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CourseSource

Lesson

Data, Distributions, and Hypotheses: Exploring Diversity and Disturbance in the Tallgrass Prairie

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Abstract

Proper hypothesis generation, data handling, graphing, and communication are essential skills that undergraduate majors in biology are expected to master. However, students rarely get hands-on practice that helps them to effectively develop these skills. The purpose of this lesson is to provide students with the opportunity to practice scientific techniques in the context of exploring how the timing of fire disturbance shapes plant community structure in the tallgrass prairie ecosystem, which provides an excellent model system for exploring how disturbance influences species composition. Over the course of four lab sessions, advanced undergraduate students read primary literature, work in teams to form testable and falsifiable hypotheses, replicate a published sampling design at a local field site, and graph, analyze, and interpret their own data. At each step in the scientific process, students complete short written assignments that provide opportunities for assessment and feedback. At the end of this lab module, student groups are given real-world scenarios, asked to form management decisions that integrate the content of their own results with social, economic, and political constraints outlined in their scenario, and then present and defend their proposed solution to the class. This four-week lab module allows students to engage in the process of science and emphasizes the development of quantitative reasoning skills. Student learning is assessed using in-class formative assessments and written summative assessments.

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Supporting Materials: Supporting Files S1. Disturbance and Diversity – Week 1 Lab Handout; S2. Disturbance and Diversity – Week 1 Pre-Lab Quiz; S3. Disturbance and Diversity – Week 1 Instructor Presentation; S4. Disturbance and Diversity – Week 1 Post-Lab Writing Assignment; S5. Disturbance and Diversity – Week 1 Solutions Guide; S6. Disturbance and Diversity – Week 2 Lab Handout; S7. Disturbance and Diversity – Week 2 Pre-Lab Quiz; S8. Disturbance and Diversity – Week 2 Example Data Sheet; S9. Disturbance and Diversity – Week 2 Post-Lab Writing Assignment; S10. Disturbance and Diversity – Week 2 Solutions Guide; S11. Disturbance and Diversity – Week 3 Lab Handout; S12. Disturbance and Diversity – Week 3 Pre-Lab Quiz; S13. Disturbance and Diversity – Week 3 Example Data Set; S14. Disturbance and Diversity – Week 3 Post-Lab Writing Assignment; S15. Disturbance and Diversity – Week 3 Solutions Guide; S16. Disturbance and Diversity – Week 4 Lab Handout; S17. Disturbance and Diversity – Week 4 Pre-Lab Quiz; and S18. Disturbance and Diversity – Week 4 Solutions Guide.

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Learning Goal(s)

Students will:

- learn how to collect, organize, and present data in appropriate graphical formats.
- gain a quantitative understanding of the role of disturbance in shaping the tallgrass prairie ecosystems.
- become familiar with the field of restoration ecology.

Learning Objective(s)

Students will be able to:

- present and interpret data in a graphical format using an existing long-term data set from a published manuscript.
- identify different sources of variation within a data set and the consequences of grouping biological units into larger entities for the interpretation of results.
- apply transect-based vegetation sampling to estimate plant community composition, richness, and diversity in two different prairie restoration parcels with different burn regimes.
- summarize the transect-based vegetation data in graphs and figures to make comparisons that align with hypotheses and predictions.
- conduct simple statistical analyses to test explicit hypotheses and predictions.
- interpret statistical outputs and infer the biological implications of their results.

INTRODUCTION

Ecological communities are dynamic, with species interactions being constantly shaped by environmental conditions that vary in both space and time. In the past, ecologists emphasized an "equilibrium" approach to understand the processes that determine the distributions and abundances of species, which assumes that populations and communities are always moving toward a steady state that determines community structure. More recently, ecologists have emphasized that non-equilibrium conditions and variable environments, such as those created by natural disturbances, play key roles in shaping community diversity. Furthermore, responses to disturbance can vary among species and functional groups as well as with the extent, frequency, and intensity of disturbance.

Grassland ecosystems provide excellent model systems for exploring the role of disturbance in determining species composition because fire and grazing are frequent, natural disturbances that are largely responsible for the very existence of the biome (1). Fire and grazing prevent trees and shrubs from establishing, thus allowing the persistence of grasses and forbs adapted to resisting, recovering, and even benefiting from these disturbances. Several long-term studies from tallgrass prairie ecosystems provide exciting opportunities for students to work with published data to evaluate hypotheses and practice analyzing data (e.g., 2,3). Here, we describe a four-week lab module that uses published long-term data from Konza Prairie (4) to evaluate the effects of fire disturbance on plant communities, functional groups, and species in tallgrass prairie ecosystems. This lesson extends the goals of previously published lessons (e.g., 2,3) by using the analysis of published data sets to motivate hypotheses about the role of fire disturbance in shaping diversity in a local restored prairie ecosystem. Students then engage in collecting and analyzing their own data, comparing it to the published data from Konza, and considering how these scientific results interact with social, economic, and political constraints to shape prairie management strategies.

