Energy and Ecosystems: Prairie, Water and Woods Sampler

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This sampler contains some of the content from the *Energy and Ecosystems (E&E) Teacher's Guide*; those sections have an asterisk in the following Table of Contents:

Table of Contents

Pollinators and Consumers – CSI Ecosystem
Trophic Interactions and Food Webs
Photosynthesis
Life in a Log – Soil Structure
Fire Ecology
Home on the Range
Lesson Set 3 Assessment

Engineering Assessment
Peanut Butter and Jelly Sandwich
Problem-Based Research Component – Engineering Design

Engineering Components
*Ecosystem Services Research Components
*Ecosystem Services Research Component – Pollination
Ecosystem Services Research Component – Erosion Control
Ecosystem Services Research Component – Weather/Disturbance Regulation
Ecosystem Services Research Component – Nutrient Cycling
Ecosystem Services Research Component – Climate Regulation

Field Research Components
Field Research
Abiotic Study
*Quadrat Species Sampling – Plants and Invertebrates
Airborne and Crawling Invertebrate Survey
Pollinators and Consumers – CSI Ecosystem
Aquatic Diversity and Water Quality
Fermilab: Past, Present and Future
Fermilab Land Management Map
Fermilab Land Management
Bumblebee Watch

Resources
Planning Your Fermilab Field Trip
Special Education Considerations
Prairie Plant Key
Herbarium Specimen Collection
Things to Consider when Planning a School Prairie
Illinois Prairie Loss Maps
FQI Skill Builder
FQI – Fermilab Sites
Common Woodland Plants in Fermilab Student Plot
Common Wetland Plants at Lederman Science Center Pond
Causes and Effects of Water Chemistry
Lake/Pond Stratification and Turnover
Fermilab Surface Water Flow/Control Map
Sampling Terrestrial Invertebrates
WANTED Posters

Introduction

Ecology and the 5E Instructional Model

The ecology curriculum at Fermilab, *Energy and Ecosystems: Prairie, Water and Woods*, subscribes to the constructivist approach to science education through its commitment to set up real-world, researchable problems and/or scenarios for students to explore. Students are encouraged to formulate research questions by first becoming familiar with environmental topics and applying this knowledge base to contemporary questions. The role of the instructor is to support student exploration by presenting real-world issues, encouraging inquiry, monitoring progress, and promoting new ways of thinking.

Activities within this curriculum are hierarchical in nature, offering skill building and the opportunity to use prior knowledge as a foundation for new learning. The exploration topics investigate abiotic and biotic forces in the natural world with the ultimate goal of better understanding the interactions and relationships of the organisms at Fermilab and throughout Northern Illinois.

Fermilab provides rich databases to enhance the student inquiry process. These resources provide opportunities to compare and contrast contemporary and archived field data, some of which spans over 20 years. These raw data banks are primary sources, reflecting longitudinal data stores that are fully accessible for student use.

Students, in the role of citizen scientists, also have the opportunity to add to the databases. Their efforts will enrich and strengthen the body of knowledge needed by onsite field ecologists. As of 2016, the most prolific database is prairie related. Student researchers have contributed to the prairie data since 1993. While prairie data will still be collected, Fermilab ecologists now also need species data from the wetland and woodland areas. As restoration in these areas continues, surveys showing evidence of progress are critical. The opportunity for research questions that originate as the result of these new data collections is limitless.

Ecosystem Services

Throughout civilization, there are certain aspects of the natural world toward which humans gravitated to settle. These traditionally are areas with access to water, shelter and food sources. Not much has changed over the thousands of years that humans have walked the earth. Water, shelter and food remain survival staples. Consider the location of many of the world's greatest cities in proximity to oceans, large lakes and rivers. Particularly in the last 150–200 years, considerable human innovation has altered the natural plan in developed countries. Due to these innovations, including modern transportation modes and what we now consider to be business and household necessities, many humans are more and more separated from the natural places. This separation can serve to insulate humankind from the power and especially the value of the natural world. Without proper functioning of ecosystems within our natural world, life as we know it could perish in a frightfully short time. We are directly reliant on ecosystem services.

