Chapter 2. Biocore Prairie Restoration Project

Authors: Janet Batzli and Seth McGee

The material in this Chapter provides specific information about prairie ecology, the Biocore Prairie, the history and management of the area, as well as guidance on assignments culminating in the generation of a research proposal and a final paper based on your research in the Biocore Prairie. Results and ideas from your project will contribute to our continuing restoration efforts and even (perhaps) inspire a larger project in summer months.

Learning Objectives

By the end of this unit you should be able to:

1. Recognize several native prairie plant species and explain how they are adapted to life in a tallgrass prairie ecosystem.
2. Recognize several non-native weed species and explain how their adaptations allow them to survive and grow even after attempts to remove them from the prairie.
3. Work in a group to make observations, discuss, evaluate, and generate testable questions for a prairie project
4. Generate a specific hypothesis, biological rationale, and experimental design for your research
5. Carry out a scientific investigation that will address your hypothesis
6. Communicate your research in the form of a research proposal and final scientific paper

Schedules and Logistics

Field trips to Biocore Prairie will take place weeks 1, 2, 4 and 5 of the semester (four weeks out in the field!). We will go rain or shine, so please come dressed appropriately for the weather. We recommend wearing **long pants, long sleeves, and close-toed shoes (not sandals)** for all of our field labs because we may encounter insects, scratchy brush, and/or poison ivy. We also recommend a **water bottle**, **sunscreen and/or a hat** since we will be outside for several hours. Also, bring a **camera** if you have one- it is always beautiful out there!

For the first two weeks of lab, we will meet at the Picnic Point parking lot. We will go to the prairie, rain or shine, but keep your eye on email for instructions if the weather gets particularly bad. Bring your lab manual, carbonless lab notebook and a pencil. During the first week of lab out at the prairie, we will go on a short tour, discuss prairie ecology, organisms, and adaptations, and do some detailed observations to help in the development of potential study questions. Then, you will work with a group to explore project ideas you would like to explore further the next week.

One aspect of the prairie that you should notice is that vegetation on trails/firebreaks and prairie borders often have different species than those in the interior. These path species are adapted to trampled soil and the movement and presence of people, and are, therefore, not representative of the rest of the prairie community. The prairie is composed of a different set of species that mix with path species at the interface or ecotone resulting in higher diversity than is present in either path or field. This is called the *edge effect*. When you are making observations to represent the prairie, be sure to keep this in mind and don't trample like a buffalo—unless that is part of your experiment!

How do we know what we know in the science of Ecology?

Introduction to Prairie Ecology
Some background information to help in the formation of a scientific investigation in the Biocore Prairie

Prior to European settlement, the uplands of southern Wisconsin were a shifting mosaic of vegetation, including **prairies** (a community of grasses and non-grassy herbaceous plants with few to no trees), deciduous forest, and **oak savanna**, a community with widely scattered trees (usually white and burr oaks) and an understory often dominated by grasses. Prairies once occupied up to two million acres in Wisconsin, sometimes existing in large patches and at other times occupying the rocky soils of small hilltops. By the 1900s rich prairie soils had been plowed and used for agriculture. Fires that maintained prairie plant communities were suppressed. Today, prairie ecosystems in Wisconsin are very rare and *endangered ecosystems*. Following agricultural settlement- it is estimated that only one half of one percent of the original prairie still remains in small patches called **remnants**. Prairie restorations are an attempt to reintroduce flora into areas known historically to support prairie and savanna, but whole ecosystems are made up of more than flora. The ultimate goal and biggest challenge for most prairie restorations is to create a system that provides suitable habitat and encourages natural interaction among plants, animals, microorganisms, and the physical environment that characterizes prairie. In some cases, this goal may be unrealistic since the total area undergoing restoration is small, the space between restorations is interrupted by agriculture and human dominated landscape, and the introduced invasive species impose strict competition difficult for natives to overcome. Despite these challenges, there are many restoration projects underway including Biocore Prairie restoration project that you will be studying.

Abiotic Environment

Most prairie soils are rich due to the abundant, deep root growth and subsequent decomposition. Wind is ever present and unyielding in prairie given few trees and relatively flat landscape. The drying force of wind is a challenging element for which most prairie plants have evolved adaptations to mitigate. Fire is a natural disturbance in prairies, discouraging non-native plants and tree growth. Precipitation, in the form of rain and snow, play a crucial role in the development of prairies. On the high plains, short grasses thrive in the rain shadow east the Rocky Mountains. In the Midwest plains states that receive higher precipitation, mid-sized to tall grasses dominate the landscape. The Biocore Prairie is mostly composed of tallgrass prairie which would be the prevalent type of prairie in southern WI, but it also contains examples of short grass prairie in drier sites.

Figure 1. Left image of prairie leaves -grasses and forbs including compass plant (big lobed leaves) and small delicate leaves of purple prairie clover.

Biotic Environment

Prairie Plants

The dominant plants in prairies are perennial **grasses** and **forbs** (non-grass flowering plants). These plants are perennial meaning that they live more than one year as opposed to annuals that complete their whole life cycle in one year.

Prairie perennials retain permanent underground structures (roots and underground stems) from year to year but die down to the soil surface each winter.