This module targets advanced undergraduate students and beginning graduate students. Over four laboratory sessions, students read primary literature, work in teams to form testable and falsifiable hypotheses, collect data, and evaluate their results through graphing exercises and simple statistical analyses. At three different points in the module, students complete short written assignments that provide opportunities for instructors to assess understanding and provide feedback. In the final activity, students work in teams to evaluate real-world scenarios for prairie conservation and management by developing management strategies that integrate their understanding of prairie dynamics with various social, economic, and/or political constraints. Following this exercise, students present and defend their proposed solutions to the class. This four-week lab allows students to engage in the process of science, with an emphasis on the development of quantitative reasoning skills.

The initial inspiration for this module came from a one-day field lab that investigated plant diversity under different burning regimes at a prairie restoration site using a protocol provided by the instructor. N.C.E. (corresponding author) extended and modified the lab into a four-week module that guides students through different stages of the scientific process and empowers students to develop questions and testable hypotheses based on published research, conduct the fieldwork to address those hypotheses, graphically analyze the data, and reflect on the implications of their findings. The second author, H.J.D., incorporated the use of a published paper to provide students with the opportunity to critically review the literature, generate their own hypotheses for a local system, and then consider the type of data that would enable them to test their hypotheses. By critically examining a published paper on a related question and in the same study system, students can visualize the outcome of their study before they implement it and recognize that their own study could, in theory, be publishable. While this lab module is developed in the context of tallgrass prairie ecosystems, the structure of this exercise provides a more general framework that could be adapted to other plant communities that are actively managed using controlled disturbances (e.g., mowing, logging, grazing). We provide guidelines for applying this lab to other systems in the Discussion.

Intended Audience

The intended student populations for this lesson are upper-level undergraduate students and beginning graduate students in ecology or related fields.

Required Learning Time

This lesson plan spans four 3-hour laboratory periods, providing a total of 12 hours of active in-class learning time. However, the module could easily be scaled up to serve as a full semester-long project in which students spend additional time on each stage of the overall project. For example, students can easily explore additional literature, sample more field sites (or more extensively at a single site), spend more time on data analysis and graphical presentation, and consider prairie conservation management in greater detail.

Prerequisite Student Knowledge

We have conducted this lab module in an advanced Ecology course for upper-division undergraduate students and graduate student majors in biology, and our expectations are closely aligned with the core competencies stated in Vision and Change (5). The only prerequisite for our course is either an introductory Ecology and Evolutionary Biology course for undergraduate students or graduate student standing. While not required, some background in introductory statistics is advantageous; specifically, students familiar with chi-square and t-tests are better prepared to interpret the results of the statistical analyses conducted in the third week of the module. We expect students to have had some prior experience reading primary literature, formulating hypotheses, predicting outcomes, and communicating results. Throughout the four-week module, we help students refine these skills by providing frequent feedback through formative and summative assessments.

Prerequisite Teacher Knowledge

Instructors teaching this course need to be familiar with basic aspects of experimental design (e.g., replication, randomization; 6,7), basic data manipulation and graphing functions in Microsoft Excel, simple data analyses (t-tests and chi-squared tests; 8), and the distinction between species richness and diversity. They need to be capable of leading discussions regarding the content of primary literature, data collection, and data analysis. In addition, the instructor should be familiar with the vegetation at the site where the students conduct surveys in Week 2 and able to generate a visual key that the students can use to aid in

plant identification. Finally, instructors should be prepared to provide targeted feedback to students throughout the duration of the four-week lab module.

SCIENTIFIC TEACHING THEMES

Active Learning

Activities outside of class: We ask students to read assigned material prior to each lab to prepare for the planned activity. We also assign a post-lab writing assignment after each of the first three labs.