Ecosystem services are defined as the important benefits for human beings that arise from healthy functioning ecosystems (Costanza, 1997). Broad benefits of ecosystem services include:

- Gas regulation (production of oxygen and carbon dioxide needed for photosynthesis and respiration)
- Climate regulation (Transpiration by plants helps regulate temperature and relative humidity.)
- Disturbance regulation (storm protection/flood control/erosion buffer)
- Water regulation (natural filtration and flood control; water cycle)
- Erosion control/sediment retention (Root systems hold soil in place; plants block wind.)
- Soil formation (Decomposition/Detritus processing add nutrients to form rich, organic soil.)
- Pollination (fertilization of plants essential to life on Earth)
- Biological control (trophic dynamic relationships/keystone species; food chains/food webs)
- Refugia (habitat for migration/visiting species)
- Food production (Native plants and animals are food/medicine sources; commercial farming)
- Raw materials (biofuels; hemp fiber; multitudes of uses for native plants and animals including medicinal value)

NOTE: Examples are **not** inclusive. Many other advantages may be considered within this context.

Costanza, R. et al. "The value of the world's ecosystem services and natural capital." *Nature.* Vol. 387. 15 May 1997, pp. 252-260.

Habitat Communities of the Fermilab Site

Known for its international role in particle physics research and accelerator science, Fermilab has a more local side to it; the land. Surrounding us, former farmland has filled in with suburbs and shopping centers, busy roads and growing cities. Fermilab has remained a tranquil oasis, a quiet refuge known by many local citizens as a haven with trails, quiet streets, coyotes and wildflowers everywhere you look. Indeed the rich mosaic of remnant habitats, coupled with the aggressive prairie restoration program, has created a very nice place to work and visit. These habitats continue to be restored for biodiversity and ecosystem function.

The classifications scientists use to describe natural communities give a short, simple name to a very complicated thing. When we talk of "oak savannas" or "tallgrass prairies," we are referring to communities that may include hundreds of species of plants, and—when you add up all the beetles, spiders, snails, and centipedes—thousands of species of animals. When we study a natural area and decide what communities are present, we look at the entire biota, historic evidence and abiotic factors.

The land within the boundaries of Fermilab has everything from agriculture to lakes, prairies, swamps, oak savannas and sedge meadows. It is a microcosm of many ecosystems found in the Midwest. We categorize these areas by community type to determine how to best restore and maintain them.

Some examples:

Tallgrass Prairie
Tallgrass prairie communities are dominated by grasses intermixed with abundant forbs on mineral soil. Trees and shrubs may be present, but less than 10% of the area has a tree or shrub canopy. Soils are deep and fine-textured—usually silt loam or clay loam derived from loess or glacial till. This includes the typical, “black-soil” prairies.

Topography varies from level to moderately sloping and soil moisture ranges from dry to wet. The tallgrass prairie ecosystem has suffered extreme losses throughout its range since European settlement, with 99.9% being lost in the prairie state—Illinois (Sampson and Knopf, 1994). Wet and mesic tallgrass prairies are critically imperiled globally.

Open Water
Lakes and ponds represent open water habitat communities at Fermilab. Open water communities have submerged, emergent and shoreline vegetation that can provide important microhabitat structure for aquatic wildlife such as fishes, mussels, snails and other invertebrates. Most open water at Fermilab is also vital to Laboratory operations as part of the Industrial Cooling Water system. Invasive species occurring in open waters are zebra mussels, *Phragmites*, reed canary grass, and purple loosestrife.

Woodland
Woodlands are less dense than forests but have greater stems per acre than the oak savanna community type. A conservative woodland shrub and herbaceous layer may be present in the best quality remnants, with a diversity of spring ephemerals. Soils can be

deep and loamy and hydrology ranges from dry-mesic to wet-mesic. Vernal pools may also be present in woodlands. In the absence of fire, many woodland areas became forest communities after European settlement. Such sites can be most easily recognized by failure of the canopy tree species (e.g., oaks and hickories) to reproduce, with few, if any represented, in the seedling or sapling layer. This is because they are not shade-tolerant (light-limited). High-quality woodlands are imperiled systems globally (Faber-Langendoen, 2001).