Grassland vegetation is adapted to a drier climate than temperate deciduous forest. Typical **leaf adaptations** are compound or highly lobed leaves to decrease the leaf surface area exposed to the hot summer temperatures (Fig. 1). Some species have thick, hairy leaves that help plants conserve water. Prairie plants have **highly adapted root systems** to the often droughty soil conditions. Plants may have several thick tap roots or a mass of fiberous roots all penetrating to great depth (Fig 2). Some species roots may grow as deep as 15 feet allowing them to tap remote moisture reserves not accessible to plants with surficial root systems like those of many weedy and invasive annual or perennial species. The deep root system of prairie plants are also a means of energy storage after frequent disturbances such as fire. **Fires** are a natural part of the prairie ecosystems and most prairie species have special adaptations that allow them to survive frequent fires.

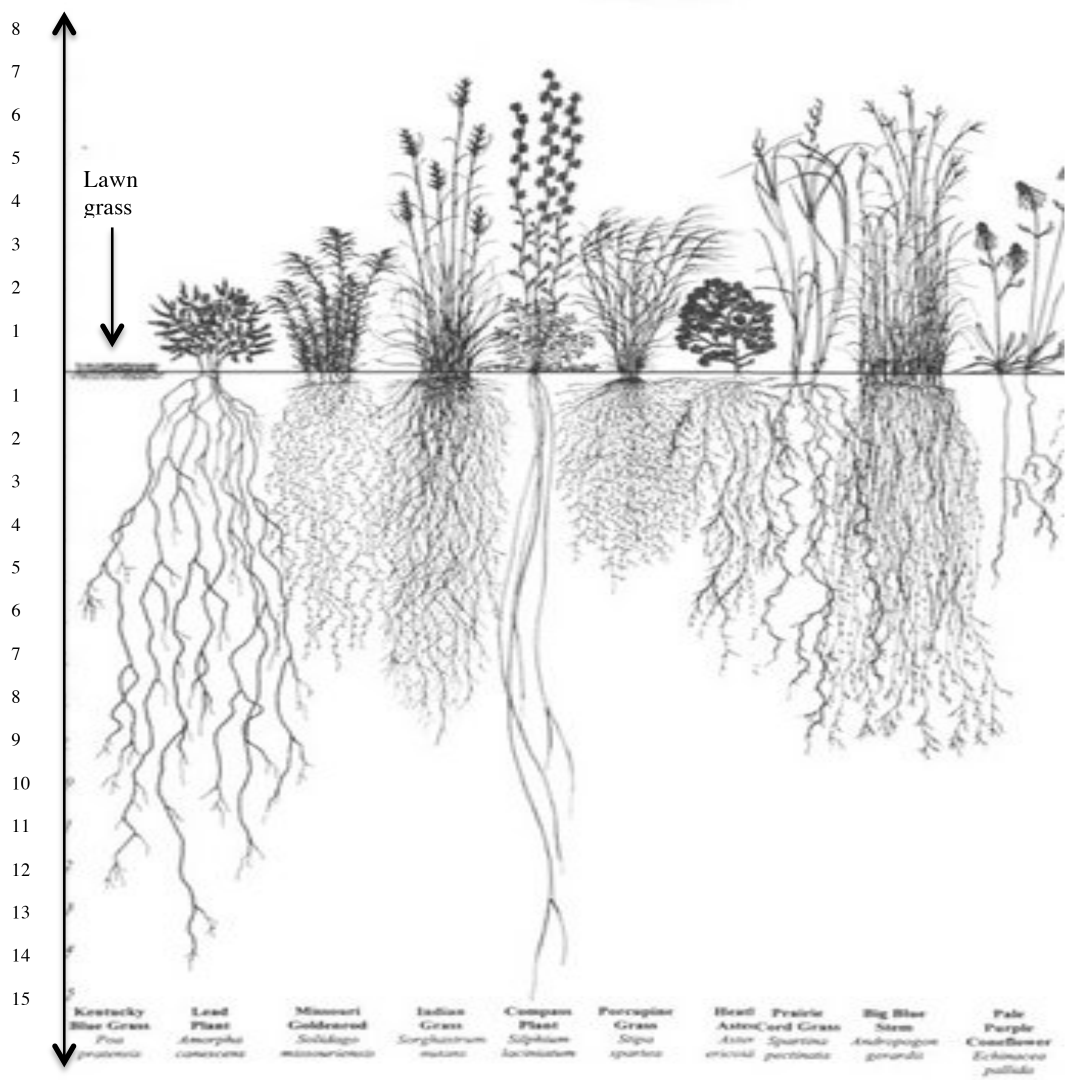

Fig 2. Root systems of prairie plants. Compare the roots of lawn grass on the far left with the deep tap and fibrous roots of prairie plants. Scale on the left indicates the number of linear feet above and belowground. Artwork from Conservation Research Institute.