Activities in class: In the first week, we introduce students to the prairie module by critically reading and evaluating a published paper that motivates the study that students will conduct in subsequent weeks. We provide students with a set of research questions about how tallgrass prairie plant communities are shaped by the season of burning and ask them to work in small groups to generate hypotheses for these questions. Students graph relevant data from the Towne and Kemp (2003) paper (see Tables 1 and 2 of the published research article) and interpret the graphs in light of their hypotheses. In the second week, students visit a tallgrass prairie and conduct transect-based vegetation sampling to quantify plant species composition and diversity in two different prairie restoration parcels subjected to different burning regimes. Here, students collect the same type of data that they evaluated in the Towne and Kemp (2003) paper to address the questions and hypotheses that they generated in Week 1. During the third week, students graph their data and conduct simple statistical tests to evaluate the hypotheses they developed during the first week of the module. In the fourth week, we challenge students to develop strategies for prairie management that integrate their understanding of prairie plant community dynamics with "real-world" constraints outlined in one of five randomly-assigned management scenarios.

Assessment

This four-week lab module makes use of formative assessments to measure student learning in the laboratory. Some of the formative assessments consist of observing and guiding students as they generate hypotheses, produce graphs, perform statistics, and apply their knowledge to develop solutions for real-world challenges in habitat conservation, restoration, and management. Summative assessments of student learning consist primarily of three post-lab writing assignments.

Inclusive Teaching

We designed this module to promote cooperative learning and foster an inclusive learning environment for students of diverse backgrounds (9). We incorporated effective team-based learning (TBL) methods (10,11) by designing all in-lab activities around small, permanent student teams who work together to formulate hypotheses and then collect, analyze, and interpret data. Students conduct brief reflective writing assignments outside of class between lab sessions to ensure that their effort on these exercises is not time-limited (9). In the fourth week, we use a modified "jigsaw" design to promote cooperative learning among students with different backgrounds (12) and empower students to apply their knowledge to solve relevant problems (13) in environmental conservation and management. The challenges are open-ended with no "right" answer and require that students consider socially and culturally diverse issues relevant to resource management. After students work in teams to discuss an assigned scenario, they come together as a class so that each team is prepared to explain and defend a unique scenario (i.e., a team-based "jigsaw" design). This approach allows students to present their vetted solutions in the context of a supportive team, while also being exposed to alternative perspectives and ideas developed by other teams that addressed different scenarios.

LESSON PLAN

We designed this tallgrass prairie module to be executed over four lab sessions. We teach this module in an advanced undergraduate ecology course that has 3-hour lab sessions, but the emphasis on open-ended group work makes it possible to compress or extend the length of each lab without making major structural changes in content. In the first week, students first learn about a long-term research study at the Konza Prairie Biological Station (KPBS) that evaluates how fire, grazing, and climate shape community and ecosystem processes in the Konza tallgrass prairie. Students graph and evaluate patterns in published data from KPBS (4) to develop hypotheses that they will test the following week at a local field site. The second lab is in the field, where students collect data from a local tallgrass prairie to test their hypotheses (please see Discussion for suggestions for how to extend this module to non-prairie systems). In the third lab, students analyze, graph, and interpret their data. In the fourth and final lab, we challenge students to apply their knowledge to propose solutions to real-world challenges in environmental resource management.

Prior to each week's lab period, we provide students with materials that they review to prepare for the upcoming lab activities. We provide details of each week's activities, along with an estimated time budget for each lab, in the timeline below. During the first 5-10 minutes of lab each week, students take a brief, low-stakes (~5-point) quiz on the material that they were assigned to review prior to coming to lab. Students know in advance that they will be required to take these quizzes at the beginning of each class to evaluated their preparedness. We prefer to administer the quizzes on paper at the very beginning of the lab session (rather than online prior to labs, for example) to ensure that students work independently and without the reading materials in hand. Example quizzes (and keys) are provided in the supporting materials; however, since we teach multiple sections of this lab each semester, we often vary the questions to ensure that the contents of the quizzes are not passed from students in earlier sections to those in later sections.

We assign brief writing assignments between consecutive lab sessions that require students to reflect on the material they learned in the previous lab and consider the steps they will take in the subsequent lab. These writing assignments align with different sections of a scientific paper: the writing assignment following the Week 1 Lab is the Introduction, Week 2 is the Methods, and Week 4 is the Discussion and Significance (the Results section is developed during the Week 3 Lab).

Week 1: Plant Responses to Fire Disturbance at Konza Prairie

Pre-lab student preparation

The instructors distribute the Week 1 Lab Handout (Supporting File S1. Disturbance and Diversity – Week 1 Lab Handout) and

the Towne and Kemp (2003) journal article to the students one week before the first lab activity with instructions to read these materials before arriving to lab.

In-lab activities

Students take a pre-lab quiz (Supporting File S2. Disturbance and Diversity – Week 1 Pre-Lab Quiz) during the first five minutes of the lab session to hold students accountable for preparing for the activities – i.e., by reading the Week 1 Lab Handout and associated journal article (4) prior to coming to lab. Next, the instructor presents a brief slide presentation (Supporting File S3. Disturbance and Diversity – Week 1 Instructor Presentation) that introduces the tallgrass prairie, prairie plant functional groups, and important sources of disturbance in prairie ecosystems. This presentation is provided to reinforce the key concepts of the module and offer students the opportunity to ask questions about the pre-lab reading assignments.

