Biodiversity and Edge Effects: An Activity in Landscape Ecology

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ABSTRACT Biodiversity and the conservation of biodiversity have received increased attention during the last few decades and these topics have been implemented into many G7–12 science curricula. This work presents an exercise that may be used in middle and high school classrooms to help students better understand spatial aspects of biodiversity. The following activity was successfully implemented into 8th grade science classes to strengthen student understanding of biodiversity. In the activity, students are provided a sample dataset created using point-count surveys of avian species along a transect extending from forest interior to open field locations. Students are asked to calculate and analyze total bird density (n), species composition, species richness (S), and species diversity (H'). By analyzing the data, students observe how these measures change along the vegetation gradient. The activity can easily be adjusted to accommodate a variety of skill levels and class times.

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Human modification of the landscape has many deleterious effects including habitat destruction and the subsequent loss of species. With a growing human population, increased species extinction is expected (Wilson, 1992; Vitousek et al., 1997). As a result, biodiversity and the conservation of biodiversity have received increased attention during the last few decades. Educators may find it difficult to not only teach the key concepts included in biodiversity units, but also to provide hands-on activities for student learning. Active participation and collaboration are effective ways to increase comprehension and interest in course material (Powell, 2003; Handelsman et al., 2004). In this activity, students analyze a dataset to quantitatively describe biodiversity. The specific goals of the activity are to teach students how to quantify biotic communities and to demonstrate the relationships between organisms and their habitats. After completion of the exercise, students should have a better understanding of habitat edge as one factor that influences biodiversity across the landscape.

Biodiversity can be defined in a number of ways, but is generally considered to be the variety of organisms in a geographic area (MacDonald, 2003). Because biodiversity is a broad term, it can be measured in a number of different ways as well. The simplest approach is to document the total number of species in a given area, called species richness (S). Richness is a useful measure of biodiversity, but it does not quantify the rarity of species or the abundance of the represented populations (termed *species evenness*). One of the most commonly used mathematical measures of diversity is the Shannon index (H') which takes into account species richness and evenness. The index can be calculated:

$$H' = -\sum p_i \ln p_i$$

where p_i is the proportion of the ith species and ln is the natural logarithm (Ludwig and Reynolds, 1988). While these measures of biodiversity are important, it is often helpful to characterize the composition of species. An easy way to quantify species composition is to calculate the relative density (%) of each species represented to determine their contribution to the total number of individuals. Together these measures provide valuable information on community assemblages and may be used to study factors that influence biodiversity and species composition across an environmental gradient.

Birds are excellent organisms to illustrate concepts in biodiversity and they should be good study organisms for middle and high school students. Bird watching is a popular past-time and amateur ornithologists regularly make important contributions to the scientific study of birds. For these reasons, birds were selected in this activity to teach foundation concepts in biodiversity. To simplify the exercise, specific bird species were not used. This should not detract from the activity because most students would not know behavioral traits or ecology of species.

A species' habitat is defined by the geographic location and the life needs required such as water, food, and cover. Habitat elements vary across the landscape and influence the distribution, density, and structure of populations (Morrison et al., 2006). Edges or transition areas between adjacent habitats have long been recognized as locations with increased biodiversity since they contain species that utilize both sides of the discontinuity in addition to species that utilize only one side (Kroodsma, 1984; McCollin,

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Abbreviations: H', Shannon diversity index; n, number of individuals; S, species richness; SLOSS, single large or several small.

1998; Odum and Barrett, 2004). Although edge habitats support high diversity, it is important to note that abundant edge created by anthropogenic means has negative aspects. The anthropogenic alteration of habitats causes landscape fragmentation. Fragmented landscapes with abundant edge may cause species isolation, allow for the colonization of alien species such as Japanese honeysuckle (*Lonicera japonica* Thunb.) and tree-of-heaven [*Ailanthus altissima* (P. Mill.) Swingle], and result in higher rates of nest predation and brood parasitism for passerine birds (Blake and Karr, 1987; Knapp and Canham, 2000). Because many birds nest in edge habitats, these sites attract predators such as raccoons (*Procyon lotor*) and brood parasites such as brown-headed cowbirds (*Molothrus ater*), which deposit eggs in nests of other bird species (McCollin, 1998; Stephens et al., 2003; Groom et al., 2005).

To document biodiversity changes along an environmental gradient, field data must be collected. Point-count surveys are widely used in many ornithological studies (Ralph et al., 1995). A point-count survey is conducted by standing at an established location for a predetermined amount of time (e.g., 10 minutes) and documenting the number of birds of each species within a known radius (e.g., 20 meters). To directly compare data, surveys must be conducted in the same manner at all points. The data collected during these surveys is generally in the form of total number of individuals encountered by species.