Prairie Animals and Interactions

Animals that live in prairies are adapted to grassland habitat. There are a large number of **bird species** that are found in prairies- some as permanent and others as temporary residents. Birds such as gold finches, eastern meadowlark, bobolink, and sandhill cranes eat a large array of prairie seed or insects, and utilize diverse vegetation for perch and nesting sites. Although few restorations are large enough to sustain **large animals** such as bison and elk, smaller mammals such as deer, coyotes, rodents are plentiful in many restorations including the Biocore Prairie (i.e. 5 different coyotes were captured and radio tracked in the Biocore Prairie in winter 2014!). These animals often have specific adaptations of body structure, color or behavior that help them survive in different prairie habitats. Some grazing mammals, have broad, flat-topped teeth or teeth that grow continuously (rodents) especially adapted to feed on tough prairie grasses containing silica. Many birds and **small mammals** such as *Peromyscus leucopus* (white footed mouse) and *Microtus pennsylvanicus* (meadow vole) utilize insects and seeds of prairie plants as a major source of nutrition, and exploit different microhabitats in the prairie to avoid competition or predation. For example, meadow voles tend to burrow and tunnel in dense prairie vegetation and are most active at night which helps conceal their presence from predators, while deer mice may forage at anytime and in more exposed locations—even climbing to the highest point of an 8 ft. tall prairie dock plant to find seed.

Insects are, by far, the most numerous animals in the aboveground part of prairies and include many species of bees, moths, butterflies, beetles, and grasshoppers. Some insects are specialists to prairies, others are more general to many communities found in Wisconsin. Pollinating insects such as bees, flies, butterflies, and moths are attracted to flowers through numerous mechanisms including flower color, size, fragrance, pollen, UV light reflectance (fig 3) and the promise of a nectar reward. Ground dwelling insects such as grasshoppers, crickets, ants, beetles may spend much of their life cycle in the soil or surface litter (decomposing leafy debris). These insects feed on leaves, stems and roots, on decaying material or on other insects.

Fig. 3 Image of *Rudbeckia* flower exposed to UV light 365nm. The outer ring of light colored petal tips reflects UV light is highly contrasted with dark center containing pollen and nectar. The petals serve as landing strips to guide insect pollinators. (Photo credit Klaus Schmitt; http://photographyoftheinvisibleworld.blogspot.com)

Below ground in the **soil**, you will find bacteria, fungi, insects, earthworms and nematodes (tiny <2.5 mm long, soil worms AKA round worms) (Fig 3.) that are crucial for soil turn over and formation. Soil nematodes are numerous with high densities in most soils. They can be beneficial or detrimental (plant parasitic nematodes), and vary in abundance and distribution based on plant compounds and the abundance of particular microorganisms (bacteria or fungi) present in the soil. Earthworms are familiar to anyone who has dug in the garden or has done a little fishing. Important fact: Earthworms are not native, but rather were introduced to the upper Midwest and Canada from Europe. Earthworms digest large amounts of dead plant material, pulling fallen leaves and stems underground, producing nutrient-rich casings, and mixing and aerating the soil as they move. Their voracious appetite for dead plant materials has drastically altered soils organism communities and the way nutrients cycle through forest and prairie ecosystems. Soil microorganisms are essential to the health of the soil and the plant community. Soil microbes breakdown decaying plant and animal remains creating humus—a nutrient rich component of soil important to plant growth and nutrition.

Interactions of Prairie Organisms

Prairie animals and plants interact in a dynamic way. Animals utilize prairie plants for food, cover, and a structural environment in which to interact with other animals and microorganisms. Many, but not all, prairie plants rely on animals for pollination, seed dispersal, aspects of soil formation and nutrient acquisition. Some animals eat prairie plant seed and, therefore, influence the number and types of seed that will remain to germinate in a restoration.

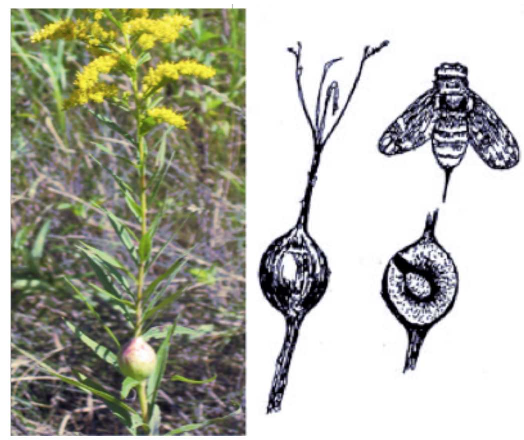

Figure 4. Image and illustration above of goldenrod gall and emerging goldenrod gall fly (*Eurosta solidaginis*).

Although there are many positive or mutualistic interactions, some plant- animal- microbe interactions are not mutually beneficial. Prairie plants utilize a variety of defense mechanisms to avoid being eaten. Spines, thick hairs, gooey resins, waxes, and toxic chemicals all act to deter herbivores from eating most plants. However, many animals have evolved mechanisms to overcome these challenges. For instance, some insects have developed chewing or piercing mouthparts that allow them to tear through thick leaf cuticle (outer leaf covering) and the tough plant cell walls to tap into the sugary plant vascular system for a meal. Monarch caterpillars can eat and store toxic latex produced by milkweed plants, which results in monarch caterpillars and butterflies being toxic to potential predators. Another example is the goldenrod gall flies that have evolved the capacity to feed exclusively on goldenrod plants and induce the plant to create a gall tumor in which the insect makes its home (Fig. 4). Some plants produce antibiotics or other anti-microbial compounds in leaves, stems and roots to confer resistance to bacterial or fungal pathogens. Prairie plants have long been sought after for their medicinal value and are now a focus in the on-going search for new pharmaceutical drugs. Finally, and importantly, many forb plants produce brightly colored, patterned, or fragrant flowers while others produce large quantities of high sucrose nectar, all of which are alternative mechanisms to attract different types of pollinating insects.