Written by Ryan Campbell, Fermilab Ecologist

Engineering Components

Ecosystem Services Research Components

The ecosystem services research components portion of the unit is a chance for students to apply new science knowledge by giving practical reasoning for a facility, like their school, to restore an ecosystem on their property. This project will benefit students by giving them another location to conduct research and by giving them an opportunity to participate in a local restoration project. Students will need to understand and apply concepts needed to develop and maintain a restored ecosystem but also be able to communicate the benefits that the restored ecosystem gives back to the community.

Students choose an ecosystem services research component based on interest and relevance to their initial research project. There should be a clear connection to the ecosystem service they choose to research and the benefits to their restored schoolyard ecosystem. For example, if there is a part of the schoolyard that is constantly sunny and dry, possibly even too dry for grass to grow, a prairie restoration might be a good fit for this area. The prairie would add an aesthetic quality with its interesting plants and insects as well as increase pollination for all plants around the school. The prairie would also be able to grow in this hot, dry area, not needing to be watered or maintained throughout the year. This part of the project should add reason to restore an ecosystem on school grounds and can be used as argumentation if students choose to communicate their project to stakeholders in an effort to bring their project to fruition.

The emphasis in this project is the connection between how ecosystems and humans benefit each other. Students should take the opportunity to look at this relationship as valid arguments for restoration projects and should consider all stakeholders when creating this argument. Students should communicate clearly and support arguments with benefits for the restored ecosystem and for the human populations that interact with the restored ecosystems.

Students should be encouraged to look for other ecosystem services and explore further to satisfy their interest. Often a restored ecosystem will provide multiple benefits to communities, not just one. Encourage students to explore questions and ideas as they create their arguments and support ideas.

<u>Sample Activity</u>

Ecosystem Services Research Component – Pollination

Topic: How can pollination be increased in a restored ecosystem?

Brief Lesson/Lesson Set Description:
Students will ask a question that can be answered through research. They will design and implement a plan to solve school site problems with the creation of a restored ecosystem (prairie, woodlands, or pond).

Performance Expectations:

ETS 1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-LS1-4. Use argument based on empirical evidence and scientific reasoning to support an explanation for how characteristic animal behaviors and specialized plant structures affect the probability of successful reproduction of animals and plants, respectively.

Assessment:
Find the Engaging in Argument from Evidence rubric to progress monitor students' growth through the practices. Find Science and Engineering Practices rubrics in the *Introduction* section.

Objectives: Students will:

- Identify a question about how restored ecosystems can help solve ecological issues.
- Research the question.
- Develop a solution to help contribute to a solution and an implementation plan.
- Communicate conclusions.

Narrative/Background Information:
Student-generated questions foster the inquiry-based platform integral to world-class platform integral to world-class science education. Field-based learning differs from lab-based research in that it is difficult, if not impossible, to control some of the variables.

Field-based research focuses on data collected for an ecosystem over a period of years. In the field, the problem becomes "messy." Without the ability to create controls, a variety of factors can contribute to a situation. Designing research questions takes considerable thought. While students can easily gather data from within their classrooms, if it is possible to provide the unique experience of a field study, it is encouraged.

This activity can easily incorporate all disciplines within the middle school. Research questions can also be differentiated and accommodate all styles of learners. Encourage students to think about their interests and to spend time brainstorming potential questions before they settle on a topic to investigate.

Possible Preconceptions/Misconceptions:
Students may need direction on how to ask scientific questions that can be researched, how to collect data if conducting field research, and how to analyze that data once it is collected. Mini-lessons on how to conduct research, collect data, make sense of that data, and how to use the findings as support for an argument, could be done throughout student work.