Following the presentation, students work in small groups to complete the "Figure Set Activity" portion of the Lab 1 Handout (Supporting File S1. Disturbance and Diversity – Week 1 Lab Handout, pp. 3-6). First, students work in teams to form hypotheses about how the timing of fire disturbance affects different plant functional groups in the tallgrass prairie, drawing upon the information in the Week 1 Lab Handout and the introductory slide presentation. Next, each team presents their hypotheses to the class. The instructor records the hypotheses on the board and facilitates a general discussion that compares and contrasts the hypotheses proposed by different groups. After the class develops a consensus set of hypotheses to pursue, students return to working in small teams to complete Parts 1 and 2 of the Figure Set Activity, which involves graphing and interpreting data provided in Towne and Kemp (2003) to evaluate their hypotheses. In our course, students complete the data entry and graphing exercise using Microsoft Excel. Instructors need to be familiar with Excel spreadsheets, the Excel Workbook Gallery, and simple statistical analyses in Excel (e.g., by completing online tutorials or simply practicing with the program) to be prepared to assist students with this activity.

Post-lab writing assignment

After the first lab, students write one paragraph that summarizes their understanding of the relationships between the seasonal timing of fire disturbance, plant functional types, and plant community richness and diversity (Supporting File S4. Disturbance and Diversity – Week 1 Post-Lab Writing Assignment), based on the information covered in the Week 1 lab activities. Students are also asked to develop hypotheses and predictions for a list of questions (as well as one original question) that motivate the data collection that will take place in the following lab. This writing assignment serves as both a reflection exercise and a means to prepare for the second week of lab.

A key for the Week 1 Pre-Lab Quiz, example responses for the Week 1 Lab Activity and Post-Lab Writing Assignment, and a rubric for the writing assignment are included in the supporting materials (Supporting File S5. Disturbance and Diversity – Week 1 Solutions Guide). We ask students to submit a hard copy of the writing assignment at the beginning of the Week 2 lab, although online submission prior to lab would also be appropriate.

Week 2: Plant Responses to Seasonal Timed Fire Disturbance at Prophetstown State Park

Pre-lab student preparation

Prior to beginning the second lab, in addition to completing the brief post-lab writing exercise (Supporting File S4. Disturbance and Diversity – Week 1 Post-Lab Writing Assignment), students also read the handout for the next lab (Supporting File S6. Disturbance and Diversity – Week 2 Lab Handout).

In-lab activities

In the second lab, students collect data on the relative abundance of plant functional groups present at two prairies with different timed fire disturbances at Prophetstown State Park in Prophetstown, Indiana. This location has two adjacent parcels of managed tallgrass prairie that were planted at the same time with the same seed mix but have different burn regimes: one is burned each spring, and one is burned each fall (see Supporting File S6. Disturbance and Diversity – Week 2 Lab Handout, p. 4 for additional information about the site). Prior to leaving for the field, students complete a brief in-class quiz to evaluate preparedness (see example provided in Supporting File S7. Disturbance and Diversity – Week 2 Pre-Lab Quiz). At the field site, the instructor distributes a visual key to the plants at the site and demonstrates the sampling methodology (described in Supporting File S6. Disturbance and Diversity – Week 2 Lab Handout). We recommend that the visual key, which needs to be developed by the instructor prior to the lab, includes photographs of the plant taxa that occur at the site and descriptions of distinguishing traits. After this introduction, students spend the remaining time working in their teams to collect plant community composition data along transects (some teams of two may be combined into teams of four, depending on the size of the class). A copy of the data sheet that we use for this activity, which could be modified for use at other locations, is provided in supporting materials (Supporting File S8. Disturbance and Diversity – Week 2 Example Data Sheet).

In our class at Purdue University, we reserve the last ~20 minutes of class for students to meet with the site director to learn about the history and challenges of prairie restoration activities at the site. This discussion provides useful background and context for the Week 4 lab, which focuses on prairie management strategies.