Biocore Prairie Restoration Background and History

As far as the site records go back, the area where the Biocore Prairie is situated at the base of Picnic Point supported savanna and upland forest. In the early 1900s, the area was part of a private farm that was turned over to the University for establishment of the College of Agriculture experimental farm and orchards. When the experiment station was moved to central Wisconsin, this area was left fallow, allowing 40-50 years of weed seed to accumulate in the soil.

In 1997, the Biocore program staff, students and volunteers began restoring the old agricultural field to tallgrass prairie for ecological educational research opportunities as well as public outreach and enjoyment. The Biocore Prairie is a central research site for Biocore 382, for undergraduate independent research projects offered under directed study, Biocore Bird Observatory, service learning opportunities, and collaborative research and teaching efforts with other UW-Madison programs and departments. Over the last 17 years, the Biocore Prairie team has been hand-pulling weeds, burning, preparing soil, sowing prairie seed, transplanting prairie seedlings, and mowing fields and fire breaks. Happily, we can report that our hard work is paying off with a growing area of establishing prairie. Summer 2014 was very interesting as a result of late spring warm up and cool summer temperatures led to compressed growing season. The extreme winter of 2013-2014 surely impacted the length of growing season, and may influence what you observe in terms of flowers, pollinating insects, and other prairie organisms this fall. It will be interesting to study what is going on!

See this set links to short videos to give you a feel for:
The sights and sounds of the Biocore Prairie https://www.youtube.com/watch?v=OiI1hsGE2Oc
Intro to Biocore Prairie from 2016 Prairie Crew https://youtu.be/lsfg27k5cFI
Overview of the Biocore Prairie https://www.youtube.com/watch?v=XdzV5362_ws
The Prairie Underground https://vimeo.com/122019432

The following pages are provided as a brief record of our accomplishments to date and to give you a feel for where we are today.

The Restoration Process:
Establishment of a functional prairie ecosystem is a very complicated and multifaceted process. The items listed below are just a few of many considerations when undertaking a prairie restoration and management project.

1. ***Site Preparation***- We have used several different methods to prepare the site for planting including; rototilling/plowing, mowing, growing cover crops (e.g. oats), spraying Roundup herbicide, and addition of high carbon substrates (e.g. sawdust). One important thing to consider is the severity of the weed problem. If there is a tremendous amount of weed seed in the soil, you do not want to turn the soil over and bring weed seed to the surface where it can germinate and produce more weed seed.
2. ***Selection, collection, and planting of prairie seed-*** After reviewing historical documents describing the composition of prairies in South-central Wisconsin prior to settlement, we have selected a set of species that we feel are representative of the plant diversity of that time. Plant materials have been collected from other near-by restorations, from prairie remnants, and purchased from seed companies. Seed was hand broadcast or drilled into the ground in late fall or early spring.
3. ***Hand planting seedlings***- We have grown and transplanted young seedling plants of rare species that are difficult to establish from seed. This process is very laborious and expensive, since we often must water the new seedlings through dry summers.
4. ***Interseeding***- After the restoration is underway, we have found that some prairie species establish well, while others are missing. In these cases, we have gone into an area and have seeded specific species of interest (e.g. wood lily *Lilium philadephicum*, difficult to establish species).
5. ***Weed Control*** There are several techniques that we have used to control weeds on the Biocore Prairie. Each technique is specific to the types of weeds that are of concern. The most

Fig. 5 Spring 2007 prescribed burn

effective weed control usually uses a combination of techniques including:

- ✓ *Prescribed burning*- Burning is very important for our restoration. Areas are burned regularly, often on an annual basis, in young restorations to help control weeds remove woody plants that are not fire adapted. Burning encourages prairie plant growth by burning dead organic material and exposing soil to sunshine and warming temperatures in early spring. To have a successful burn, the restoration has to have built up a significant amount of dead plant material to serve as fuel. Forbs often decompose rapidly, leaving little to burn. Dead grass stems and leaves, on the other hand, tend to remain through the winter and serve as an optimal fuel source. Since 2004 we have attempted to burn areas of the prairie each spring, sometimes successfully and sometimes not. Spring 2007, 2010, 2014 and Fall 2011, 2012 were all very successful burns at the Biocore Prairie (Fig. 5).
- ✓ *Mowing*- timed to cut weeds before they flower and go to seed. Mowing does not remove or kill roots, but generally reduces the weeds energy reserve and keeps weeds under control. Mowing is particularly good for controlling annual weeds that depend on annual seed dispersal for reproduction. Mowing is not effective for grasses or other weeds that have growing points (meristems) close to the ground.
- ✓ *Hand pulling*- this technique is reserved for more problematic weeds that have large energy reserves stored in roots, are biennial or perennial or can reproduce asexually. Hand pulling is obviously very labor intensive, and not efficient in most cases. However, we do hand pull weeds if the problem is not wide spread. (good for burdock, curly dock, sweet clover, bull thistle, garlic mustard)
- ✓ *Herbicide*- this is a good choice (and last resort) for the most tenacious weeds (crown vetch, reed canary grass, leafy spurge, Canada thistle) that continue to be a problem after we have tried other control techniques. Much care goes into choosing and applying herbicides, since some can be very toxic to non-target organisms.