Process:

1. Students explore a few examples of relationships between animals and plants that result in pollination for the plant. Students choose one of the relationships that most intrigues them to research.
2. Students are encouraged to brainstorm questions that could be researched about the chosen relationship. Questions should revolve around how to increase pollination and the effects that the increase of the pollination will have on the ecosystem. Students will conduct the research, taking notes in their science journals. Students may use the *SIMply Prairie* website as well as other sites to search for longitudinal data that has been collected on their question. http://ed.fnal.gov/data/life_sci/prairie/
3. Students should plan a field-based research component to collect additional data on their chosen organisms. This additional data should contribute to solutions that help increase the likelihood that pollination will increase and produce more plant life within the chosen ecosystem.
4. Students need to decide on how they might collect their own data in the field and design protocol for collecting data either at school, at home, or while at Fermilab.
5. Students conduct both classroom and field-based research, collecting data that supports the answer to their question and contributes to their solution. They should work through unexpected variables to collect data in field-based research and remember that the lack of data is data!
6. Students will maintain a science journal to record findings, sketch, create models, record ideas and write down other questions they have.
7. Students make a recommendation for a solution that would add to increased pollination in their ecosystem. A written explanation of why an increase in pollination is beneficial to the ecosystem should be included.

Field Research Components

<u>Sample Activity</u>

Quadrat Species Sampling – Plants and Invertebrates

How do abiotic factors affect biotic factors in an ecosystem?

Lesson Number 3 in a Series of 3 (if completed in Set 1); also found in Research section

If completed within the Research section, note that skill builders, *Estimating Percentages* and *Quadrat Study: School Lawn*, are prerequisites.

Topic: Utilizing estimating skills, identifying plants, recognizing the relationship between specific plants, invertebrate and other animal populations and collecting data to indicate health of an ecosystem by looking at the biodiversity of an ecosystem

Brief Lesson/Lesson Set Description: ***(Connection to Fermilab Natural Areas)***
Students will engage in quadrat sampling, a land management surveying technique. Plants and animals, especially invertebrates, within a meter square will be observed, identified or categorized, and counted. Special note will be taken to establish relationships and interactions between organisms to identify adaptations and behaviors.

Species sampling is integral to the ongoing wellbeing of the Fermilab natural areas. After establishing a baseline of what exists in an ecosystem, ongoing monitoring is essential to assess the health and progress or decline of the area. Noting which species are evident in a study site from year-to-year and sometimes season-to-season enables researchers to predict future trends, enrich and/or take preventative measures as deemed appropriate. Longitudinal data is a critical component of land management. (See *Resources – Land Management* documents.)

Science and Engineering Practice: Using Mathematics and Computational Thinking

Crosscutting Concept: Scale, Proportion and Quantity

INVESTIGATION

Objectives: Students will:

- Investigate the floristic quality, species diversity and importance value of plants on a designated plot.
- Observe and record invertebrate activity on the plot.
- Interpret these data over time to draw conclusions about the progress of woodland, pond and/or prairie restoration as well as the affinity of specific invertebrates to specific plants. NOTE: Prairie data is available from 1992. Woodland, pond and invertebrate data will be available beginning in 2017.
- Write a concise summary of these findings.
- Apply these findings to other comparable restoration sites—recognizing that

weather, fire and other abiotic factors influence the ecosystems.
- Determine past trends and speculate about future trends using current and historic data.

Narrative/Background Information:
<u>Plants</u>
The student quadrat studies on the Fermilab site were originally completed only in prairie sites. The prairie land presently on site at Fermilab is reminiscent of the original tallgrass prairie that once covered 400,000 square miles of the Midwest and around 40,000 square miles in Illinois. Currently, over 1,100 acres of prairie has been planted on the Fermilab site. This reconstruction process has been in progress since 1975. As prairie plants have been added, careful notice has been taken as to the progress and the succession of these plants. This survey has been accomplished via plot observation and by quadrat studies executed primarily by middle level students. The *Particles and Prairies* data began in 1992 and provides a wealth of information representing thousands of quadrats. Long-term data coupled with abiotic measurements is critical in determining trends. The quadrat sampling is now expanded to include woodlands, ecotones and pond species. Even sessile or slower-moving pond organisms can be surveyed using a quadrat method.

A quadrat is an area of predetermined size (Fermilab uses M^2), ideally selected randomly to avoid bias, which is used to survey the organisms within its confines. Plants, insects and other organisms may be recorded, noting abundance, surface area covered and/or any other data desired. Relationships and interactions between organisms are often revealed by careful observation of the quadrat.