Post-lab writing assignment

In the post-lab assignment for Week 2 (Supporting File S9. Disturbance and Diversity – Week 2 Post-Lab Writing Assignment), students write a brief summary and justification of the methods they used to collect their data to reinforce the rationale behind the sampling approach. Specifically, students write three paragraphs that collectively mirror the structure of the Methods section of a journal article: the first paragraph summarizes the study area, the second paragraph describes the field sampling methodology, and the final paragraph describes the qualitative comparisons that they will make to test the predictions they developed in the previous week's writing assignment (Supporting File S4. Disturbance and Diversity – Week 1 Post-Lab Writing Assignment). Example responses and a rubric for grading the writing assignment are provided in the supporting materials (Supporting File S10. Disturbance and Diversity – Week 2 Solutions Guide).

Week 3: Data Analysis and Interpretation

Pre-lab student preparation

To prepare for the third lab, students complete their second writing assignment (Supporting File S9. Disturbance and Diversity – Week 2 Post-Lab Writing Assignment) and read the handout for the upcoming lab activity (Supporting File S11. Disturbance and Diversity – Week 3 Lab Handout). The instructor compiles the data that the students collected the week before and makes it available for the students to access in class (e.g., posting it online for students to download, e-mailing a copy to each student, or providing it directly at the beginning of the lab period).

In-lab activities

After administering a pre-lab quiz (Supporting File S12. Disturbance and Diversity – Week 3 Pre-Lab Quiz), the instructor briefly summarizes the goals of the Week 3 lab (i.e., data analysis and interpretation). Students then work in their teams to construct graphs and perform simple statistical tests to assess the hypotheses and predictions that they generated in the Week 1 Post-Lab Writing Assignment (S4). The lab handout (Supporting File S11. Disturbance and Diversity – Week 3 Lab Handout) provides detailed instructions that guide students through transforming their raw data to mimic the Towne and Kemp (2003) study and then graphing, statistically analyzing (using t-tests and chi-square tests in Microsoft Excel), and interpreting their results for two of four possible questions. An example data set and analyses are provided in the supporting materials (Supporting File S13. Disturbance and Diversity – Week 3 Example Data Set). The final step of the assignment requires students to summarize their results to practice writing the "Results" and "Discussion" sections of a scientific paper.

Post-lab writing assignment

In the writing assignment following the Week 3 lab activity, students consider the broad implications of their results in the context of habitat conservation, restoration, and management (see Supporting File S14. Disturbance and Diversity – Week 3 Post-Lab Writing Assignment). The class is asked to evaluate five different scenarios for prairie conservation and/or management. The instructor distributes one of the five scenarios to each student, taking care to ensure that each scenario is addressed by approximately the same number of students. Each scenario introduces constraints and challenges that can influence the degree to which a student's conclusions from the first three labs can be applied to broad-scale prairie conservation, restoration, and/or management. Students identify the goals and constraints associated with each scenario, find and summarize two papers that can inform their approach to meeting the goals and/or addressing the constraints, and develop ideas for management strategies that could accomplish the goals described in their scenario. This activity prepares students for the discussions that are the focus of the fourth (and final) lab.

A key to the pre-lab quiz, example graphs, results, and responses to the lab activity, and a guide and rubric for evaluating the post-lab writing assignment are provided in the supporting materials (Supporting File S15. Disturbance and Diversity – Week 3 Solutions Guide). The guide also provides suggestions for structuring the lab activity to ensure that data analyses and graphs align with hypotheses and predictions (14).

Week 4: Broader Significance and Real-World Applications

Pre-lab student preparation

Students prepare for the final lab activity by independently completing and submitting the previous post-lab writing assignment (Supporting File S14. Disturbance and Diversity – Week 3 Post-Lab Writing Assignment), which includes finding two papers that are relevant to their assigned scenario (described above). They are also assigned the final handout (S16. Disturbance and Diversity – Week 4 Lab Handout) to read prior to the lab.

In-lab activities

In the fourth and final lab activity, students first complete the brief pre-lab quiz to assure preparedness (Supporting File S17. Disturbance and Diversity – Week 4 Pre-Lab Quiz). Students then work in groups to discuss possible solutions to different real-world challenges associated with the conservation, restoration, and management of tallgrass prairie ecosystems. Each group is composed of students who evaluated the same scenario in the Week 3 Post-Lab Writing Assignment. In their teams, students strive to reach consensus on the primary goals and constraints of their scenario, discuss relevant literature (from the papers they have brought to lab), and develop a prairie management plan that draws upon the concepts they have learned in previous weeks. Each team also develops questions for the scenarios being addressed by other teams. Towards the end of lab, each team informally presents their scenarios and proposed management plans to the entire class, providing the opportunity for peer feedback and class discussion.

One way to elevate discussion in the Week 4 lab is to invite local prairie conservation, restoration, and management practitioners to participate. In addition to introducing further realism into the scenarios that are discussed, the presence of practitioners exposes students to alternative careers in ecology, conservation, and natural resource management.

