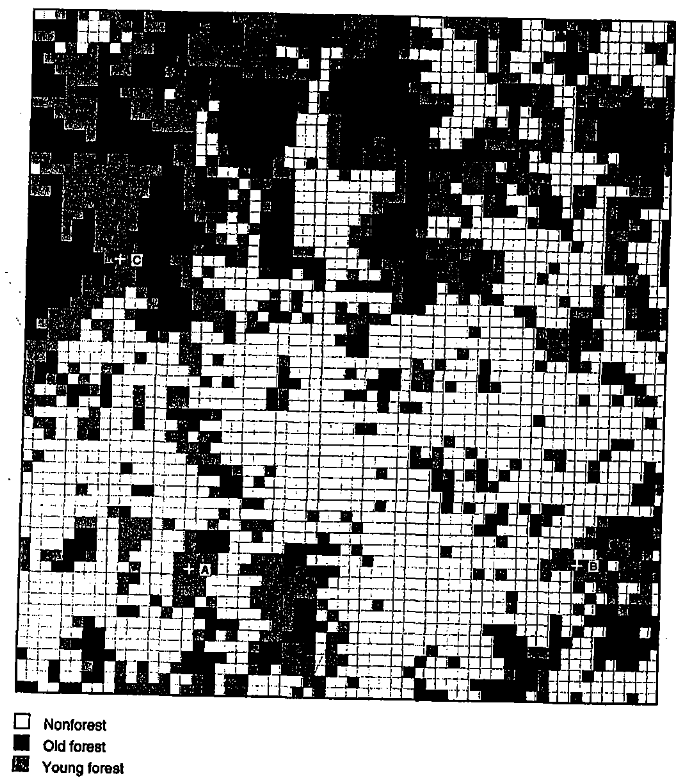

FIGURE 14.1
Land-cover map of study area in Madison County, North Carolina, USA. Each grid cell is 100 × 100 m. Focal cells are marked with a white cross (+) located to the left of the label (A, B, or C). A larger, printable version is available from the CD under the directory for this chapter.

the three primary land-cover types: **nonforest** (mostly agricultural lands with houses), **young forest**, and **old forest**. The young (early succcessional) forest areas were established after agricultural abandonment around 1950. The old forests were established well before 1950 and show few signs of previous agricultural uses besides woodland grazing.

EXERCISES

You will use data based on a field study designed to test for the influence of landscape context on herbaceous species occurring in patches of young forest. Using the land-cover map (Figure 14.1), half-hectare study plots were randomly located within patches of young forest at least 200 meters apart. The vegetation within each plot was sampled. In addition, a land-cover map was used to determine the proportion of old forest in an 81-hectare square window (9 × 9 cell area centered on the study plot).

In Exercise 1, you will collect landscape context data and calculate species richness for three practice sites to ensure that you understand how these data were collected. Then, in Exercise 2, you will conduct a more extensive analysis using data from 80 plots. While Exercise 2 focuses on plant species diversity, Exercise 3 will address the effect of landscape context on selected species.

EXERCISE 1
Data Collection

LANDSCAPE CONTEXT DATA

Land-cover maps can be used to characterize the landscape surrounding individual sample points. For this study, we are interested in the percentage of a 81-hectare "landscape neighborhood" that is composed of old forest. These old forests serve as a reservoir of species that may colonize a patch of young forest as it develops. The procedure for quantifying landscape context used here is identical to that used for the larger data set you will analyze in Exercises 2 and 3.

Using the land-cover map (Figure 14.1), measure the portion of old forest surrounding study plots A, B, and C as follows. Note that the location of each study plot is identified by a white cross (+), and to the right of the actual plot is a plot label (A, B, or C). You may wish to use the larger version of Figure 14.1 which can be printed from the CD.

1. Sketch an 81-hectare window (9 × 9 cells) on the map to delineate the neighborhood around each study plot. Center the window on the focal cell indicated with a white cross (to the left of the label).
2. Count the number of cells of old forest in the window and record your findings in Table 14.1 which can be viewed using Adobe Acrobat Reader and then printed from the CD.

3. Calculate the percent of old forest in the window surrounding each plot. Again, record your results in Table 14.1.

PLOT-LEVEL VEGETATION DATA

The study plots were also surveyed in the field, and a species list of herbaceous plants was compiled for each plot. Examine the species lists for plots A, B, and C in Table 14.2 on the CD. Tally up the total number of species per plot and enter the count on the last line of Table 14.2.

Question 1. Which plot has the greatest species richness?

Question 2. Look at the land-cover maps and describe the pattern of land cover in the vicinity of each of the three plots.

Question 3. From this small sample, does it appear that species diversity is related to the abundance of old forest in this landscape?

EXERCISE 2
Effects of Landscape Context on Species Richness

Next, you'll determine if the abundance of old forest in the surrounding landscape affects local species richness using a much larger data set (Table 14.3 or **context.xls** on the CD). You can analyze the data "by hand" using the table, or using a spreadsheet. Note that the landscape context measurements have already been determined for you.

1. To streamline the analysis, classify the plots into four landscape context categories based on the percentage of old forest in the surrounding landscape: (a) <10% old forest, (b) 10–39%, (c) 40–60%, and (d) >60%.
2. Calculate the mean ($\overline{x}$) species richness and standard deviation (s) for each of the four landscape context categories using the following formulas:

$$\overline{x} = \frac{\sum x_i}{n} \qquad s = \sqrt{\frac{\sum(\overline{x} - x_i)^2}{n-1}}$$

where x_i is an individual datum for a plot and n is the number of data points (i.e., 20 in this case). Enter your results in Table 14.4 which can be printed from the CD.