Description and Restoration History of Areas in Biocore Prairie

We have established 3 general areas in the prairie as depicted in Figure 6. Although we do not expect you to be intimately familiar with each Area, we provide the following information to introduce you to the site and for background on what you will see in the field. The following page describes these areas in greater depth.

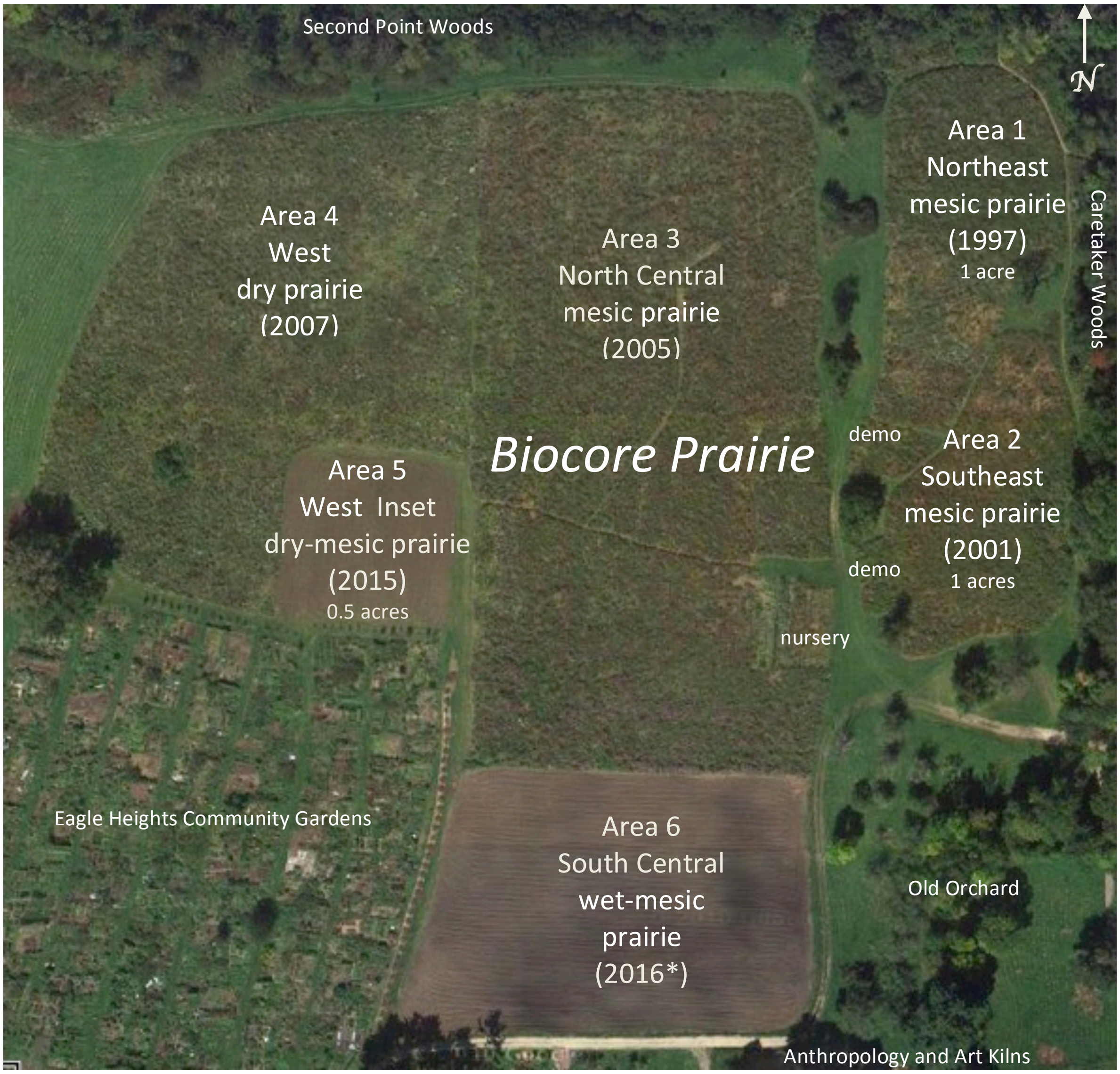

Figure 2. Biocore Prairie aerial photo (Sept. 2010 Google Earth) indicating established Areas 1-6, intended prairie communities, area size, and dates planted (*estimated planting date Fall 2016). Areas are labeled 1-6 based on the order of the planting dates. Note the proximity of the prairie to community gardens, forest and grassy margins, all of which have unique edge communities.

Area 1: oldest area established in 1997 subdivided into Area 1a and 1b.

- *Area 1a (~0.5 acres)*- land sloping toward Lake Mendota. Prairie plant community is currently dominated by Canada goldenrod and lacking in grasses required to fuel a strong burn. The area is susceptible to invasion by non-native weeds and woody plants given its proximity to foot trails and forest. The Biocore staff and students have concentrated on hand pulling of problematic weeds and planting seedlings in this area.

- *Area 1b (~0.4 acres)* This area was rototilled in spring 2004 and split into six plots for an experiment testing different prairie plant seed mixes. After a slow start and heavy infestation of weeds such as Canada thistle, the area is progressing.