One of the goals of the quadrat study is to determine the importance value of any given species. Importance value is calculated by considering the relative dominance + relative frequency + relative density. Importance value is not simply asking which organism is present in the greatest number; it involves much more criteria. For example, what if one organism is much larger than another or common only in one location? The importance value gives a more accurate picture of which organisms have the greatest impact. This information is critical when trying to predict future trends and better succeed in managing ecosystems.

Species diversity reflects how many different species are present. In a healthy natural area, we may find hundreds of different species. Restored natural areas can take a long time to approach this number. In time, maintenance methods and natural succession may increase the species diversity of native plants and invertebrates and decrease the diversity of invasive species. A common indicator of the maturity and health of a natural area is its species diversity. Quadrat studies help to quantify these trends.

Ecologists at Fermilab are especially interested in floristic quality or FQI. FQI (Floristic Quality Index) formula is: (mean of coefficients of conservation (C) of all the plants found) times (the square root of the number of species (N) in that area). Per Swink and Wilhelm ([1]Swink, 1994), the FQI is an indication of native vegetative quality for an area: 1–19 indicates low vegetative quality, 20–35 indicates high vegetative quality, and above 35 indicates “Natural Area” quality. FQI is the indicator used to measure the success of restorations on Fermilab.

[1]Literature cited: Swink, F. and G. Wilhelm. 1994. *Plants of the Chicago Region*, 4th ed., Indiana Academy of Science, Indianapolis.

***Refer to the Resources section for more information about the FQI and the formula used to calculate Floristic Quality Index and the importance of abundant data to establish a reliable ecosystem analysis.*

FQI is calculated in the same manner for prairies, woodlands and wetlands. The native mean C is also an indication of native vegetative quality. For the 2015 Fermilab prairie quadrats, with mean of C = 7.6, N = 47, there is an FQI = 52, which is considered diverse in native plants. As students collect data from woodlands and ponds, longitudinal data for those ecosystems will provide ongoing information to support these areas.

Invertebrates

As students collect plant data, they also will observe invertebrates within the quadrat. Notable specimens such as bumblebees, butterflies, dragonflies, etc., within close proximity to the quadrat may also be recorded as *observed*, but not counted with the data. (See Quadrat Invertebrate Data student sheet.) It is important to make careful note of which invertebrate is visiting specific plants. This relationship is integral to understanding the interactions within the ecosystem. It is also linked to biodiversity; the more diverse the plant community, the more diverse the invertebrate community.

The wings, legs and mouthparts of the invertebrate hold clues as to its niche. A leaf-chewing invertebrate has different adaptations than a predatory organism, most dramatically in the mouthparts. Invertebrates that feed solely on vegetation are primary consumers, dependent frequently on a specific plant, such as monarch butterflies and milkweed. Monarch larvae prefer the fleshy leaves of the milkweed plants and are often found on plants of the milkweed genus Asclepias. Interestingly, mature female monarchs subsist on a liquid diet, including nectar from many species of forbs, juicy fruits and even a picnic watermelon slice. Male monarchs have been known to absorb minerals through their feet in an act known as “mud-puddling.”

At one time, there were at least eight species of bumblebee species foraging on the Fermilab ecosystems. Tongue length plays a major role on which bumbles are found on specific plants. For example, only the long-tongued bumblebees such as *Bombus pennsylvanicus*, frequent the Monarda plant. The long tongue of this species can reach deep into the individual vase-like corollas of this forb. The short-tongued *Bombus affinis* prefers the centers of disc forbs like multiflora rose and sunflowers.

Invertebrates are critical elements in an ecosystem serving as pollinators, decomposers, nutrient providers, eliminator of pests, food for other organisms, and all-around fascinating critters. In the Fermilab ecosystems, invertebrates *native* to the area fulfill an important niche and are to be guarded. Unfortunately, exotic (non-native) invertebrates often are evident, notably the Asian beetle. This iridescent beetle causes tremendous damage to many plants, especially showy tick trefoil.

Other Organisms
Ecosystems are not composed only of plants and invertebrates. Fish and amphibians are present in the ponds, lakes and streams; reptiles, including a variety of snakes and turtles, are occasionally seen; birds adapted to wetlands, woodlands and prairies are prolific; and mammals abound, though all students may see is the evidence of their presence. Scat, tracks, matted grass or browse lines imply deer in an area. Students should be aware and document indications that other animals have been in an ecosystem, remembering that many animals move from ecosystem to ecosystem depending on their needs. Deer, for example, hang out in woodlands during the heat of the day, graze and often bed down in the prairie, and drink where there is fresh water. All the organisms play specialized roles within the ecosystems. (See *Trophic Interactions and Food Webs* – Set 3.)