TEACHING DISCUSSION

The activities in this four-week laboratory module promote an integrated understanding of community ecology, restoration ecology, and natural resource management, while advancing students' quantitative reasoning and statistical skills. We have found that this extended, multi-week investigation improved student learning gains relative to a one-day version of this lab that had previously been conducted in this course, which focused on the material and activities that we present here in Week 2. The four-week module provides students with the same hands-on experience collecting data in a field setting, while also addressing several process goals that could not be accomplished in the one-day lab activity. Specifically, the analysis of the published data in Towne & Kemp (2003) in Week 1 allows students to independently reproduce patterns documented in a published manuscript, which prepares them to collect their own data in the field and guides the formation of their own hypotheses and predictions. Data collection in Week 2 allows students to actively practice the methods used by Towne & Kemp (2003)and connect the physical work of sampling to the graphs, tables, and results in a published paper. The opportunity to analyze their own data in Week 3 reinforces the concepts and data visualization skills learned in Week 1,

while allowing students to extend these skills to analyze and visualize their own data. At this stage, students often encounter results that contrast with those reported in Towne & Kemp (2003), introducing the important role of contingency and context-dependence in community ecology (see examples in S18. Disturbance and Diversity – Week 4 Solutions Guide) and the importance of long-term data for accurately understanding an ecosystem. Students express a higher level of investment and ownership over the material when analyzing their own data; they are also more confident (or forgiving) in their critiques of the Towne & Kemp (2003) paper as they encounter limitations in their own data set. Finally, the opportunity to apply their understanding of prairie ecology to address "real-world" problems in conservation and management during the Week 4 discussion is particularly well-received by students with interests in policy, social science, and conservation. The discussions on this final day are consistently lively, particularly if practitioners that grapple with the challenges described in the scenarios are able to participate. Overall, the highly collaborative, team-based approach that runs throughout the module challenges students to work together to interpret and synthesize literature, collect data, and solve problems that do not have simple solutions or "right" answers.

An overarching goal of this four-week module is to pair a critical reading of a scientific paper with a student-driven, field-based investigation that allows students to replicate the methods from the published paper in an alternative setting. We choose to have students conduct the field portion of the study at a local a restoration site to provide the opportunity to introduce restoration ecology in the Week 3 lab, which then provides a useful context for the applications that are the focus of the Week 4 lab activity. The lab materials that we provide were originally developed around our access to a local prairie restoration (Prophetstown State Park) that is in close proximity to Purdue University. However, the goals of this module can be met through the study of a variety of ecosystems, and we encourage instructors to modify the materials as needed for use in other locations. The materials can be most easily extended to ecosystems that are managed using controlled disturbances that aim to mimic natural processes that influence biodiversity. To do this, we recommend that instructors first locate a local property that uses disturbance as part of its management plan (such as logging, haying, burning, grazing, or flooding) and that will allow students to visit the site and sample vegetation in Week 2. Management practices that involve disturbance are usually grounded in scientific studies; consequently, the instructor can likely identify a published paper that evaluates the role of disturbance in that ecosystem to substitute for the Towne & Kemp (2003) paper in the Week 1 Figure Set Activity. The materials that we provide here (see Supporting Files) can be most easily adopted if the focal paper in Week 1 presents data from different plant functional groups in table format, providing a straightforward launching point for the fieldwork in Week 2 and subsequent analyses in Week 3. Overall, we are optimistic that the structure of this four-week module can provide a framework for organizing hypothesis-driven data collection, analysis, and interpretation in a variety of systems, making it possible for students to meet the learning goals of this module while gaining knowledge about local ecosystems and organisms.