Area 2: *(~0.9 acre)* This area was an old dirt pile placed on the site during the construction of the UW Hospital. The dirt pile in combination with the underlying sediment provides a nutrient poor, yet, heterogenous soil for prairie plant establishment. In 2000, this area was plowed repeatedly and seeded in a cover crop of oats and planted in prairie plants in spring 2001. Over the last several years, Biocore staff and student workers have transplanted hundreds of young prairie plants into this area and watered them during dry periods. The team hand weeded problematic weeds such as garlic mustard, thistles, Queen Anne's lace, sweet clover, burdock and curly dock. This area currently supports most of the 57 prairie species originally planted as surveyed by Biocore 382 students in fall 2005.

Area 3*:(~4.5 acres)*
The entire area was planted in Round-up Ready soybeans during summers 2003, 2004, and 2005 and treated three times each season with Roundup herbicide to control weeds in preparation for seeding with prairie plants. The soybean planting and repeated herbicide treatment appeared to diminish the Canada thistle, a problematic weed. In November 2005, 53 species of prairie plants were hand planted into Area 3 by 45 Biocore 381/382 students (plus friends and family!). Summer 2006-2010 were great growing seasons- with plenty of rain, seasonal drought, and warm weather. From our management team's observations and vegetation analysis, we counted 50 prairie species (of 53 planted). In 2015, prairie grasses and forbs continued to grow and establish. This is very exciting and remarkable to see, particularly following a couple of rough years and poor success in the beginning! The problematic weed in Area 3 continues to be Canada thistle.

Area 4: (~2.5 acres)
This area is unique and particularly well suited to grow dry adapted or 'short-grass' prairie species. It slopes to the west with relatively dry soil in the easternmost region. The eone-half of the site furthest east was planted in short grass species including little blue stem, prairie dropseed, and side oats grama together with many forbs. Whereas the western one-half slopes toward a moist ditch was planted with tall grass species including big blue stem and Indian grass. Although planting in this part of Area 3 was somewhat later than Area 3a and 3b, the prairie plant community is starting to establish. Problematic weeds in Area 3c are Canada thistle, leafy spurge, and reed canary grass.

Area 5: *(~0.5 acres)*
In 2010, the Biocore Prairie enlarged to include a small area previously part of the Eagle Heights Community Garden. This area has many remnants of the garden including sprouts of herbs and vegetables, and regular long depressions in the soil as evidence of many years of rototilling and row cropping. The area has been plowed and mowed through summer 2014. We will continue weed management and site preparation for prairie planting in November 2015.

Area 6: *(2 acre)*
Area 6 was originally treated and planted in the same way as Area 3 in 2005. Although the rest of Area 3 developed in prairie very well, area 6 was plagued with tenacious weeds including stinging nettle, crown vetch, and Canada thistle. This area's deep organic layer is rich in nitrogen and other nutrients that encourage weed growth. In fall 2008, 2009 and summer 2010-12, this area was deep plowed to turn over and bury all vegetation, both weeds and prairie plants. In spring and summer 2009, the area was planted in oats, mowed and sprayed with herbicide to reduce growth of weeds (particularly crown vetch, Canada thistle, reed canary grass). In spring and summer 2013 and 2014, we planted oats with the intention of depleting the nutritive content of the soil, making it less fertile for weed growth. We will continue weed control in this area for at least one more growing season before replanting prairie in Fall 2016.

Demo gardens & Nursery: In 1999 and 2000 we set up two demonstration gardens and a nursery area as a point of interest for visitors, as a visual reminder of our goal, and as a source of seed in the new planting areas. These areas now have many thriving prairie species that are producing seed and expanding their vegetative growth. They also attract many seed eating birds, butterflies and other insects. These areas are used extensively by the Biocore Bird Observatory group led by Dr. Mara McDonald who monitors migratory and resident bird populations that move through the Biocore Prairie (see website for data collected by this group http://waa.uwalumni.com/lakeshorepreserve/birdbanding.html).

Fig. 7 Grid Map of Biocore Prairie
In summer 2004, a civil engineering surveying class did a detailed survey using high accuracy GPS (global positioning system) resulting in a permanent, 20x20 meter grid overlay map of the entire prairie that is geo-referenced to the Dane County coordinate system (accurate to 5cm). Brass monuments were installed at the corners of each grid square to help us start to map the data we are collecting in a systematic way. This work establishes a valuable base map from which students can accurately locate study plots, and analyze spatial correlations of soils, hydrology, and vegetation.

***NOTE about further study in the Biocore Prairie:** The Biocore Prairie Restoration offers many opportunities to pursue independent study projects or senior thesis work in future semesters. Although we will only be at the Biocore Prairie for two lab periods in Biocore 382, students are a huge part of the success of this project and we hope you take pride in the site, returning with friends and family, coming out to volunteer, or frequenting the area during a run. Let us know about your interests and we will help you get involved! Contact Janet or Seth to volunteer for activities like seed collecting, monitoring long-term experiments, prairie planting, or prairie burn at the Biocore site.

A great deal of effort and resources have gone into this project. We hope to establish a prairie ecosystem on the site and provide ample opportunities to study ecology in this living laboratory. We want to learn as much as we can about ecological research and the process of restoration, not only to guide our own efforts as we expand the prairie in the future, but also to help others undertaking prairie restorations on similar sites. For this reason it is important to document exactly what we have done and the results of our data collection. Your data is valuable!!