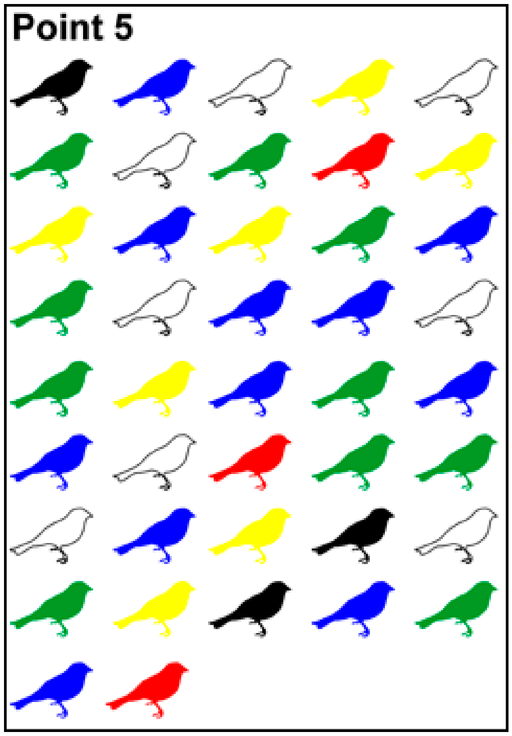

Fig. 1. An example of the data sheets given to each group. Species are denoted by color.

Materials and Methods

The exercise was designed for use with approximately 30 students during a 55-minute class period, but can be adjusted for smaller class sizes and shorter or longer periods. The exercise was completed during a unit on the conservation of life and natural resources and students had already been briefly exposed to basic terms such as species, habitat, and species richness the previous day. Student assessment was based on student participation and group data analysis, but grades could be based on laboratory reports that include tables and/or graphical representation of the results for advanced or upper-level classes.

Preparation

Sample data sheets were prepared for each group. Each data sheet included bird shapes of varying colors (Fig. 1). Each bird image represented an individual and color denoted the species. Species were coded by color to simplify identification and to make the data sheets visually appealing to students. Basic colors (e.g., black, blue, green, orange, red, yellow, and white) were used to prevent confusion. Each data sheet corresponded to a location where a point-count was conducted to quantify the avian community. The points were oriented in a northeast direction and extended from a forest interior location to a location in an open field. A map was created to show the location of each point-count survey (Fig. 2). During the activity, students were divided into six groups of approximately five students. Each group was provided sample data for one point. The proper program was opened on the class computer before the start of the activity because the students used computer software to calculate species diversity.

Lecture

On the day of the activity, students were asked to hypothesize why the number of individuals and species composition differs from one location to another before a brief 15 minute lecture was given. The lecture covered biotic community measures, biotic and abiotic characteristics of forest interior, forest edge, and open field habitats, and explained the purpose and direction of the activity. Students were introduced (or re-introduced) to the terms density (*n*), species composition, species richness (*S*), and species diversity (*H'*). Basic definitions and examples were provided and students were shown how to calculate these measures. Discussion on habitat differences focused on sunlight, temperature, humidity, food sources, cover, and predation. Pictures of the three habitat types were shown to illustrate the concepts. Students were then asked to predict which of the three habitat types (forest interior, edge, or field) would

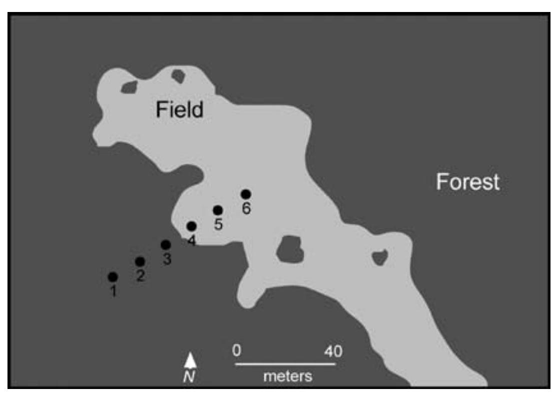

Fig. 2. Map of the study area showing the location of each point-count survey.

support the highest number of individuals, the highest species richness, and the highest species diversity.

Table 1. **Relative density (%) values of each species from each of the surveyed locations.**

Species	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6
Black	10	12	12	10	7	8
Blue	20	27	24	19	26	23
Green	10	15	14	19	24	18
Orange	0	0	12	13	0	0
Red	50	34	24	13	7	0
Yellow	10	12	12	15	17	13
White	0	0	4	10	19	38
Total	100	100	100	100	100	100

Students were told how the data were collected to teach about a field technique and to provide additional background information on the activity. Students were then told the collected field data is being graphically shown for them to use in their analyses. The location of each point was also discussed and students were shown the map so they could develop a better understanding of the spatial aspects of the project. Lastly, students were provided an activity handout that contained the step-by-step procedure to analyze the data and an answer sheet to complete the exercise. Because students are only analyzing one transect, this is not an appropriate scientific study. However, students can be told the activity could be replicated along other transects to determine if a general pattern could be observed.

Assignment

Using the provided dataset, groups were asked to calculate: (1) total bird density (*n*: the total number of individuals), (2) species composition using relative density (the percentage contribution of each species to the total number of individuals), (3) species richness (*S*: the total number of species), and (4) species diversity using the Shannon index (*H'*) for their assigned point. The students calculated species diversity with a computer program (Microsoft Excel) using an already prepared macro. Once all students had completed the calculations, tables and figures were drawn on the white board by members of each group. Group discussion followed and students were asked to explain the spatial pattern of change using the different biotic community measures. Students were then asked to predict how the values would change if the transect continued across the field and back into the forest interior on the other side or if the transect passed through one of the tree islands in the field.