SUPPORTING MATERIALS

- **S1. Disturbance and Diversity – Week 1 Lab Handout.** Background information and lab description to be provided to students prior to the first lab.
- **S2. Disturbance and Diversity – Week 1 Pre-Lab Quiz.** Brief quiz given to students at the beginning of the lab period to underscore the expectation that students complete the pre-lab reading assignments prior to coming to lab.
- **S3. Disturbance and Diversity – Week 1 Instructor Presentation.** A slide presentation that the instructor presents to the class in the first lab to provide background information about prairie ecosystems and prairie plant physiology.
- **S4. Disturbance and Diversity – Week 1 Post-Lab Writing Assignment.** Instructions for a post-lab writing activity that asks students to generate the "Introduction" section of a scientific paper that establishes the goals, hypotheses, and predictions for the field activities that will be performed the following week.
- **S5. Disturbance and Diversity – Week 1 Solutions Guide.** A guide for instructors that provides example student responses for the pre-lab quiz, lab activity, and post-lab writing assignment for Week 1. A rubric for the Week 1 Post-Lab Writing Assignment is included.
- **S6. Disturbance and Diversity – Week 2 Lab Handout.** Background information on restoration ecology, description of the field site where the lab will take place, and protocol for sampling vegetation.
- **S7. Disturbance and Diversity – Week 2 Pre-Lab Quiz**. Brief quiz given to students at the beginning of the lab period to evaluate student preparedness for the second lab.
- **S8. Disturbance and Diversity – Week 2 Example Data Sheet.** An example of a data sheet that can be distributed to students to record plant composition at the field site during the second lab activity.
- **S9. Disturbance and Diversity – Week 2 Post-Lab Writing Assignment.** Instructions for a post-lab writing activity that asks students to generate the "Methods" section of a scientific paper that summarizes the protocol they used to sample prairie vegetation in the Week 2 lab activity and anticipate the analyses they will do in Week 3.
- **S10. Disturbance and Diversity – Week 2 Solutions Guide.** Instructor guide with the key for the Week 2 Pre-Lab Quiz, notes for the Week 2 field activity, and example responses and associated rubric for the Week 2 Post-Lab Writing Assignment.
- **S11. Disturbance and Diversity – Week 3 Lab Handout.** Instructions for students on how to organize, graph, and statistically analyze their data to address their hypotheses.
- **S12. Disturbance and Diversity – Week 3 Pre-Lab Quiz.** Brief quiz given to students at the beginning of the lab period to evaluate student preparedness for the third lab.
- **S13. Disturbance and Diversity – Week 3 Example Data Set.** An example data set on prairie plant community composition at Prophetstown State Park and associated graphs and analyses for the Week 3 lab.
- **S14. Disturbance and Diversity – Week 3 Post-Lab Writing Assignment.** Student instructions for the final post-lab writing assignment, which asks students to consider alternative scenarios for prairie management. Each student is assigned one of the five scenarios to evaluate in the assignment.

- **S15. Disturbance and Diversity – Week 3 Solutions Guide.** Instructor guide for Week 3 that includes a key for the Week 3 Pre-Lab Quiz, example responses for the Week 3 lab activities, and a rubric for the Week 3 Post-Lab Writing Assignment.
- **S16. Disturbance and Diversity – Week 4 Lab Handout.** Student instructions for structured discussions that take place during the fourth lab of the module.
- **S17. Disturbance and Diversity – Week 4 Pre-Lab Quiz.** Brief quiz given to students at the beginning of the lab period to evaluate student preparedness for the fourth lab.
- **S18. Disturbance and Diversity – Week 4 Solutions Guide.** Instructor guide for Week 4, including a key for the Week 4 Pre-Lab Quiz and notes for facilitating constructive discussions during the lab activity.

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Table 1. Lesson Teaching Timeline

Activity	Description	Estimated Time	Notes
Lab Session 1			
Prior to lab: Instructor provides lab preparation materials to students	Distribute Towne & Kemp (2003) article and Week 1 Lab Handout to students.	~90 minutes (outside of class; varies by student)	Full citation of paper to distribute: Towne, G.E. and K.E. Kemp. 2003. Vegetation dynamics from annually burning tallgrass prairie in different seasons. Journal of Range Management 56:185-192. • S1: Disturbance and Diversity – Week 1 Lab Handout.
Pre-lab quiz	Short individual quiz on pre-lab readings to ensure student preparedness.	5-10 minutes	Quiz is given at the beginning of lab. • S2. Disturbance and Diversity – Week 1 Pre-lab Quiz. • S5: Disturbance and Diversity – Week 1 Solutions Guide (includes key to quiz).
Slide presentation	Instructor presents a brief overview on tallgrass prairie ecosystem and the four-week lab module.	30 minutes	• S3: Disturbance and Diversity – Week 1 Instructor Slide Presentation.
Figure set activity	Students work in small groups to formulate hypotheses, create figures from data provided in Towne & Kemp (2003), draw conclusions, and answer the questions provided in the Week 1 Lab Handout (S1: Disturbance and Diversity - Week 1 Lab Handout).	~140 minutes (flexible)	1. Instructor reconvenes the class after groups have developed hypotheses and predictions. Class discussion aims to reach consensus on hypotheses for the entire class. 2. Students may need assistance creating graphs in Excel while working through Exercises 1-3. • S5: Disturbance and Diversity – Week 1 Solutions Guide (provides example student responses and graphs).
Post-lab: Writing assignment (due prior to the next week's lab)	Students write one paragraph that synthesizes their work in the Week 1 Lab and states hypotheses and predictions for the Week 2 field sampling.	~60-120 minutes (outside of class, varies by student)	• S4: Disturbance and Diversity – Week 1 Post-Lab Writing Assignment. • S5: Disturbance and Diversity – Week 1 Solutions Guide (provides rubric for evaluating post-lab writing assignment).
Lab Session 2			
Prior to lab: Instructor provides lab preparation materials to students	Distribute Week 2 Lab Handout to students.	~ 30 minutes (outside of class; varies by student)	• S6: Disturbance and Diversity – Week 2 Lab Handout.
Pre-lab quiz	Short individual quiz on Week 2 Lab Handout to ensure student preparedness.	5-10 minutes	Quiz is given at the beginning of lab. • S7: Disturbance and Diversity – Week 2 Pre-lab Quiz. • S10: Disturbance and Diversity – Week 2 Solutions Guide (includes key to quiz).
Field sampling	Students work in teams to sample vegetation according to the protocol in the Week 2 Lab Handout.	~140 minutes (varies with travel time to field site)	• S8: Disturbance and Diversity – Week 2 Example Data Sheet (for students to use to record data in the field).
Post-lab: Writing assignment (due prior to the next week's lab)	Students write three paragraphs that summarize their field methods in the Week 2 Lab and anticipates the analyses they will do in the Week 3 Lab.	~60-120 minutes (outside of class, varies by student)	• S9: Disturbance and Diversity – Week 2 Post-Lab Writing Assignment. • S10: Disturbance and Diversity – Week 2 Solutions Guide (provides rubric for evaluating post-lab writing assignment).