3. Calculate a 95% confidence interval for each of these means using the following formula: 95% $CI = \overline{x} \pm \frac{1.96s}{\sqrt{20}}$. Enter your results in Table 14.4.
4. For each possible pair of landscape context categories (e.g., <10% and 10–39%), determine whether the confidence intervals overlap. Nonoverlapping confidence intervals indicate that species richness dif-

fers between the two categories of landscape context; overlapping confidence intervals indicate that the mean species richness values are not significantly different at the $P \leq 0.05$ level.

Question 4. Prepare a bar graph on a separate sheet of paper plotting *mean species richness* (y axis) against *old forest in landscape* (x-axis). Summarize the trends evident in the table and bar graph.

EXERCISE 3
Influence of Landscape Context on the Presence of Individual Species

Next (using Table 14.3 from the CD), you'll determine the importance of landscape context for several individual species: *G. aparine*, *A. triphyllum*, *V. canadensis*, and *D. lanuginosum*.

Galium aparine (cleavers) is a sprawling, prickly plant found in many different forest and nonforest habitats (Newcomb, 1977). Fruits, stems, and leaves have small hooks that attach to fur and feathers allowing propagules to be transported by vertebrates. It is able to grow in a wide variety of forested habitats but is most abundant in moist, fertile areas.

Arisaema triphyllum (jack-in-the-pulpit) is widespread in young and old forested habitats. It produces red berries eaten and dispersed by birds and mammals. A single plant may live over five years, and individuals store energy in an underground corm. Each year an individual produces a single flower that is either male or female. Moreover, individuals are able to change sex from year to year (Doust et al., 1986).

Viola canadensis (Canada violet) and *Disporum lanuginosum* (yellow mandarin) are found in mesic woods (Weakley, 1995). They seem to be sensitive to forest disturbance because they are most abundant in the old forest (least disturbed) sites. The violet is more widespread and over ten times more abundant than the mandarin. Both species are dispersed by ants.

Based on the life-history information presented above, classify each species according to habitat needs (specialist or generalist) and dispersal ability (good or poor). Enter your results in Table 14.5 from the CD. Before conducting any analyses, using Table 14.5 and the information on each species' life history, hypothesize about the effects of landscape context on each of these species. That is, hypothesize whether you think each species should be negatively or positively correlated with the percent of the surrounding landscape neighborhood occupied by old forest.

Next, you will use contingency table analysis to determine whether the presence/absence of specific species is affected by landscape context.

1. Consider the species *Galium aparine.* Using the data in Table 14.3 from the CD, count the total number of plots in which this species is present in plots with < 10% old forest in the landscape neighborhood. This constitutes the **"observed"** value. Record this number in the *Galium aparine* table found in Table 14.6, in the row labeled "Present," then "Observed," under the column labeled "<10%." Repeat for the other landscape context categories.

2. Similarly, determine the number of plots in which this species is absent. Record your counts in the Table 14.6 in the row labeled **"Absent,"** then **"Observed."**
3. Calculate the row and column totals for the **observed** data. Add the two row totals; this sum is called the **grand total.**
4. Next, calculate the **expected** value for each landscape context category, for present and absent (8 calculation), using the following equation:

$$expected = \frac{(row\ total) * (column\ total)}{grand\ total}$$

Enter your results in the table in the rows labeled "Expected" for the appropriate categories.

5. A chi-square (χ^2) statistic can be used to test for a statistically significant influence of landscape context on the presence or absence of each species. This type of statistic is frequently used in contingency table analyses. Calculate the chi-square value as follows: $\chi^2 = \sum \frac{(observed - expected)^2}{expected}$. Enter your results in Table 14.7 from the CD.
6. If the χ^2 value exceeds 7.81, presence is significantly dependent on landscape context at the $P < 0.05$ level. This test has degrees of freedom = 3. Ask your instructor for assistance if this type of statistical test is unfamiliar to you. Determine whether the χ^2 test for *Galium aparine* is significant or not significant and record in Table 14.7.
7. Repeat steps 1–6 for the other three species.

Question 5. Describe the results for the four species based on the numbers in the contingency tables and the statistical analysis.

Question 6. How do these results compare with your initial hypotheses?

DISCUSSION QUESTIONS

1. According to your results in Exercise 2, is species richness correlated with landscape context at the scale used in this analysis?
2. List some ecological processes that might have produced the patterns observed in Exercise 2. These proposed mechanisms can serve as hypotheses to be tested in further field studies.
3. Do the patterns of presence/absence shown by the four species seem to be affected by landscape context? If yes, propose some plausible mechanisms. How does the natural history of each species relate to its pattern of presence/absence?

4. Would changing the size of the "landscape window" (e.g., to more than or less than 81 ha) affect the findings? How would using (a) a much smaller and (b) a much larger window affect your ability to detect an effect of landscape context?
5. This exercise focused on the effect of surrounding old forest on herbaceous plant communities. What other land covers or landscape elements might affect plant or animal communities? List some other landscape elements and their hypothesized effects.
6. Pick one of your hypothesized elements from Discussion Question 5 and design a study to test for its effects.
7. Can you think of a situation in which landscape context would affect an ecosystem process (e.g., nutrient cycling) within a patch?

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