Schedule
Your Assignments

Week 1:

Prairie observation (check assignment- due in lab)

Week 2:

Prairie Observations & Questions Assignment (2% individual assignment)
Download a copy of the Prairie Observation & Questions Assignment from Biocore Prairie subdirectory on Biocore 382 in Learn@UW. Complete assignment and hand in at the beginning of lab during Week 2.

Week 3:

A. Experimental Design Worksheet (check assignment- 1/individual)

- Download a copy of the Experimental Design Worksheet from Biocore Prairie subdirectory on Biocore 382 in Learn@UW.
- In week 2, your research team will develop one testable question as the focus of your research. Testable questions may be unique or based on projects begun by the summer Biocore "prairie crew".
- On your own, complete the experimental design worksheet based on the testable question. Come to your week 3 discussion section prepared to share your worksheet with your team.
- You will then work with your research team during discussion to share and combine ideas. By the end of discussion, come to consensus on ONE experimental design to pursue for your project. *Note:* You may be asked to change your question and/or your protocol based on practical limitations. We appreciate your flexibility!
- Turn in your group material and schedule worksheet to TA for check assignment credit.

B. Paper review and critique (5% assignment- 1/two person pair):

- Go to Biocore 382 Learn@UW and download a copy of the paper review worksheet and electronic copies of sample papers and follow instructions with a partner (assigned by your TA).
- Hand in paper review and critique plus a Group Effort Analysis (GEA) form (also found on Learn@UW) in lab.

C. Informal Feedback Presentation

This is an ungraded but extremely valuable activity where your group will have an opportunity to propose your research project to the class in a 15 minute informal Powerpoint presentation and solicit constructive feedback from the group. We will discuss details for preparation of these presentations during week 2 lab and week 3 discussion section. Guidelines for preparing these presentations are in the Biocore Writing Manual (p. 42).

Week 4:

A. Formal Peer Review (2% assignment): A draft of your *research proposal paper* is due the week of Sept. 21 (see syllabus for details on peer review and due date). You will be doing a formal peer review (for a grade) on a draft of your partner's *research proposal* **prior** to discussion. Your grade on this assignment will be based on how well you peer review your partner's paper. Be sure to exchange contact information with your partner during lab and **exchange your paper with your partner at least 24 h before discussion.** (This means you have to have an almost completed draft to exchange 24 h before discussion!). Have your review written out and be ready to discuss with your partner during discussion. Use the Peer Review rubric on p. 41 of the Biocore Writing Manual for guidance on criteria for excellent peer review. Blank peer review forms can be found on Learn@UW in the "Writing Documents" file.

B. Research proposal (8% assignment) Your research proposal paper includes the following sections- *title, introduction section including a visual diagram of the biological rationale and hypothesis (see example on p. 11 of Biocore Writing Manual), methods, expected & alternative results, implications, literature cited.* Please use the *Biocore Writing Manual* (especially the research proposal rubric) as your guide. Pay close attention to the content and format of figure/table legends. Due 48h following discussion week of Sept 21 (in Wed lecture or in Wed/Thurs lab). Your *research proposal paper* should follow the format described in the *Biocore Writing Manual* and should be approximately 5 pages long (not including your figures).
The purpose of this paper is:

- To give you an intimate introduction to the Biocore Writing Manual, specifically the instructions for writing a scientific paper and using rubrics.
- To give you experience developing a research question, biological rationale, hypothesis, method to test, presenting expected and alternative data in the form of figures, and formulating logical implications based on the hypothesis and expectation results.
- To give you practice deciding what details are of greater or lesser importance in writing a scientific paper (i.e. what is the variable, what is the context of the study, what is the question, why is the variable important in the context of the study, how will you test your question)

The appropriate format and style for your paper are described in the Biocore Writing Manual. You should concentrate your reading on the 'Structure of a Lab Report' and 'Research Proposal Rubric' that offer a detailed guidelines that will be used by your peers and TA to review (and grade) your paper. It is essential for you to study the writing manual carefully before completing the assignment. Your paper needs to be complete yet concise. This means that you need to think carefully about what information is essential and what is unnecessary.
For this assignment, we expect you to utilize (and cite!) the information included in the lab manual (primarily information from Chap. 1 and Chap. 2) as well as at least two (2) primary literature papers that logically supports your background, biological rationale and implications. You may include more literature if you like. In addition, you may need more in-depth information about the topic you choose to investigate even if you do not use this information in your paper. If there are terms or ideas you come across that you are not familiar with—LOOK THEM UP! (this is standard for any assignment). Feedback on your paper from your peers and your TA will be based on the criteria presented in the Biocore Writing Manual (starting on "Receiving Feedback").

Week 7:
Formal Peer Review (2%) and Final Ecology Research Paper (15%)
The peer review will be run similar to what you did in Week 4 (i.e. exchange draft with partner, review and conference with partner during discussion section week of Oct 12). In this paper you will introduce your research study, describe methods, data you collected and analyzed and you will discuss your conclusions based on data. Your paper will include all aspects of a scientific research paper as outlined in the Biocore Writing Manual (i.e. title, abstract, introduction, methods, results, discussion, literature cited).