Activity	Description	Estimated Time	Notes
Lab Session 3			
Prior to lab: Instructor provides lab preparation materials to students	Distribute Week 3 Lab Handout to students	~30 minutes (outside of class; varies by student)	• S11: Disturbance and Diversity – Week 3 Lab Handout.
Pre-lab quiz	Short individual quiz on Week 3 Lab Handout to ensure student preparedness	5-10 minutes	Quiz is given at the beginning of lab. • S12: Disturbance and Diversity – Week 3 Pre-Lab Quiz. • S15: Disturbance and Diversity – Week 3 Solutions Guide (includes key to quiz).
Data visualization and analysis	Students work in teams to visualize and statistically analyze their data in MS Excel	~160 minutes (flexible)	Instructor needs to be familiar with data visualization and analysis in MS Excel to assist students as needed. • S13: Disturbance and Diversity – Week 3 Example Data Set. • S15: Disturbance and Diversity – Week 3 Solutions Guide (includes examples of student responses to lab activities).
Post-lab: Writing assignment (due prior to the next week's lab)	Students consider various scenarios for prairie conservation and management	~120 minutes (outside of class, varies by student)	1. Instructor assigns each student to 1 of the 5 scenarios described in the assignment. 2. Students respond to prompts and identify two relevant journal articles. 3. This assignment prepares students for next week's lab activities. • S14: Disturbance and Diversity – Week 3 Post-Lab Writing Assignment. • S15: Disturbance and Diversity – Week 3 Solutions Guide (provides rubric for evaluating post-lab writing assignment).
Lab Session 4			
Prior to lab: Instructor provides lab preparation materials to students	Distribute Week 4 Lab Handout to students	~15 minutes (outside of class; varies by student)	• S16: Disturbance and Diversity – Week 4 Lab Handout.
Pre-lab quiz	Short individual quiz on Week 4 Lab Handout to ensure student preparedness	5-10 minutes	Quiz is given at the beginning of lab. • S17: Disturbance and Diversity – Week 4 Pre-Lab Quiz. • S18: Disturbance and Diversity – Week 4 Solutions Guide (includes key to quiz).
Small group discussions about assigned scenarios	Students work with other students who were assigned the same scenario in the Week 3 Post-Lab Writing Assignment to reach consensus	~90 minutes (flexible)	1. Instructor facilitates small group discussions and promotes consensus within groups. 2. When possible, inviting practitioners to join these discussions is an effective way to increase the authenticity of this exercise. • S18: Disturbance and Diversity – Week 4 Solutions Guide (includes examples of student responses to lab activities and suggestions to instructors for facilitating discussions).
Informal presentations and class discussion	Teams report out to the class with outcomes of small-group discussions	~80 minutes (flexible)	1. Presentations are informal. 2. Instructor can structure the class discussion around the questions that teams will have prepared in the previous small-group discussions. • S18: Disturbance and Diversity – Week 4 Solutions Guide (includes suggestions to instructors for facilitating discussions).