Abiotic Factors
Organisms, both plant and animal, are highly dependent on abiotic factors. As students collect biological data, they should also record as many abiotic details as possible, including but not limited to time of day, weather conditions, soil temperature and saturation level, light intensity, etc. (See *Abiotic Study* – Set 1.)

History
Many of the organisms found on a site are influenced by the history of the site. Is the plot a virgin site, in succession phase or fully restored? Much of the Fermilab campus was once farmland and homesteads. Prior to that period, it was mostly prairie. Historical information is available on the Fermilab website at http://history.fnal.gov/prehistory.html. (See resource *Fermilab: Past, Present and Future – Introduction.*)

Prior Student Knowledge Expectations:
- Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
- Familiarity with the characteristics of the most common plants and invertebrates in the ecosystem
- Ability to use a field guide and/or key to assist in identification
- General understanding of collaborative behaviors

Possible Preconceptions/Misconceptions:
- Underestimation of the diversity in a flourishing ecosystem
- Unfamiliarity with the strength of the form vs. function factors/interconnections of organisms
- Underestimation of the importance of abiotic factors in the balance of nature

Vocabulary: canopy, estimate, percentage, quadrat, understory, FQI, niche

ENGAGE:
Students have prior knowledge gained from the estimating percentages and lawn quadrat activities. Ask students to share in their research teams what they feel might be the biggest challenges as they work in a natural ecosystem. How do they plan to overcome these challenges? After a brief discussion, show the video and ask students if the challenges they suggested need to be amended. How will they meet these challenges?
https://www.youtube.com/watch?v=sCs1d8GLzKU

Quadrat

This is a field experience involving identifying and counting plants within a meter square using scientific protocols; collecting and using data over time to recognize and predict trends.

This investigation may be completed in conjunction with the Invertebrate and Other Animals segment that follows.

Materials: (per student group)

- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Flora Field Guide
- Quadrat Data sheet
- 1 decimeter square
- Access to "Report Your Data: Find Your Teacher/Leader" on the Fermilab website: http://eddata.fnal.gov/lasso/quadrats/teacher-q3.lasso

Process:

1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the quadrat procedures found at http://ed.fnal.gov/data/life_sci/data/prairie_watch.html.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify plants.
5. Proceed to a natural area site. Use a "random site generator" (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.
6. <u>If requested</u>, students will carefully note invertebrates and their habits within their quadrat on the Quadrat Invertebrate Data sheet using available identification tools.
7. Using meter sticks and the following data sheets, students will map the location of the plants in their quadrat, drawing the most abundant first.
8. Once plants are drawn, students will use the meter sticks to get the exact location of each larger plant within the quadrat.
9. Before students complete the plant sheets, remind them to <u>informally</u> note on the Quadrat Invertebrate Data sheet any invertebrates on and around specific plants within the quadrat. Informally note also other animals and/or evidence of their recent presence. Organisms and/or evidence of organisms beyond the quadrat are notable as observations, but will not be part of the formal data.
10. Students will generate an accurate count for each plant present in their quadrat and record this on the code sheet. (This will be easy for the larger individual species; more difficult for the abundant species.) For very abundant organisms such as grasses, we count each soil surface clump as a separate plant. If there is simply too much to count this way, count a representative 1% section of your quadrat and multiply by the appropriate number of similarly covered sections as learned in the *Quadrat Study: School Lawn*.

11. Determine the percent cover for each plant species.
12. Enter into the computer the number of different species of plants found in the quadrat and the estimated percent cover. Repeat this procedure for the number of different non-native (weed) species found. The computer will use the class data and calculate the importance value and species diversity for each.

Invertebrates and Other Animals

Field experience involving identifying and counting invertebrates within a meter square using scientific protocols and collecting data to contribute to a database that will be accessed by students and ecologists in the years to come; observation of other animals by actual sightings and/or evidence helps students make inferences about relationships/interactions.