Helpful Tips for Paper Writing:

- If you are having trouble starting, seek out your classmates to discuss assignments.
- Be sure you understand the scope of the assignment BEFORE you start to write. Use the FINAL PAPER RUBRIC in the Biocore Writing Manual—refer to it often during the writing process.
- Make bulleted notes or an outline with ideas for appropriate content for each section For example: INTRODUCTION- subunits: background information about factor/variable and system, observations/question, assumptions about the study system associated with variable, biological rationale, hypothesis and approach; METHODS-further description of system (if necessary), sampling location(s), experimental design, procedure, and replication. Etc….] In each section, write notes and questions to yourself concerning what you know and what you don't know, and what you need to investigate further.
- Look up any terms or concepts you are not familiar with.
- PUT PEN TO PAPER (or keyboard to software) and start to WRITE—knowing that the key to writing a good paper is to write, reread, reflect, rewrite, get feedback, revise and edit. Writing is a multi-step process that is not accomplished without spending a great deal of time and effort doing it!
- TOPIC SENTENCES -use them for each paragraph. Each paragraph should develop a single coherent idea, and each piece of information in the paragraph related to the topic sentence.
- When you have drafted sections of your paper READ IT OUTLOUD TO YOURSELF. REVISE. REPEAT. Wording, grammar, organization, unnecessary sentences, the flow of ideas and many other problems will jump out at you.
- BACKWARDS OUTLINE Once you have completed a draft, test the structure and logical flow of ideas by making a *backwards outline*. Read through each paragraph and write a 3-4 word phrase describing the 'gist' of the paragraph. When you have gone through the whole paper, string together your phrases. Do they make sense? Are their gaps in the logic calling for additional information? Could you have said the same thing with fewer words?
- TRANSITIONS At the sentence level, test to seed if the first few words of a sentence connect to the end of the prior sentence, and that last few words present new information. At the paragraph level, do the ideas from the last sentence of one paragraph introduce the topic sentence of the next paragraph? At the document level, the discussion section should begin by connecting clearly to the question/ hypothesis in the introduction and then move to further develop your findings. Although transitions sound like more words, they can actually help you be concise.
- Look for additional tips for "Writing a Biocore Paper" collected from former students on the last page of this chapter.
- There are many helpful books, texts, field guides and research articles about prairie restoration in the bookshelf at the back of the lab room (341 Noland). Please do not remove resources from lab!

Top Ten Tips for Writing a Biocore Paper—
From former Biocore 382 student (2008) and uTA (Kristen Fox)

As previous Biocore students, we understand how difficult learning to write scientific papers can be. The follow tips were collected from suggestions from previous peer mentors, students, TAs, and professors. We hope that they will help you become awesome writers. Good Luck!

1. **Follow the writing manual.** Everything you need to know is in there. Do yourself a favor and read the manual BEFORE you start to write noting the main points. When you begin your first paper, make an outline using the writing manual to make sure that you have the main ideas. As you write, refer back to it often and compare your draft to the examples.

2. **Start Early**! Biocore papers are intense and require lots of thought and time. You've heard it 1,000 times but seriously, don't leave this to the last minute!

3. **Use your peers**. Get together with your group and draft an outline of your papers together. Share good references and ideas with each other. Remember, you're not graded against each other so be generous with your knowledge!

4. **Know how to use a journal search engine**. Web searching can be a huge waste of time if you don't know what you're looking for. Use specific engines like Pub Med, Web of Knowledge or Google Scholar. Be specific with your search terms, and use the search optimizing info from the librarians.

5. **Start with your textbook and review articles**. Familiarize yourself with a new topic by reading general literature/ a review article. This will give you important background knowledge as well as lead you to new sources that will help you develop your rationale. Circle the references in the review that are relative to your paper and then go read those articles. This can save you lots of time by cutting back on paper searching!

6. **Be an efficient reader**. Sometimes titles can be misleading and you can waste a lot of time reading an irrelevant paper. First, read the abstract to see if the paper is really talking about what you're looking for. Next, read the introduction and glance at the figures/ discussion. If after reading, the paper is still relative, go back and pick out the important information.

7. **Think persuasively and logically**. When you're writing a proposal or final paper, you are trying to convince someone that your project is/was valid and worth doing. Set up an "argument" and take your reader through it step by step. Try making a flow chart to organize your thoughts and to make sure everything connects. As you go through each section of your paper, think about how it supports your argument. *Caution*: Let you data do the talking! Don't be overly emotional and avoid exaggerated interpretations. Always be objective and critical of your experiment.

8. **Do your graphs and tables first**! Before you try to write your results and discussion, make your graphs. It is very hard to make conclusions from raw data. Once you have your data organized, you will be able to see the relationships more clearly and interpret the data intelligently.

9. **Don't make laundry lists**. Every experiment could use more replicates, time, and accuracy so don't spend too much time discussing these in your paper. When you evaluate your data/ design acknowledge any of these flaws but don't stress over them. Instead, think about the components of your experiment that *you had control over*. Did you employ the proper controls? Were your assumptions appropriate? Did you use the right read outs? A discussion that includes these points demonstrates a deeper understanding of your experiment and shows that you can think critically beyond technical problems.

10. **Don't freak out about your grades on papers**. Your TA will grade tough and you may not be happy with your first grade. Your TA knows how much time and effort you are putting into these papers so don't get the impression that they are just trying to make your life difficult. They grade hard because they are trying to help you develop your writing skills. When you get a paper back, READ the comments. Make notes on your areas of weakness and review these when you write your next paper. If after the first few papers you are still not happy with your scores, meet with your TA and go over your writing, they will be more than happy to help.