Results and Discussion

All 30 groups (six groups from five classes) were able to complete the assignment and contribute to class discussion of the results. No groups made errors in their calculations and they all provided the correct answers. Students contributed to the creation of a table and three graphs, all drawn on the white board. By creating a table and graphs, students actively participated and were forced to work collaboratively to document the observed pattern. The table included the relative density (%) of each species of the total from the six points surveyed (Table 1). Students were asked to explain where the different species had highest relative densities and to determine the habitat preference of each species. The three figures illustrated total density, species richness, and species diversity values for the six points (Fig. 3). Students were asked to explain the bell-shaped curve showing that density, species richness, and species diversity all peaked at points three and four (the forest edge positions). The explanations they provided indicated they understood the factors that created the observed pattern. When the students were challenged further and asked to predict what values would be documented if the transect was extended back into the forest or if the transect passed through a tree island in the field, their answers were based on the documented pattern from the sample transect. Based on general class discussion, students seemed to comprehend the activity and it helped their understanding of concepts in biodiversity such as species composition, species richness, species diversity, and habitat characteristics.

The activity can easily be modified to fit the needs of advanced or upper-level classes. The easiest way to adjust the activity by student skill level is to modify the size of the

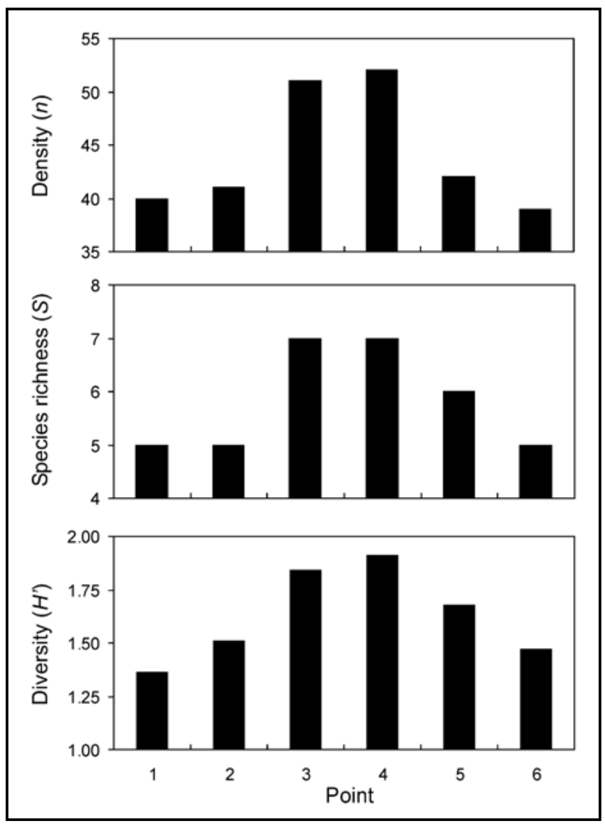

Fig. 3. Density, species richness, and species diversity from the six surveyed points. Note *y* scale varies.

dataset. The assignment can also be modified in accordance with student abilities. For example, species diversity can be calculated using a scientific calculator or one of the web-based programs that are available online (e.g., Chang Bioscience, 2004). A laboratory report where students are required to generate a table or a graph(s) to help explain the results could be used for assessment rather than class discussion when patterns were shown on the board. The activity can also be adjusted to fit shorter class times by giving the introductory lecture on the previous day or summarizing the results on the following day. I do not believe this would interfere with the continuity of the activity. Longer class periods can be filled by asking students to make additional predictions. For example, two classes finished the activity earlier than others and the additional time (approximately 5 minutes) was devoted to discussion of the shapes and configurations of reserve lands (i.e., the single large or several small [SLOSS]) debate (Diamond, 1975; Simberloff and Abele, 1982; Lomolino, 1994). To accommodate smaller class sizes students can work in smaller groups or the activity can be performed together as a class with students taking lead roles for different sections of the assignment.

Conclusion

This activity provided an opportunity for students to learn about spatial aspects of biodiversity by quantifying avian community assemblages. Specifically, students learned how to measure density, species composition, species richness, and species diversity and how these measures were influenced by habitat variations. Ancillary benefits included learning about a field technique, linking science and math, improving table and graph reading skills, and working collaboratively to complete tasks. Students were asked to make predictions about other spatial aspects of biodiversity and their responses were correctly based on the pattern they documented in the exercise. The activity provided a feeling of a true and complete scientific research project even though they did not themselves collect the field data and only one transect was analyzed. Students expressed an interest in the activity, a sense of accomplishment when it was complete, and many exhibited an increased appreciation for biodiversity issues as indicated by their questions after class and in the following weeks. In conclusion, the activity helped students more fully comprehend concepts in biodiversity and the factors that influence diversity across the landscape.

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