This investigation may be completed in conjunction with the quadrat study.

Materials: (per student group)

- Meter square quadrat
- Meter sticks (at least 2)
- Small metric ruler
- Invertebrate Field Guide/ID materials, including Common Insect Orders Guide
- Bug boxes and magnifiers
- Student sheets – Quadrat Grid; Quadrat Invertebrate Data; Other Animal Evidence
- 1 decimeter square
- Access to data collection tool on the Fermilab website: TBA

Process:

1. Complete *Estimating Percentages* and *Quadrat Study: School Lawn* from Set 1.
2. Access the data collection link website and review data resources.
3. Familiarize students with the invertebrate observation procedures found at TBA.
4. Students will work in groups of three or four. Prior to the lab, establish student roles. Assign one student as recorder, one as counter, and commission everyone to a collective effort to identify invertebrates.
5. Proceed to a natural area site. Use a “random site generator” (hurled Frisbee, hat, etc.) to identify student quadrats. Open and place quadrat meter square tool on selected area.
6. Students will note invertebrates and their habits in their quadrat on the Quadrat Invertebrate Data sheet.
7. Enter observations on other animals on the Other Animal Evidence sheet. Short essay questions may be completed back in the classroom.
8. Using meter sticks and the grid data sheet, students will map the location of invertebrates and/or animal evidence in their quadrat, noting the specific plant(s) they are visiting.
9. Students will attempt to get an accurate count for each insect order and other invertebrate and record this on the data sheet. Remind them to look under leaf litter above the soil.

EXPLAIN:
Encourage students to share plant/invertebrate/other animal sightings and/or evidence observations and the interrelationships perceived with other teams. Collectively, compare data and offer explanations for similar/dissimilar observations. Students working in the same ecosystem should compare data to make a generalization about the diversity in that ecosystem using the data from all samples.

ELABORATE:
Ecosystem services associated with this lesson:
- Disturbance regulation
- Water regulation
- Soil formation
- Pollination
- Biological control
- Refugia (safe habitat for organisms endangered or threatened)
- Food production
- Raw materials

How might ecosystem population and biodiversity studies relate to each ecosystem service?

EVALUATE:
Formative Monitoring: Students report their data at the conclusion of the activity, sharing successes and challenges, as each quadrat is different. The Student Reflection questions can be a driving factor in these discussions. It may be beneficial to project a picture of the quadrat or share the drawings so students can visualize the plant growth and learn from each other.

Summative Assessment: Based on your understanding of relationships and interactions, design a community based on your quadrat that could be self-sustaining. Make note of everything needed and the connections between each organism and abiotic components as well as to one another.

Elaborate Further/Reflection/Enrichment: What further questions do students generate? Research specific invertebrate/plant relationships; what form/function connection(s) are revealed? Based on your research, specifically what do you predict would happen if one or the other of these organisms disappeared?

Name: ____________________________

Quadrat Study: Reconstructed Prairie

1 m^2 quadrat, scale 1 cm = 10 cm

Please do not remove meter sticks and quadrat marker until your docent has checked your work and initialed here. ________

Quadrat Number Assigned by Computer ______

School	Date	Teacher	Recorder's Name

Key	Prairie Plants	Number	%	Key	Invasive Plants	Number	%
	Prairie Grasses				**Invasive Forbs**		
	Big Bluestem			1	Black Raspberry		
	Indian Grass			2	Daisy Fleabane		
	Little Bluestem			3	Wild Carrot		
	Prairie Cord Grass			4	Sweet Clovers (tall)		
	Switch Grass			5	Yarrow		
				6	Curled Dock		
	Prairie Forbs			7	Common Ragweed		
A	Saw-toothed Sunflower			9	Ground Cherry		
B	Black-eyed Susan			10	Tall Goldenrod		
C	Compass Plant			11	Common Milkweed		
D	Prairie Dock			12	Clovers (ground)		
E	Wild Bergamot			13	Thistle		
F	Showy Tick Trefoil			18	Hairy Vetch		
G	Yellowish Gentian			19	Hairy Aster		
K	Culver's Root			27	Drummonds Aster		
L	Blazing Star			28	Dandelion		
M	Mountain Mint			30	Heal-all		
N	New England Aster			31	Evening Primrose		
O	Nodding Wild Onion						
P	Pale Purple Coneflower						
Q	Wild Quinine						
R	Rattlesnake Master						
S	Stiff Goldenrod						
T	Tall Coreopsis						
U	Purple Prairie Clover						
V	White Prairie Clover						
W	Rosinweed				**Unlisted Invasive Plants**		
X	White Wild Indigo			34	Unlisted Grass-Like		
Y	Yellow Coneflower			33	Unlisted Oval Leaf		
Z	Cup Plant			32	Unlisted Round Leaf		
b	Bush Clover			35	Unlisted Triangular/Pointed Leaf		
d	Compass Dock Hybrid						
f	Foxglove Beardtongue						
g	Golden Ragwort						
r	Balsam Ragwort						
	# of Types of Prairie Plants Found				# of Types of Invasive and Unlisted Plants Found		

Date ________________ **Names:** ____

Weather ____

Quadrat Invertebrate Data Sheet

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant - Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Type of Invertebrate (Name/Sketch/Describe)	**Location of Invertebrate** (On Plant – Name Plant/ On Ground/On Web/Etc.)	**Abundance**	**Interaction between Plant and Invertebrate** (Pollinating/Eating/Etc.)

Student Team Data Sheet – Other Animal Evidence

What evidence of other animals did you note in your ecosystem? Based on evidence, what animals do you think were in the area? Use the back of the page if needed.

ANIMAL	EVIDENCE SKETCH/DESCRIPTION

List at least five relationships/interactions that you think brought the animals to your site.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________

Use another page if necessary to complete this page.

Select the relationship/interaction that you believe is the most significant and explain why you believe this to be true.

What do you believe could happen to the ecosystem if this animal leaves the area?

Suggest a plan to help ensure ongoing health and biodiversity in your ecosystem based on your understanding of why ecosystem relationships/interactions are important. Evaluate all the plans, noting the most practical and effective parts of each plan.

Name: ___________________________

Student Reflection: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Teacher Page

Student Reflection Suggested Responses: Quadrat Species Sampling – Plants and Invertebrates

1. If data has been collected at the Fermilab prairie, compare your class data with the data from 1992. What has stayed the same? What has changed? Why do you believe this is so?

   Answers will vary. Explanations should be supported with data.

2. If your data was collected at another natural area, how does the diversity compare with the existing prairie data? How do you explain your findings?

   Answers will vary. Explanations should be supported with data.

3. The natural world is filled with relationships and interactions. Which interaction(s) and/or relationship(s) did you witness? Why are those relationships important?

   Answers will vary. Correct identification of relationships is essential.

4. Comparing data from the prairie to prior years, how do you think the prairie ecosystem is doing this year? What could account for your findings? If you collected data from a woodland or pond site, how do you think that site looked 10 years ago? Support your response. [HINT: Check the Fermilab website for fire data (prairie), prevailing weather conditions, and/or evidence of other disturbance.]

   Answers will vary.

5. Based on historic data, if you feel it was a more or less productive year than prior years, explain whether you believe it was due to environmental or genetic factors.

   Answers will vary. Students should support their claim with evidence.

6. What were the abiotic conditions on the day(s) you observed and collected your data? How might these conditions have altered, deterred or enhanced your findings?

   Answers will vary. Students should include a variety of abiotic data points.

7. Consider your quadrat and mentally remove the most prominent organism. What do you think would occur within the first day? Month? Decade? Why would it matter?

Answers will vary. Explanations should be supported with data.

8. Imagine that climate change boosts the average temperature each month over ten years by 3 degrees. What do you believe will happen to the existing organisms? Utilize historic data from the Fermilab website to support your claim.

   Answers will vary. Explanations should be supported with data.

9. Why do we care? What ecosystem services does the ecosystem you surveyed provide? Why are these services important?

   Answers will vary.

Design a plan to use the relationships between plants and insects to promote a restoration project for the ecosystem you studied. Summarize your plan in several paragraphs.

Use agreed-upon criteria and media approach to support the communication of science concepts and ideas to the general public.